INTERNATIONAL PACIFIC HALIBUT COMMISSION

Celebrating 100 Years

1924-2024

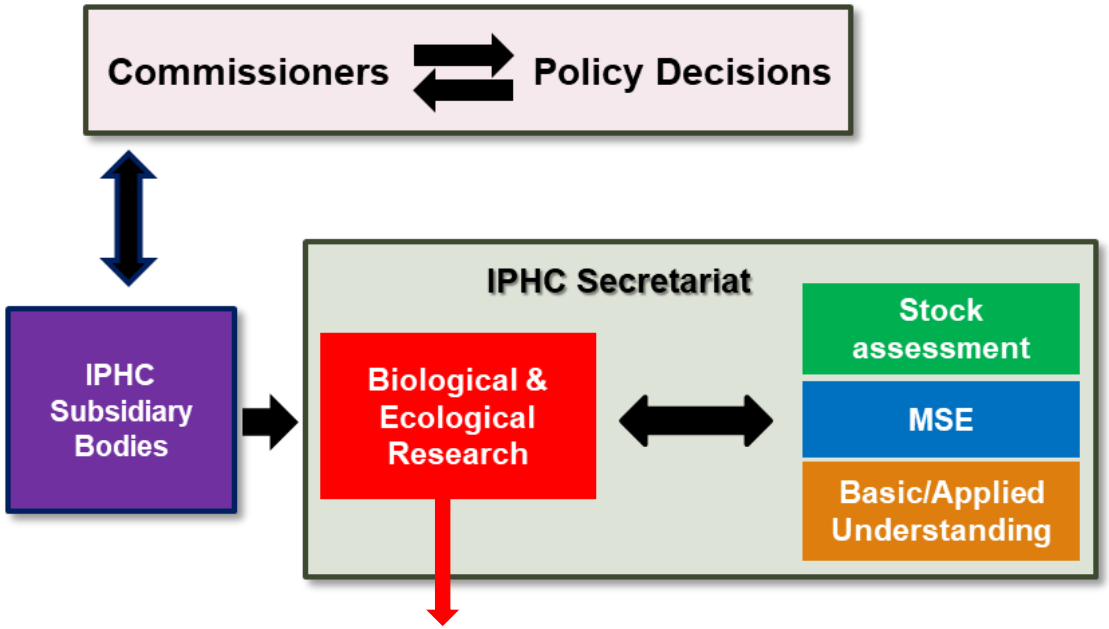
Report on current and future biological and ecosystem science research activities

Agenda item: 4.1.3

IPHC-2023-SRB023-08

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

Biological and Ecosystem Science Research



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

Research Areas:

- Migration and Population Dynamics
- Reproduction
- Growth
- Mortality and Survival Assessment
- Fishing Technology

Research activity priorization

Research areas	Research activities	Research outcomes	Relevance for stock assessment	Relevance for MSE	Specific analysis input	SA Rank	MSE Rank	Research priorization
Migration and population dynamics	Population structure	Population structure in the Convention Area	Altered structure of future stock assessments	Improve parametization of the Operating Model	If 4B is found to be functionally isolated, a separate assessment may be constructed for that IPHC Regulatory Area	2. Biological input	1. Biological parameterization and validation of movement estimates and recruitment distribution	**2**
	Distribution	Assignment of individuals to source populations and assessment of distribution changes	Improve estimates of productivity		Will be used to define management targets for minimum spawning biomass by Biological Region	3. Biological input		**2**
	Larval and juvenile connectivity studies	Improved understanding of larval and juvenile distribution	Improve estimates of productivity		Will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region	3. Biological input	1. Biological parameterization and validation of movement estimates	**2**
Reproduction	Histological maturity assessment	Updated maturity schedule	Scale biomass and reference point estimates	Improve simulation of spawning biomass in the Operating Model	Will be included in the stock assessment, replacing the current schedule last updated in 2006	1. Biological input	2. Biological parameterization and validation of recruitment variability and distribution	**1**
	Examination of potential skip spawning	Incidence of skip spawning			Will be used to adjust the asymptote of the maturity schedule, if/when a time-series is available this will be used as a direct input to the stock assessment			**1**
	Fecundity assessment	Fecundity-at-age and -size information			Will be used to move from spawning biomass to egg-output as the metric of reproductive capability in the stock assessment and management reference points			**1**
	Examination of accuracy of current field macroscopic maturity classification	Revised field maturity classification			Revised time-series of historical (and future) maturity for input to the stock assessment			**1**
Growth	Evaluation of somatic growth variation as a driver for changes in size-at-age	Identification and application of markers for growth pattern evaluation	Scale stock productivity and reference point estimates	Improve simulation of variability and allow for scenarios investigating climate change	May inform yield-per-recruit and other spatial evaluations of productivity that support mortality limit-setting		3. Biological parameterization and validation for growth projections	**5**
		Environmental influences on growth patterns			May provide covariates for projecting short-term size-at-age. May help to delineate between effects due to fishing and those due to environment, thereby informing appropriate management response			**5**
		Dietary influences on growth patterns and physiological condition			May provide covariates for projecting short-term size-at-age. May help to deleineate between effects due to fishing and those due to environment, thereby informing appropriate management response			**5**
Mortality and survival assessment	Discard mortality rate estimate: longline fishery	Experimentally-derived DMR	Improve trends in unobserved mortality	Improve estimates of stock productivity	Will improve estimates of discard mortality, reducing potential bias in stock assessment results and management of mortality limits	1. Fishery yield	1. Fishery parameterization	**4**
	Discard mortality rate estimate: recreational fishery				Will improve estimates of discard mortality, reducing potential bias in stock assessment results and management of mortality limits			**4**
	Best handling and release practices	Guidelines for reducing discard mortality			May reduce discard mortality, thereby increasing available yield for directed fisheries	2. Fishery yield		**4**
Fishing technology	Whale depredation accounting and tools for avoidance	New tools for fishery avoidance/deterence; improved estimation of depredation mortality	Improve mortality accounting	Improve estimates of stock productivity	May reduce depredation mortality, thereby increasing available yield for directed fisheries. May also be included as another explicit source of mortality in the stock assessment and mortality limit setting process depending on the estimated magnitude	1. Assessment data collection and processing		**3**
	Bycatch reduction	Development of methods for reducing bycatch and better estimate mortality	Improve mortality accounting	Improve estimates of stock productivity	May reduce depredation mortality, thereby increasing available yield for directed fisheries. May also be included as another explicit source of mortality in the stock assessment and mortality limit setting process depending on the estimated magnitude	1. Assessment data collection and processing		**3**

Research activity priorization

Research areas	Research activities	Research outcomes	Relevance for stock assessment	Relevance for MSE	Specific analysis input	SA Rank	MSE Rank	Research priorization
Migration and population dynamics	Population structure	Population structure in the Convention Area	Altered structure of future stock assessments	Improve parametization of the Operating Model	If 4B is found to be functionally isolated, a separate assessment may be constructed for that IPHC Regulatory Area	2. Biological input	1. Biological parameterization and validation of movement estimates and recruitment distribution	**2**
	Distribution	Assignment of individuals to source populations and assessment of distribution changes	Improve estimates of productivity		Will be used to define management targets for minimum spawning biomass by Biological Region	3. Biological input		**2**
	Larval and juvenile connectivity studies	Improved understanding of larval and juvenile distribution	Improve estimates of productivity		Will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region	3. Biological input	1. Biological parameterization and validation of movement estimates	**2**
Reproduction	Histological maturity assessment	Updated maturity schedule	Scale biomass and reference point estimates	Improve simulation of spawning biomass in the Operating Model	Will be included in the SA, replacing the current schedule last updated in 2006	1. Biological input	2. Biological parameterization and validation of recruitment variability and distribution	**1**
	Fecundity assessment	Fecundity-at-age and -size information			Will be used to move from spawning biomass to egg-output as the metric of reproductive capability in the SA and management reference points			**1**
	Examination of accuracy of current field macroscopic maturity classification	Revised field maturity classification			Revised time-series of historical (and future) maturity for input to the SA			**1**
	Examination of potential skip spawning	Incidence of skip spawning			Will be used to adjust the asymptote of the maturity schedule, if/when a time-series is available this will be used as a direct input to the SA			**1**

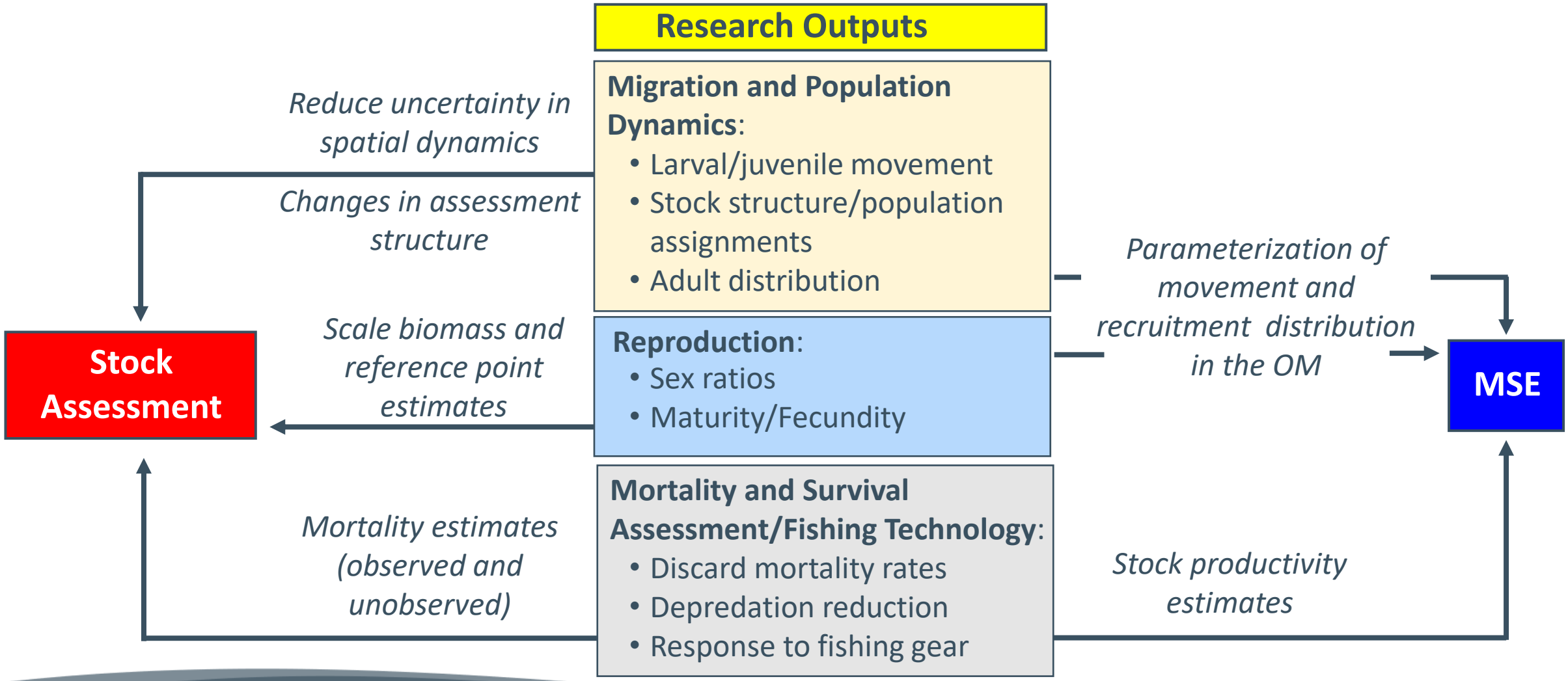
Top research priorities for stock assessment

SA Rank	Research outcomes	Relevance for stock assessment	Specific analysis input	Research Area	Research activities
1. Biological input	Updated maturity schedule	Scale biomass and reference point estimates	Will be included in the stock assessment, replacing the current schedule last updated in 2006	Reproduction	Histological maturity assessment
	Incidence of skip spawning		Will be used to adjust the asymptote of the maturity schedule, if/when a time-series is available this will be used as a direct input to the stock assessment		Examination of potential skip spawning
	Fecundity-at-age and -size information		Will be used to move from spawning biomass to egg-output as the metric of reproductive capability in the stock assessment and management reference points		Fecundity assessment
	Revised field maturity classification		Revised time-series of historical (and future) maturity for input to the stock assessment		Examination of accuracy of current field macroscopic maturity classification
2. Biological input	Stock structure of IPHC Regulatory Area 4B relative to the rest of the Convention Area	Altered structure of future stock assessments	If 4B is found to be functionally isolated, a separate assessment may be constructed for that IPHC Regulatory Area	Migration and population dynamics	Population structure
3. Biological input	Assignment of individuals to source populations and assessment of distribution changes	Improve estimates of productivity	Will be used to define management targets for minimum spawning biomass by Biological Region		Distribution
	Improved understanding of larval and juvenile distribution		Will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region		Larval and juvenile connectivity studies
1. Assessment data collection and processing	Sex ratio-at-age	Scale biomass and fishing intensity	Annual sex-ratio at age for the commercial fishery fit by the stock assessment	Reproduction	Sex ratio of current commercial landings
	Historical sex ratio-at-age		Annual sex-ratio at age for the commercial fishery fit by the stock assessment		Historical sex ratios based on archived otolith DNA analyses
2. Assessment data collection and processing	New tools for fishery avoidance/deterence; improved estimation of depredation mortality	Improve mortality accounting	May reduce depredation mortality, thereby increasing available yield for directed fisheries. May also be included as another explicit source of mortality in the stock assessment and mortality limit setting process depending on the estimated magnitude	Fishing technology	Whale depredation accounting and tools for avoidance
1. Fishery yield	Physiological and behavioral responses to fishing gear	Reduce incidental mortality	May increase yield available to directed fisheries	Fishing technology	Biological interactions with fishing gear
2. Fishery yield	Guidelines for reducing discard mortality	Improve estimates of unobserved mortality	May reduce discard mortality, thereby increasing available yield for directed fisheries	Mortality and survival assessment	Best handling practices: recreational fishery

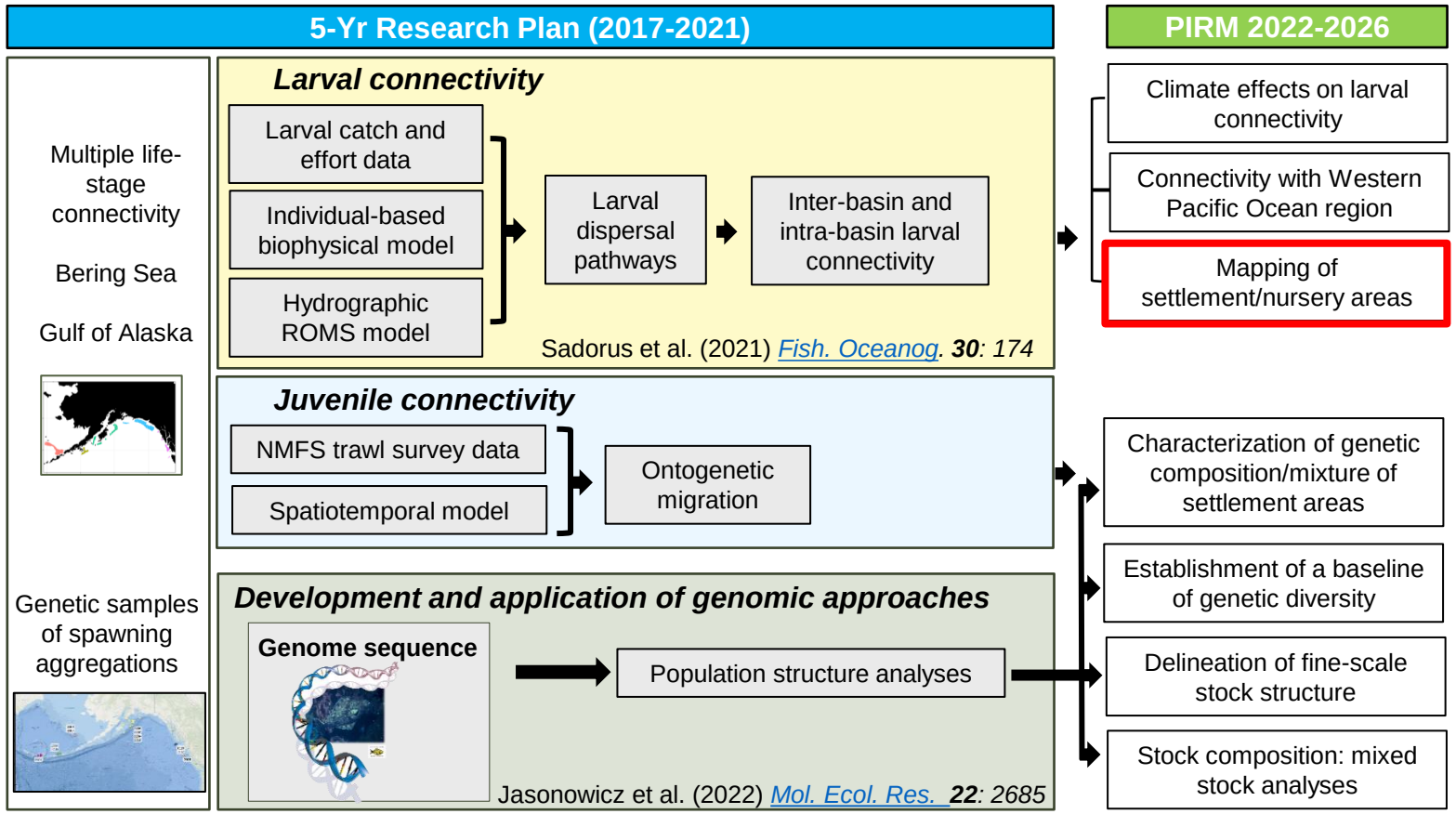
Top research priorities for MSE

MSE Rank	Research outcomes	Relevance for MSE	Research Area	Research activities
1. Biological parameterization and validation of movement estimates	Improved understanding of larval and juvenile distribution	Improve parametization of the Operating Model	**Migration and population dynamics**	Larval and juvenile connectivity studies
	Stock structure of IPHC Regulatory Area 4B relative to the rest of the Convention Area			Population structure
2. Biological parameterization and validation of recruitment variability and distribution	Assignment of individuals to source populations and assessment of distribution changes	Improve simulation of recruitment variability and parametization of recruitment distribution in the Operating Model		Distribution
	Establishment of temporal and spatial maturity and spawning patterns	Improve simulation of recruitment variability and parametization of recruitment distribution in the Operating Model	**Reproduction**	Recruitment strength and variability
3. Biological parameterization and validation for growth projections	Identification and application of markers for growth pattern evaluation	Improve simulation of variability and allow for scenarios investigating climate change	**Growth**	Evaluation of somatic growth variation as a driver for changes in size-at-age
	Environmental influences on growth patterns			
	Dietary influences on growth patterns and physiological condition			
1. Fishery parameterization	Experimentally-derived DMRs	Improve estimates of stock productivity	**Mortality and survival assessment**	Discard mortality rate estimate: recreational fishery

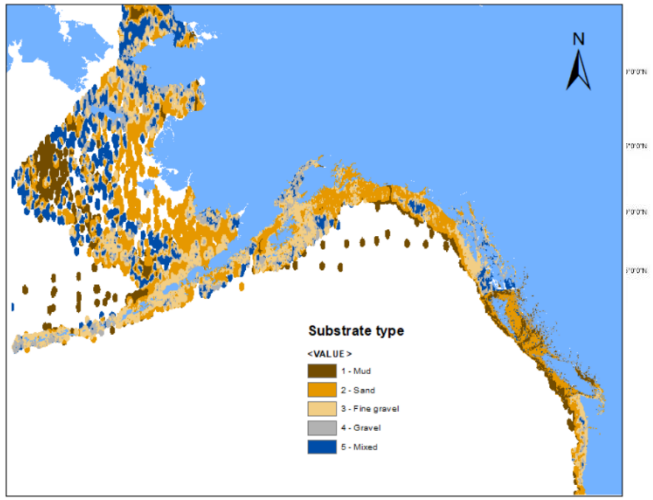
Key research outputs informing management



1. Migration and Population Dynamics



- Substrate information: usSeabed database.
- B.C. substrate layer 100-m resolution– provided by Dr. Dana Haggarty (DFO).
- Next step: bathymetry layer.



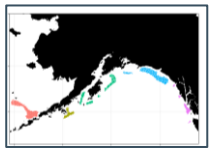
1. Migration and Population Dynamics

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*

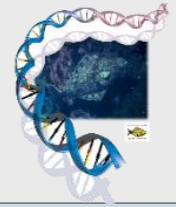
Juvenile connectivity

- 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

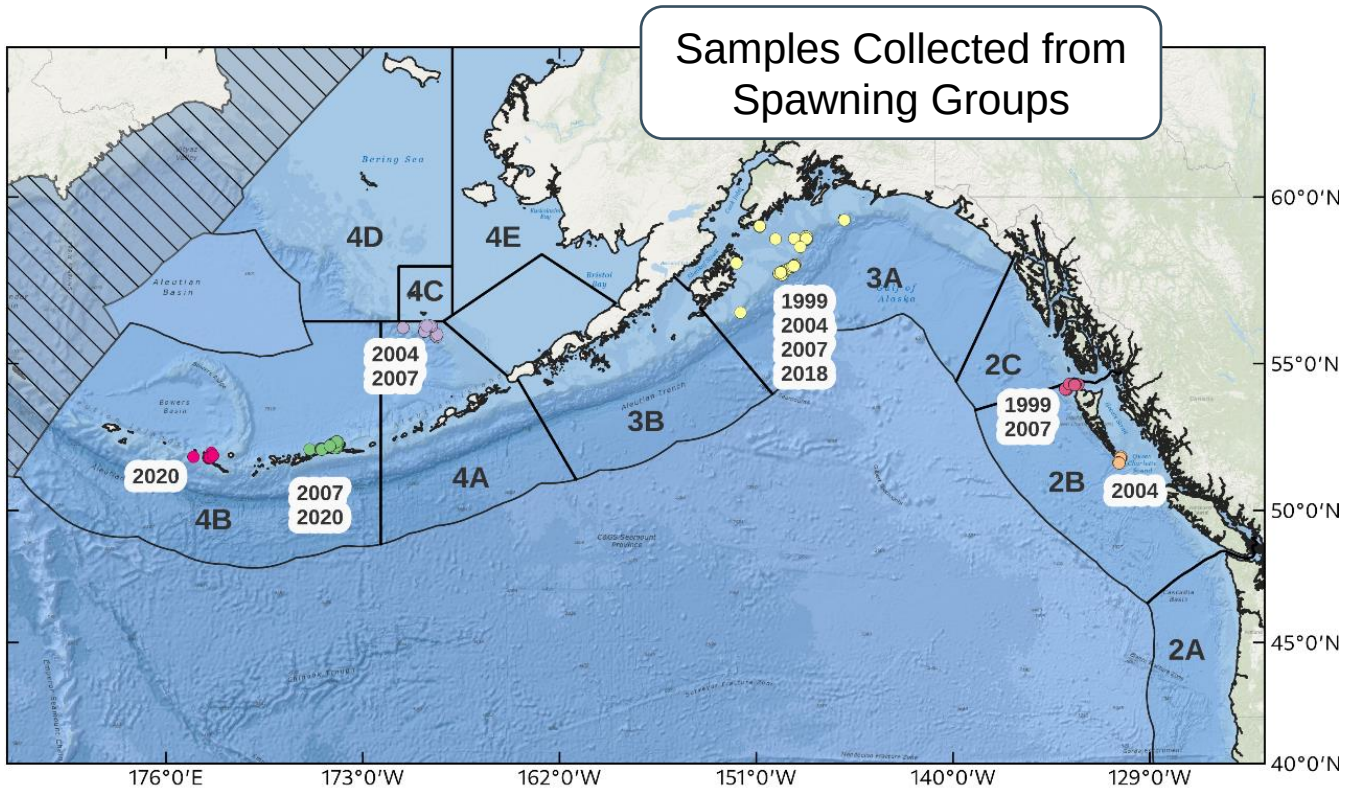
INTERNATIONAL PACIFIC HALIBUT COMMISSION

1924 100 years 2024

1. Migration and Population Dynamics

Population Genomics

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



NPRB Project 2110 (2022-2024)

- **L**ow-**c**overage **w**hole-**g**enome **r**esequencing (lcWGR)
- Allows for screening genomic variation at very high resolution
- Establish Genetic Baseline
- Identify potential local and/or environmental adaptations.

- **570 individuals (~ 50/collection)**
- **3 sequencing runs - Illumina NovaSeq S4**
- **Mean coverage - 3.5x**
- **10,230,908 autosomal SNPs**
- **4,725,899 (minor allele frequency ≥ 0.05)**

1. Migration and Population Dynamics

Pacific Halibut Reference Genome

- Version 2 - March 2022 (NCBI RefSeq: GCF_022539355.2)
- 602.2 Mbp (24 chromosomes)
- Fully Annotated (27,944 genes)
  - Provide genetic basis for life-history traits (e.g., growth, maturity, migratory behavior, etc.).
- Large(12 Mbp) sex-associated region on Chr09

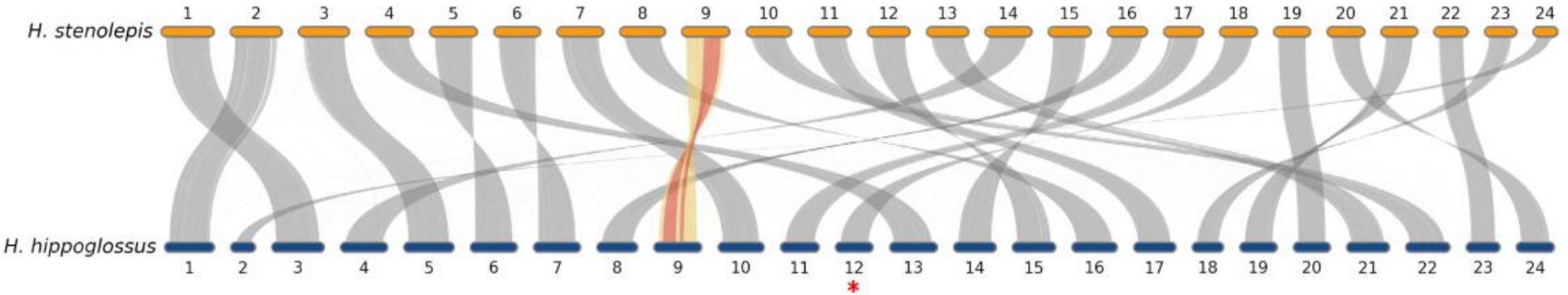
Received: 10 December 2021 | Revised: 22 April 2022 | Accepted: 11 May 2022
DOI: 10.1111/1755-0998.13641

MOLECULAR ECOLOGY RESOURCES WILEY

RESOURCE ARTICLE

Generation of a chromosome-level genome assembly for Pacific halibut (*Hippoglossus stenolepis*) and characterization of its sex-determining genomic region

Andrew J. Jasonowicz[1] | Anna Simeon[1,2] | Margot Zahm[3] | Cédric Cabau[4] | Christophe Klopp[3] | Céline Roques[5] | Carole Iampietro[5] | Jérôme Lluch[5] | Cécile Donnadieu[5] | Hugues Parrinello[6] | Daniel P. Drinan[2] | Lorenz Hauser[2] | Yann Guiguen[7] | Josep V. Planas[1]

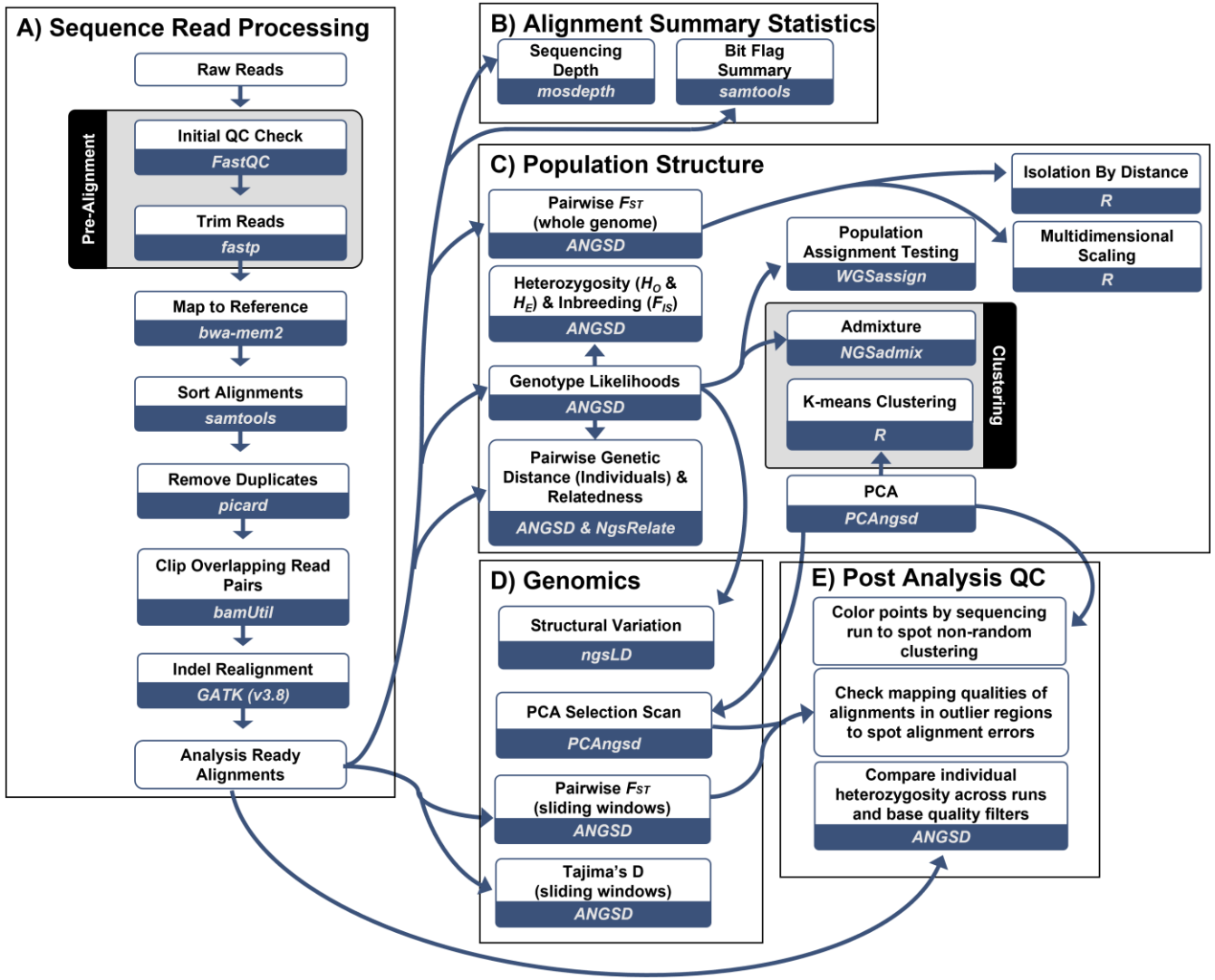


1. Migration and Population Dynamics

Bioinformatic Workflow

Figure 1. Proposed bioinformatic workflow for the interrogation of low-coverage whole-genome sequence data. This diagram tracks the flow of data through the main stages of this project:

(A) raw sequence read processing,
(B) alignment summaries,
(C) analysis of population structure,
(D) genomic analyses,
(E) quality control steps to be taken.



1. Migration and Population Dynamics

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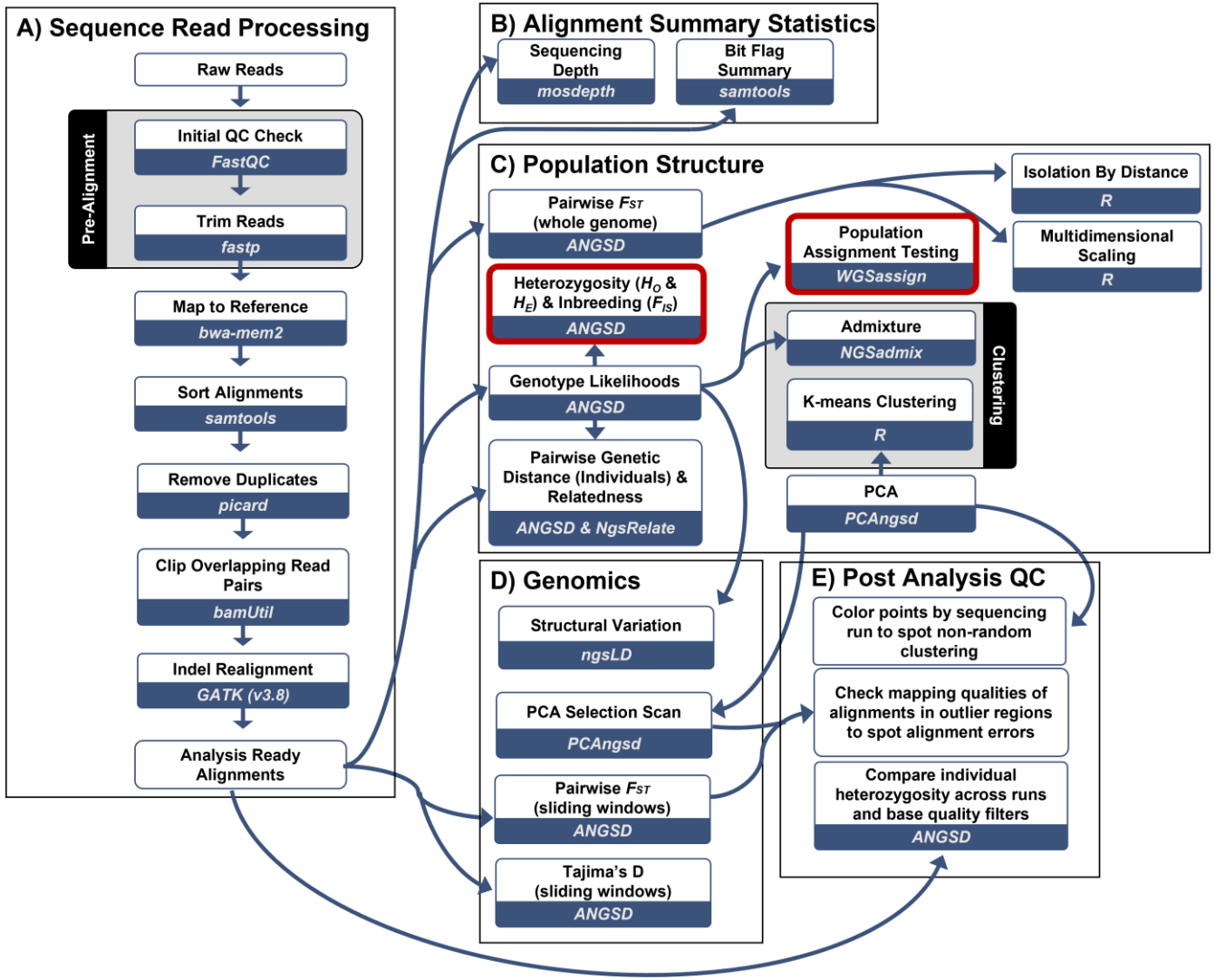


Additions since SRB022

SRB022–Rec.11 (c) – summary measures of genetic diversity
SRB022–Rec.20 (b) – population assignment testing

1. Migration and Population Dynamics

*SRB022–Rec.11 (para. 37) The SRB **RECOMMENDED** that the Secretariat include other genome-wide summary measures of diversity. Measures could include (a) measures of genome size, (b) percentages of genome as singleton and duplicated loci, (c) other summary measures of diversity including (i) number of loci with minor allele frequency (MAF)>0.01, (ii) number of loci with MAF>0.05, (iii) a measure of deviation of observed and expected heterozygosity (Fis), (iv) observed heterozygosity (Ho) and expected heterozygosity (He).*

Table 1. Summary of diversity measures estimated from low coverage whole genome sequence data for sample collections of Pacific halibut. The table includes sample sizes (N), number of loci with minor allele frequency (MAF)>0.01, number of loci with MAF>0.05.

Area	Collection Year	N	MAF > 0.01	MAF > 0.05	F_{IS}	H_O	H_E
British Columbia	1999	49	8,958,267	4,890,386	0.109	0.154	0.158
	2004	43	8,756,199	4,995,125	0.115	0.156	0.163
	2007	50	8,939,078	4,900,656	0.120	0.154	0.157
	all years	142	9,256,496	4,762,476	0.023	0.155	0.161
Central Gulf of Alaska	1999	50	9,131,547	4,993,279	0.049	0.158	0.171
	2004	50	9,065,567	5,163,204	0.029	0.162	0.189
	2007	50	9,052,210	5,052,609	0.058	0.159	0.176
	2018	49	8,627,118	4,893,881	0.172	0.153	0.153
	all years	199	9,561,613	4,862,986	-0.032	0.158	0.176
Bering Sea	2004	43	8,886,235	5,007,451	0.094	0.156	0.164
	2007	50	9,057,451	4,930,166	0.089	0.155	0.162
	all years	93	9,214,470	4,851,360	0.030	0.156	0.164
Central Aleutian Islands	2007	37	8,464,803	4,983,042	0.150	0.154	0.157
	2020	49	8,823,846	4,904,749	0.129	0.154	0.158
	all years	86	8,921,876	4,799,261	0.066	0.154	0.159
Western Aleutian Islands	2020	50	8,690,974	4,893,669	0.151	0.153	0.157
	all years	50	8,690,974	4,893,669	0.151	0.153	0.157

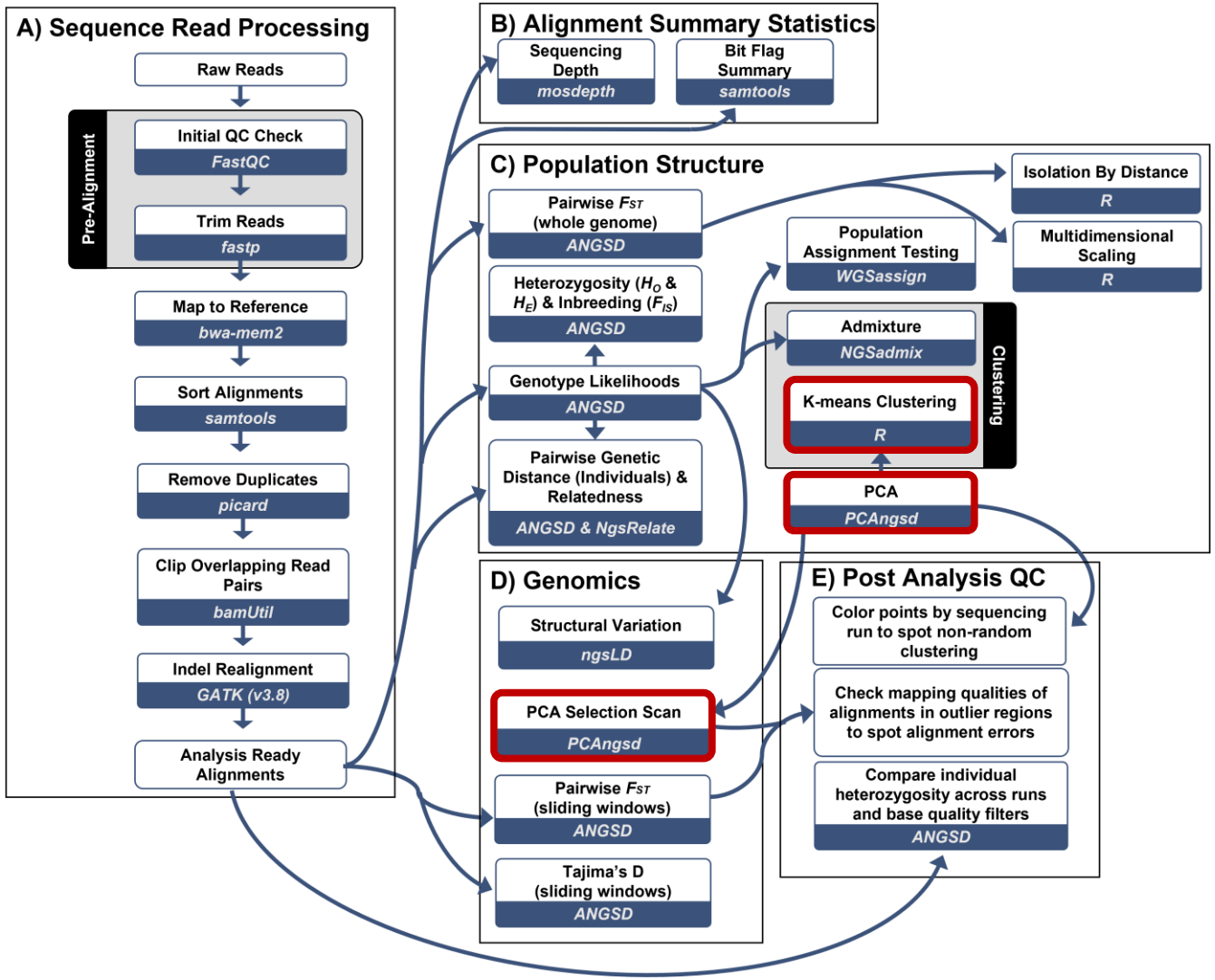
1. Migration and Population Dynamics

PCA based analyses to address components of:

***SRB022–Rec.13 (para. 39)**: SNP outlier detection & testing*

***SRB022–Rec.14 (para. 40)**: Establish statistical significance of outlier loci*

***SRB022–Rec.20 (para. 47)**: Unsupervised clustering*



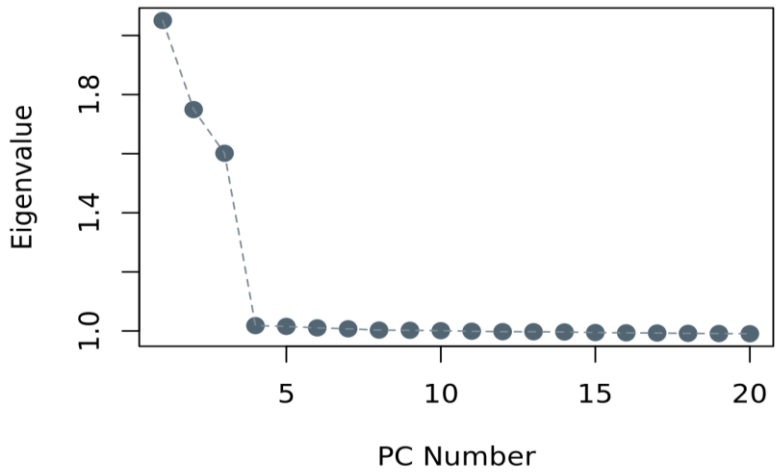
1. Migration and Population Dynamics

*SRB022–Rec.20 (para. 47) The SRB **RECOMMENDED**:*

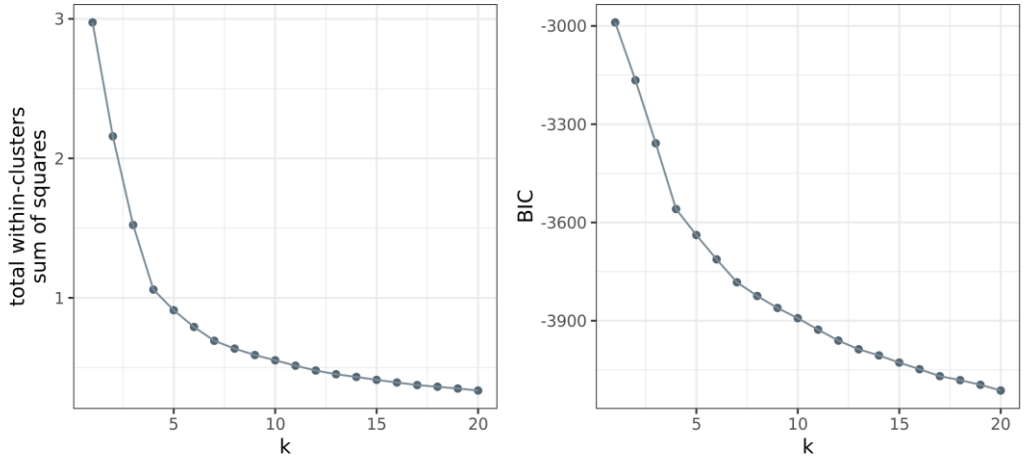
a) that the Secretariat move forward to stock discrimination to satisfy the Secretariat objective of using genetic data to define spatial structuring including unsupervised clustering methods (e.g. K-means, Structure, etc.) as well as PCA-based clustering (e.g. Discriminant Analysis of Principle Component) clustering;

b) using assignment testing and mixture analyses such as leave-one-out cross validation simulations to assess the potential accuracy of mixed stock analysis (MSA).

- PCA - 4,725,899 autosomal SNPs
- Retained top 3 PCs – Cattell's Rule



- K-means clustering in R
  - tested K=1:20
  - compared fit for each K using total within-cluster sum of squares and Bayesian Information Criterion (BIC)

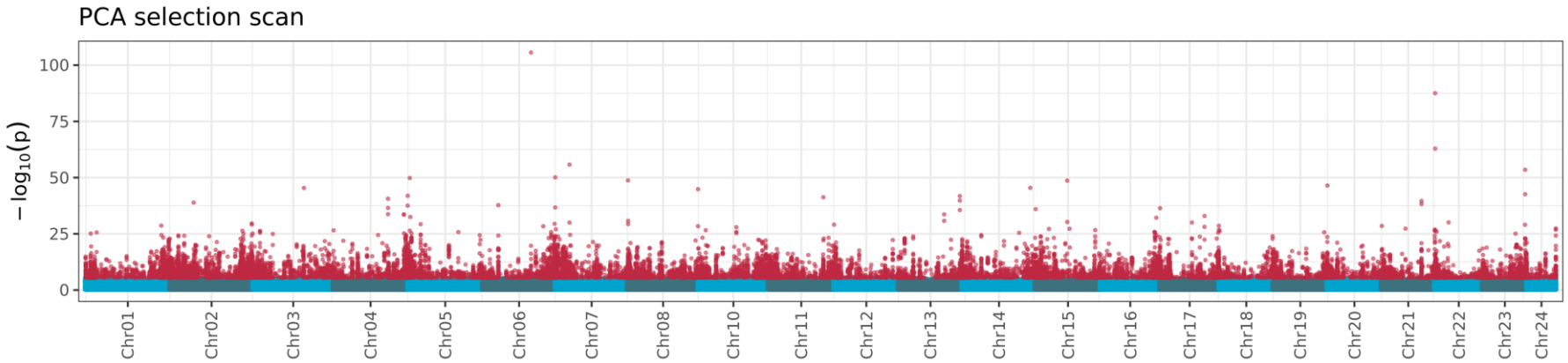


1. Migration and Population Dynamics

SRB022–Rec.13 (para. 39) ***NOTING*** *that different outlier tests are based on different assumptions and statistical approaches, the SRB* ***RECOMMENDED*** *that the Secretariat implement more than one method. Selection of specific markers would appropriately be based on concordant designation of highly population discriminatory loci identify across methods. The Secretariat is likely to have greater confidence in assignment of 'outliers' based on principles of concordance using multiple and semi-independent software packages and statistical approaches.*

SRB022–Rec.14 (para. 40) The SRB ***RECOMMENDED*** *that after statistical significance of SNP loci has been established, the Secretariat use gene set enrichment analyses to establish functional annotations for genes associated with SNPs.*

- PCA based selection scan
  - pcadapt test statistic implemented in PCAngsd (top 3 PCs)
  - robust Mahalnobis distance (χ^2 distribution with K (3) degrees of freedom)
- false discovery rate level 0.001 (Benjamini-Hochberg procedure)
- 16,272 candidate SNPs



1. Migration and Population Dynamics

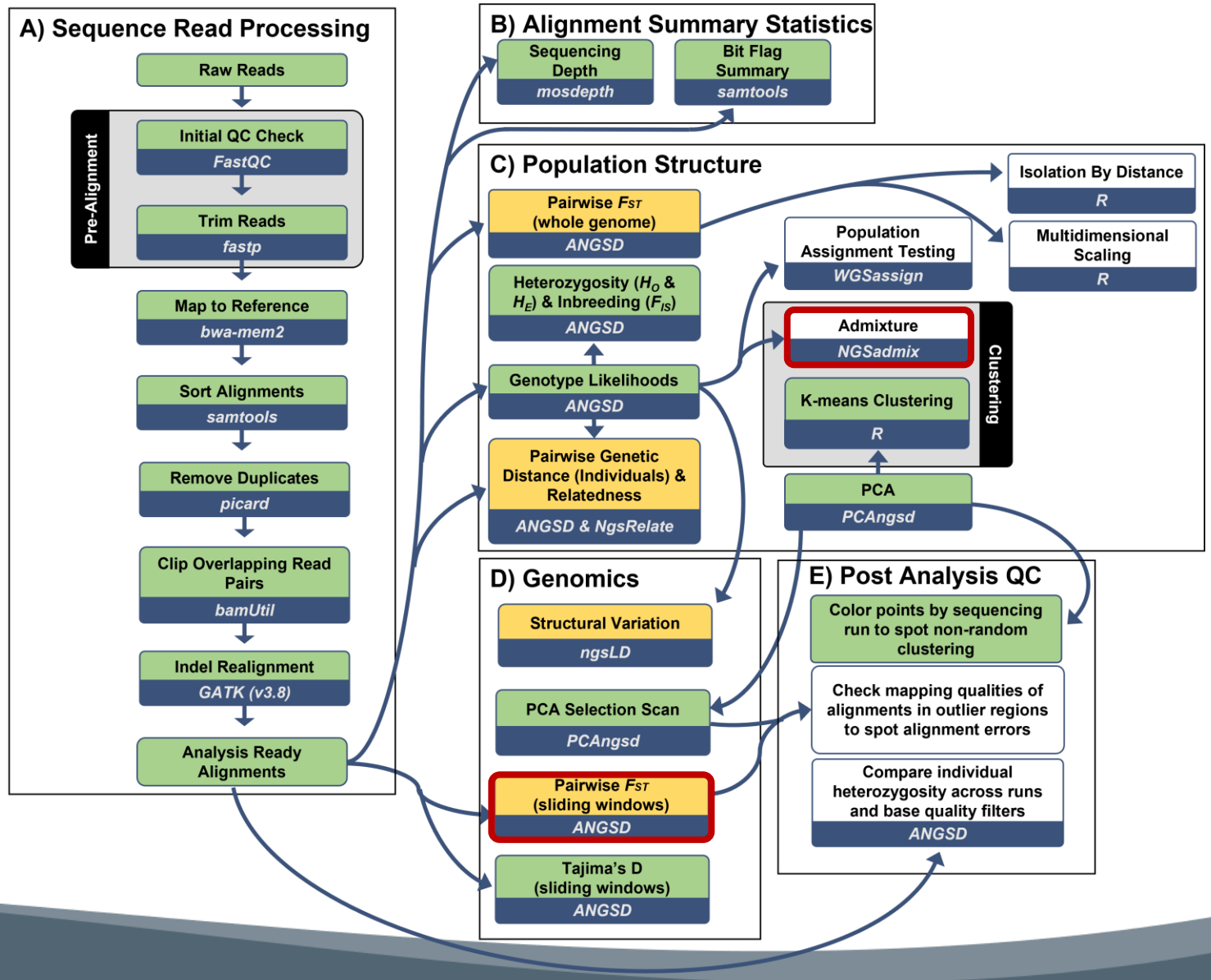
Progress Update

Current Efforts (*SRB022–Rec.13 & 14*):

- Establish statistical significance for the F_{ST} based outlier scans

Next (*SRB022–Rec.20 a*):

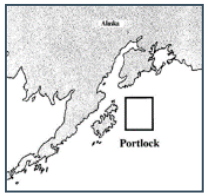
- Estimate individual admixture proportions – NGSadmix



2. Reproduction

5-Yr Research Plan (2017-2021) | **PIRM 2022-2026**

2017-2018 Field sample collection (central GOA)



30♀/ month

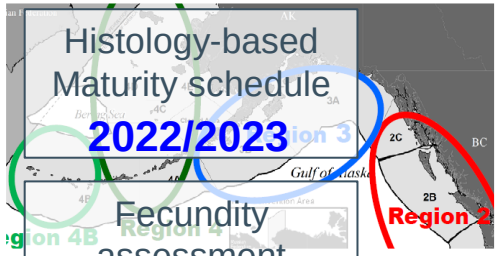
♀>90 cm FL

Seasonal characterization of reproductive development

Histological samples → Characterization of oocyte stages → Classification of female developmental stages → Classification of reproductive phases → Appropriate timing of gonad collection in FISS

Research outcomes:

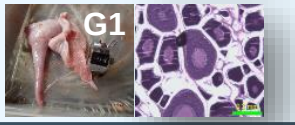
- Group synchronous
- Batch spawner
- Determinate fecundity
- Annual cycle
- Spawning time
- Reproductive delays
- June-August



Macroscopic vs microscopic maturity staging

Macroscopic maturity scores

Ovary images



Histology-based female developmental stages and reproductive phases → Assess accuracy of current field maturity classification criteria → Revise macroscopic staging criteria

Research outcomes:

- In progress

2017-2022 Commercial landings

Development and application of genetic tests for sex identification → Sex-ratio monitoring

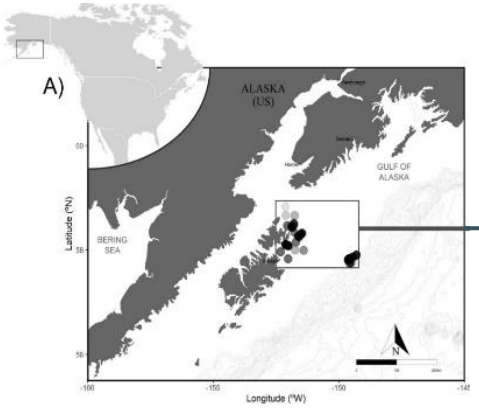
Publications:

Fish et al. (2020) *Journal of Fish Biology* ***97****: 1880–1885*

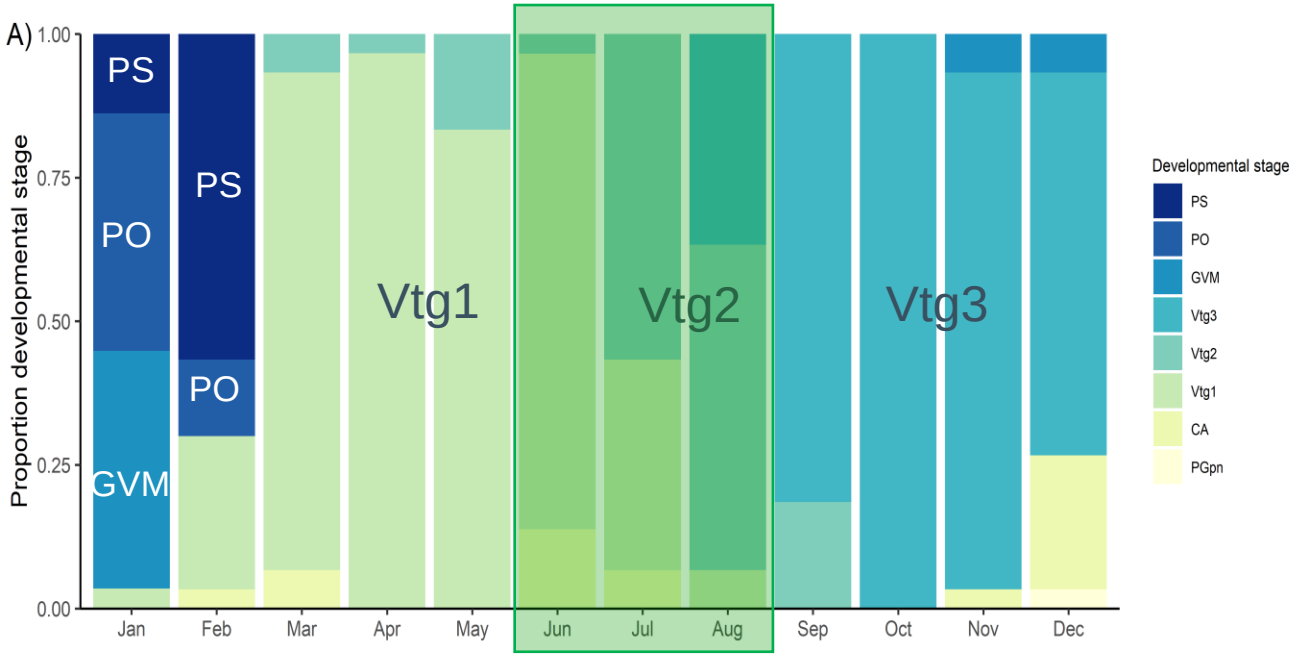
Fish et al. (2022) *Frontiers in Marine Science* ***9****: 801759*

2. Reproduction

Microscopic maturity staging: histological oocyte stages



Portlock Region (Central GOA)



FISS

Fish et al. (2022) *Front. Mar. Sci.* **9**:801759

Immature: Cortical alveoli (CA)

↓

Mature:

Vtg1 (Vitellogenic 1)

↓

Vtg2

↓

Vtg3

↓

GVM (Germinal vesicle migration)

↓

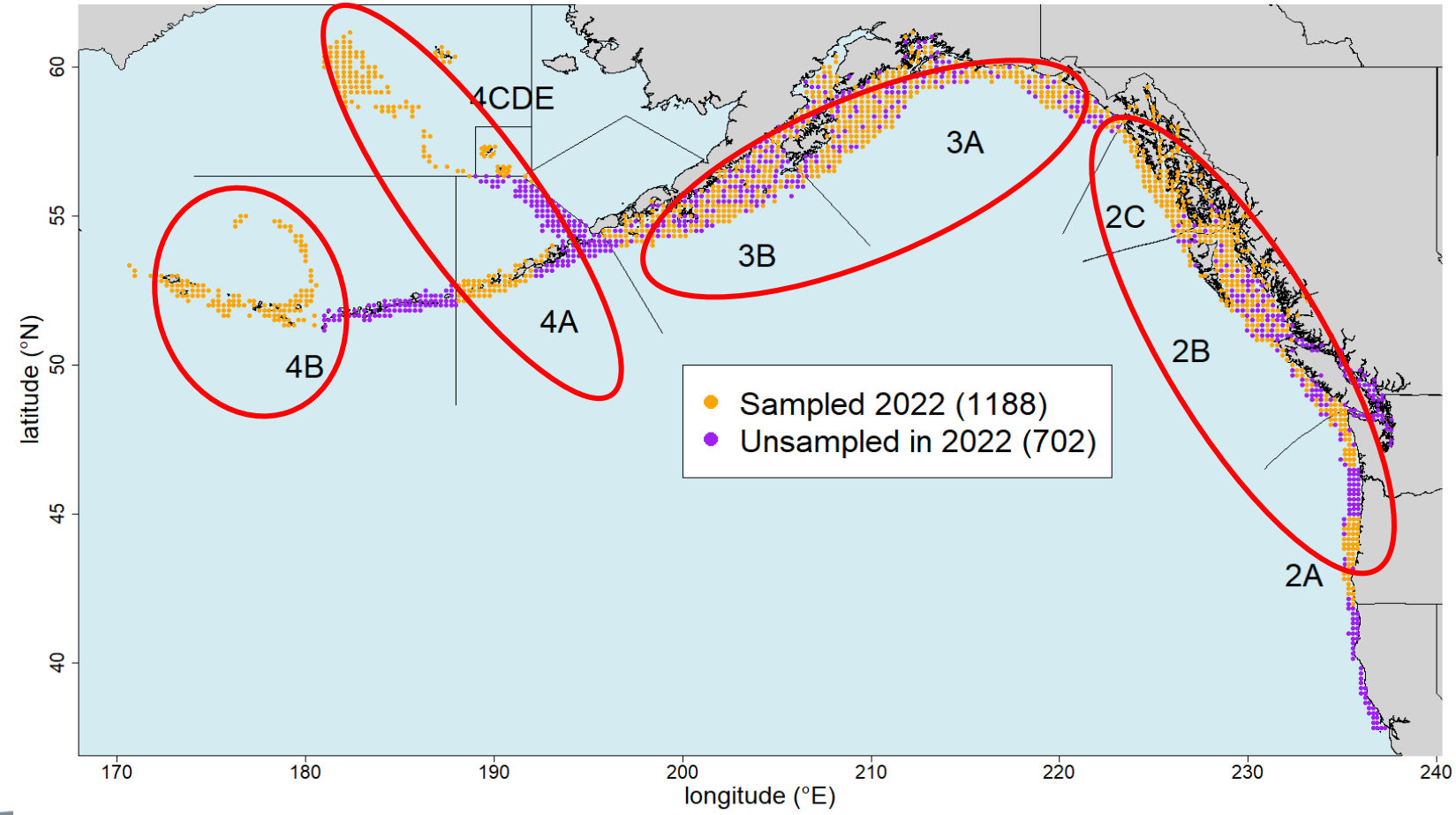
PO (Periovulatory)

↓

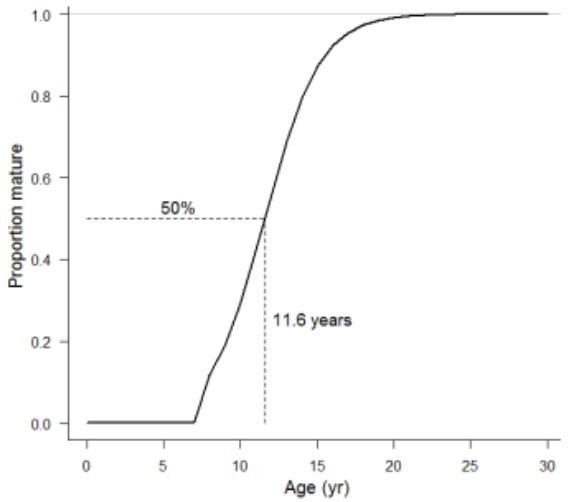
PS (Post-spawning)

2. Reproduction

FISS: ovarian sampling for histology-based maturity



- **Revise maturity estimates per biological region by histological staging**

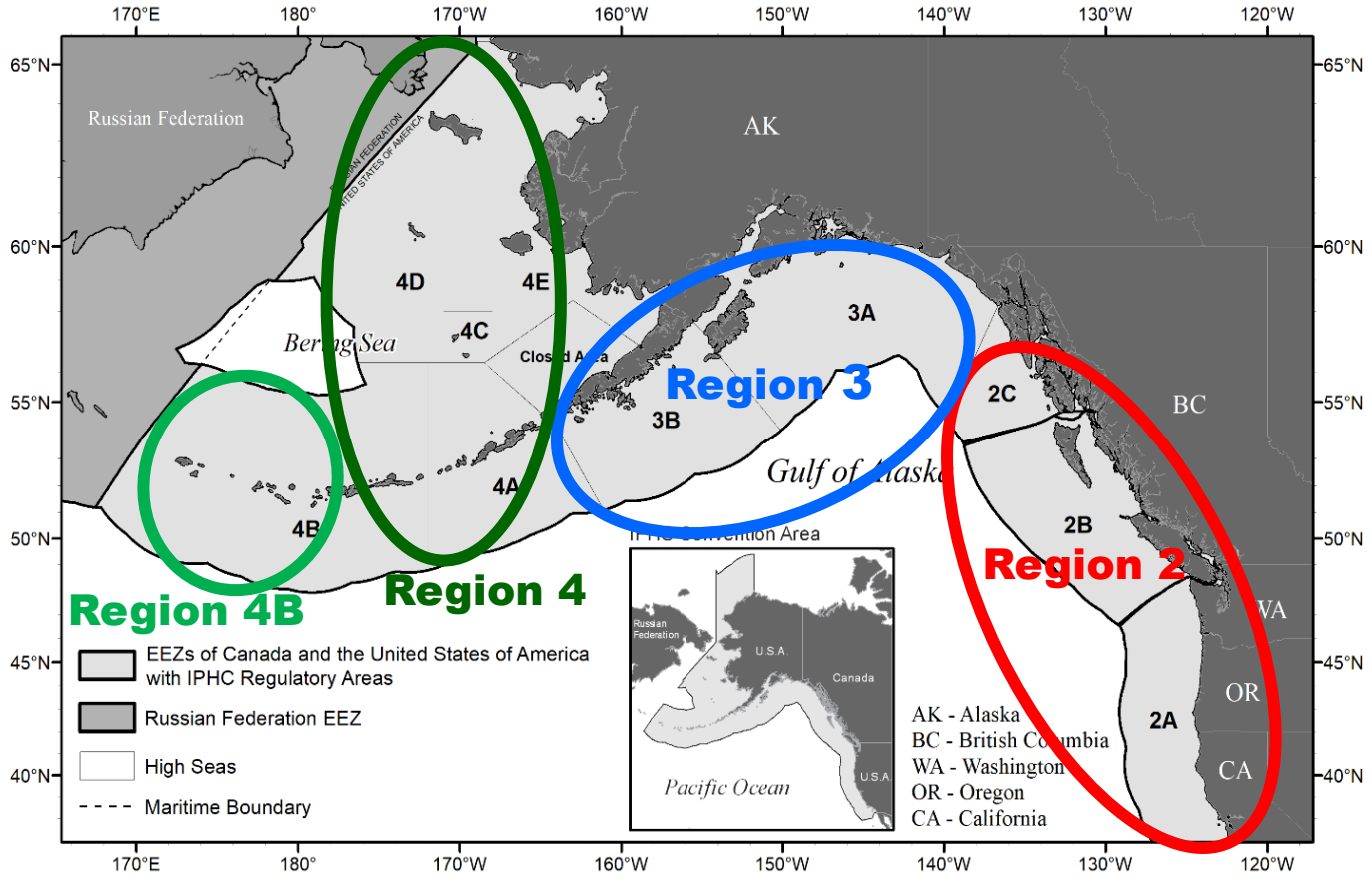


2. Reproduction

Maturity sample collection in FISS 2022/2023

Number of samples

Biological Region	2022	2023 (est.)	Total
2	437	398	835
3	348	705	1,053
4	180	-	180
4B	51	-	51
Total	1,016	1,103	2,119



2. Reproduction

Generating Maturity Ogives

- Logistic curve
  - GLM with binomial distribution (mature or immature) and logit link function
  - Length and age at 50% maturity calculated using dose.p function
  - Proportion of mature individuals (p) set to 0.5

- Length and age will be examined coastwide and among IPHC biological regions based on data available
- MARVLS R code repository: https://github.com/MARVLS/Fish-Gonad-Staging/tree/main/analyses

2. Reproduction

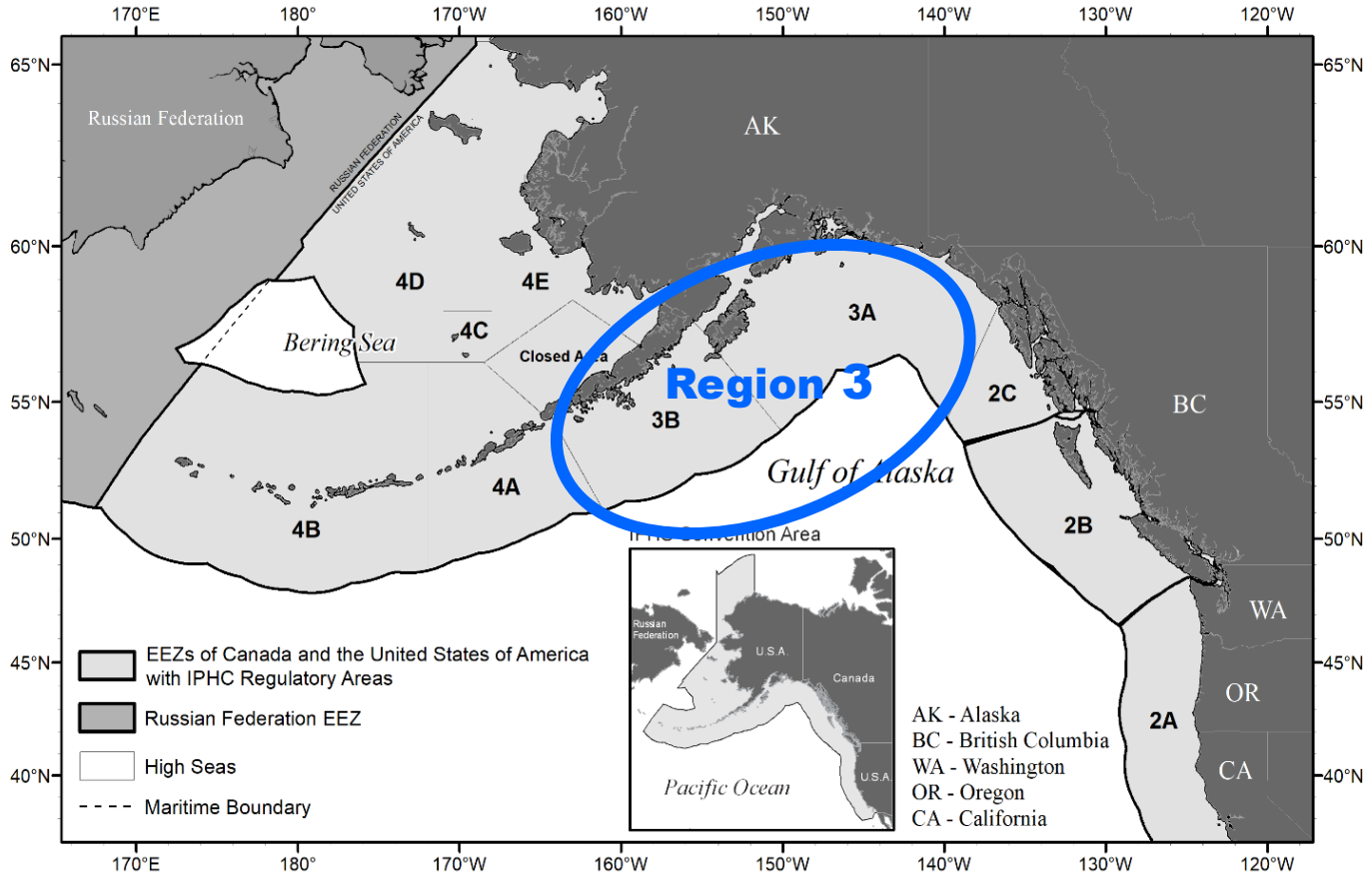
Fecundity sample collection in FISS 2023

Biological Region 3

Total = 457

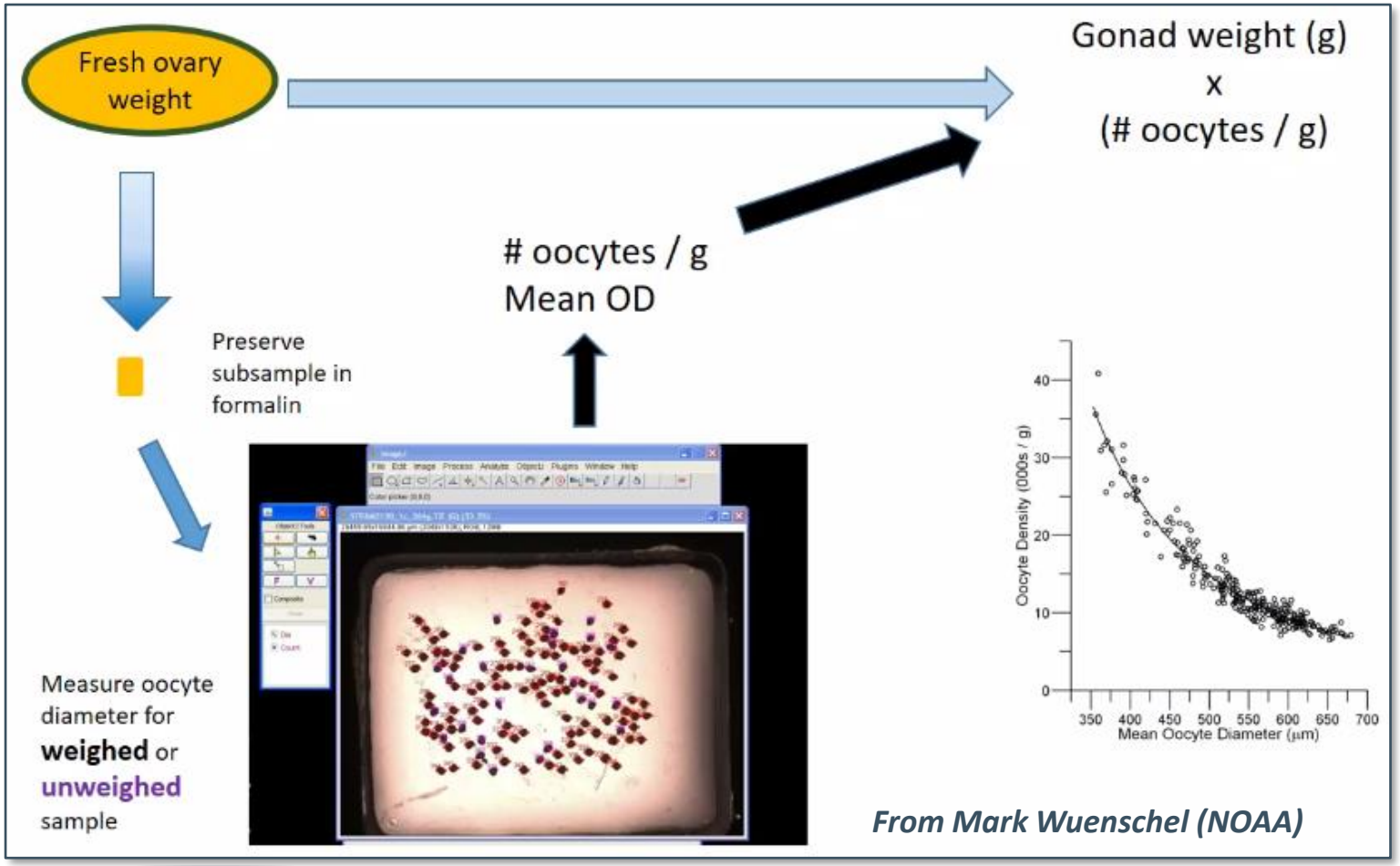
Mature (field) = 299

Ovary Weight (mature) = 255

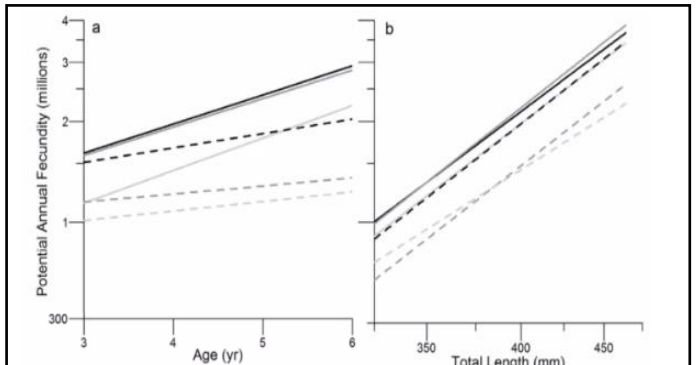


2. Reproduction

Fecundity: autodiametric method



Potential Annual Fecundity (PAF) (Total # oocytes)

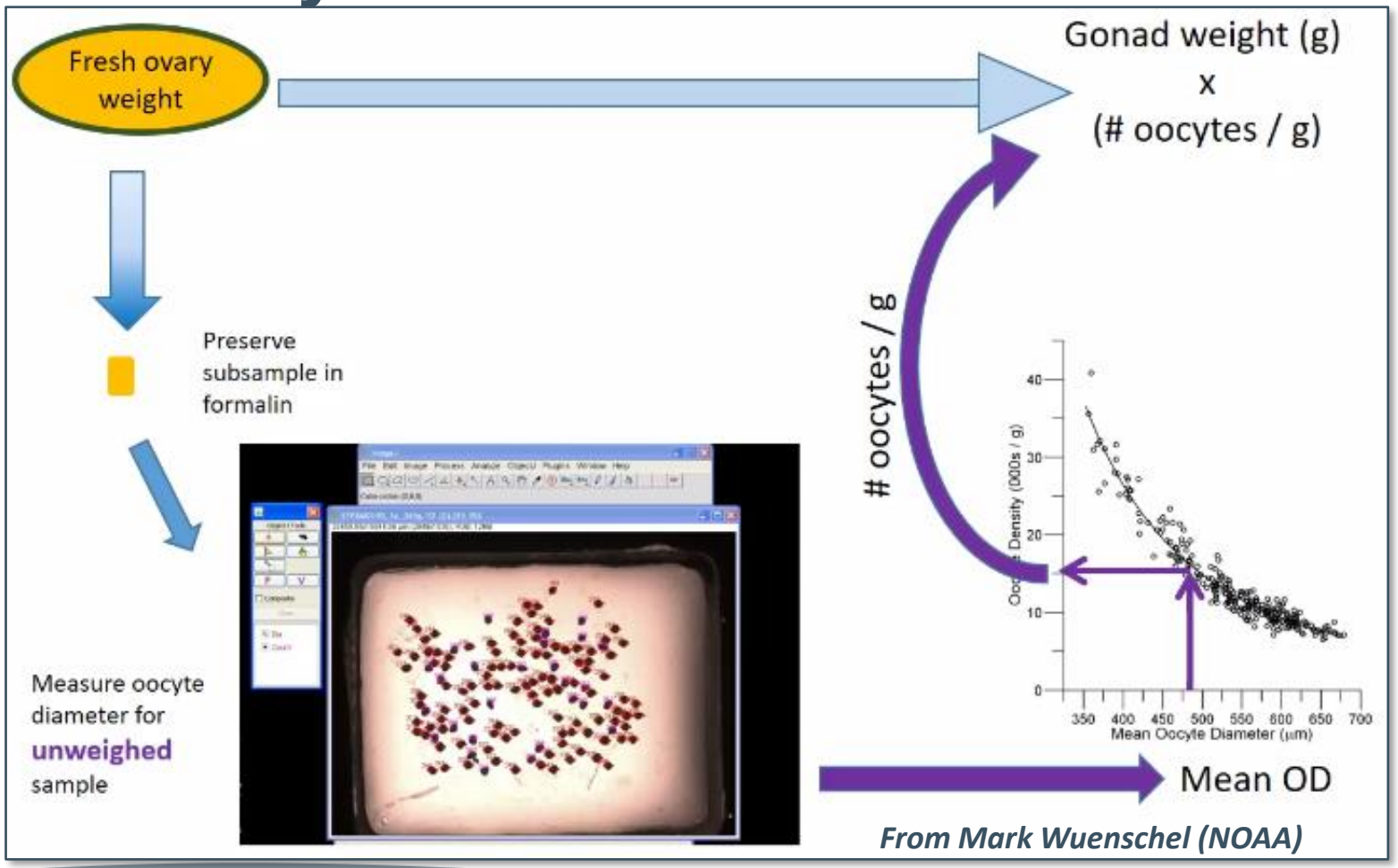


McElroy et al (2015): Yellowtail flounder

Target:
n = 250-300 fish

2. Reproduction

Fecundity: autodiametric method



Potential Annual Fecundity (PAF) (Total # oocytes)

3. Mortality and Survival Assessment

5-Yr Research Plan (2017-2021) | **PIRM 2022-2026**

Fall 2017 field experiment (GOA)

Discard mortality rate estimation: longline fishery

Capture and handling conditions
- Careful shake
- Gangion cut
- Hook strip

→ Injury and viability assessment → Survival assessment by tagging

→ Physiological condition assessment → Analysis of capture-related variables

→ Best handling practices in longline fishery

Research outcomes:
- Injury and viability profiles of hook release methods
- Physiological profile of fish under different capture and handling conditions
- Longline DMR

Summer 2021 field experiments (Sitka, AK Seward, AK)

Discard mortality rate estimation: charter recreational fishery

Capture and handling conditions
- 12/0 and 16/0 hooks

→ Injury, viability and physiological assessment → Survival assessment by tagging

→ Analysis of capture-related variables

→ Best handling practices in recreational fishery

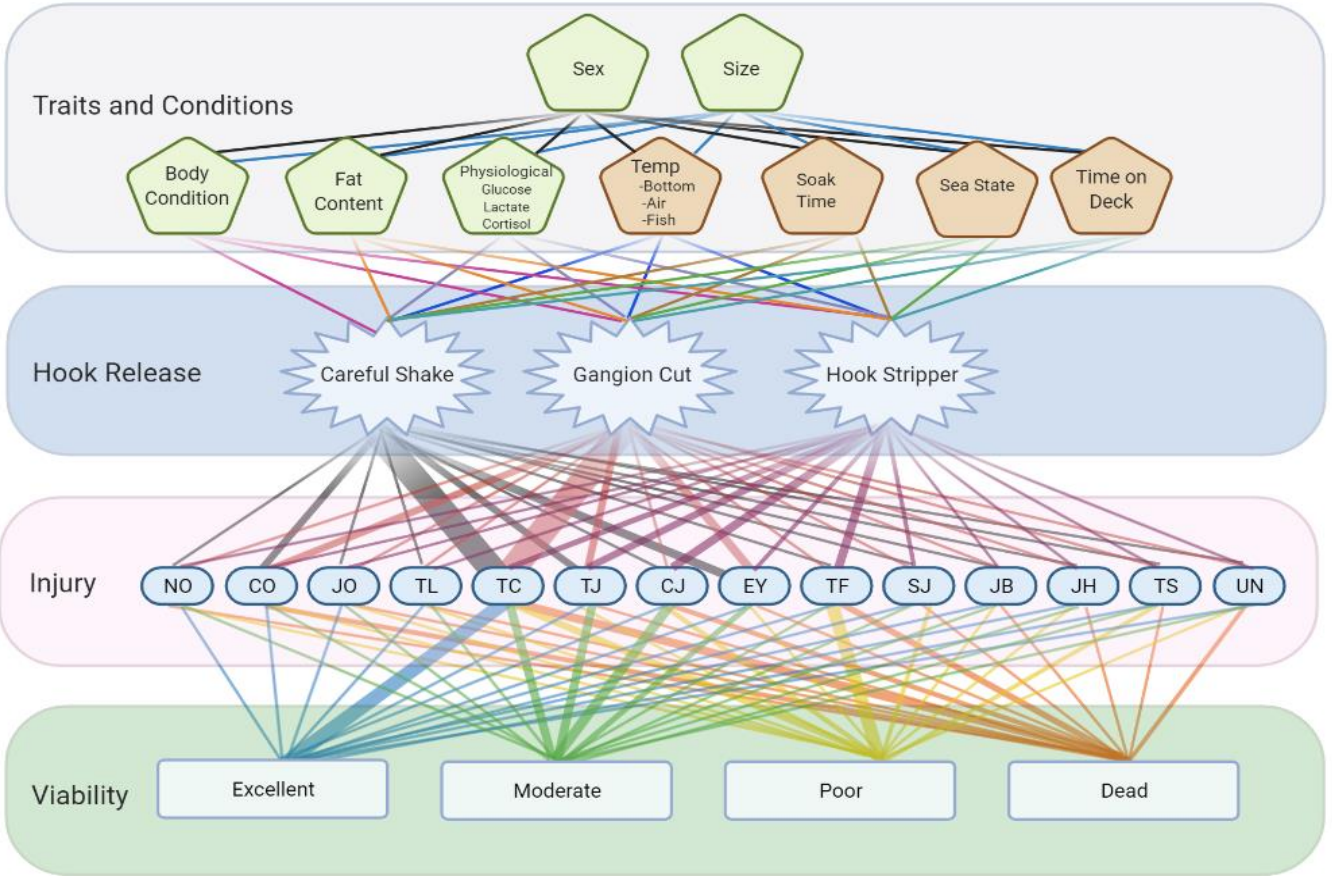
Research outcomes:
- Recreational DMR

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. (2023) Submitted.

3. Mortality and Survival Assessment

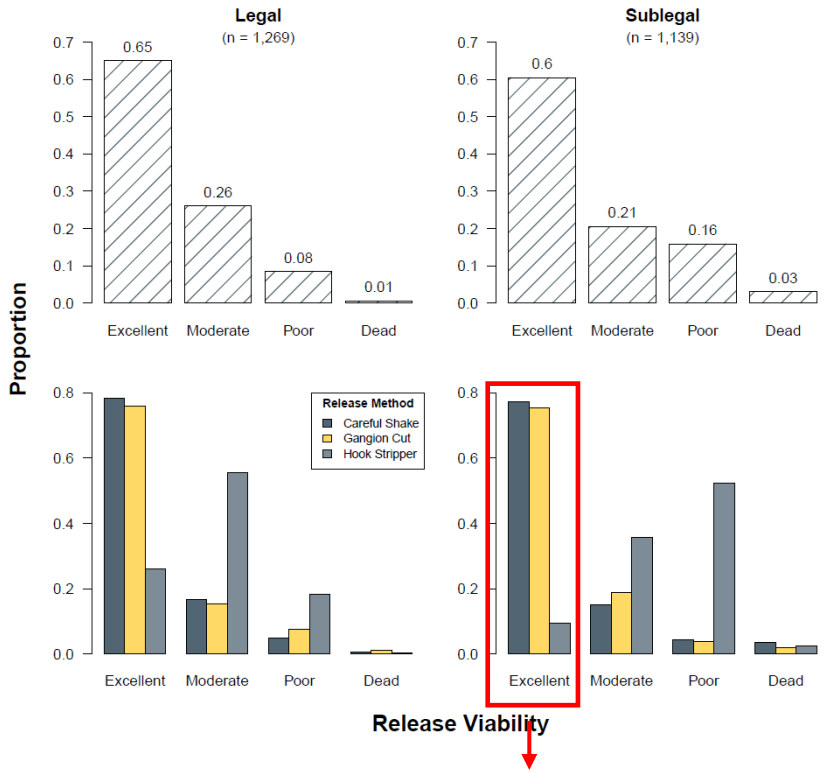
Characterization of discards in the directed longline fishery



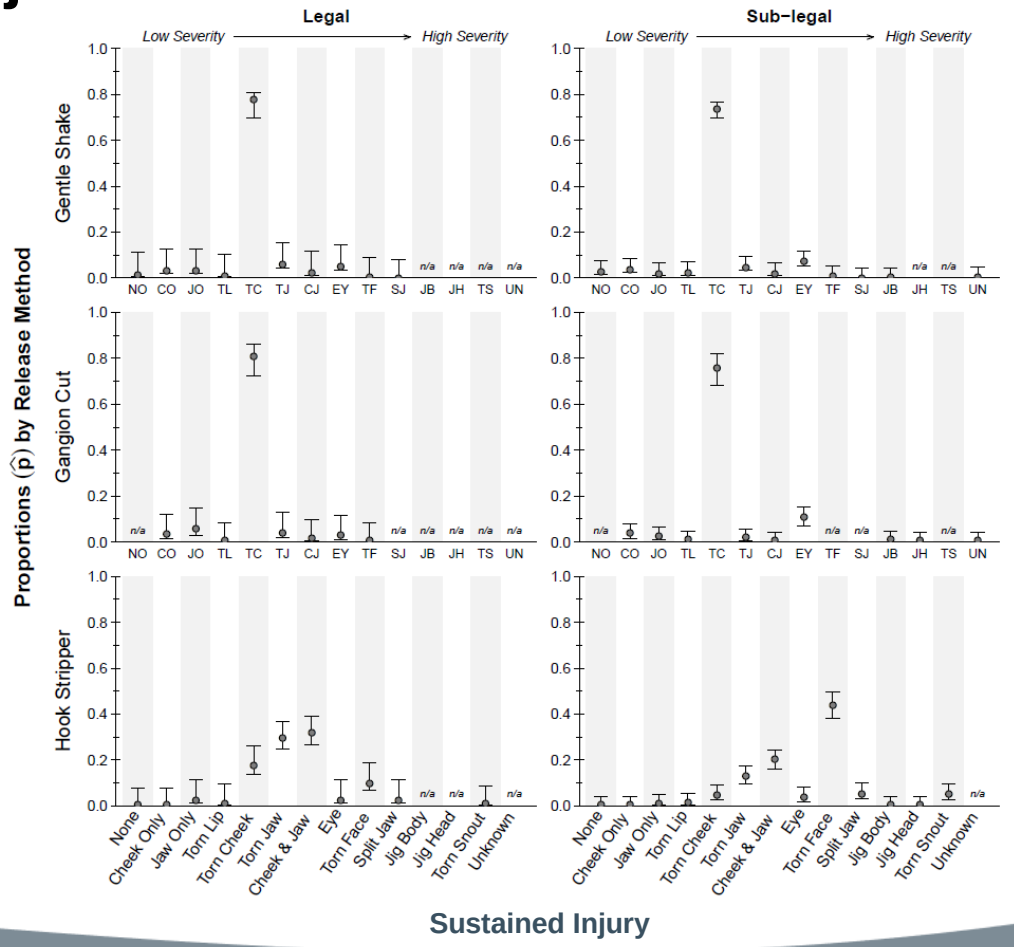
3. Mortality and Survival Assessment

Characterization of discards in the directed longline fishery

- **Hook Release Methods: Viabilities and Injuries**



Min. DMR = 4.2% (Loher et al. 2022)

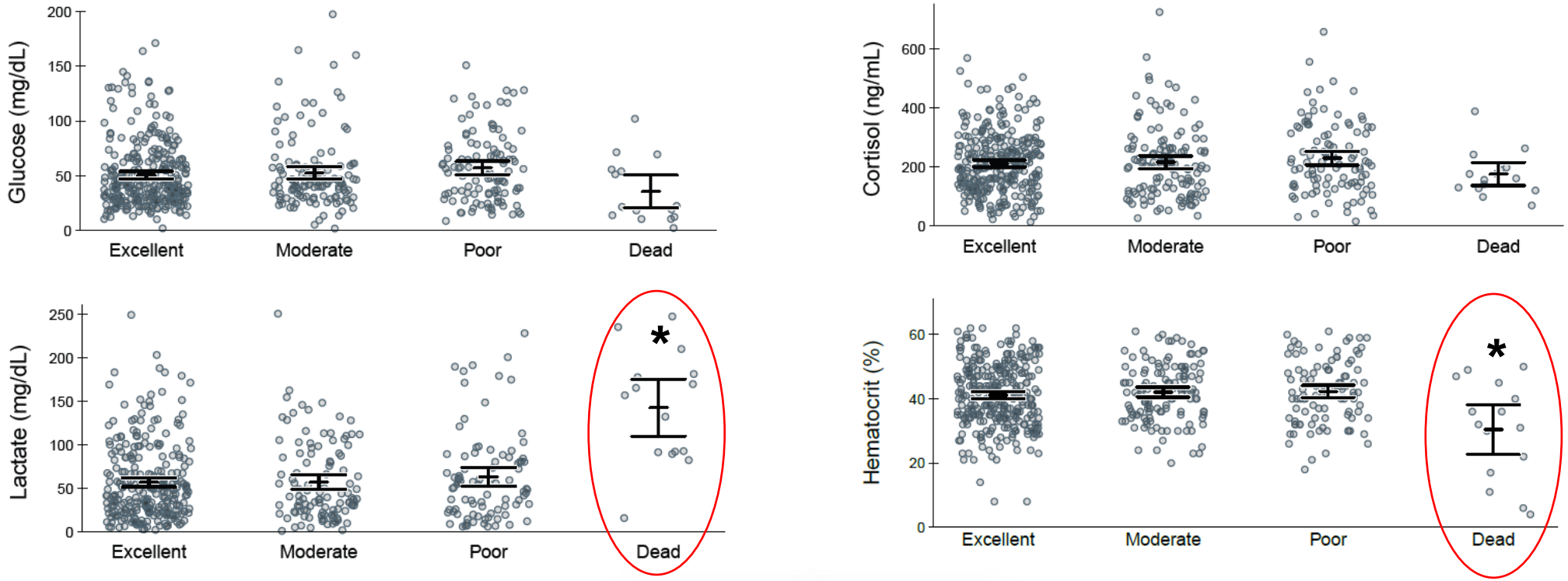


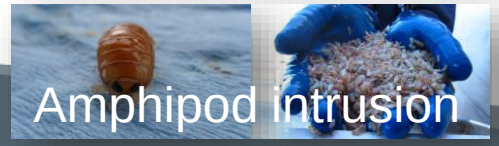
Dykstra et al. (2023) Submitted

3. Mortality and Survival Assessment

Characterization of discards in the directed longline fishery

- **Stress Indicators in the Blood**





Dykstra et al. (2023) Submitted

4. Fishing technology

NOAA FISHERIES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Bycatch Reduction Engineering Program
(BREP) NA21NMF4720534

Reducing whale depredation by protecting longline catches

Phase 1: International Workshop - 2022

Explore latest ideas in terminal gear modification and catch protection – an area previously identified as having the highest likelihood of 'breaking the reward cycle' in depredation.

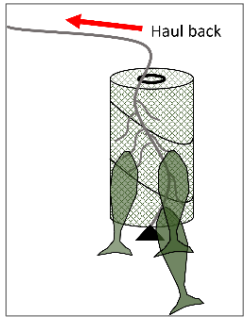
- Refine attributes discussed into two viable approaches:
  - Enclosing shuttles.
  - Branchlines with shrouds.

Phase 2: Field testing of catch protection devices - 2023

Tested selected devices for:

- Deployment / Retrieval logistics.
- Optimal configurations (weighting, attachments).
- Basic performance (species/sizes).

Shuttle



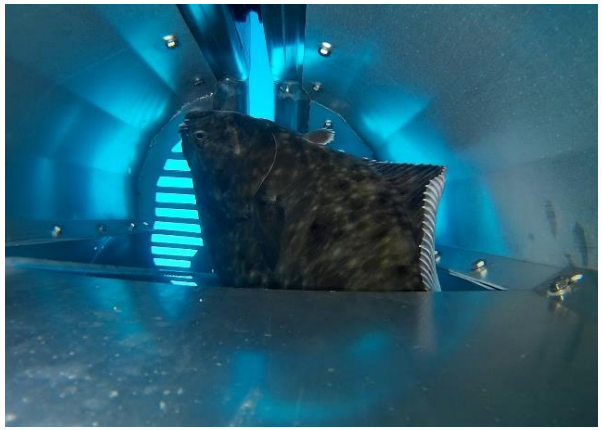
Shroud

4. Fishing technology

NOAA FISHERIES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Bycatch Reduction Engineering Program
(BREP) NA21NMF4720534

Reducing whale depredation by protecting longline catches

Phase 2: Shuttle field testing

Preliminary conclusions

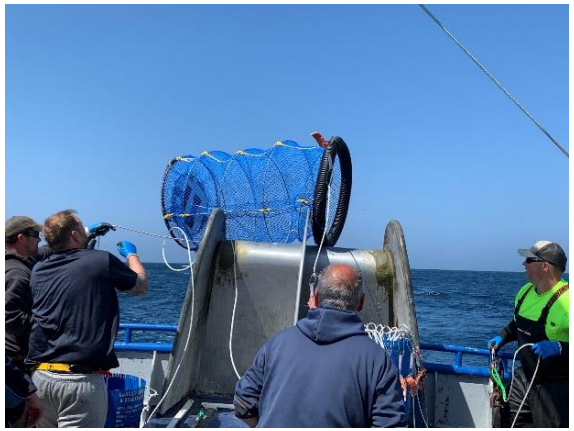
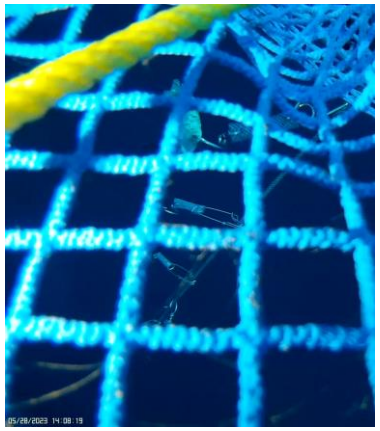
- Safely operational on a small vessel.
- Moderate learning curve to attach in-line during hauling event.
- Similar catch rates to standard gear.
- Groundline, gangion, hooks need refinement to minimize damage to fish.

4. Fishing technology

NOAA FISHERIES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Bycatch Reduction Engineering Program
(BREP) NA21NMF4720534

Reducing whale depredation by protecting longline catches

Phase 2: Shroud field testing

Preliminary conclusions

- Variable strength snaps allowed hooks to cluster.
- Shrouds generally slid down to cover the hooks, with some snarling.
- Low catch rates in final tested configuration – small footprint, lots of hagfish.
- Basic concept works – many logistical issues to sort out before scaling to fishery level.

4. Fishing technology

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

Reducing whale depredation by protecting longline catches

Phase 3a: Testing in presence of Orcas - 2024

Recently secured funding from NOAA BREP 2023 NA23NMF4720414

- Permit and vessel selection permitting:
  - 10 days of fishing in presence of Orcas.
  - Catch rate comparisons with and without shuttle device.
  - Further refinements (attachment protocols, gangion/hook strength).
  - Catch composition details (size ranges, species, catch volume).

Phase 3b: Testing in presence of Sperm whales

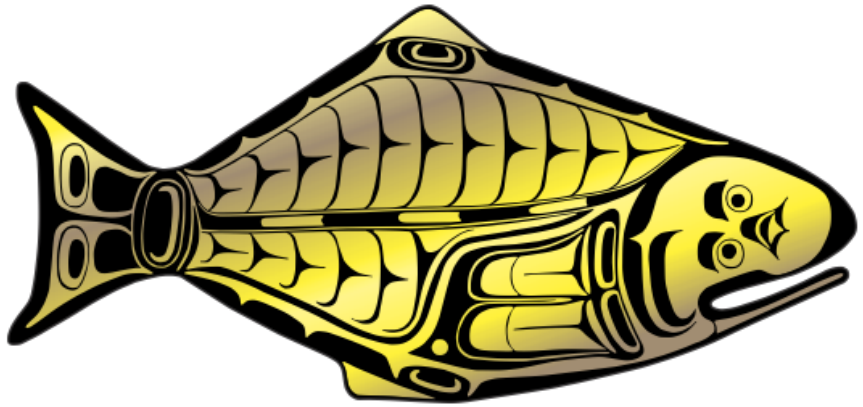
Pending funding

- Pre-proposal for funding submitted to Saltonstall-Kennedy – awaiting response.

Summary of active research grants

Project #	Grant agency	Project name	PI	Partners	IPHC Budget ($US)	Management implications	Grant period
1	Bycatch Reduction Engineering Program-NOAA	Gear-based approaches to catch protection as a means for minimizing whale depredation in longline fisheries (NOAA Award Number NA21NMF4720534)	**IPHC**	Deep Sea Fishermen's Union, Alaska Fisheries Science Center-NOAA, industry representatives	$99,700	Mortality estimations	1 November 2021 – 31 October 2023
2	North Pacific Research Board	Pacific halibut population genomics (NPRB Award No. 2110)	**IPHC**	Alaska Fisheries Science Center-NOAA, Juneau, Seattle	$193,685	Stock structure	1 December 2021 – 31 January 2024
Total awarded ($)					**$293,385**		

INTERNATIONAL PACIFIC



HALIBUT COMMISSION