INTERNATIONAL PACIFIC HALIBUT COMMISSION

Report on current and future Biological and Ecosystem Science Research activities

Agenda item: 4.1.1

IPHC-2025-SRB026-06

(J. Planas, C. Dykstra, A. Jasonowicz, C. Jones)

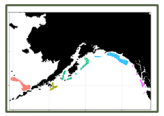
1. Migration and Population Dynamics

5-Yr Research Plan (2017-2021)

Multiple life-stage connectivity

Bering Sea

Gulf of Alaska



Genetic samples of spawning aggregations

Larval connectivity

- Larval catch and effort data
- Individual-based biophysical model
- Hydrographic ROMS model

→ Larval dispersal pathways → Inter-basin and intra-basin larval connectivity

Sadorus et al. (2021) *Fish. Oceanog.* ***30****: 174*

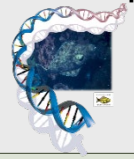
Juvenile connectivity

- NMFS trawl survey data
- Spatiotemporal model

→ Ontogenetic migration

Development and application of genomic approaches

Genome sequence



→ Population structure analyses

Jasonowicz et al. (2022) *Mol. Ecol. Res.* ***22****: 2685*

PIRM 2022-2026

- Climate effects on larval connectivity
- Connectivity with Western Pacific Ocean region
- Mapping of settlement/nursery areas
- Characterization of genetic composition/mixture of settlement areas
- Establishment of a baseline of genetic diversity
- Delineation of fine-scale stock structure
- Stock composition: mixed stock analyses

Relevance for stock assessment

- Generate potential recruitment covariates
- Define management targets for minimum spawning biomass by Biological Region

→ Improved estimates of productivity

- Determine the need for separate assessments for certain components of the stock

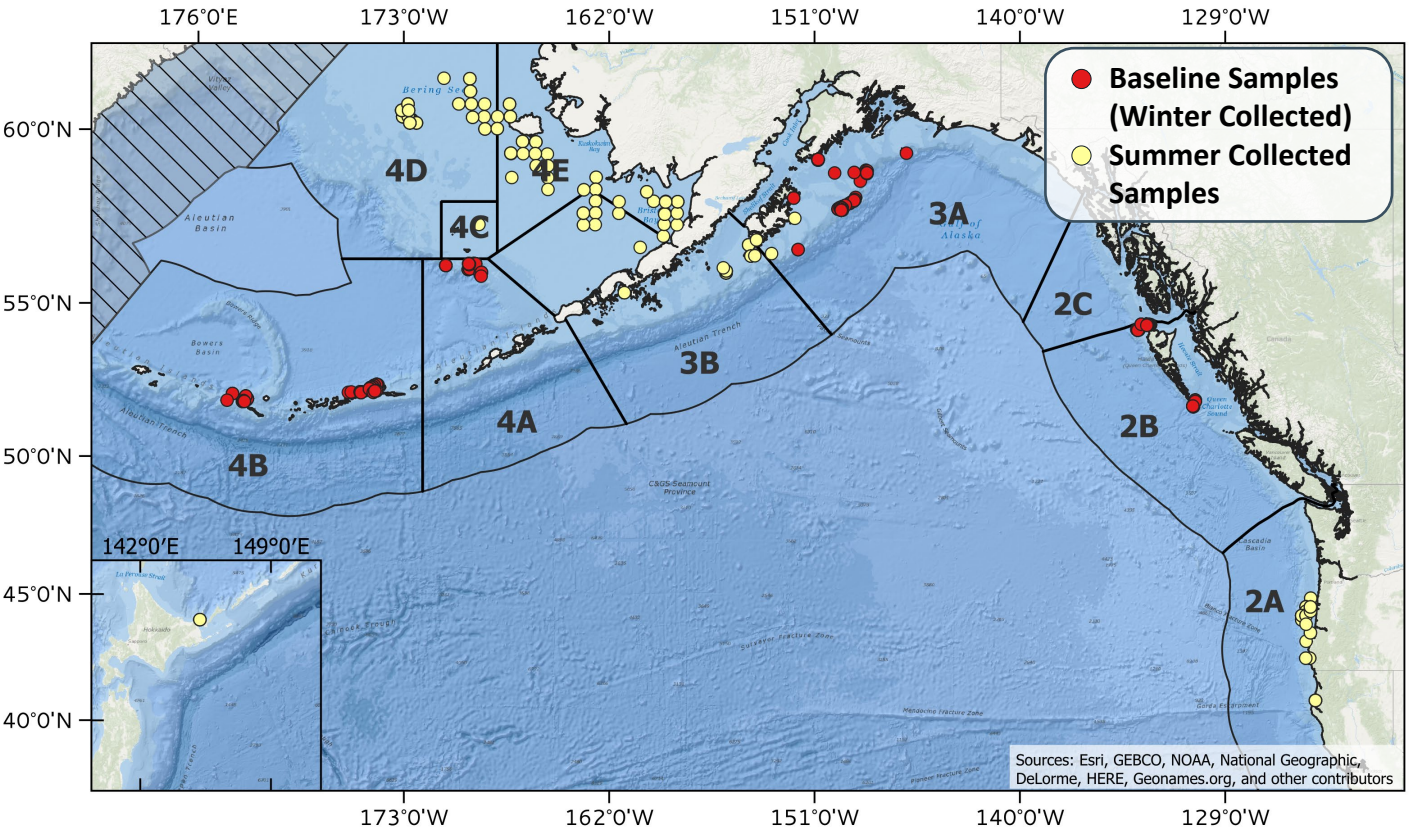
→ Potential revision of structure of future stock assessments

1. Migration and Population Dynamics

Population Genomics

Objective: Resolve the genetic structure of the Pacific halibut stock in IPHC Convention Waters

NPRB Project 2110 (2022-2024)



- Low-coverage whole-genome resequencing (lcWGR)
- Allows for screening genomic variation at very high resolution
- Conducted one additional sequencing run:
  - NovaSeq X Plus 25B – additional 384 samples.
  - To increase and balance sample sizes for the baseline set of sample collections.
  - To add summer collected samples near the latitudinal extremes of the range.

1. Migration and Population Dynamics

Population Structure – Additional samples

Methods:

Bioinformatic processing described in IPHC-2023-SRB022-09 with the following modifications:

- Removed individuals if average sequencing depth was < 1x.
- Used ngsParalog (v1.3.3) to identify genomic regions that are problematic for sequence read alignment.

Results:

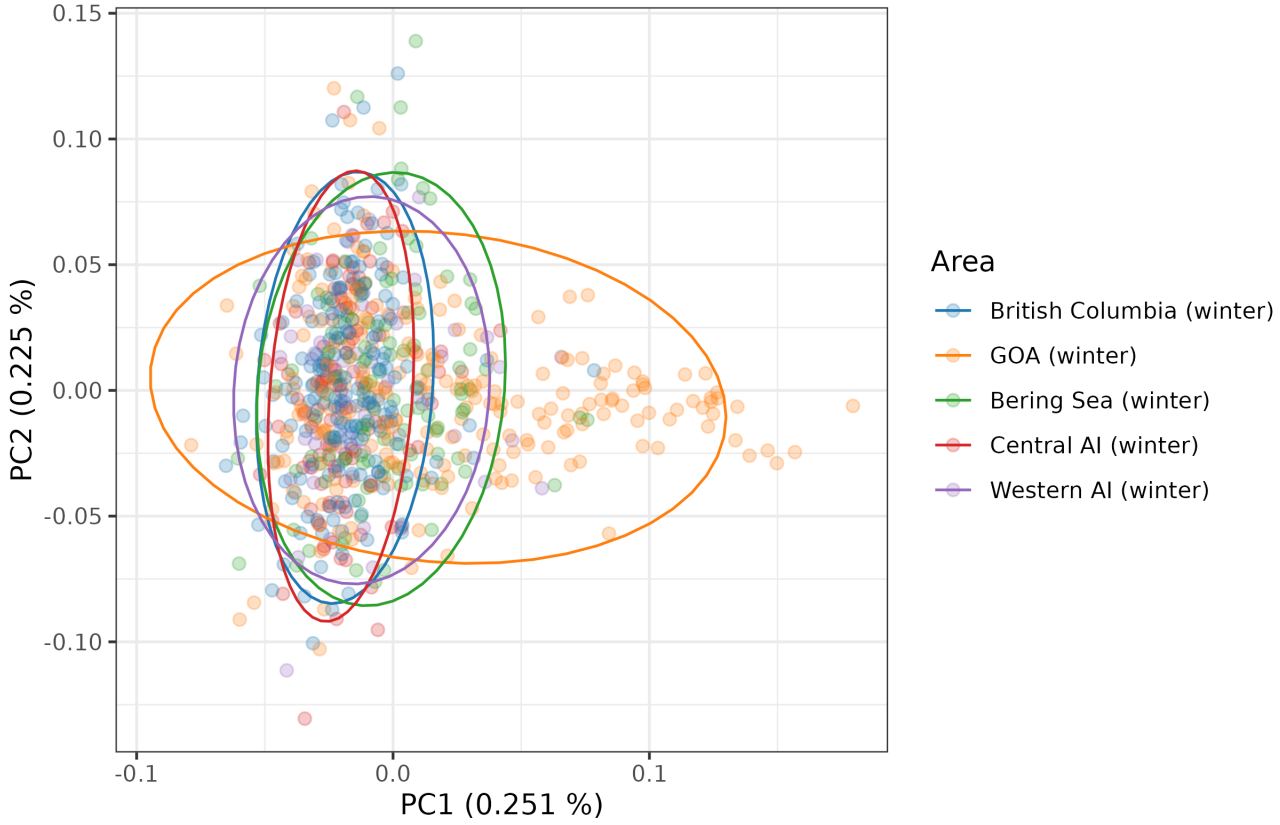
- Average coverage of 2.4x
- Included 161 additional baseline samples (731 total)
- Included 327 summer collected samples
- ~3.7 M SNPs retained for downstream analyses

Winter Collections (baseline samples)	1999	2004	2007	2018	2020
British Columbia (winter)	59	63	61		
GOA (winter)	61	61	61	60	
Bering Sea (winter)		61	61		
Central AI (winter)			61		61
Western AI (winter)					61

Summer Collections	2013	2016	2019	2022	2024
Northern CA (summer)	46				
Southern OR (FISS)				45	
GOA (NMFS Trawl)			41		
Bering Sea (NMFS Trawl)		20	75	48	
Northern Bering Sea (FISS)				48	
Rausu (summer)					4

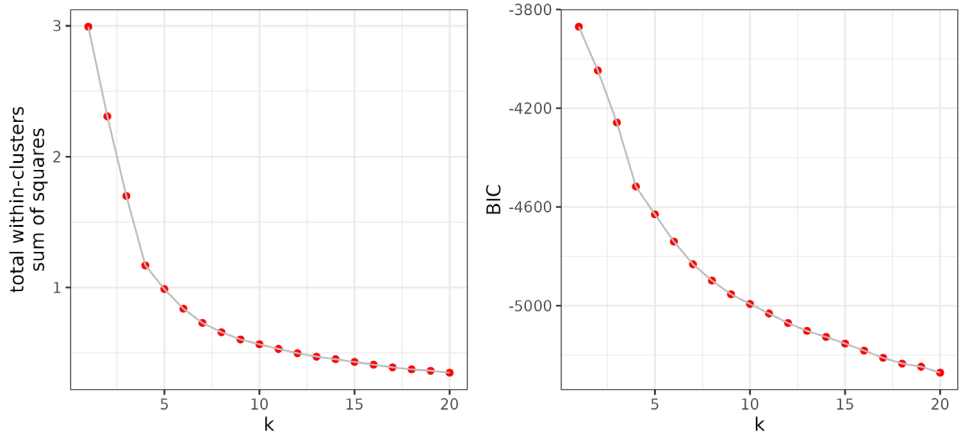
1. Migration and Population Dynamics

Population Structure – PCA & K-means clustering



- Principal components analysis (PCA) (~3.7 M SNPs)
  - ➢ Estimate covariance matrix (PCAngsd)
  - ➢ Eigendecomposition (R)
  - ➢ Iterative outlier removal procedure (> $|6\sigma|$ along one of the top 3 PCs, up to 10 iterations)
    - ✓ 22 individuals removed (n=709 in final PCA)
- K-means clustering (top 3 PCs)

K-means clustering (top 3 PCs)



1. Migration and Population Dynamics

Assignment Testing – Methods

Assignment Testing - *WGSassign*

- Reference populations defined by geographic area
- Simple Training Holdout procedure
- Recommended approach by Anderson (2010) when selecting SNPs based on allele frequency
- Referred to as the "gold standard" by Anderson (2010) and Waples (2010)

Anderson, E.C. 2010. Assessing the power of informative subsets of loci for population assignment: Standard methods are upwardly biased. Mol. Ecol. Resour. **10**(4): 701–710

Waples, R.S. 2010. High-grading bias: Subtle problems with assessing power of selected subsets of loci for population assignment. Mol. Ecol. **19**(13): 2599–2601.

50-50 train/test split
Equal number per area in training set (n=45)

Training Set	Test Set

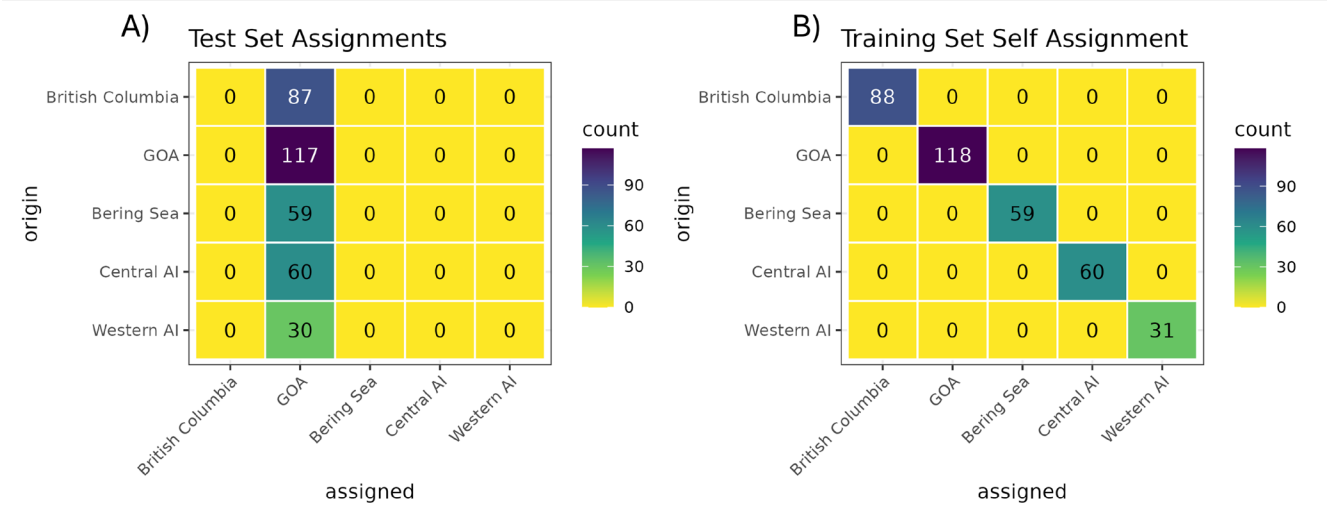
SNP Selection
• Pairwise F_{ST} among collection areas
• Top 1,000 SNPs per comparison
• At least 10 Kbp apart
• Remove any duplicates
  • 8,575 SNPs – 50-50 split
  • 9,078 SNPs – 45 per area
Define reference populations/reporting groups
• Estimate allele frequencies
	Assignment testing
	• Assign individuals back to the reference populations
	• Evaluate assignment accuracy with a set of "new" samples

1. Migration and Population Dynamics

Assignment Testing – Results

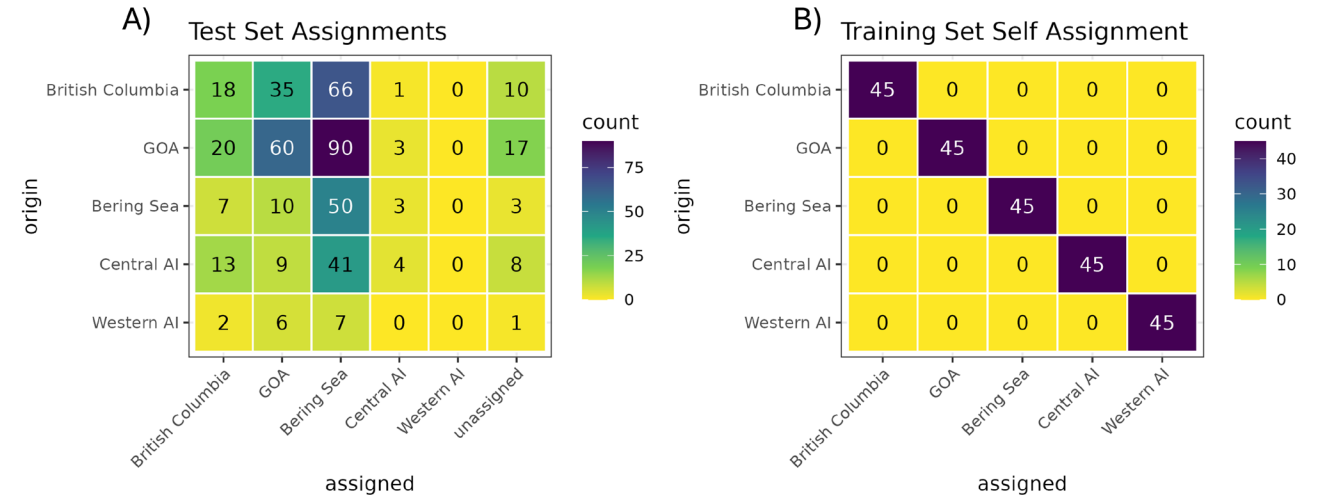
50-50 train/test split

- 33.14% assignment accuracy
- All samples assign back to Gulf of Alaska with > 95% probability



Equal number per area (n=45)

- 27.27% assignment accuracy
- 8.06% unassigned samples



1. Migration and Population Dynamics

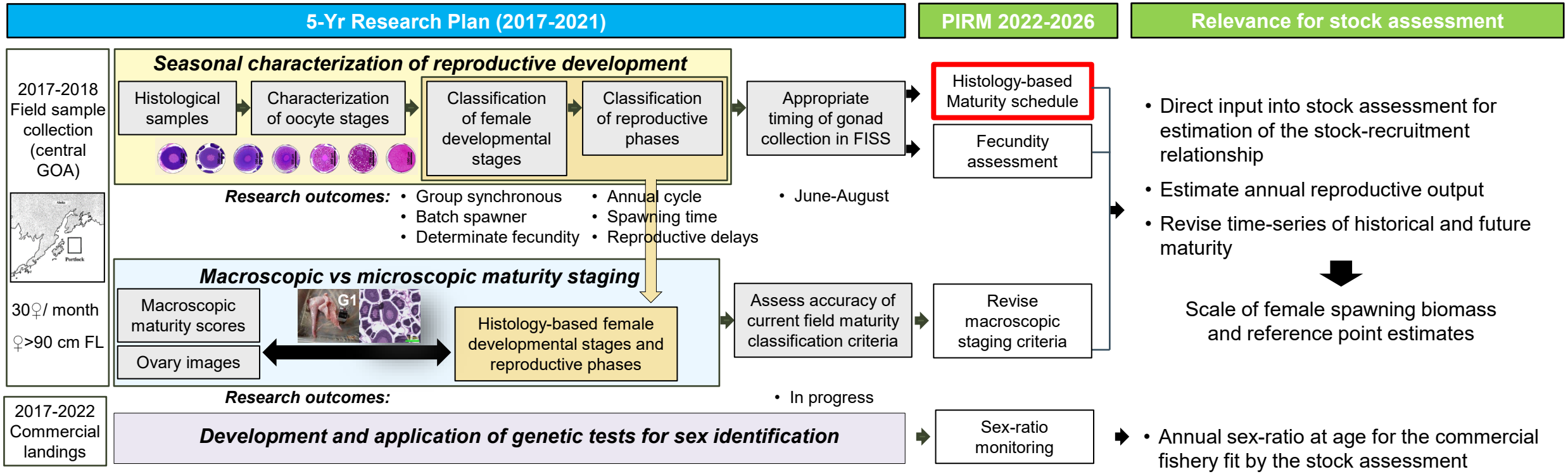
Conclusions

- Improved quality of the baseline dataset by increasing and balancing sample sizes.
- Results were very similar to those reported in IPHC-2024-SRB024-09 and continue to support the concept of a single genetic group in IPHC Convention Waters:
  - Unsupervised clustering methods failed to identify discrete genetic groups of Pacific halibut.
  - Limited ability to assign individuals back to the location in which they were sampled.

Next Steps

- Incorporate summer samples into existing analyses to examine and compare patterns of population structure over a larger spatial scale.

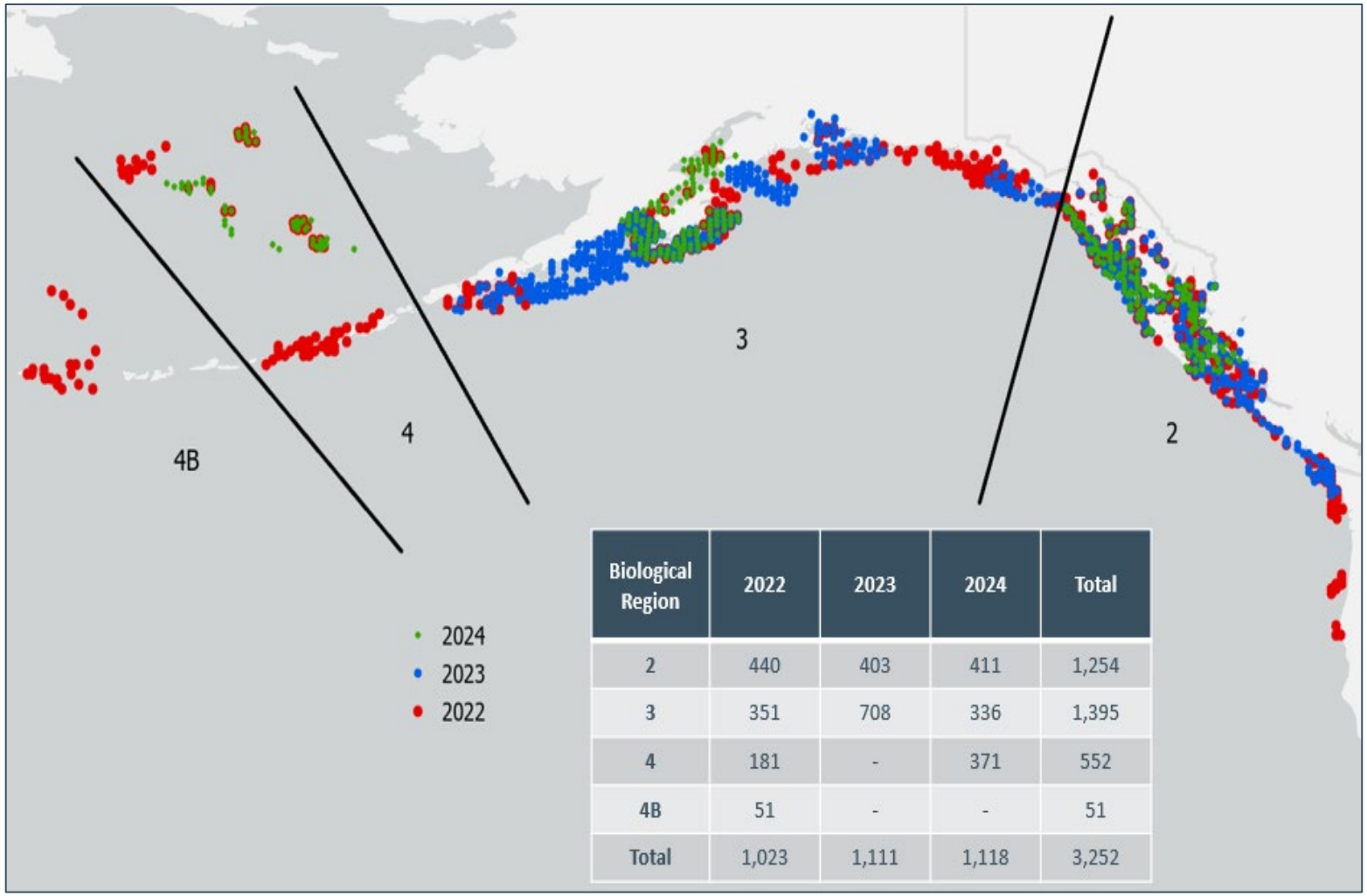
2. Reproduction



Publications: Fish et al. (2020) *J. Fish Biol.* ***97****: 1880–1885*
Fish et al. (2022) *Frontiers in Mar. Sci.* ***9****: 801759*
Simchick et al. (2024) *Gen. Comp. Endocrinol*. ***347****: 114425*

2. Reproduction

2022-2024 FISS
Collection for Histological Assessment

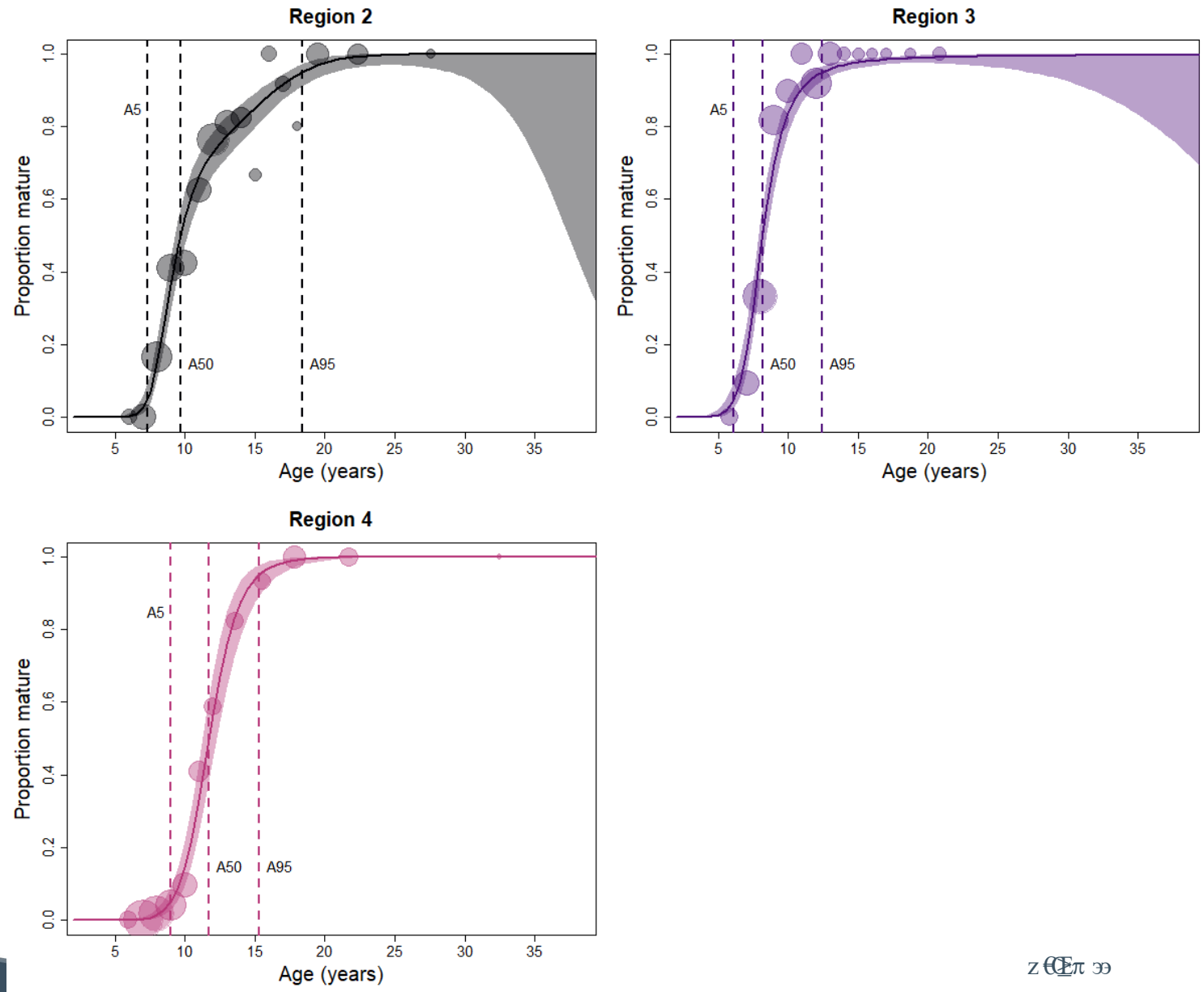


Biological Region	2022	2023	2024	Total
2	440	403	411	1,254
3	351	708	336	1,395
4	181	-	371	552
4B	51	-	-	51
Total	1,023	1,111	1,118	3,252

2. Reproduction

Histology-based ogives by biological region and year

- GAM s(log(Age) * Region) + Year * Region
- AIC = 2327.73
- k = 5
- EDF
  Region 2 = 2.99
  Region 3 = 2.36
  Region 4 = 1.00
  Region 4B = 1.00



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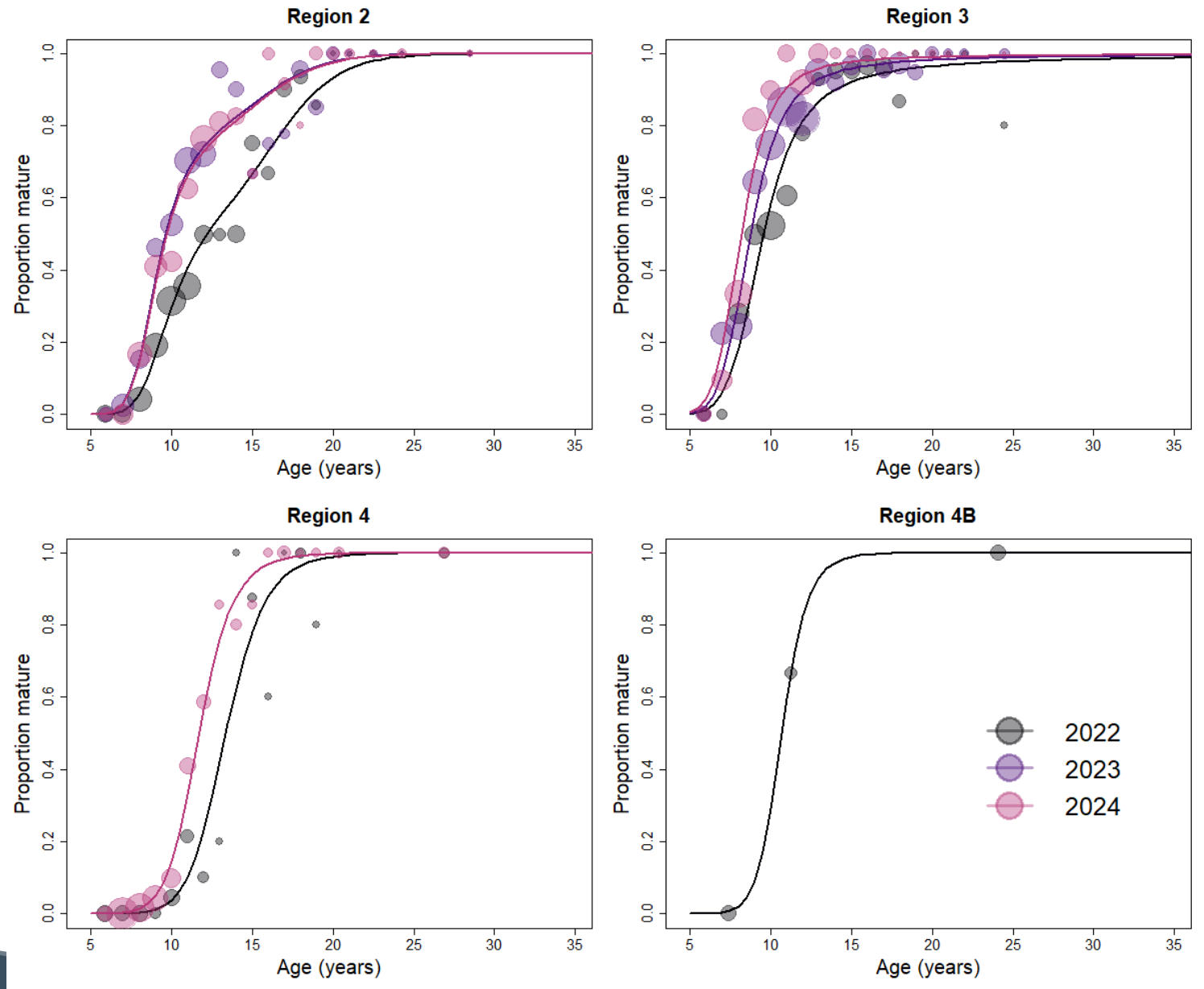
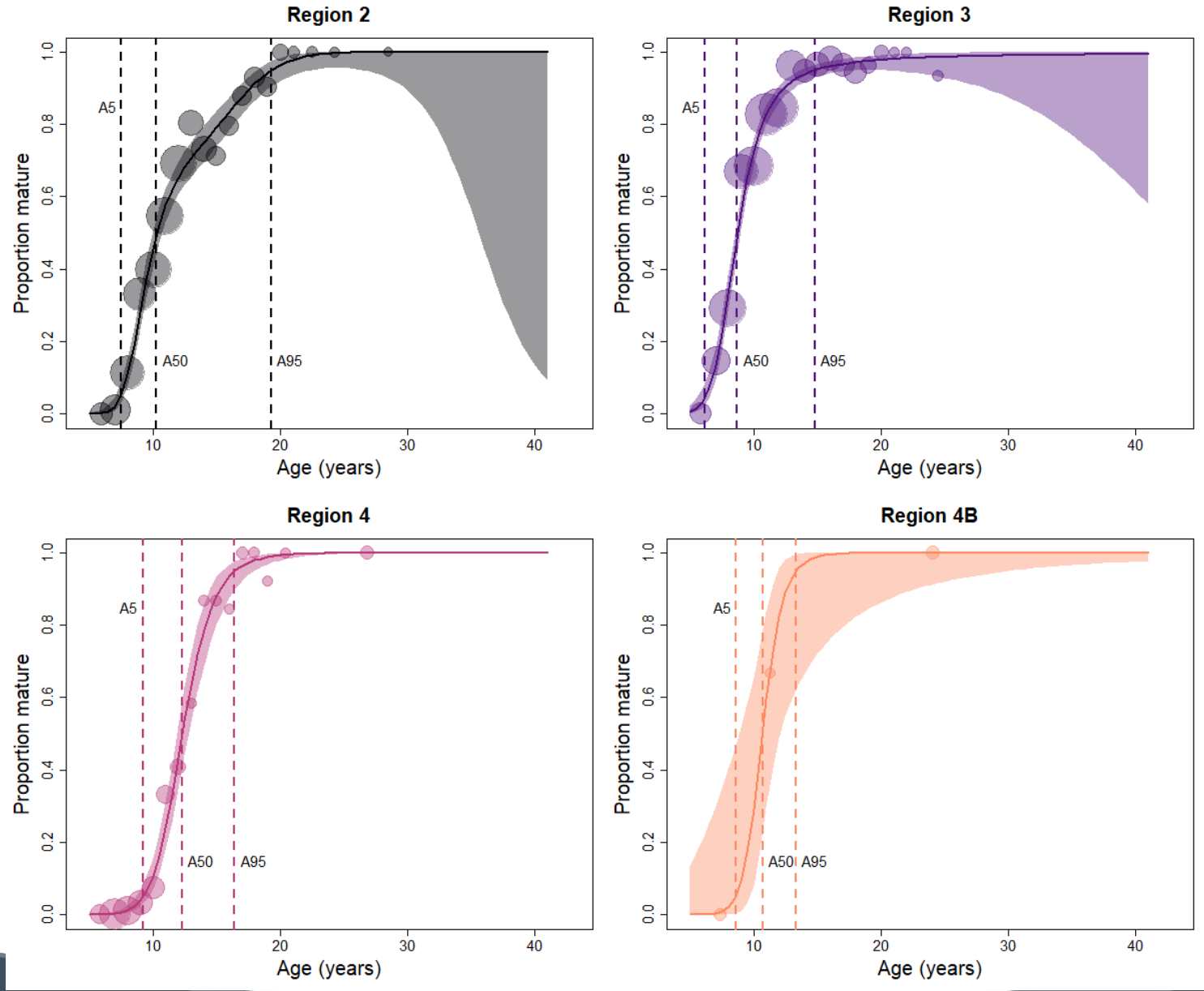


2. Reproduction

Histology-based ogives by biological region (2022-2024)

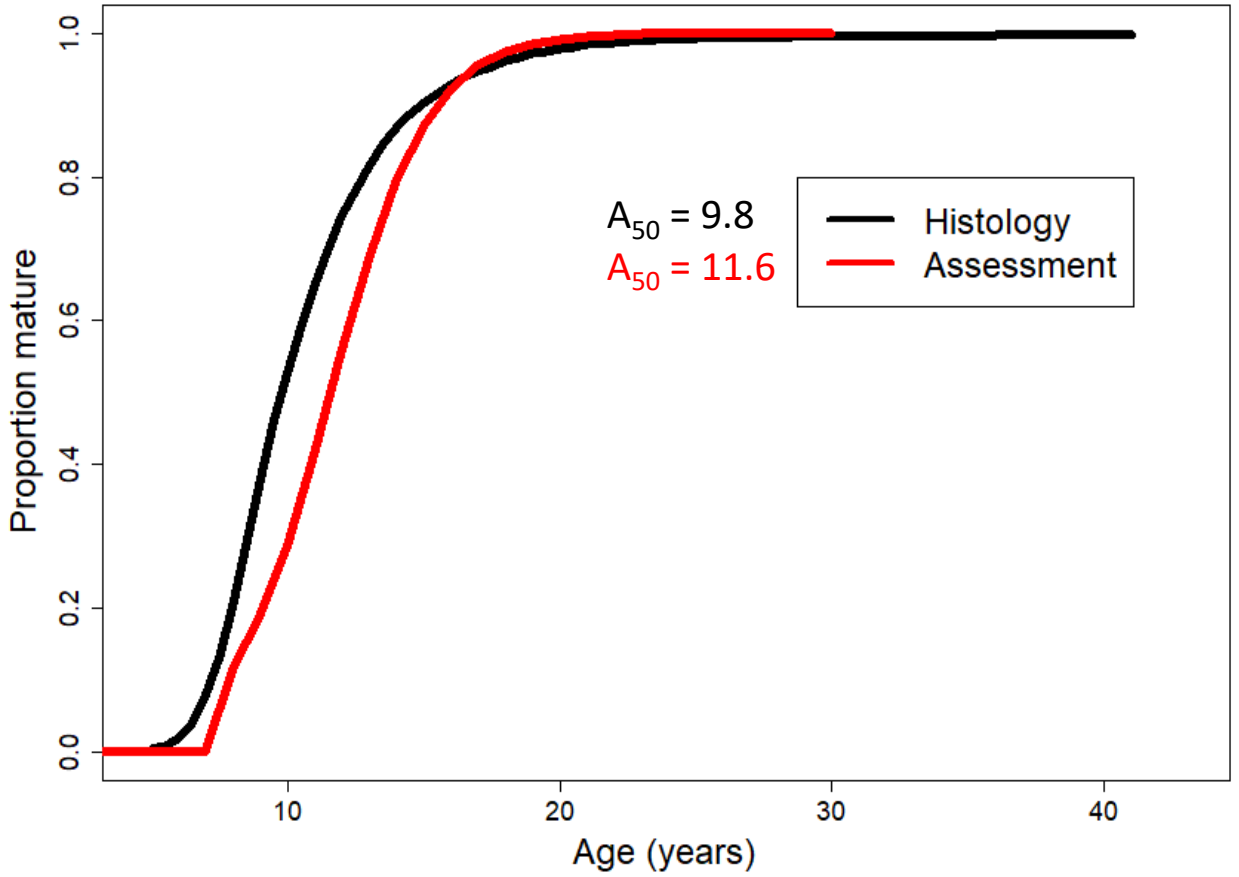
- GAM s(log(Age) * Region)
- AIC = 2414.87
- k = 5
- EDF
  Region 2 = 3.17
  Region 3 = 2.27
  Region 4 = 1.00
  Region 4B = 1.00



2. Reproduction

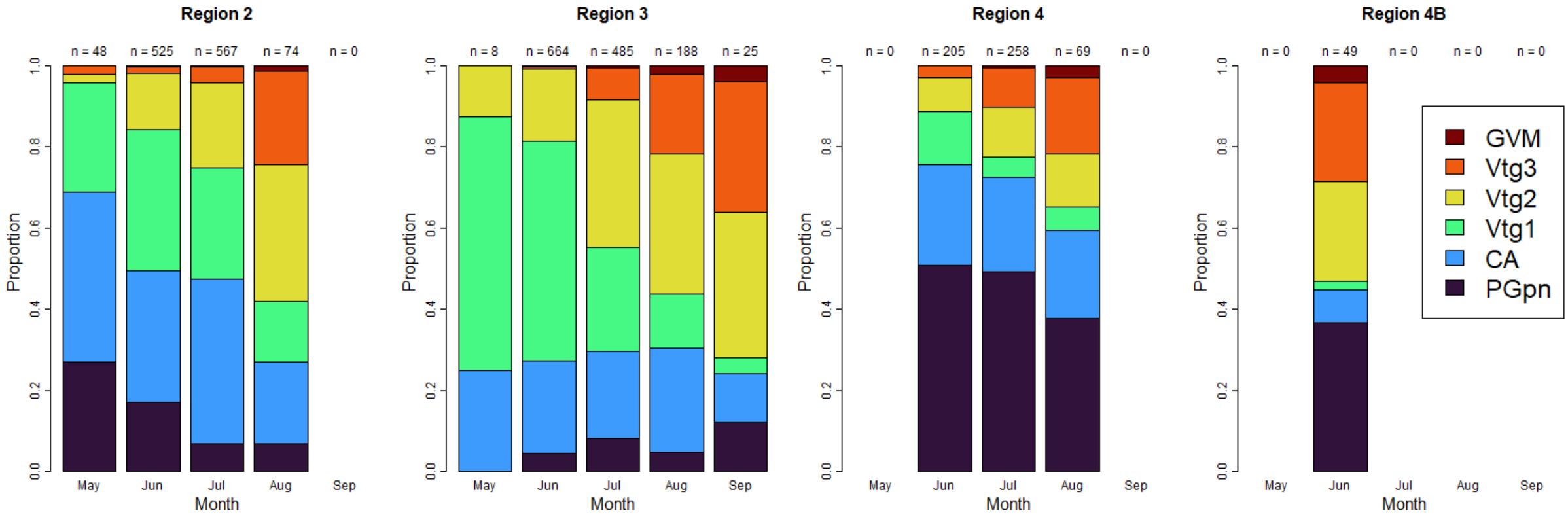
Histology-based coastwide ogive

- GAM s(log(Age) * Region)
- Coastwide ogive calculated from weighted regional ogives using average FISS space-time model abundance estimates from 2022-2024
- Coastwide ogive falls between Biological Regions 2 and 3



2. Reproduction

Female Developmental Stages: 2022-2024



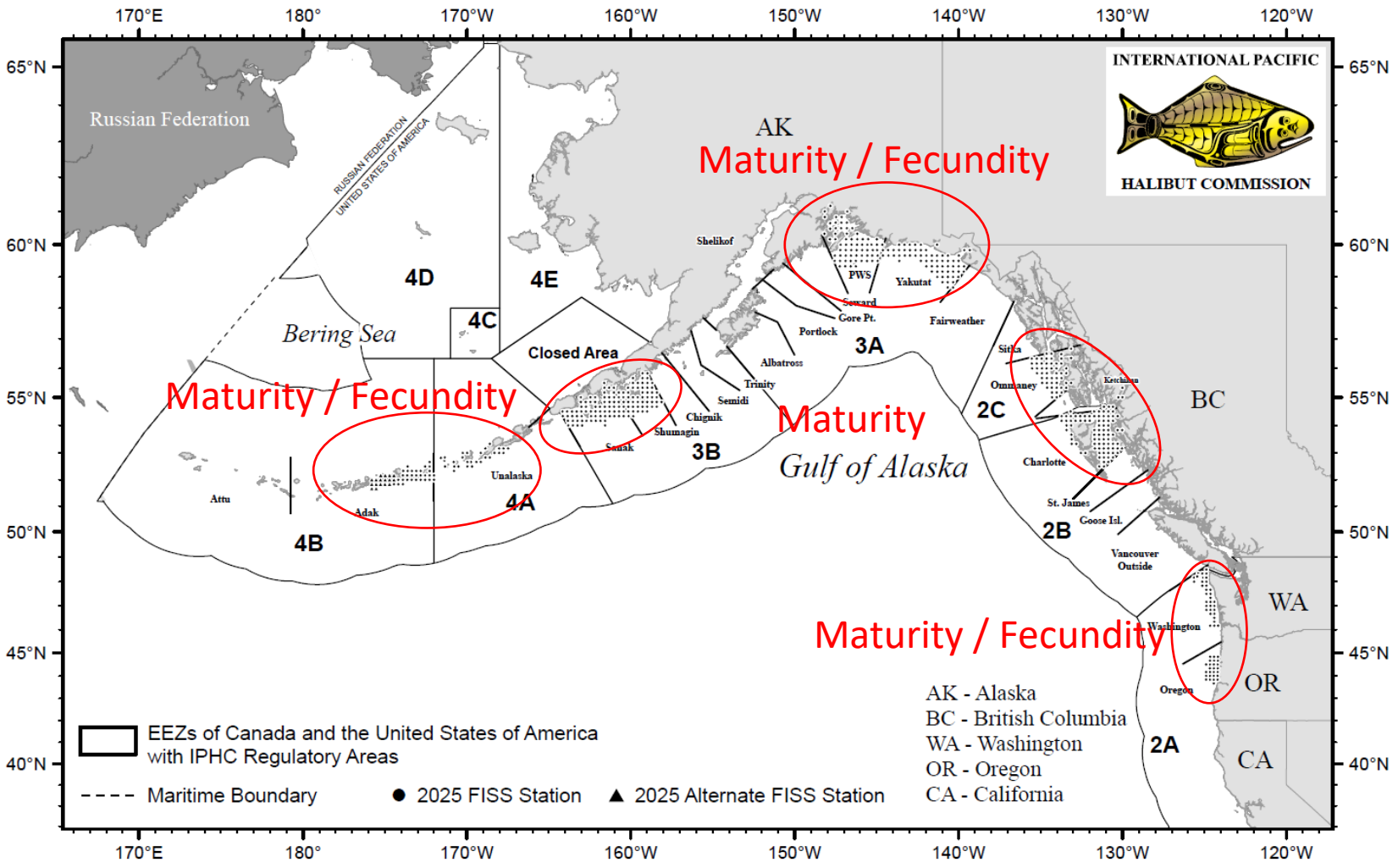
- Earlier maturation in Regions 4 and 4B
- Oocyte development progressively faster from east (Region 2) to west (Region 4B)

2. Reproduction

Histology-based ogive

2025 FISS Collection

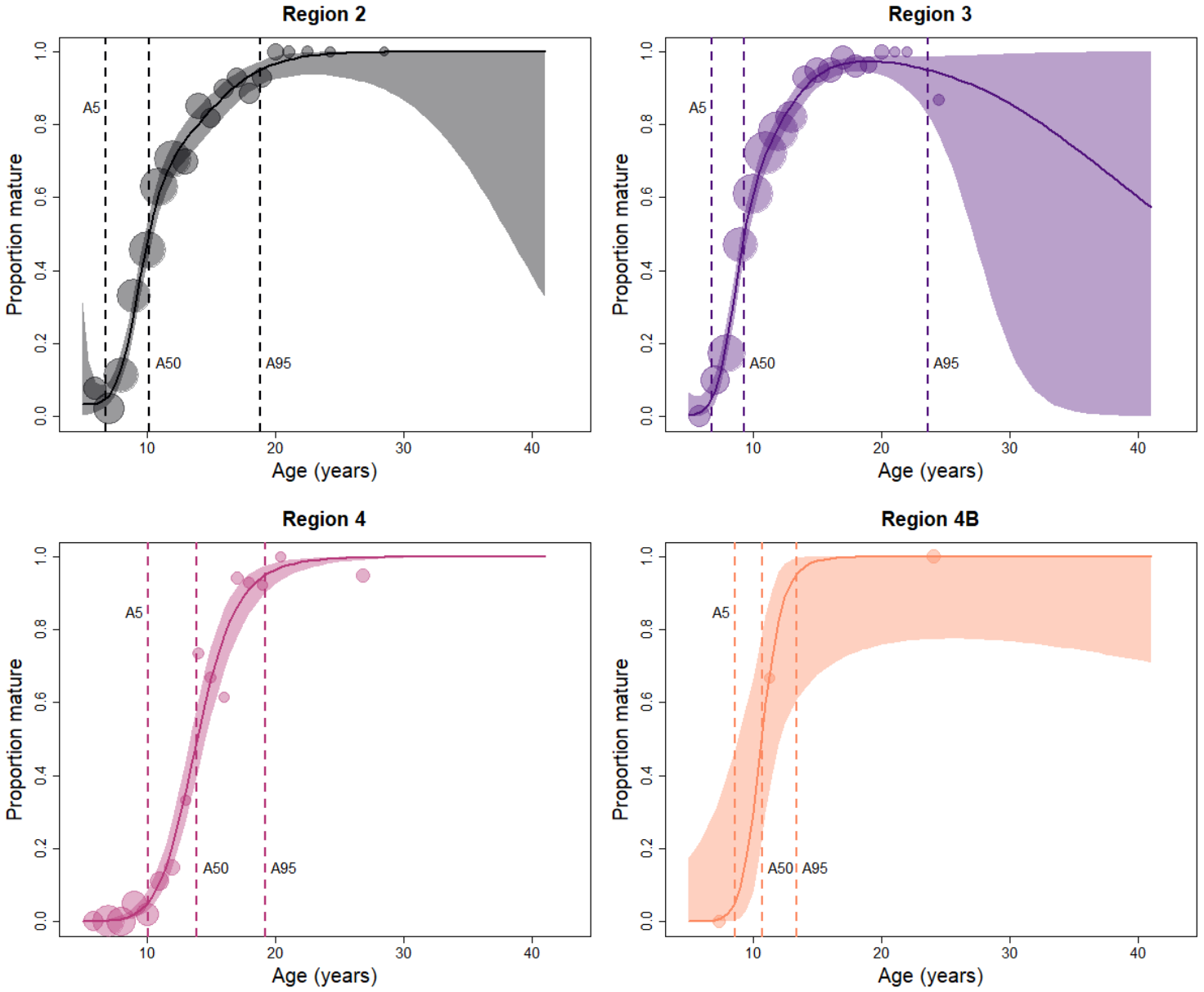
Biological Region	2025 (Target)
2	400
3	400
4	188
4B	414
Total	1,402



2. Reproduction

Visual (macroscopic)-based ogives by biological region (2022-2024)

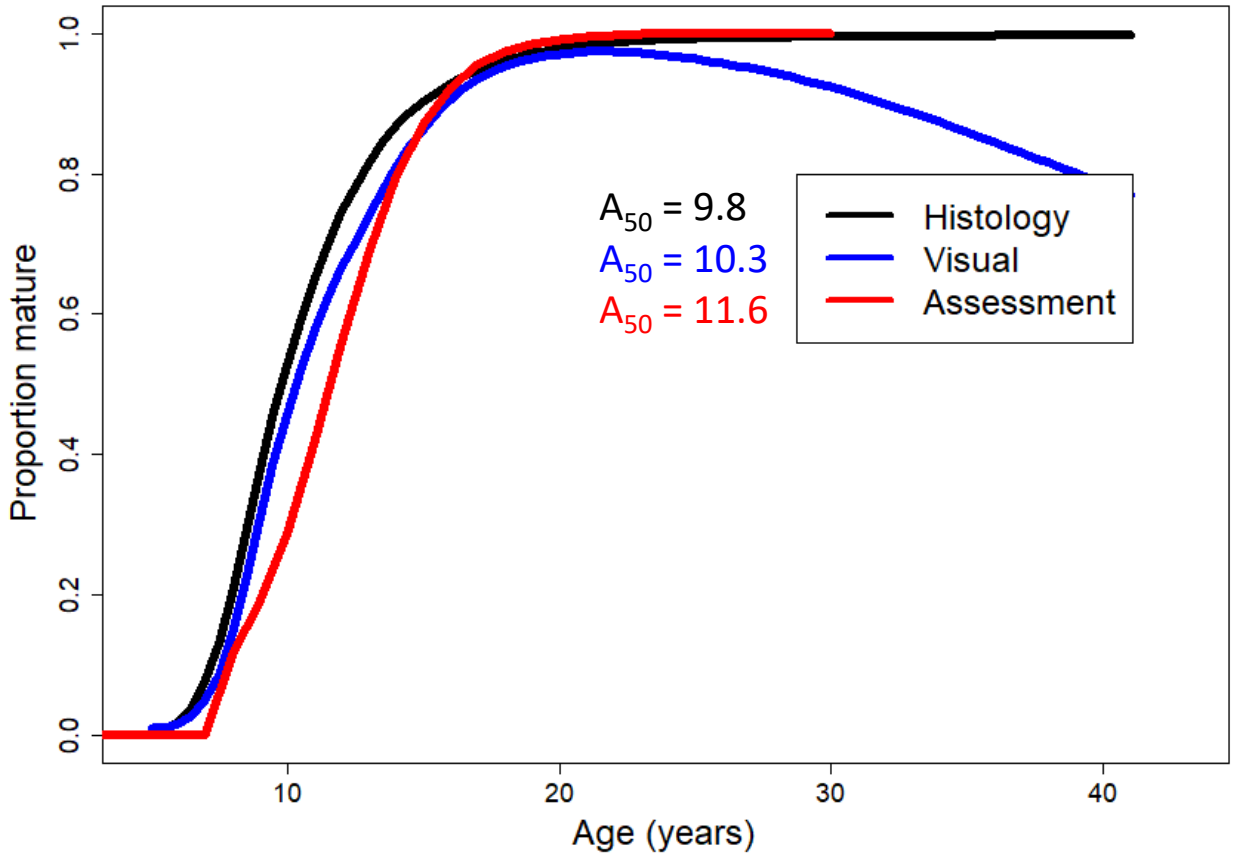
- GAM s(log(Age) * Region)
- AIC = 2518.67
- k = 8
- EDF
  Region 2 = 4.46
  Region 3 = 4.46
  Region 4 = 1.00
  Region 4B = 1.02



2. Reproduction

Visual (macroscopic)-based coastwide ogive (2022-2024)

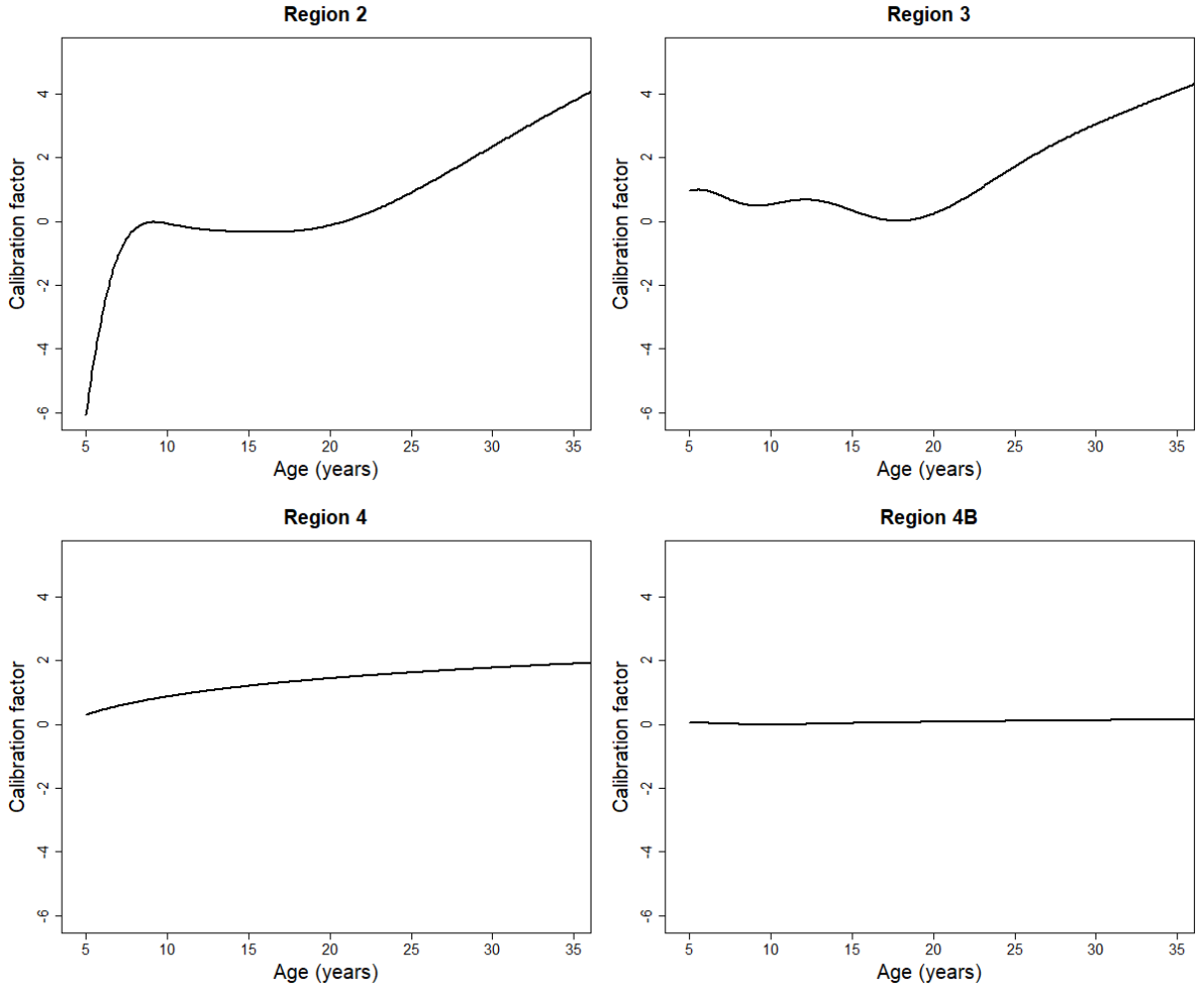
- GAM s(log(Age) * Region)
- Coastwide ogive calculated from weighted regional ogives using average FISS space-time model abundance estimates from 2022-2024



2. Reproduction

Histology-visual ogive calibration

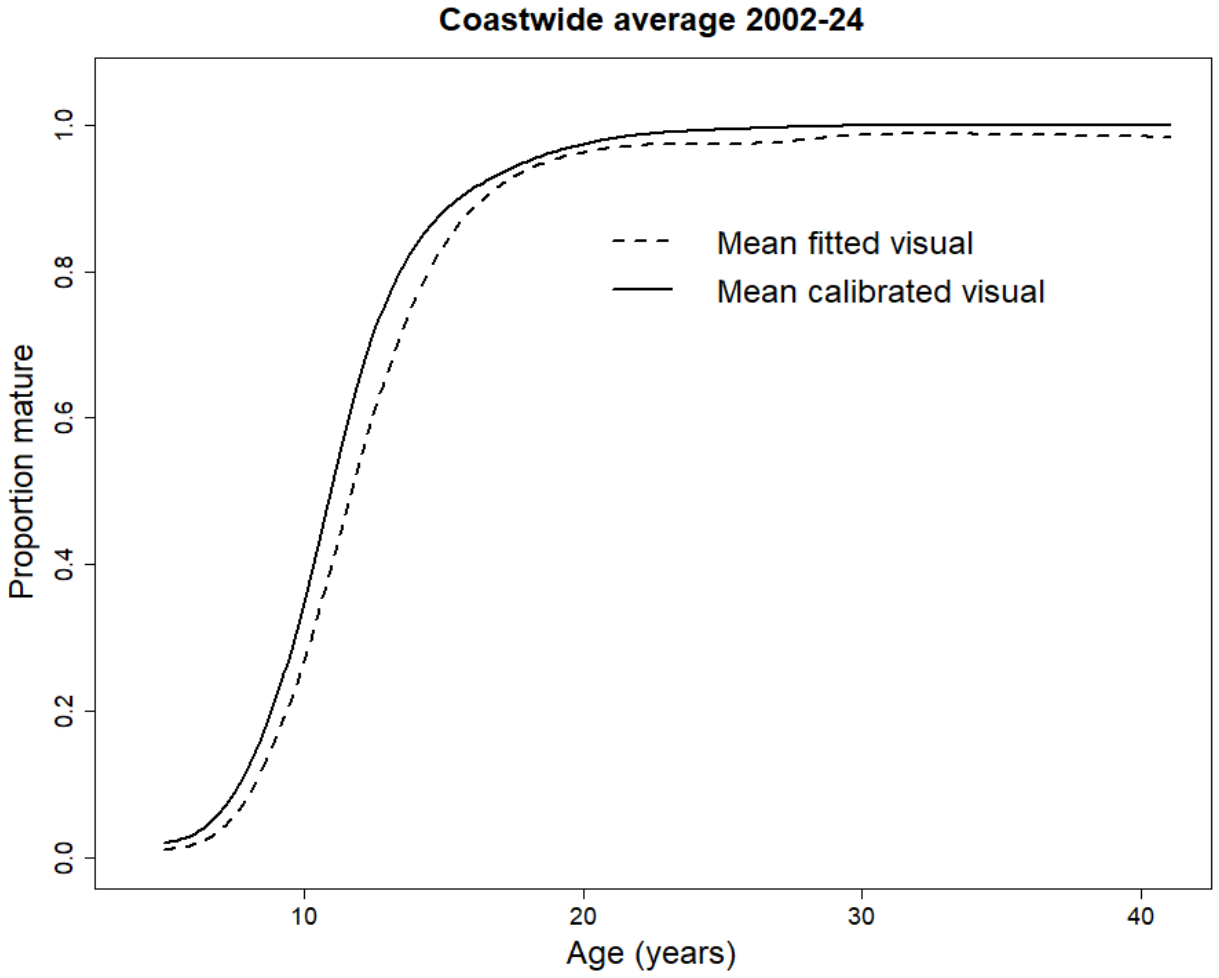
- Calibration between visual and histology estimates from 2022-2024
- The calibration factor at age, $\delta(a)$, is estimated as the difference between the histological and visual model estimates of maturity at age a on the logit scale.
- Estimated for each Biological Region
- Positive = shifted up for a given age
  Negative = shifted down



2. Reproduction

Calibrated historical visual-based coastwide ogive (2002-2024)

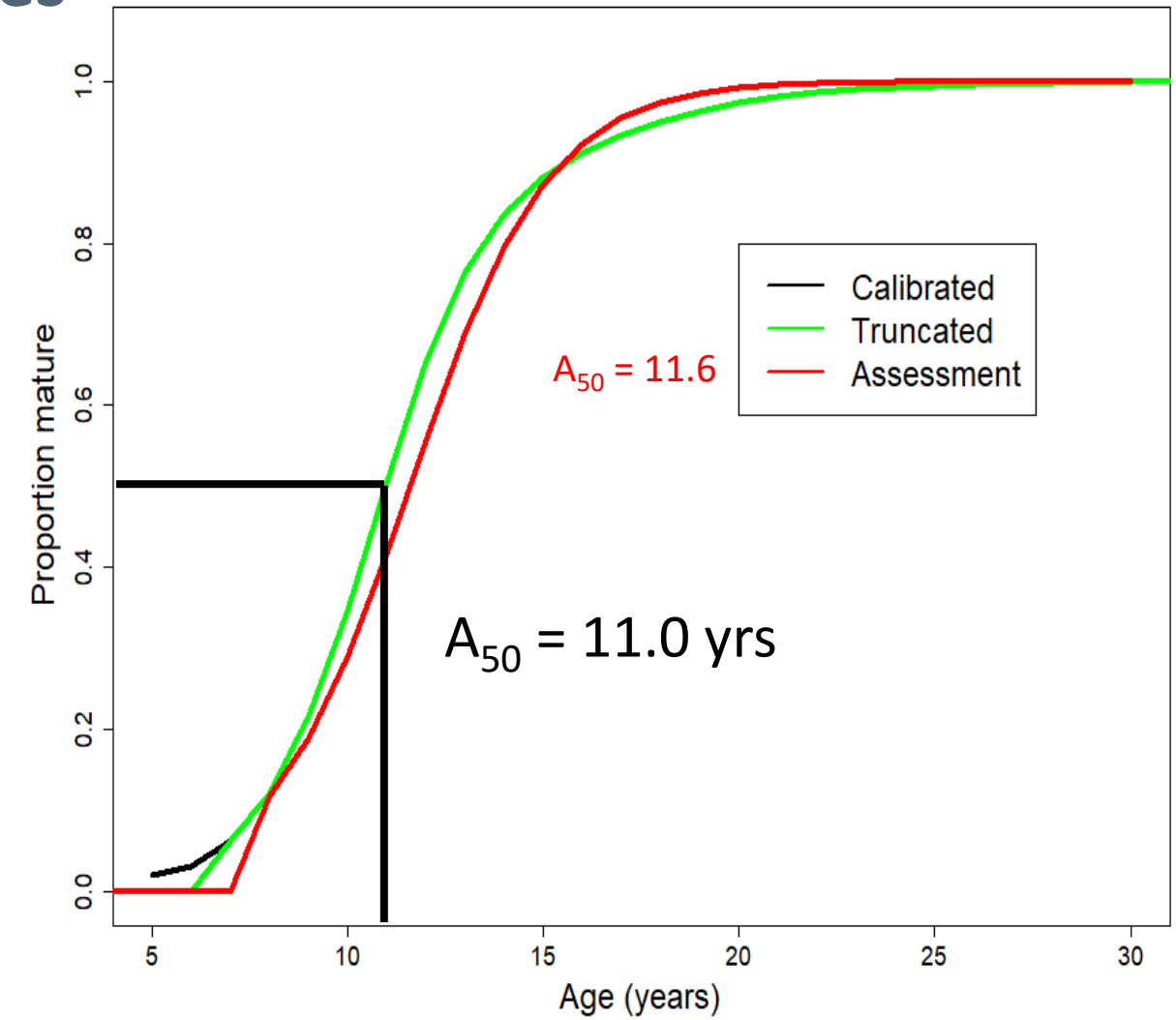
- Coastwide fitted visual maturity ogives by year estimated using three-year rolling data windows
- Applied calibration factor to obtain coastwide calibrated visual ogives
- Averaged across all three-year rolling data windows to obtain final coastwide calibrated visual maturity ogive (i.e. 2003-2005, 2004-2006, etc.)



2. Reproduction

Visual (macroscopic)-based estimates

- Comparison of new coastwide calibrated visual ogive (2002-2024) vs. current assessment ogive (2002-2003)
- Visual maturity estimates from the average 2002-2024 calibrated coastwide ogive are slightly to the left of current assessment ogive
- Truncated to zero < Age 7



2. Reproduction

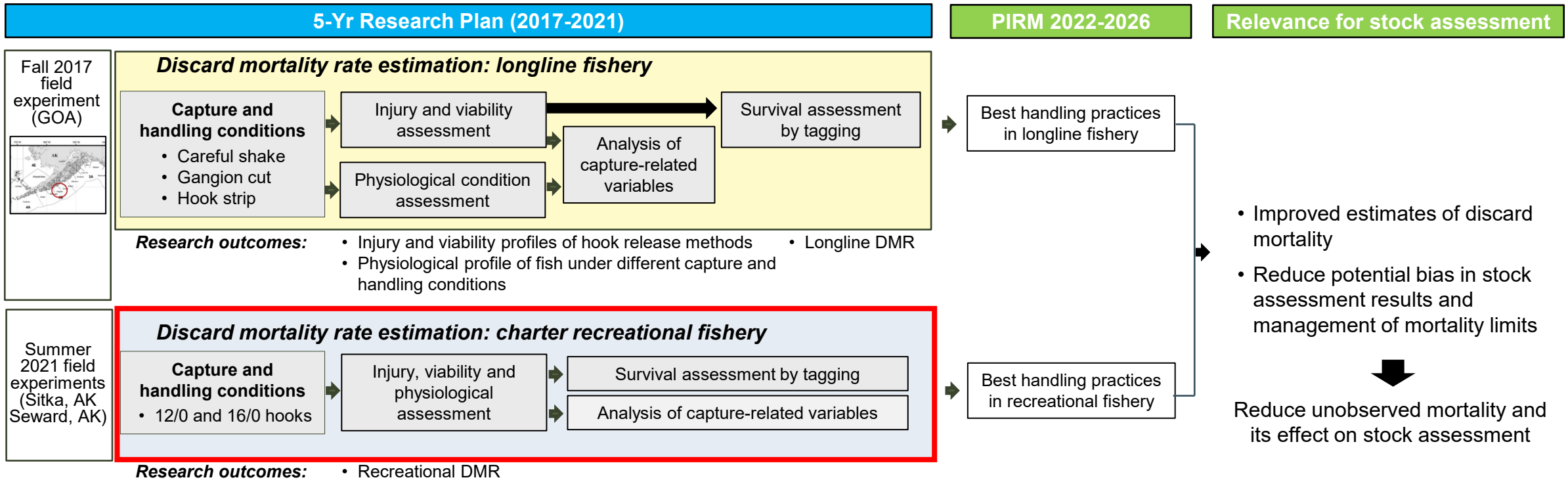
Conclusions

- Histology-based maturity estimates:
  - Region 3 continues to show higher proportion of mature females at younger ages
  - Regional and coastwide ogives have shifted to the left from 2022-2024

- Visual-based maturity estimates:
  - Maturity estimates have shifted back and forth from 2002-2024 (not consistent)
  - Calibrated coastwide ogive has shifted slightly to left of current assessment ogive

- Fecundity (next step in reproductive journey):
  - Samples collected in 2023 and 2024 (continue in 2025+)
  - Question: Is female Pacific halibut fecundity proportional to body weight?

3. Mortality and Survival Assessment



External funding: Saltonstall-Kennedy NOAA (2017-2020); NFWF (2019-2021); NPRB#2009 (2021-2022)

Publications:
Kroska et al. (2021) *Conservation Physiology* ***9****: coab001*
Loher et al. (2022) *North American Journal of Fisheries Management* ***42****: 37-49*
Dykstra et al. (2024) *Ocean & Coastal Management*. ***249****: 107018*.
} Longline fishery

Dykstra et al. In Preparation } Recreational fishery

4. Fishing technology

5-Yr Program of Integrated Research and Monitoring (2022-2026)

Relevance for stock assessment

Summer 2023 pilot test

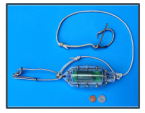
Investigate new methods for whale avoidance/deterrence to reduce whale depredation in the longline fishery

International Workshop on Protecting Fishery Catches from Whale Depredation → Catch protection device selection and production:
- Shuttle
- Slinky pot-Shroud

→ Pilot testing → Catch protection device refinement and improvement → Field testing in presence of whales:
- Killer whales (orcas)
- Sperm whales

Research outcomes:
- New tools for fishery avoidance and/or deterrence
- Improved estimation of depredation mortality

Collaboration with PSMFC



Investigate behavioral and physiological responses to fishing gear to reduce bycatch

Use of artificial illumination to reduce bycatch → Method refinement and improvement

Circle hook modifications to reduce rockfish bycatch → Method refinement and improvement

Research outcomes:
- New methods for reducing bycatch
- Improved estimation of bycatch mortality

- Increasing available yield for directed fishery.
- Reduce potential bias and uncertainty in the stock assessment.

↓

Improve mortality accounting

External funding: Bycatch Reduction Engineering Program NOAA NA21NMF4720534 (2021-2023), NA23NMF4720414 (2023-2025)

Publications: Lomeli et al. (2021) *Fisheries Research* ***233****: 105737*

Lomeli et al. (2023) *Ocean & Coastal Management* ***241****: 106664*

4. Fishing technology

NOAA FISHERIES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Bycatch Reduction Engineering Program
(BREP) NA23NMF4720414

Reducing whale depredation by protecting longline catches

Next phase: Testing shuttle in the presence of depredators

Secured funding from NOAA BREP 2023 NA23NMF4720414

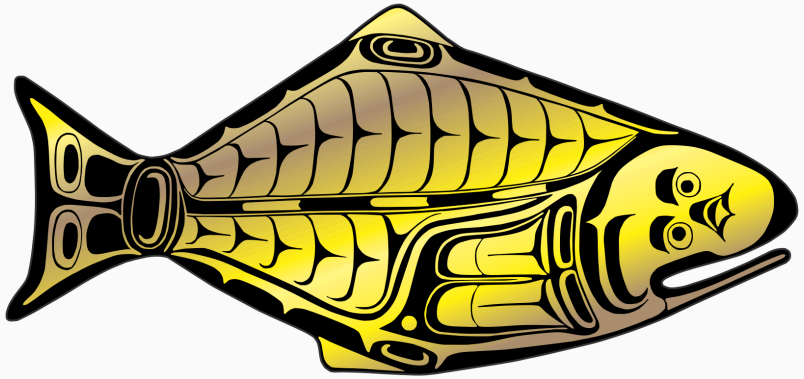
- Objectives:
  - 8 days of fishing in the presence of Orcas on the F/V Oracle.
  - Further refinements (attachment protocols, gangion/hook strength).
  - Catch rate comparisons with and without shuttle device.
  - Catch composition details (size ranges, species, catch volume).

- Field study scheduled for May 2025 in IPHC Regulatory Area 4A.

Summary of awarded research grants to IPHC

Project #	Grant agency	Project name	PI	Partners	IPHC Budget ($US)	Management implications	Grant period
1	Bycatch Reduction Engineering Program-NOAA	Full scale testing of devices to minimize whale depredation in longline fisheries (NOAA Award Number NA23NMF4720414)	IPHC	Alaska Fisheries Science Center-NOAA	$199,870	Mortality estimations due to whale depredation	November 2023 – April 2026
2	Alaska Sea Grant	Development of a non-lethal genetic-based method for aging Pacific halibut (R/2024-05)	IPHC, Alaska Pacific U. (APU)	Alaska Fisheries Science Center-NOAA (Juneau)	$60,374	Stock structure	January 2025-December 2026
				Total awarded ($)	**$260,244**		

INTERNATIONAL PACIFIC



HALIBUT COMMISSION

https://www.iphc.int/