INTERNATIONAL PACIFIC HALIBUT COMMISSION

100 years

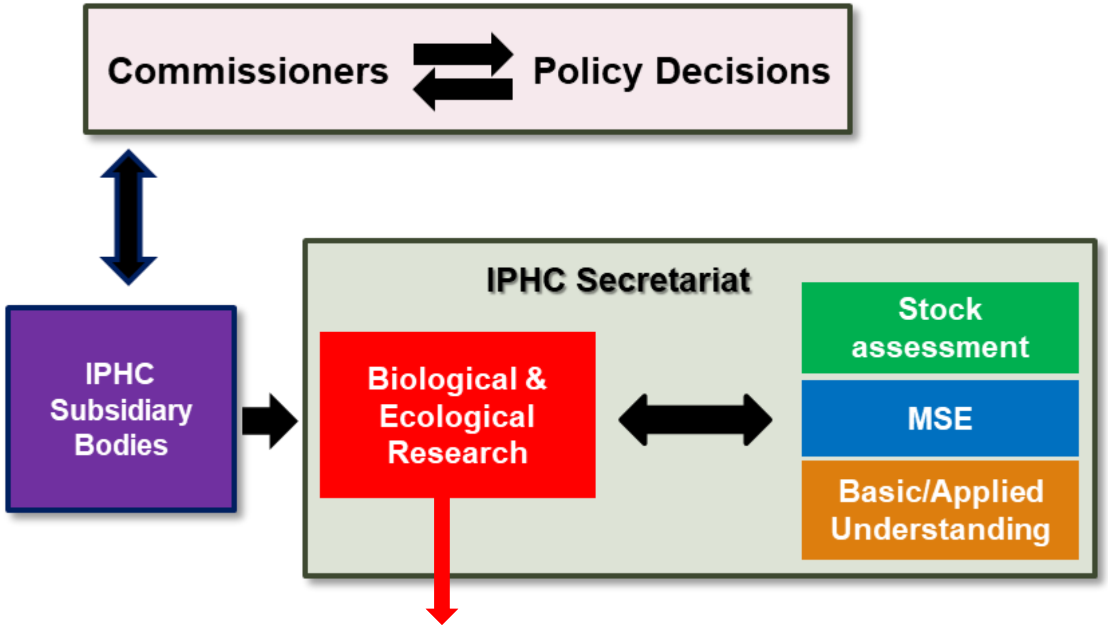
Report on current and future biological and ecosystem science research activities

Agenda item: 5.1.1

IPHC-2023-RAB024-06

(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

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Description of IPHC research activities

- **Overview of biological and ecosystem science research activities within the IPHC 5-year Program of Integrated Research and Monitoring (2022-2026)**
- **Core research streams: Updates for key ongoing research activities**

1. ***Migration and population dynamics:*** *Genetic population structure (A. Jasonowicz)*
2. ***Reproduction:*** *Update of maturity schedules (C. Jones)*
3. ***Mortality and survival assessment:*** *Discard mortality rates and post-release survival of in the guided recreational fishery (C. Dykstra)*
4. ***Fishing technology****: Whale depredation mitigation strategies involving longline catch protection devices (C. Dykstra)*

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1. Migration and Population Dynamics

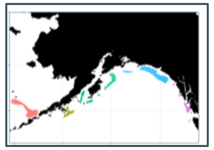
5-Yr Research Plan (2017-2021)

PIRM 2022-2026

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*

→ PIRM 2022-2026:
- Climate effects on larval connectivity
- Connectivity with Western Pacific Ocean region
- Mapping of settlement/nursery areas

Juvenile connectivity

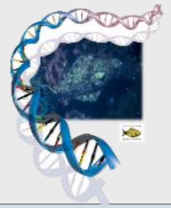
- NMFS trawl survey data
- Spatiotemporal model

→ Ontogenetic migration

→ PIRM 2022-2026:
- 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

Development and application of genomic approaches

Genome sequence



→ Population structure analyses

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

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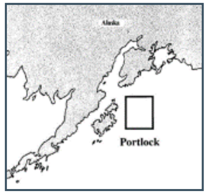
2. Reproduction

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 ➔ Histology-based Maturity schedule **2022/2023** ➔ Fecundity assessment **2023**

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

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*

3. Growth

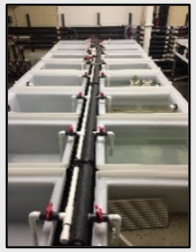
5-Yr Research Plan (2017-2021) | **(2022-2026)**

2016-2018 Age-0 summer collections (Kodiak)

Fish rearing at Hatfield Marine Science Center (Newport)

Identification and validation of physiological growth markers

Growth laboratory experiments



→ Temperature manipulations → Transcriptomic and proteomic profiling → Temperature-responsive growth markers → Validation studies

→ Density manipulations → Transcriptomic and proteomic profiling → Density-responsive growth markers

→ Handling manipulations → Transcriptomic and proteomic profiling → Handling-responsive growth markers

(2022-2026):

- Environmental influences on growth patterns
- Dietary influences on growth patterns and physiological condition

Research outcomes:
- Differentially-expressed genes
- Differentially-expressed proteins
- Validated growth markers

Environmental influences on growth patterns

Research outcomes:
- Effects of temperature on growth rates
- Temperature-specific molecular responses

External collaborators: Behavioral Ecology Program at AFSC-NOAA (Newport, OR), Alaska Pacific University, UW
External funding: NPRB Grant#1704 (Sept. 2017-Feb. 2020)
Publications: Planas et al. (in preparation)

4. 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*
- Dykstra et al. (2023) Submitted.

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5. Fishing technology

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

Summer 2023 pilot test

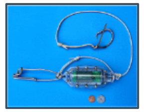
Investigate new methods for whale avoidance/deterrence to reduce whale depredation in the longline fishery

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 the presence of:
- 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 Pacific halibut 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

External funding: Bycatch Reduction Engineering Program NOAA (2022-2025)

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

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

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Description of IPHC research activities

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- **Core research streams: Updates for key ongoing research activities**

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  2. ***Reproduction:*** *Update of maturity schedules (C. Jones)*
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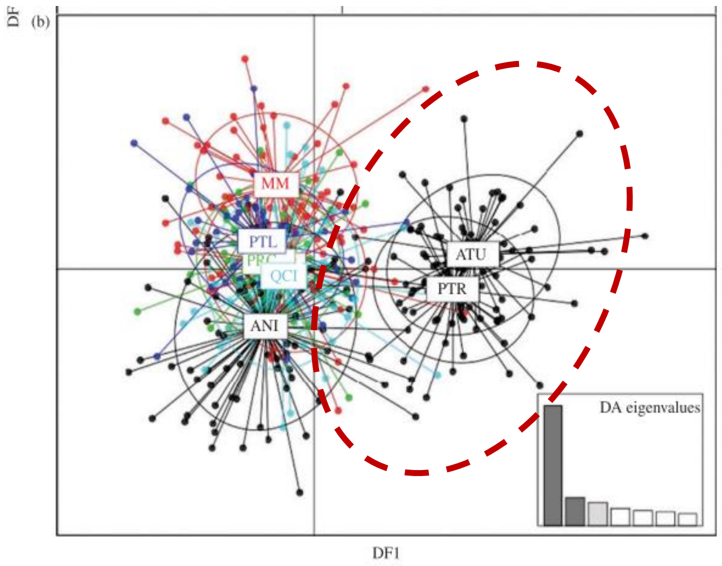
Migration and Population Dynamics

- Previous genetic studies – results suggest potential genetic differences between Pacific halibut in Aleutian Islands other areas
- Oceanographic features in the Aleutian Islands & Bering Sea may restrict geneflow



Use genomic methods to characterize population structure of Pacific Halibut in IPHC Convention Waters

Nielsen, J. L., S. L. Graziano, and A. C. Seitz. 2010. Fine-scale population genetic structure in Alaskan Pacific halibut (*Hippoglossus stenolepis*). Conservation Genetics 11(3):999–1012.

Drinan, D. P., H. M. Galindo, T. Loher, and L. Hauser. 2016. Subtle genetic population structure in Pacific halibut *Hippoglossus stenolepis*. Journal of Fish Biology 89(6):2571–2594.

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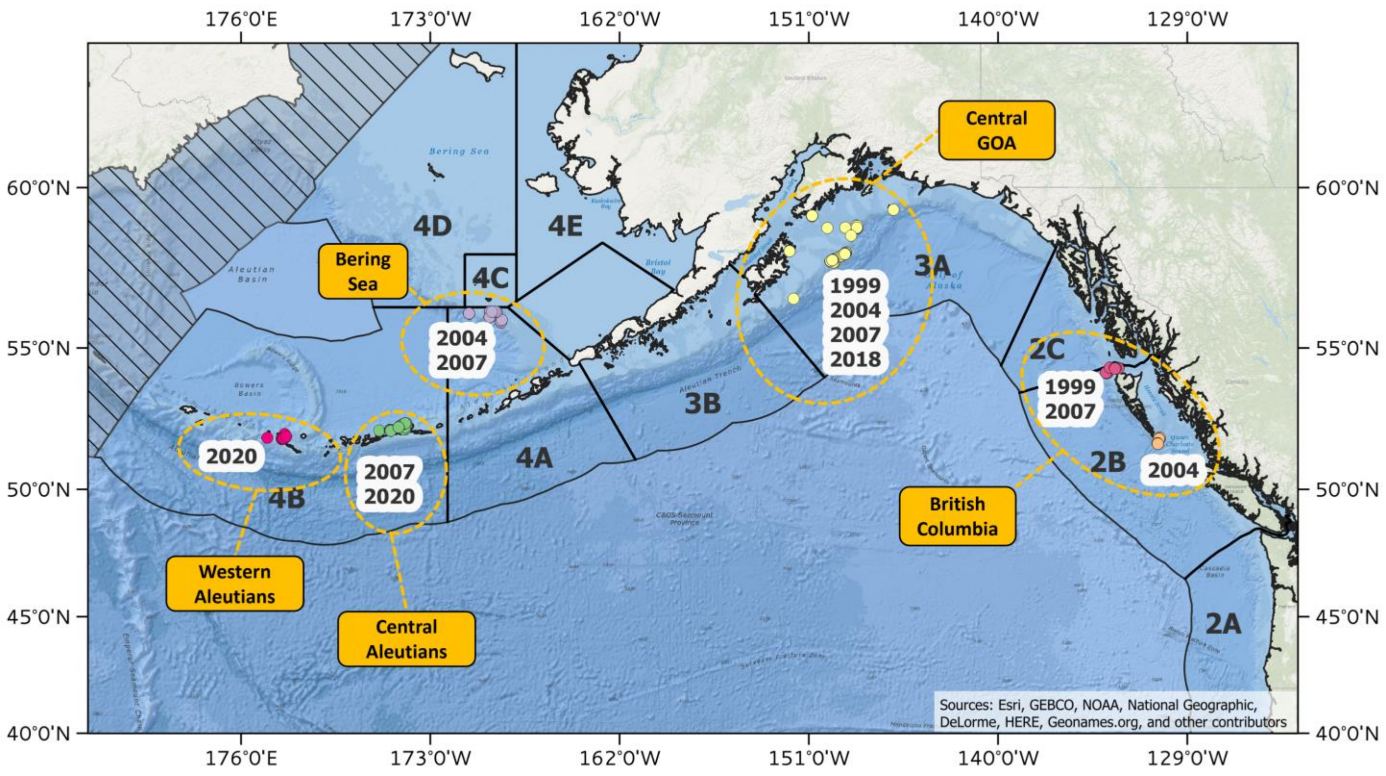
Migration and Population Dynamics

Samples Collected from Spawning Groups



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

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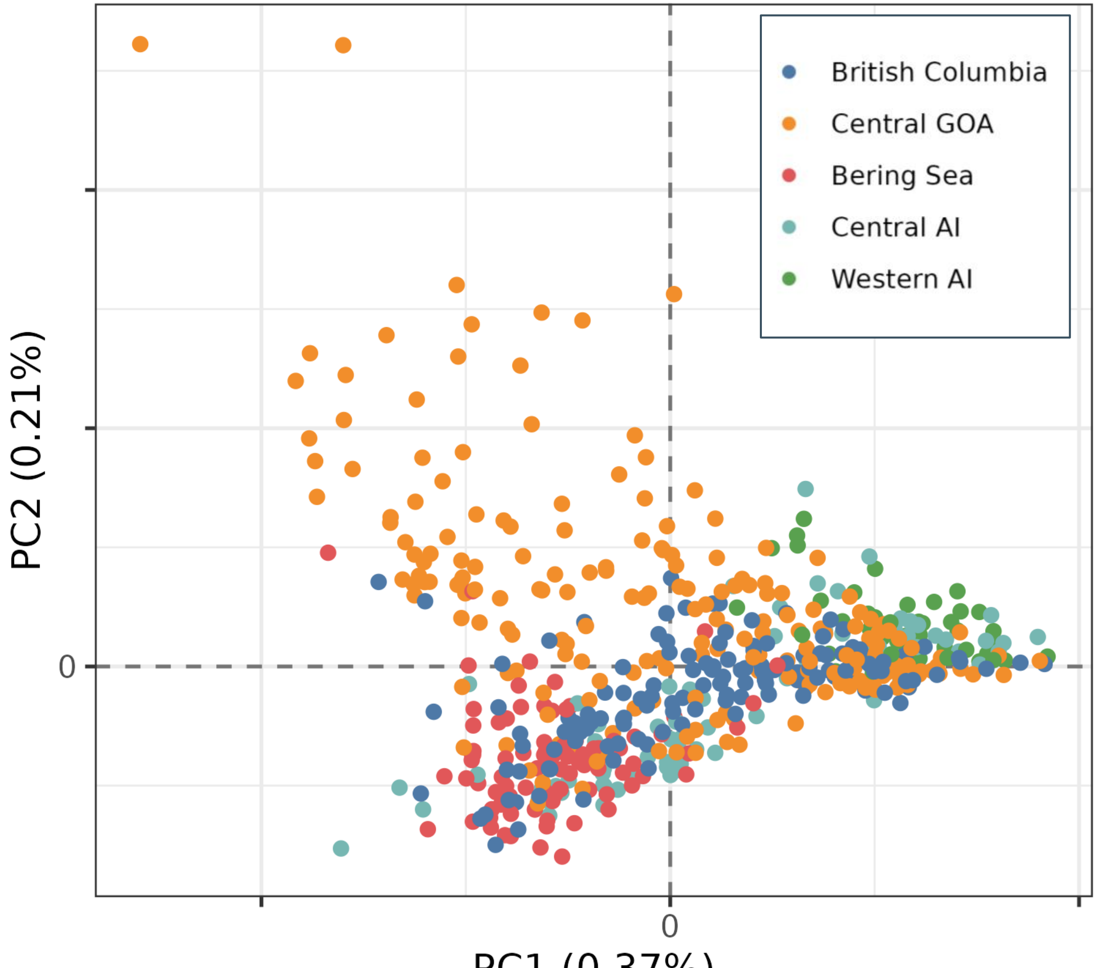
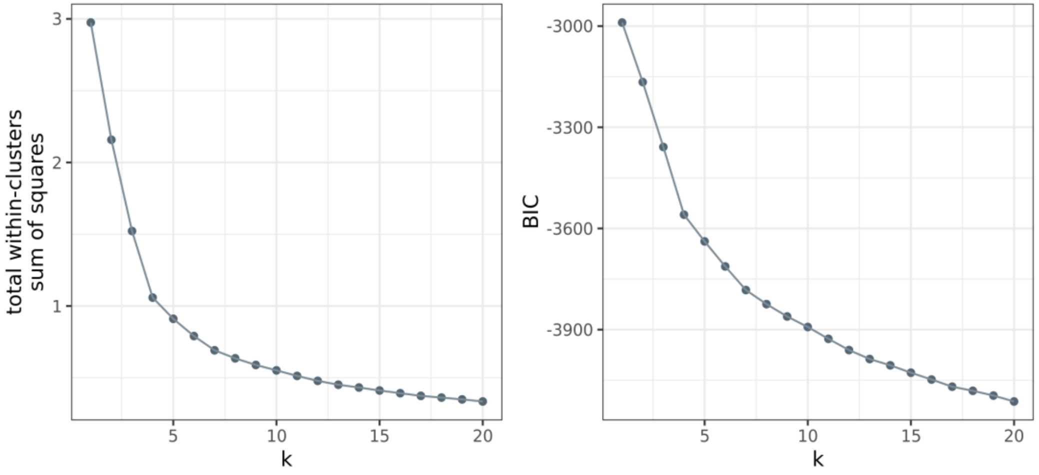
Migration and Population Dynamics



- Principal components analysis (PCA)
  - Dimensionality reduction technique
- Clustering algorithm (K-means) to test for the presence of discrete groups

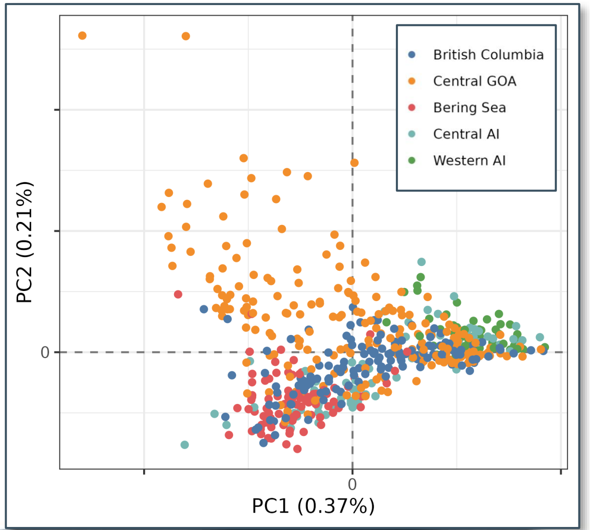
K-means clustering (top 3 PCs)

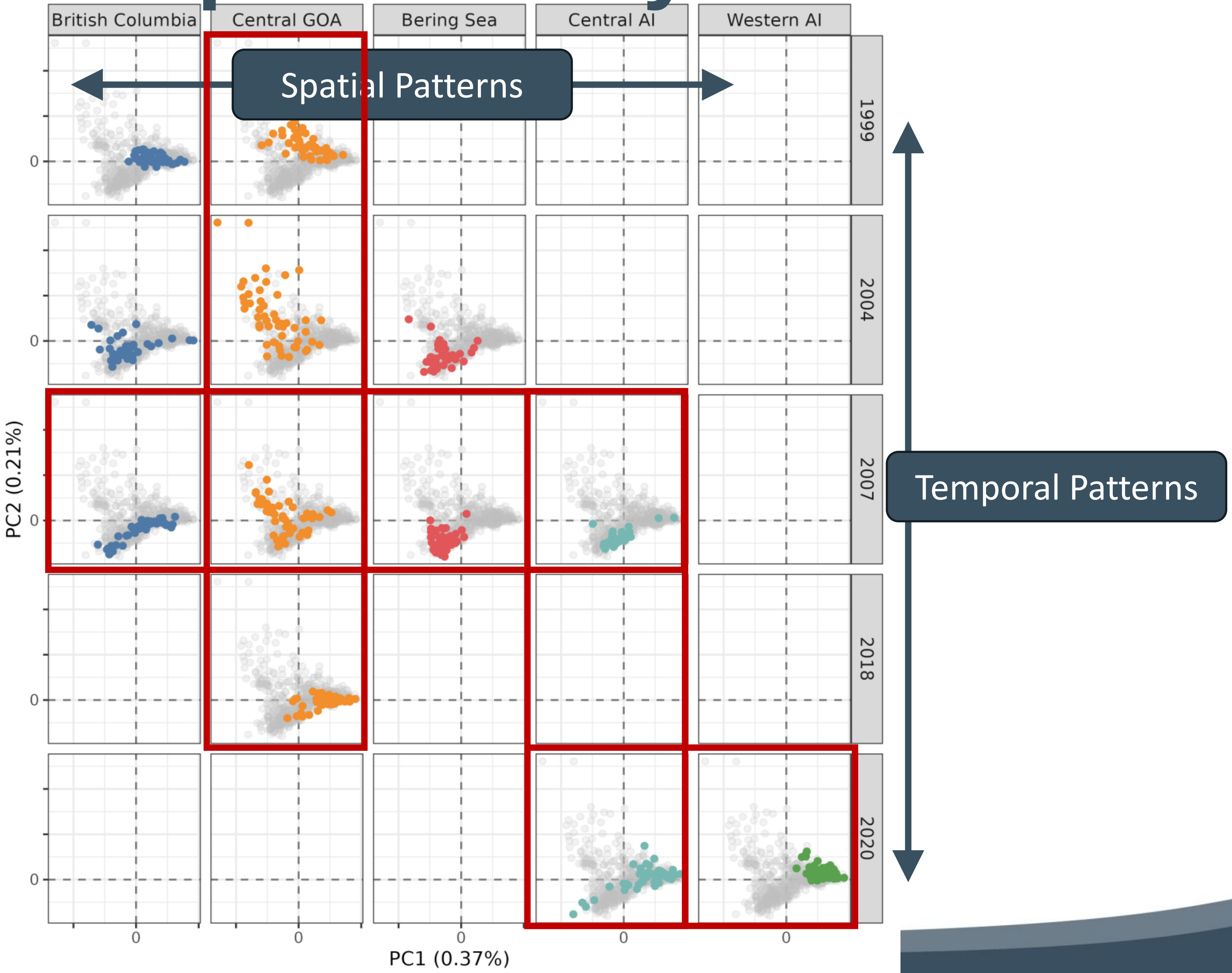


Unable to detect discrete groups using PCA & full set of genome-wide SNPs

Migration and Population Dynamics

- 1 sample collection per panel (colored points)
- all other samples plotted for reference (gray points)
- empty panel = no samples





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Migration and Population Dynamics

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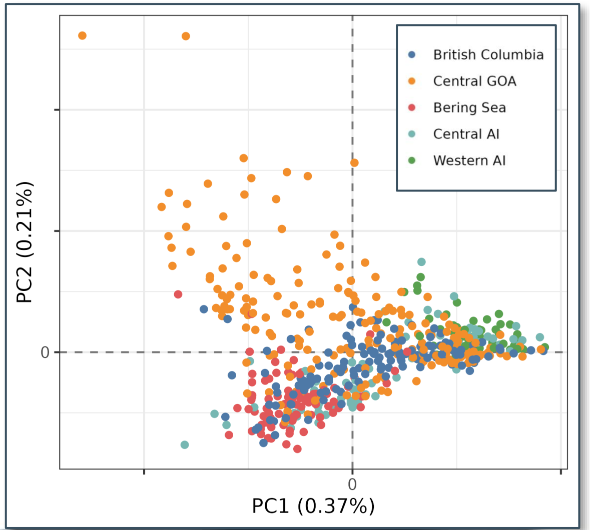
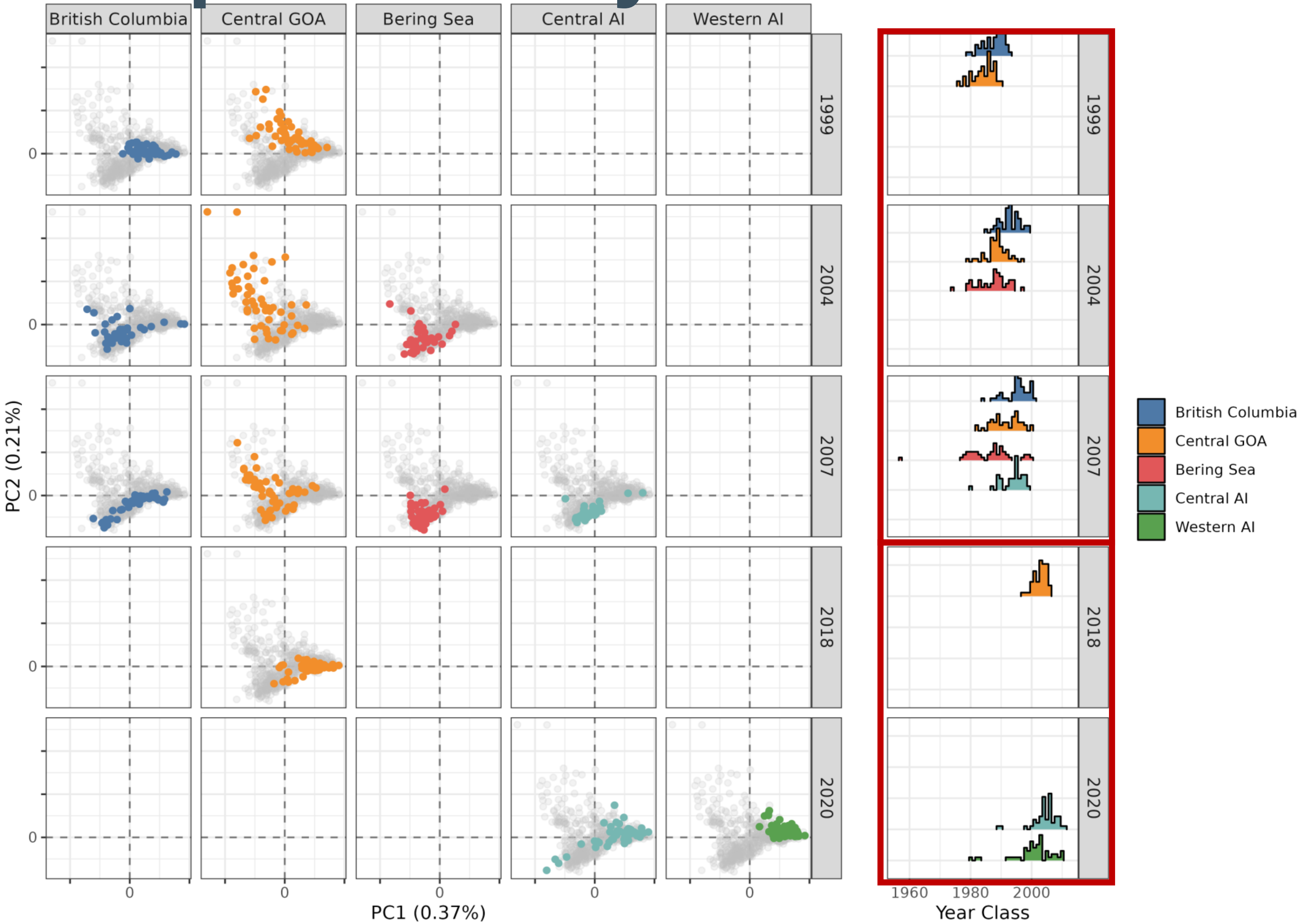




Reproduction

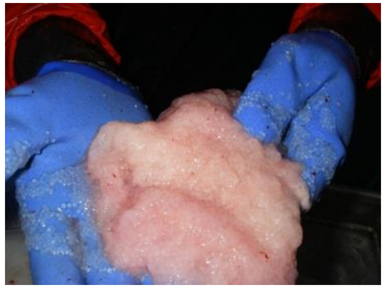
Current maturity estimates

- Visual assessment (macroscopic)
- Fishery-Independent Setline Survey (FISS)

Immature (1)

Mature (2)

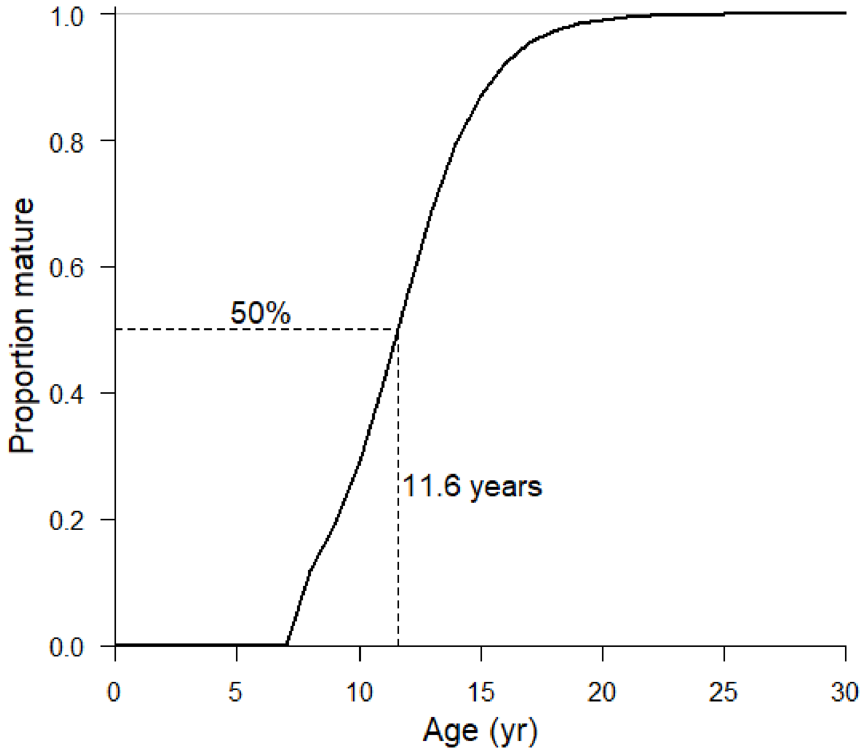
Spawning (3)



Resting (4)

Immature

Mature



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Reproduction

Maturity staging: based on histological oocyte stages

Female oocyte stages

Immature

Mature

Table 1.

Pacific halibut oocyte histology					Oocyte diameters (µm)	
Growth phase (acronym)	**Developmental stage (acronym)**	**Description**	**Photo**	**Sample size**	**Mean ± SD**	**Range (min - max)**
Primary Growth (PG)	One nucleolus (PGon)	Oocytes are small, angular, and compact with a single large nucleolus. Cytoplasm granules stain dark purple.		51	116 ±89	36 - 381
	Perinucleolar (PGpn)	Oocytes are larger and rounder than PGon Nuclei develop and flatten around the nucleus. Cytoplasm granules stain light purple.		55	235 ± 92	103 - 479
	Cortical alveolar (CA)	First cortical alveoli appear as white stain in the periphery of the oocyte.		237	445 ± 80	195 - 664
Secondary Growth (SG)	Primary vitellogenesis (Vtg1)	Yolk globules first appear at the periphery, stain pink, and fill inwards occupying up to 1/3 of the cytoplasm.		663	544 ± 69	362 - 750
	Secondary vitellogenesis (Vtg2)	Yolk globules transition from only the periphery of the ooplasm and fill inwards to the nucleus.		341	686 ± 91	465 - 910
	Tertiary vitellogenesis (Vtg3)	Yolk globules completely fill the ooplasm to the central nucleus and coalesce into larger yolk globules.		500	1171 ± 216	706 - 1644
Oocyte Maturation (OM)	Germinal vesicle migration (GVM)	The nucleus begins to migrate through a cytoplasm fully filled with large yolk globules.		302	1271 ± 257	811 - 1769
	Periovulatory (PO)	Nucleus no longer visible and the yolk globules coalesce into a central yolk mass. Oocyte is still within the follicle wall.		54	2037 ± 270	1600 - 2811
	Postovulatory follicle (POF)	Collapsed empty follicle wall remaining after a periovulatory oocyte is expelled.				

Females are assigned to a developmental stage based on the most advanced oocyte stage present

Fish et al. (2020) *J Fish Biol.* **97**:1880-1885

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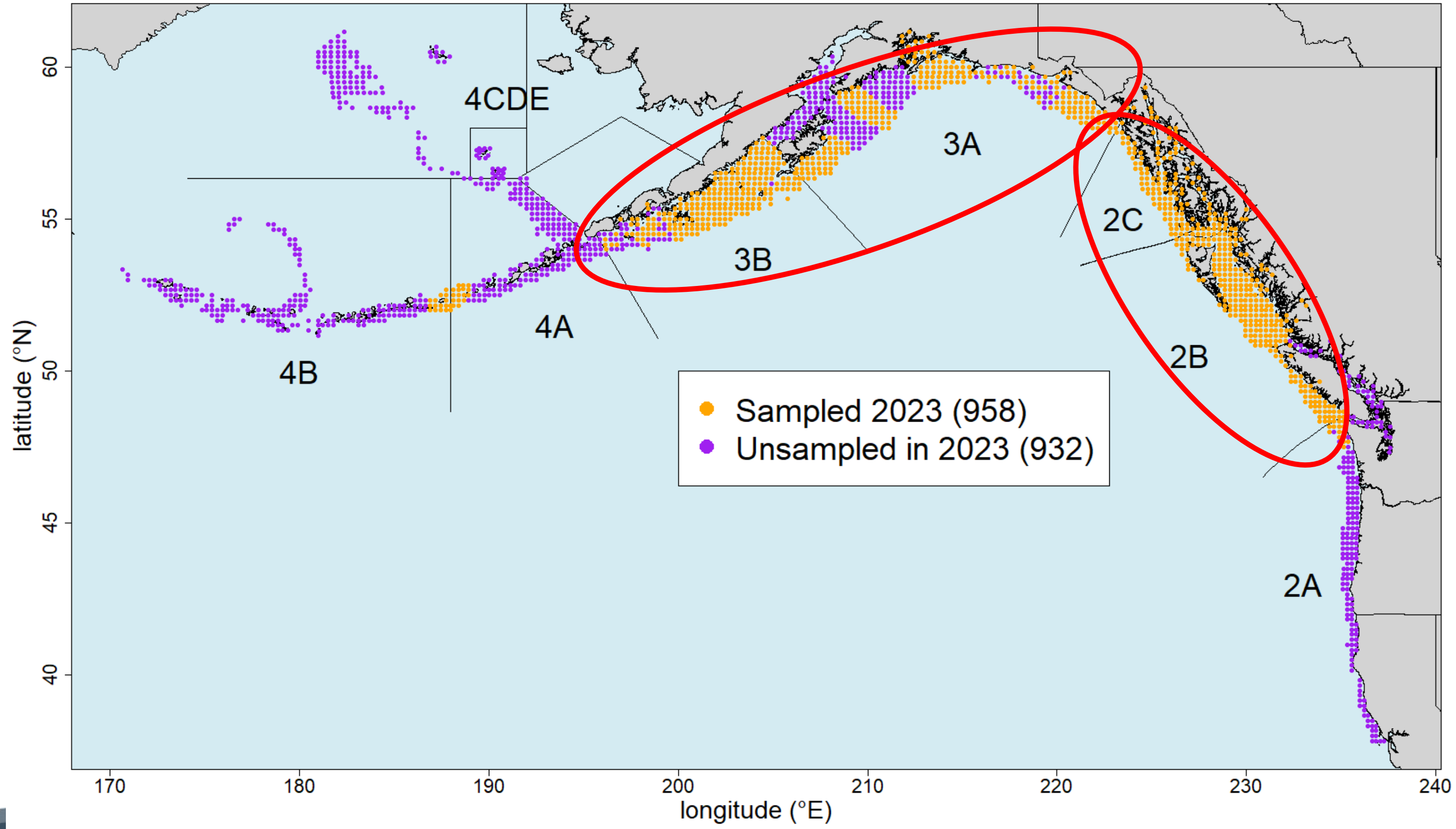
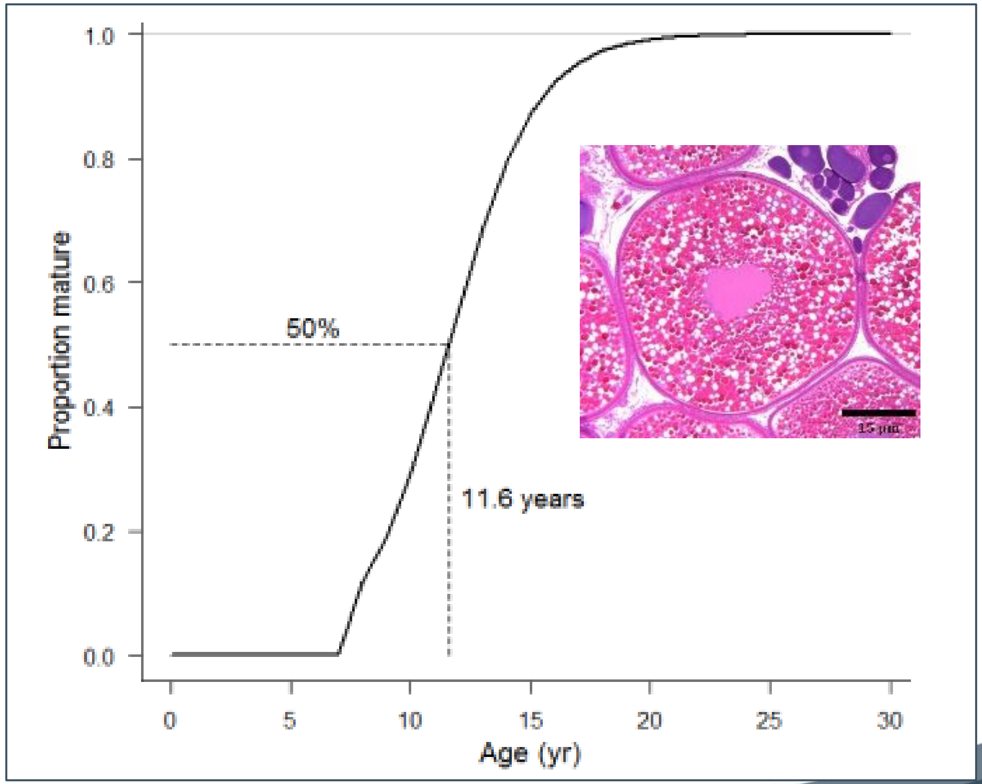
Reproduction

Coastwide sampling for histology-based maturity



- Revise maturity estimates coastwide / biological region by histological staging



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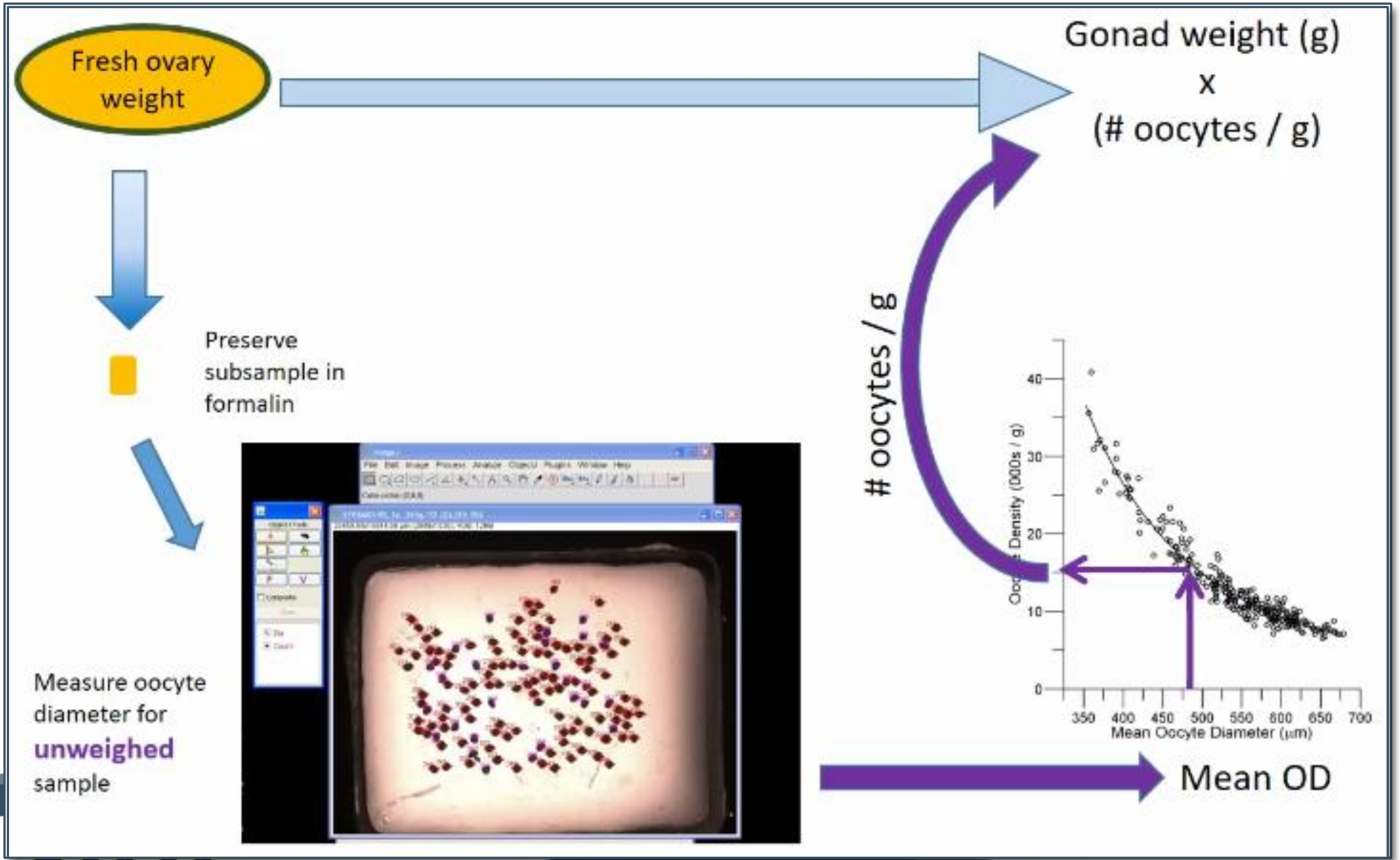
Reproduction

Fecundity: Auto-Diametric Method



➡

Fecundity (Total # oocytes)

- **McElroy et al (2013): Winter flounder**
- **McElroy et al (2015): Yellowtail flounder**

Target:
N = 250-300 fish

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Reproduction

Fecundity sample collection in FISS 2023

Biological Region 3

- Total = 452
  - Mature (field) = 295
    - Ovary Weight (mature) = 255

Collection Dates

30 May – 21 August 2023

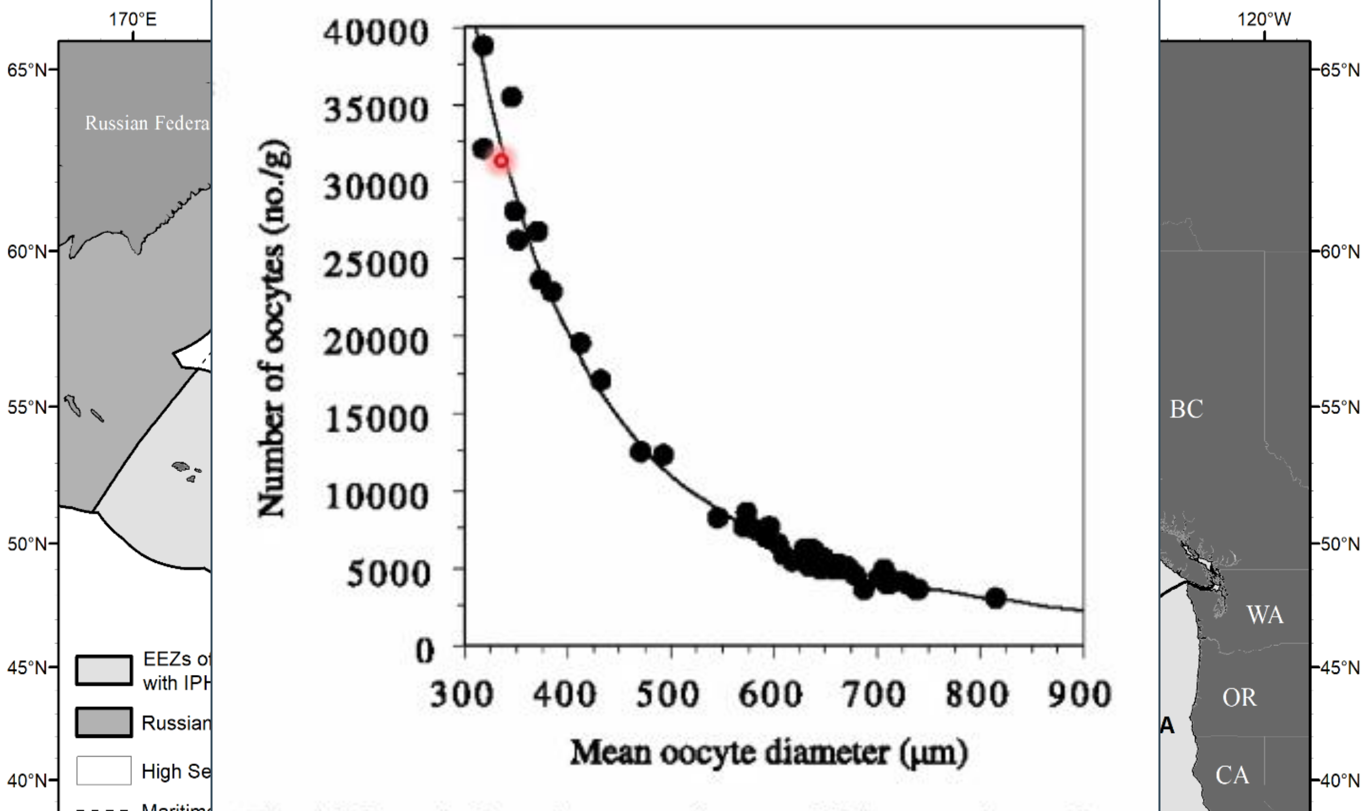

Fig. 4. Mean vitellogenic oocyte diameter (OD) versus the number of vitellogenic oocytes per gram of fresh ovary (NG).

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Mortality and Survival Assessment

DMRs in the guided recreational fishery

- Conduct experimental fishing in which Pacific halibut are subjected to typical recreational gear and handling practices, to:

    1. Investigate relationships between hook size and catch size
    2. Develop injury and physiological stress profiles.
    3. Quantify and characterize survival






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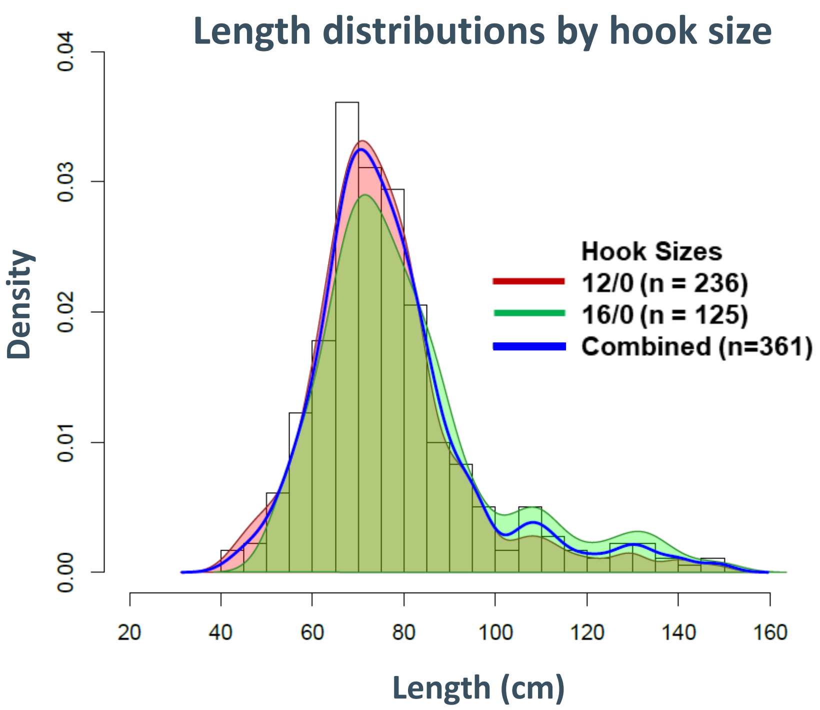
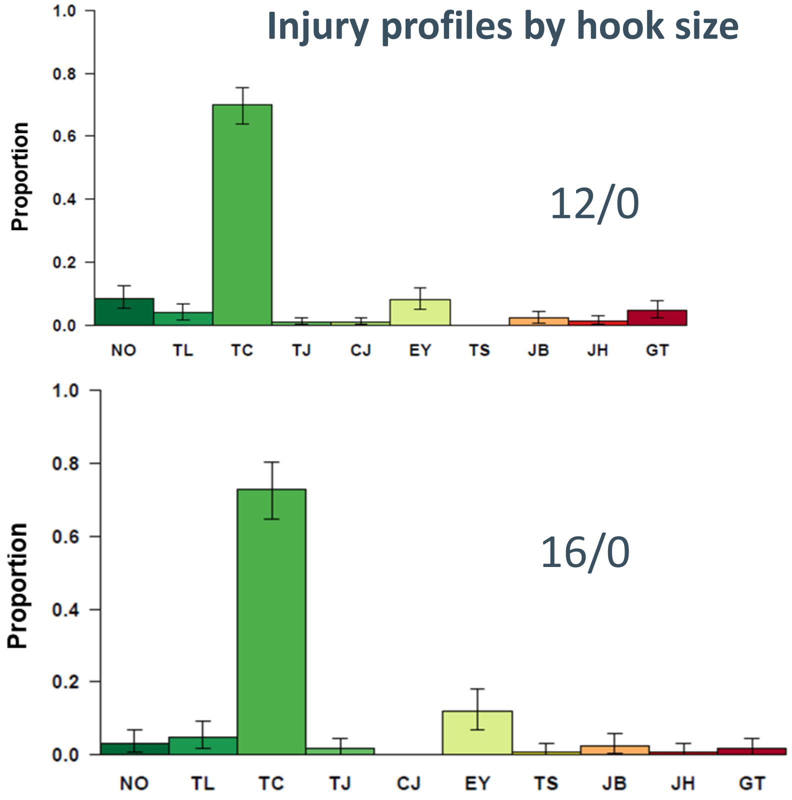
NFWF

Mortality and Survival Assessment

DMRs in the guided recreational fishery

Results: 1. Hook size and relation to fish size and injuries





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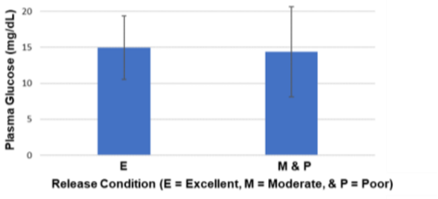
Mortality and Survival Assessment

DMRs in the guided recreational fishery

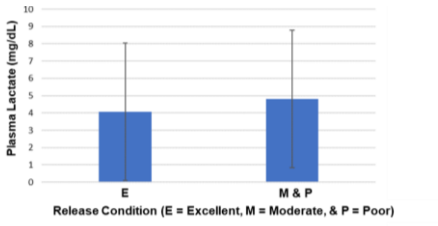
Results: 2. Physiological stress profiles

Plasma levels by <u>release condition</u>

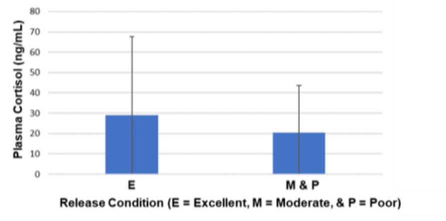
Glucose



Lactate

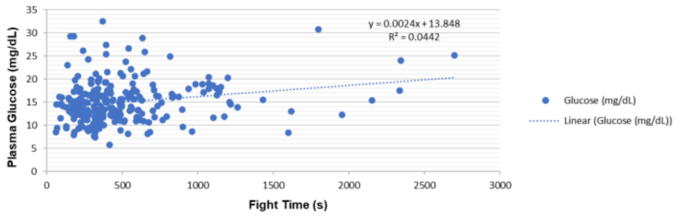


Cortisol



Plasma levels by <u>fight time</u>

Glucose



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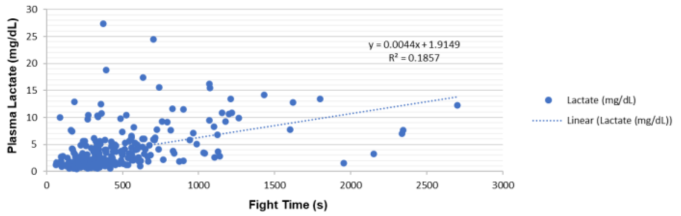
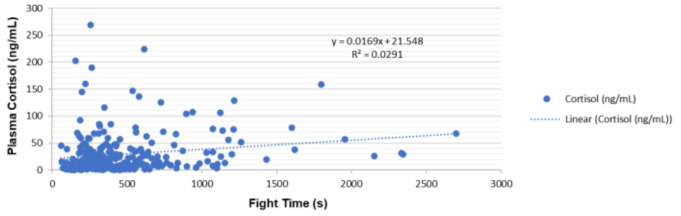


Cortisol

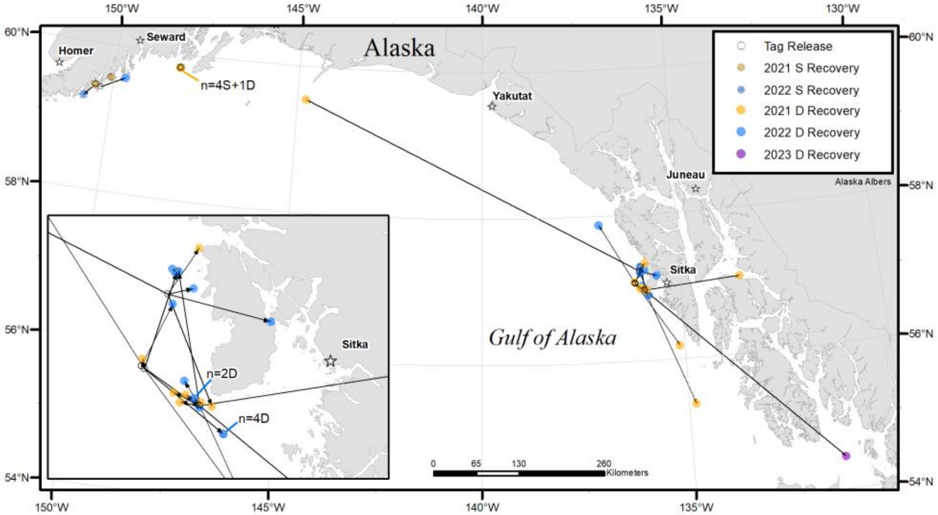


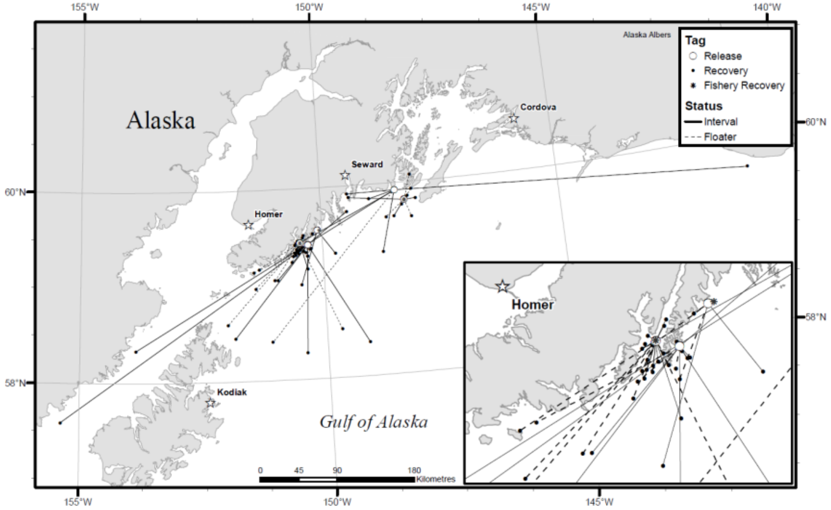
Mortality and Survival Assessment

DMRs in the guided recreational fishery

Results: 3. Quantify and characterize survival

- Wire tags = 281 (all viabilities) – 34 recovered to date





- sPATs = 80 (**only** on Excellent viability) – 76 provided functional data
  - ***Mortality rate estimate***: **1.35%** (95% CI of 0.00-3.95% for Excellent viability)

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Fishing technology

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

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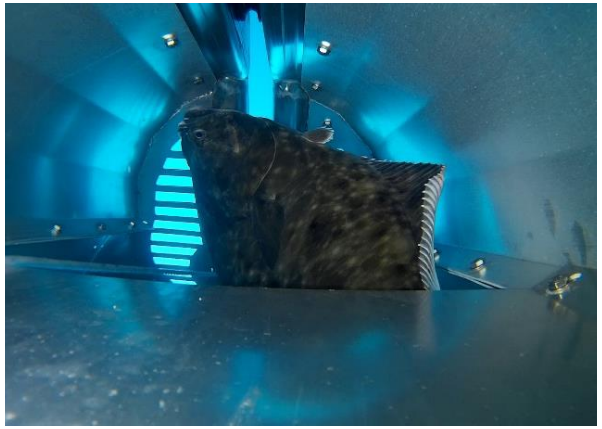
Fishing technology

Reducing whale depredation by protecting longline catches

Phase 2: Shuttle field testing

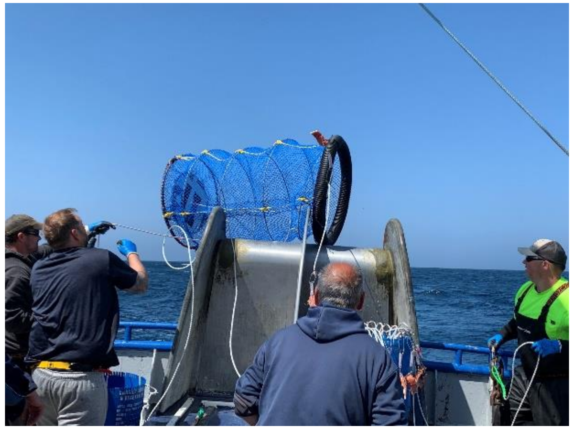
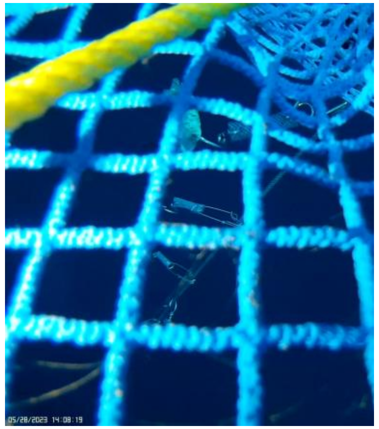
Preliminary conclusions

- 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.

Fishing technology

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.

Fishing technology

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).

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

Phase 3b: Testing in presence of Sperm whales

Pending funding

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