INTERNATIONAL PACIFIC HALIBUT COMMISSION

Report on current and future biological and ecosystem science research activities

Agenda Item 4.1.3
IPHC-2023-SRB022-09
(J. Planas)

Outline

Progress and future activities in key research areas:

1. **Migration and Population Dynamics**
2. **Reproduction**
3. **Mortality and Survival Assessment**
4. **Fishing Technology**

IPHC's 5-year Program of Integrated Research and Monitoring (2022-26)

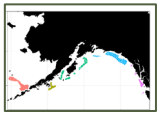
1. Migration and Population Dynamics

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*

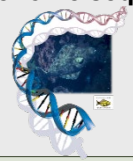
Juvenile connectivity

- 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*

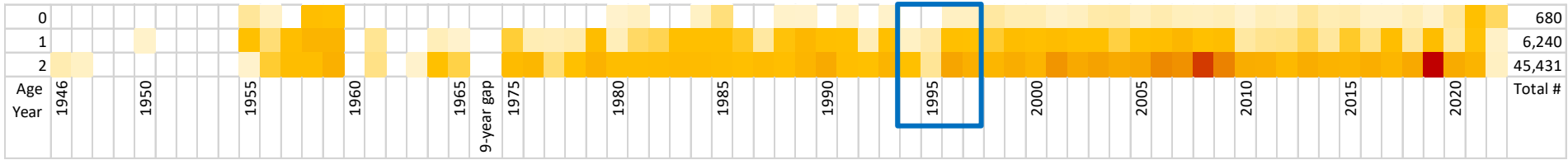
PIRM 2022-2026

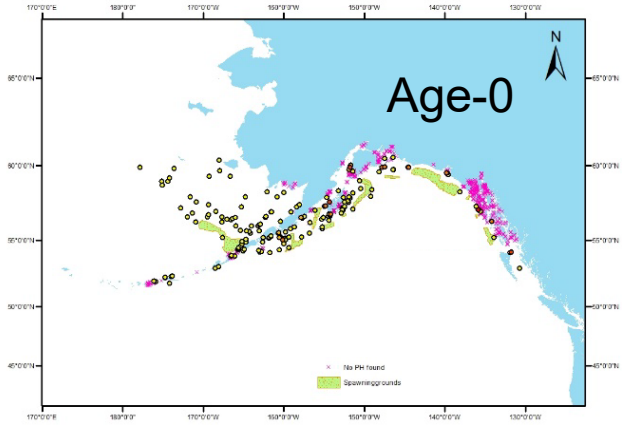
- Climate effects on larval connectivity
- Connectivity with Western Pacific Ocean region
- Mapping of settlement/nursery areas
- Characterization of genetic composition/mixture of settlement areas
- Establishment of a baseline of genetic diversity
- Delineation of fine-scale stock structure
- Stock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

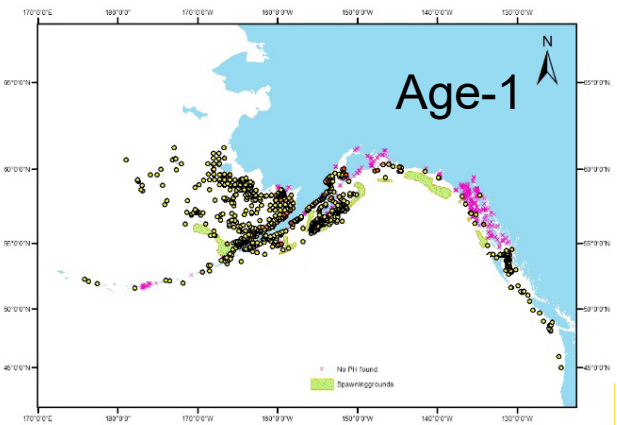
1. Migration and Population Dynamics

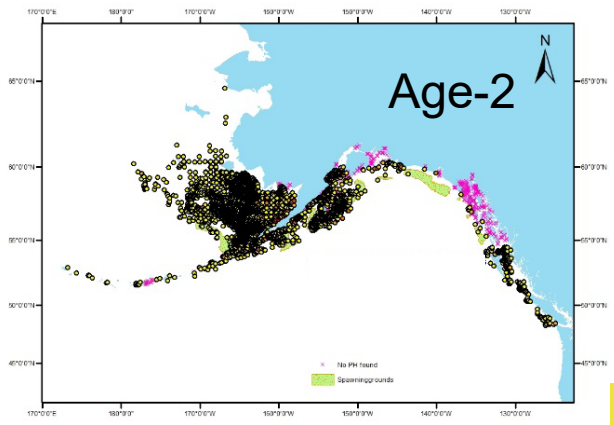
Mapping of juvenile habitat

- 52,356 Pacific halibut records thus far (11 different sources)
- 1,430 sites where Pacific halibut are absent
- Cooperative work ongoing with Alaska Coastal Observations and Research





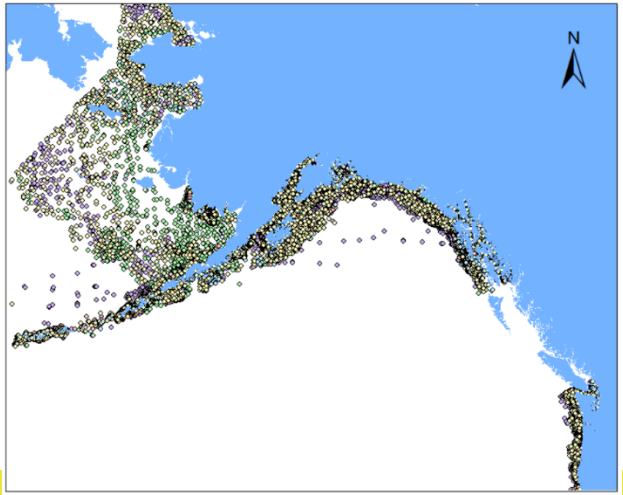


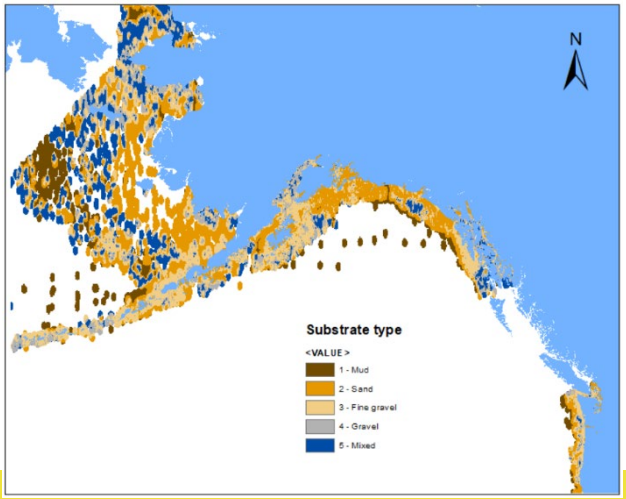


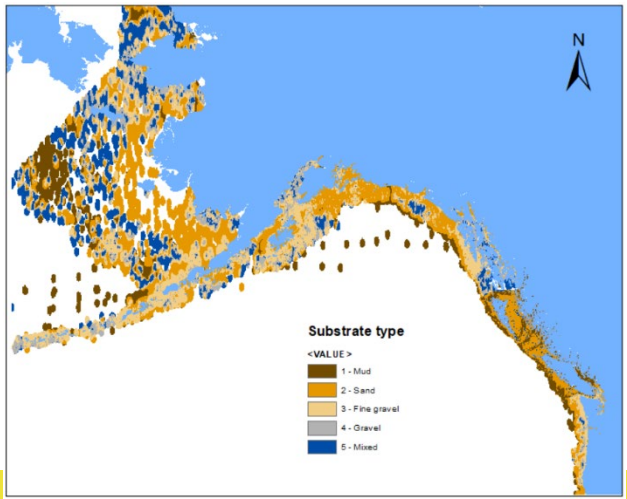
1. Migration and Population Dynamics

Mapping of juvenile habitat – substrate layers

- usSeabed database (USA) - Buczkowski et al. (2020)
- Inverse distance weighting to create substrate layer for USA
- British Columbia substrate layer 100-m resolution (Gregr et al., 2021) – provided by Dr. Dana Haggarty (DFO)
- Next step: add bathymetry







1. Migration and Population Dynamics

5-Yr Research Plan (2017-2021)

Multiple life-stage connectivity

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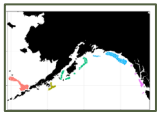

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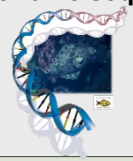

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PIRM 2022-2026

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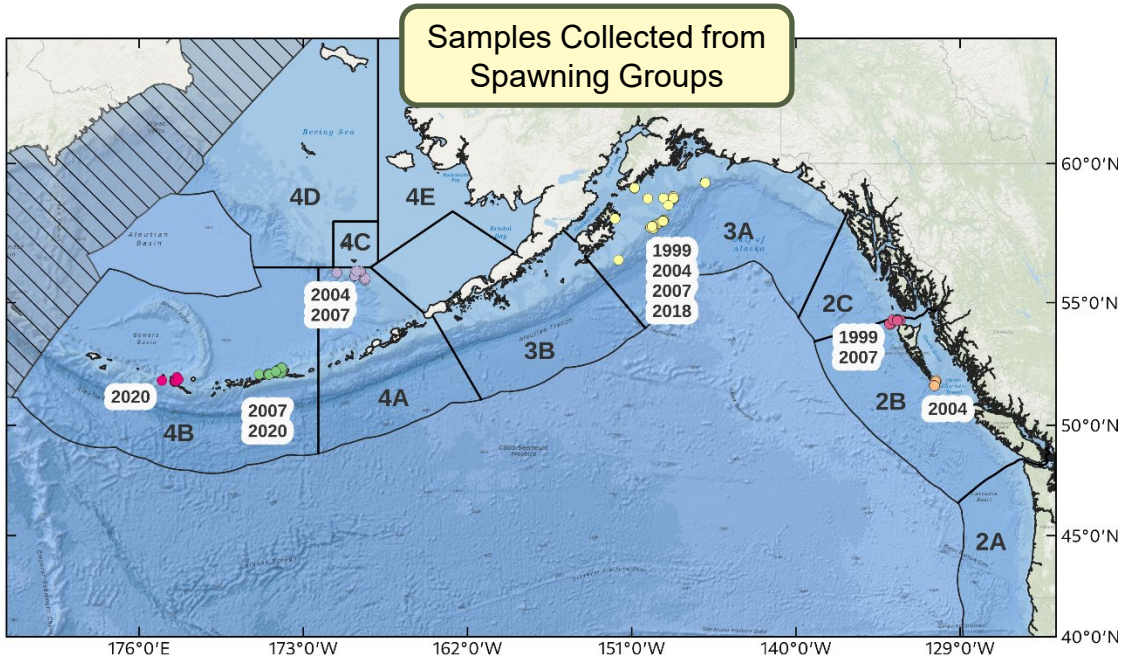
1. Migration and Population Dynamics

Population Genomics

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

Pacific Halibut Genome

- Version 2 – March 2022
- Establish Genetic Baseline
- Identify potential local and/or environmental adaptations.
- Provide genetic basis for life-history traits (e.g., growth, maturity, migratory behavior, etc.).

1. Migration and Population Dynamics

Sequencing

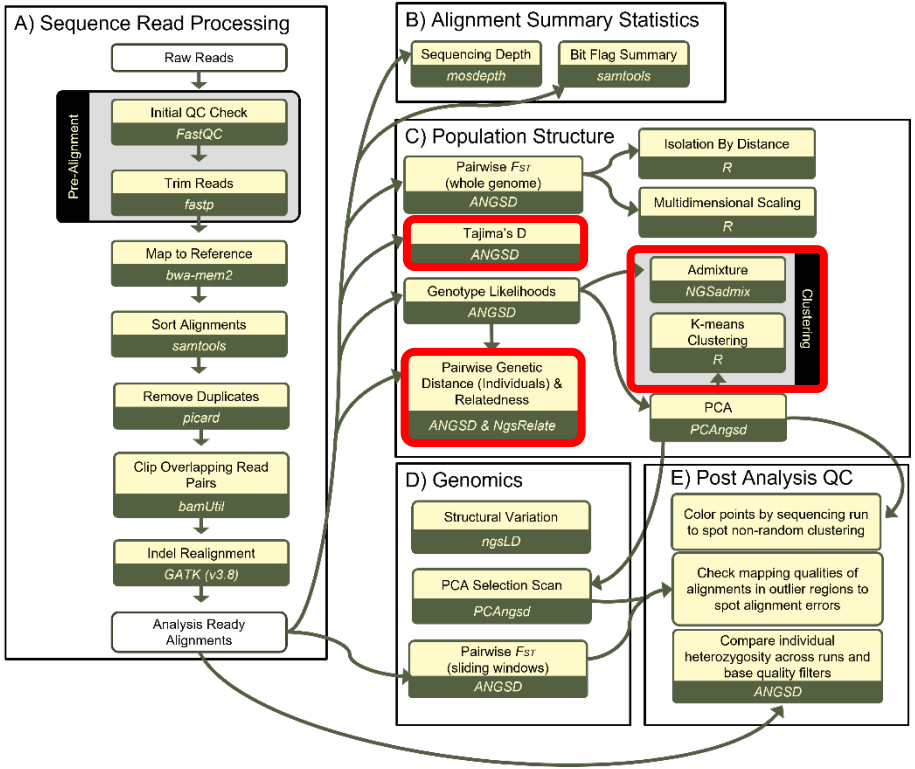
- 2x150 bp paired end reads
  - Illumina NovaSeq S4
  - Novogene Corporation (Sacramento, CA, USA)
- 16,429,218,225 total sequence reads
- ***610 Samples Sequenced (604 passed QC)***

Genomic Sequencing	Sequencing Run # 1	Sequencing Run # 2	Sequencing Run # 3
Number of samples*	250 (247)	250 (249)	110 (108)
Sequencing Platform	Illumina NovaSeq S4	Illumina NovaSeq S4	Illumina NovaSeq S4
Raw Reads Per Sample (Millions)**	24.8 (11.5-47.2)	24.9 (13.0-51.6)	27.7 (14.1-85.8)
Reads Retained (%)**	71 (62-77)	71 (57-77)	70 (59-75)
Coverage Per Sample (x)**	3.7 (1.8-5.9)	3.7 (1.8-7.0)	4.2 (1.8-11.6)

Table 1. Summary of raw sequence data and genome alignments for three Pacific halibut lcWGR sequencing runs. Summary statistics are only calculated for samples retained for further analyses (>1.5x coverage) *numbers in parenthesis indicate number of samples with > 1.5x coverage. **expressed as mean (min – max).

1. Migration and Population Dynamics

Workflow

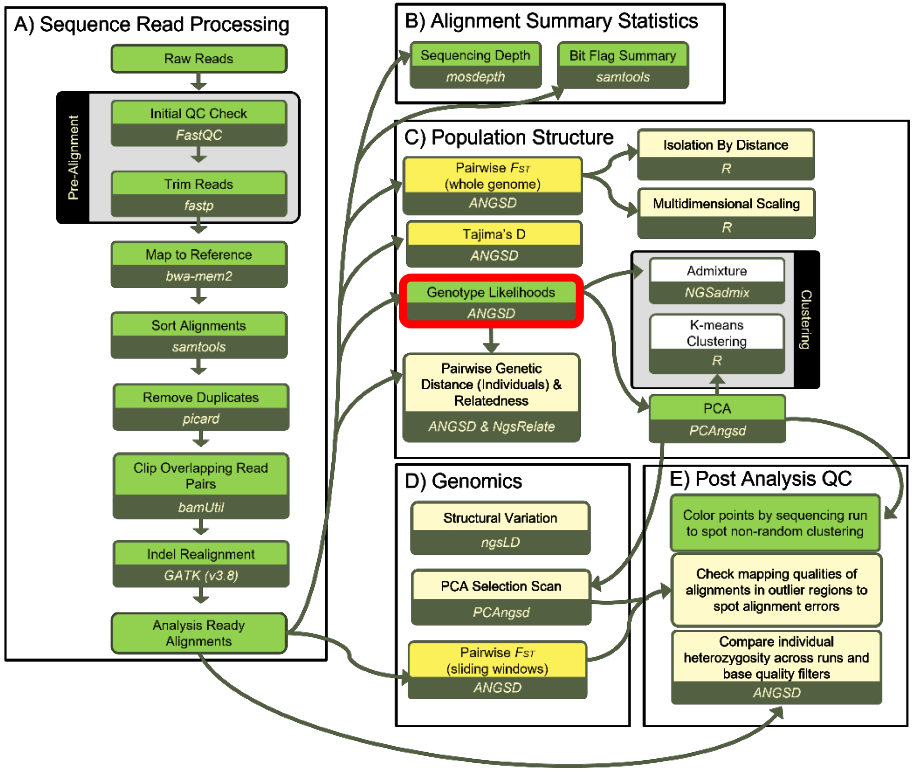


*SRB021–Rec.11 (para. 47) **NOTING** the flow chart presented in Figure 1 of paper IPHC-2022-SRB021-09, the SRB **RECOMMENDED** that (i) additional analyses be conducted in areas of unsupervised clustering for individuals, and (ii) estimate measures of genetic variation among individuals within and among sampling groups to characterize inter-individual relationships, which could provide further indication of admixture. The coefficients of relationship among individuals within sampling location and levels of pair-wise variance in SNP allele frequency between sampling locations can be used to identify 'source' and 'sink' regions.*

*SRB021–Rec.12 (para. 48) The SRB **NOTED** that in the sub-area of Population Genetics and Structure, the Secretariat intends to use Site Frequency Spectral (SFS) analyses. Both selection and population growth can produce similar SFS patterns in data. As such, the SRB **RECOMMENDED** testing using a 'Tajima D' analysis and estimate levels of excess of low frequency SNP alleles within sampling areas (or reporting units).*

1. Migration and Population Dynamics

SNP-detection



SNP Detection & GL Estimation

-GL 2: GATK model for GL estimation
-doMajorMinor 1: Infer major and minor from GL
-doMaf 1: assume fixed major and minor alleles
-minMaf 0.01: filter sites with MAF <= 1%
-SNP_pval 1e-6: Filter sizes based on probability they are variable
-minInd: site required in > 80% of individuals
-setMinDepth: total read depth > 604
-setMaxDepth: total read depth < 3624
-minMapQ 20: discard low quality alignments
-minQ 20: discard low quality bases

- **10,230,908 autosomal SNPs**
- **4,725,899 (minor allele frequency ≥ 0.05)**

1. Migration and Population Dynamics

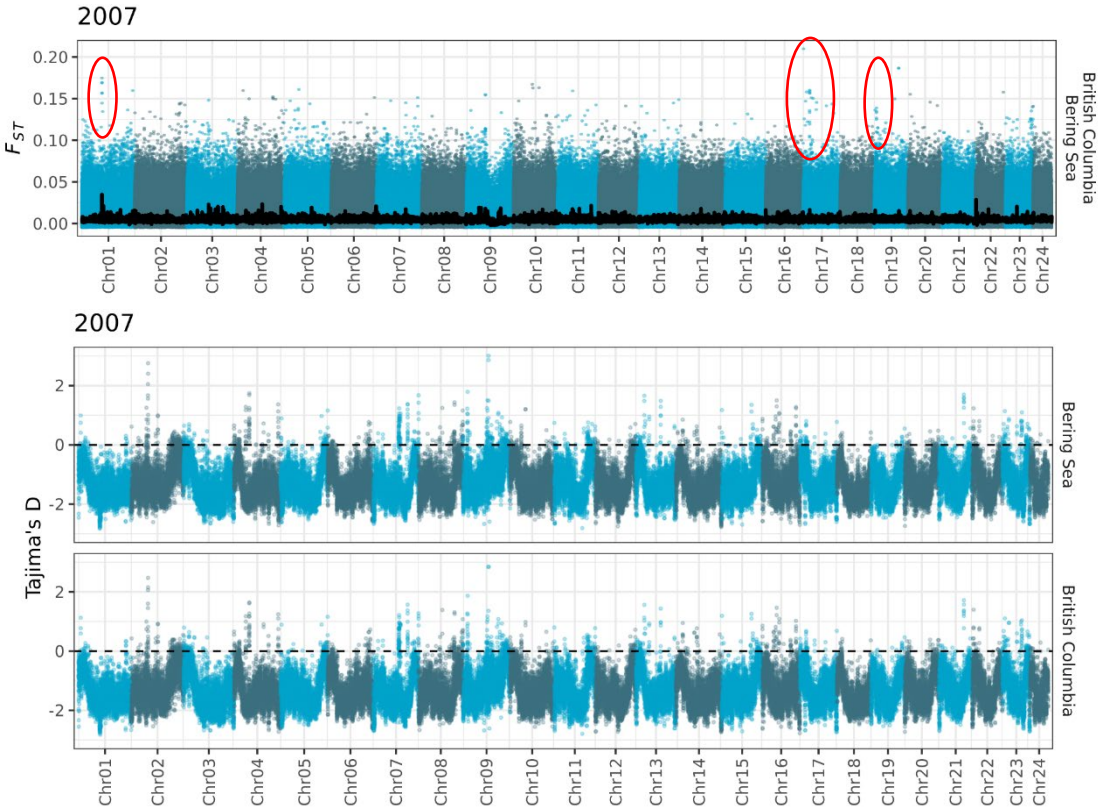
Preliminary results

Pairwise F_{ST}

- Requires a predefined population groups
  - 0 = complete panmixia
  - 1 = complete separation

Tajima's D

- Single population statistic
  - D > 0 : excess of common variants
  - D = 0 : observed variation fits expectation
  - D < 0 : excess of rare variants

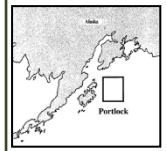


2. Reproduction

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

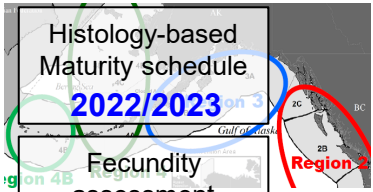
Histological samples → Characterization of oocyte stages → Classification of female developmental stages → Classification of reproductive phases

Research outcomes:

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

Appropriate timing of gonad collection in FISS

- June-August



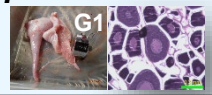
Histology-based Maturity schedule **2022/2023**

Fecundity assessment **2023**

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

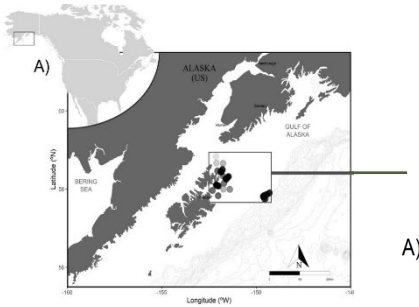
2017-2022 Commercial landings

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

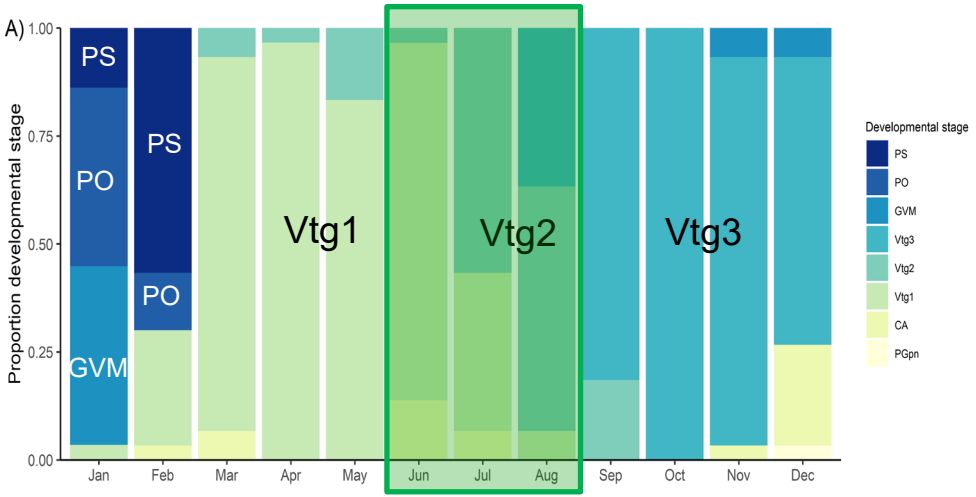
Publications: Fish et al. (2020) *Journal of Fish Biology* ***97****: 1880–1885*
Fish et al. (2022) *Frontiers in Marine Science* ***9****: 801759*

2. Reproduction

Microscopic maturity staging: histological oocyte stages



Portlock Region (Central GOA)



FISS

Immature: Cortical alveoli (CA)

↓

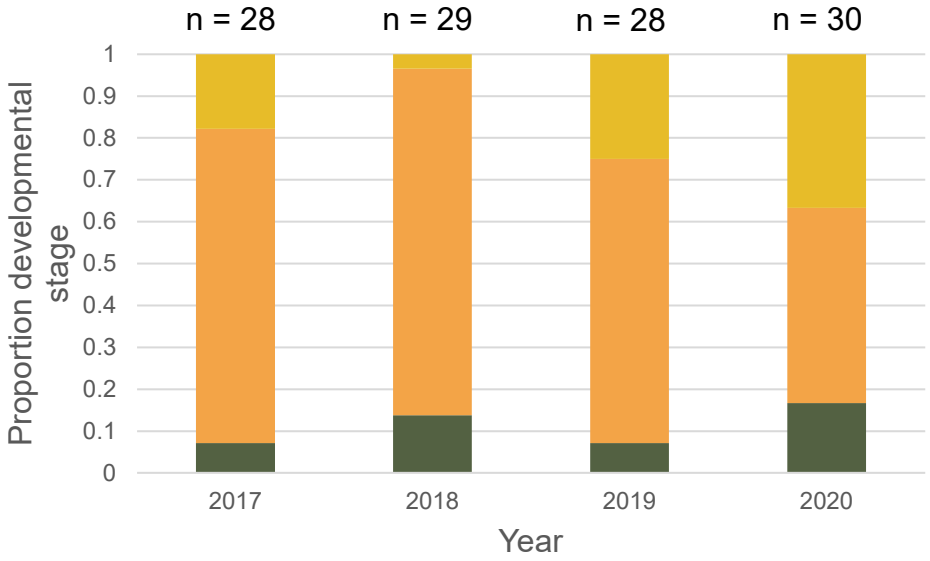
Mature:
- Vtg1 (Vitellogenic 1)
- ↓ Vtg2
- ↓ Vtg3
- ↓ GVM (Germinal vesicle migration)
- ↓ PO (Periovulatory)
- ↓ PS (Post-spawning)

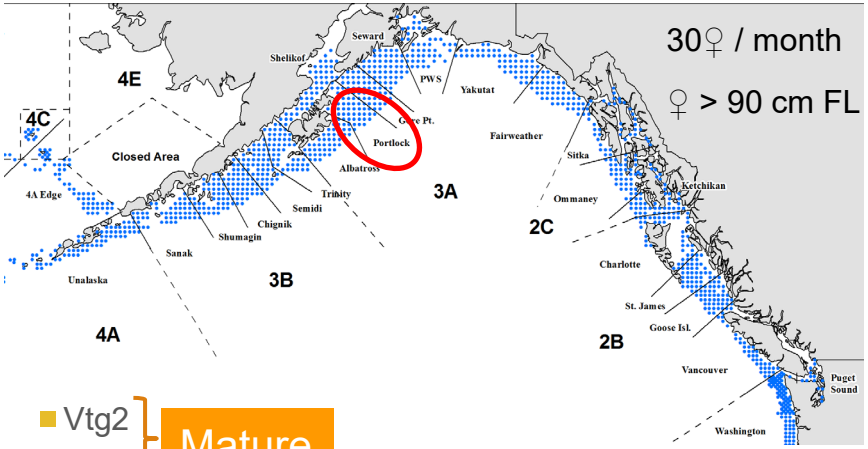
Fish et al. (2022) *Front. Mar. Sci.* **9**:801759

2. Reproduction

Pilot study: temporal differences in developmental stages

2017 – 2020: June sample collection (July in 2020)

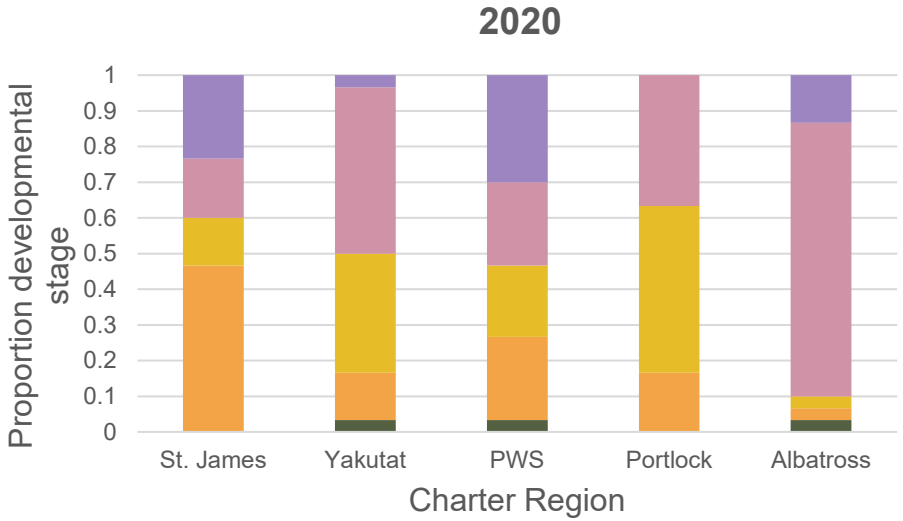


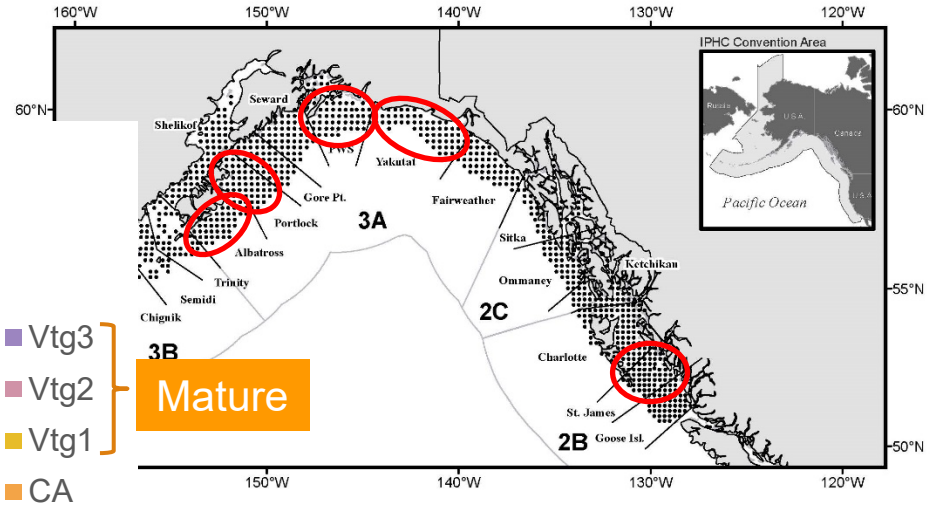


2. Reproduction

Pilot study: spatial differences in developmental stages

Samples collected in July/August 2020 in 5 regions: St. James, Yakutat, PWS, Portlock, Albatross



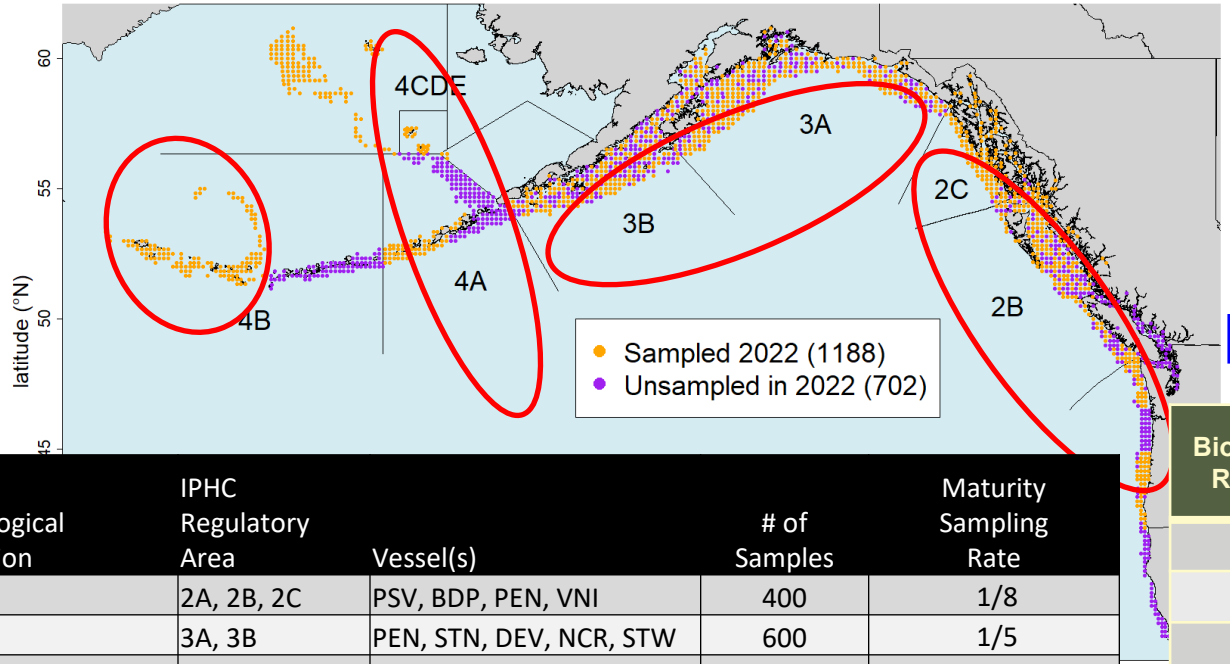


30♀ / region

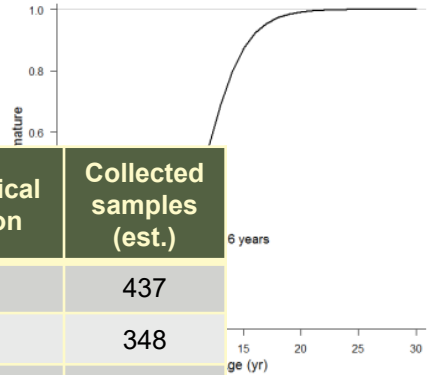
♀ > 90 cm FL

2. Reproduction

FISS 2022: ovarian collection for histology-based maturity



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

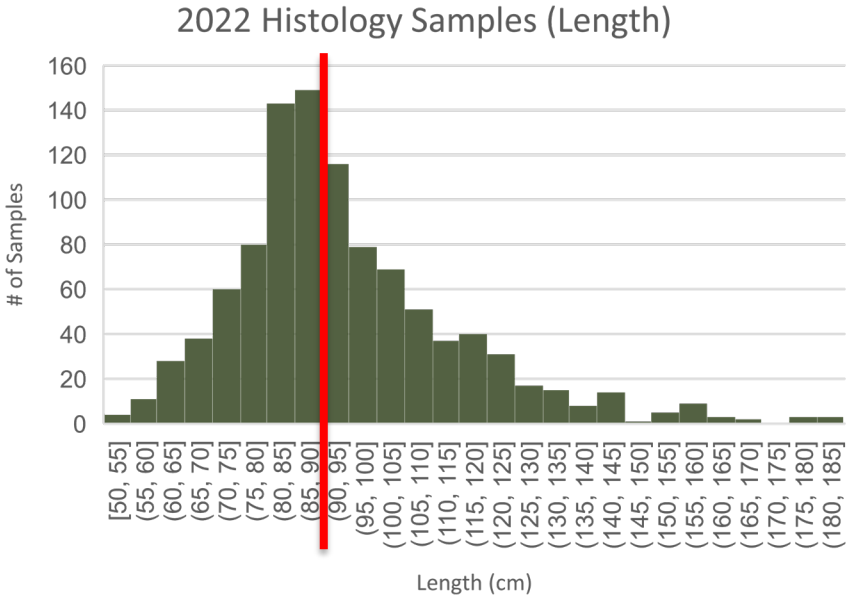


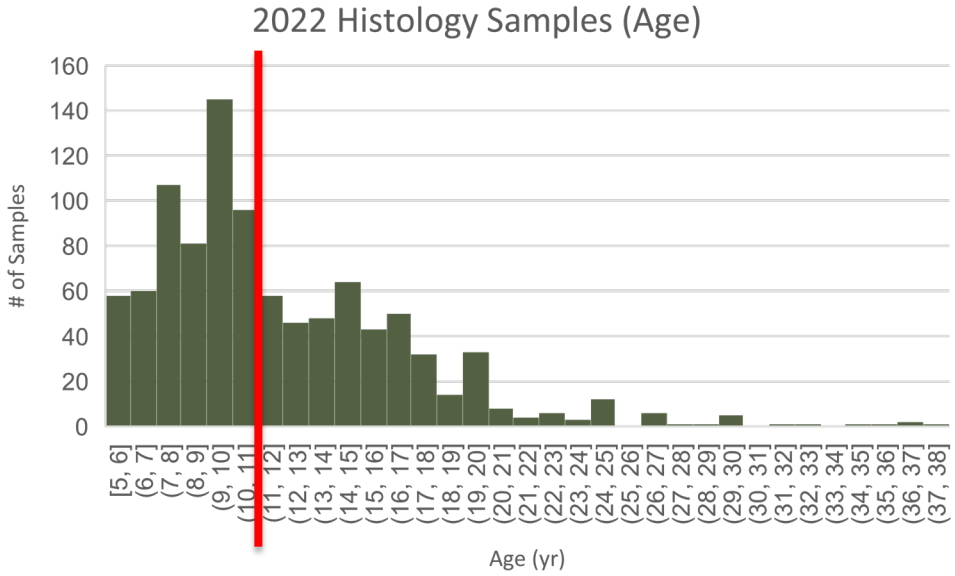
Biological Region	IPHC Regulatory Area	Vessel(s)	# of Samples	Maturity Sampling Rate
2	2A, 2B, 2C	PSV, BDP, PEN, VNI	400	1/8
3	3A, 3B	PEN, STN, DEV, NCR, STW	600	1/5
4	4A, 4CDE, CLS	KSU, STW	400	1/5
4B	4B	KSU	258	1

Biological Region	Collected samples (est.)
2	437
3	348
4	180
4B	51

2. Reproduction

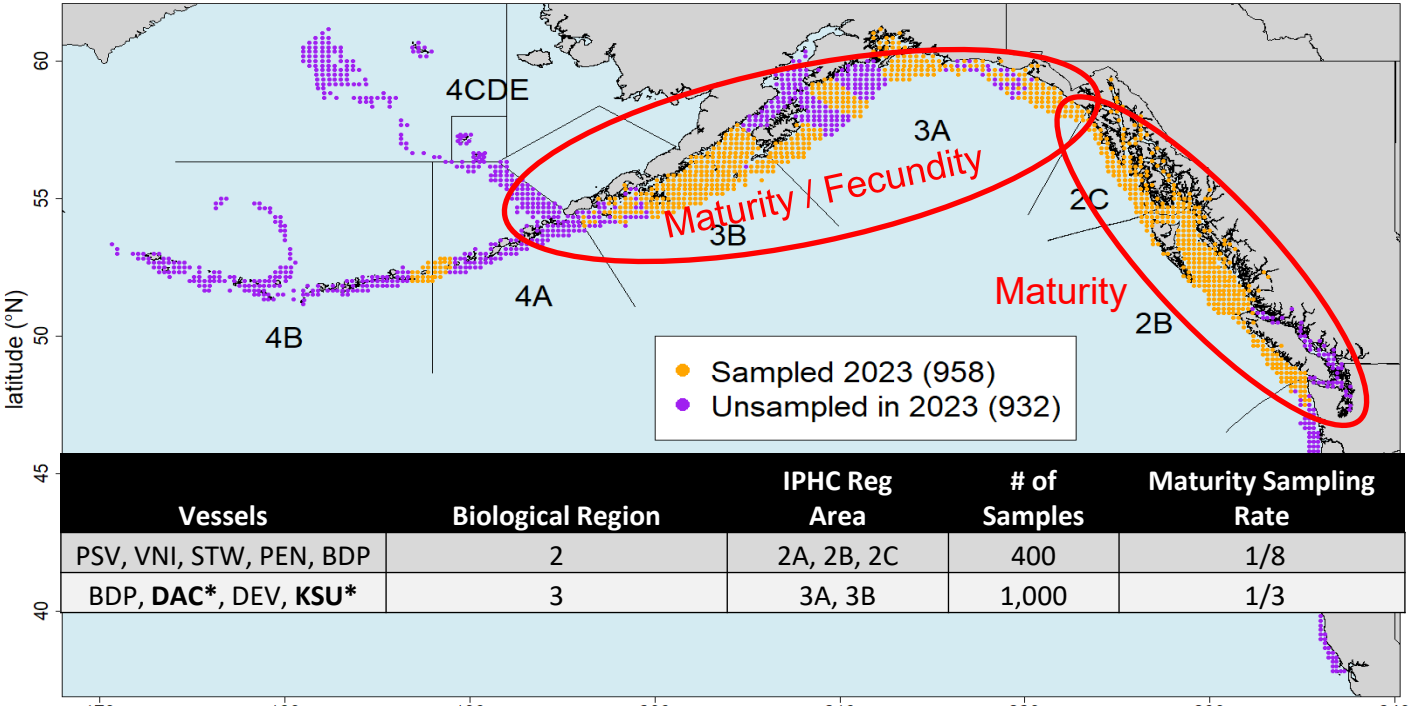
FISS 2022: ovarian collection for histology-based maturity





2. Reproduction

FISS 2023: ovarian collection for maturity/fecundity estimations



Vessels	Biological Region	IPHC Reg Area	# of Samples	Maturity Sampling Rate
PSV, VNI, STW, PEN, BDP	2	2A, 2B, 2C	400	1/8
BDP, **DAC***, DEV, **KSU***	3	3A, 3B	1,000	1/3

Vessel	Maturity Vial #'s
PSV	1 - 80
VNI	81 - 160
STW	161 - 360
PEN	361 - 520
BDP	521 - 720
DAC	721 - 920 (x2)
DEV	921 - 1120
KSU	1121 - 1520 (x2)

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

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

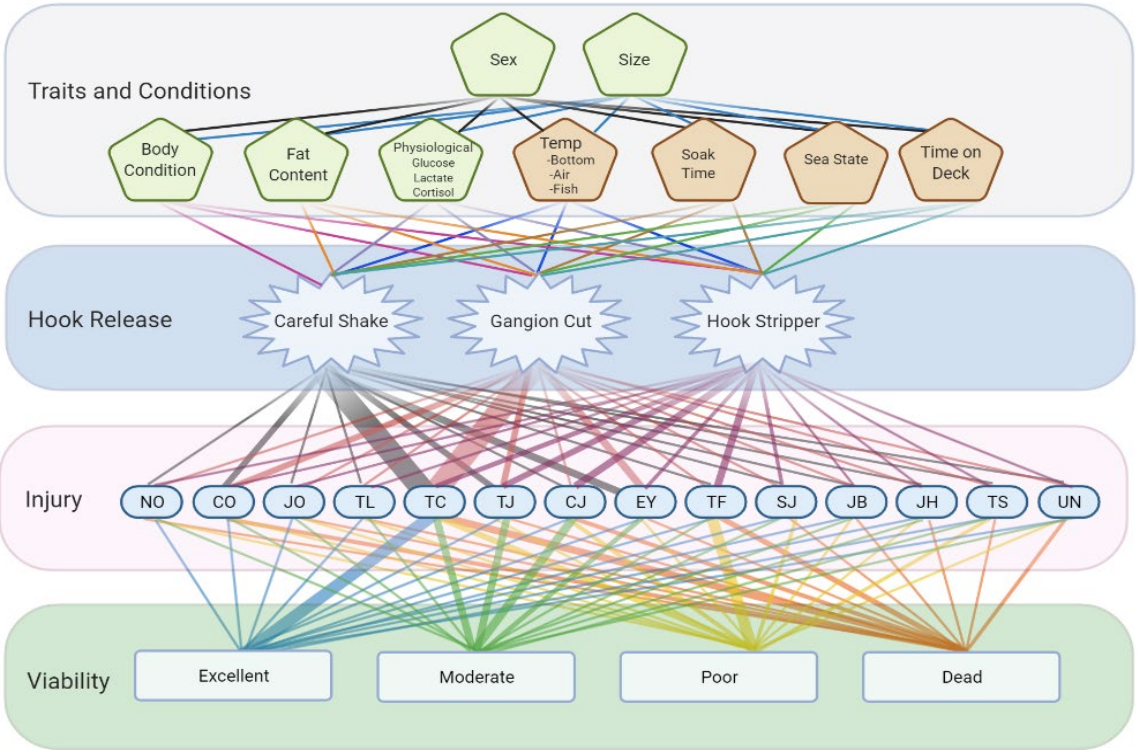
External funding: Saltonstall-Kennedy NOAA (2017-2020); NFWF (2019-2021); NPRB#2009 (2021-2022)

Publications: Kroska et al. (2021) *Conservation Physiology* ***9****: coab001*

Loher et al. (2022) *North American Journal of Fisheries Management* ***42****: 37-49c*

3. Mortality and Survival Assessment

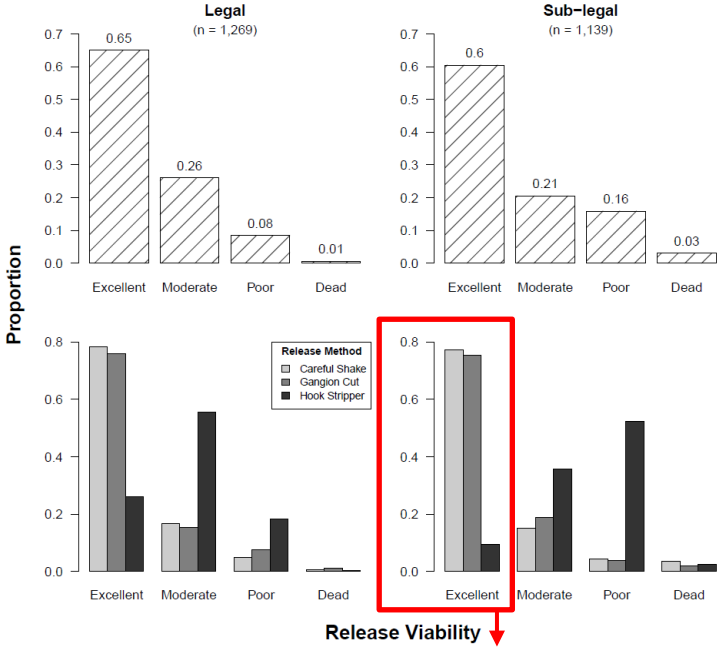
Characterization of discards in the directed longline fishery

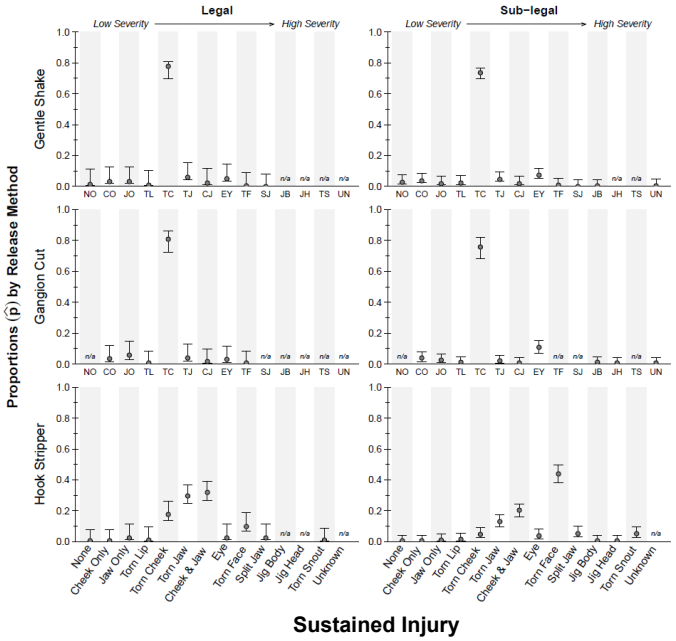


3. Mortality and Survival Assessment

Characterization of discards in the directed longline fishery

Hook Release Methods: Viabilities and Injuries



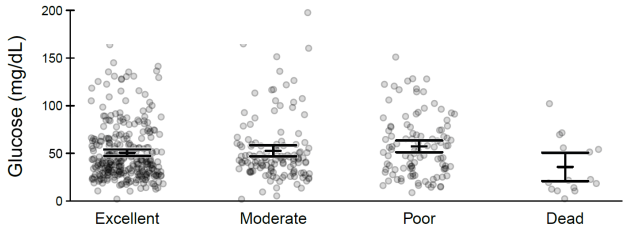


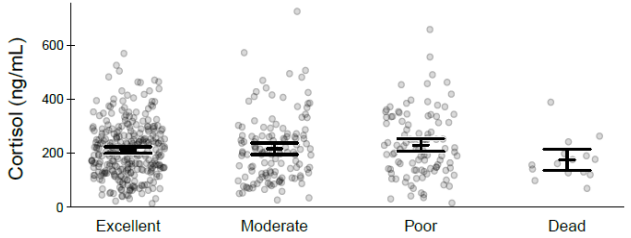
Min. DMR = 4.2% (*North Amer. J. Fish. Manag.* ***42***: 37-49)

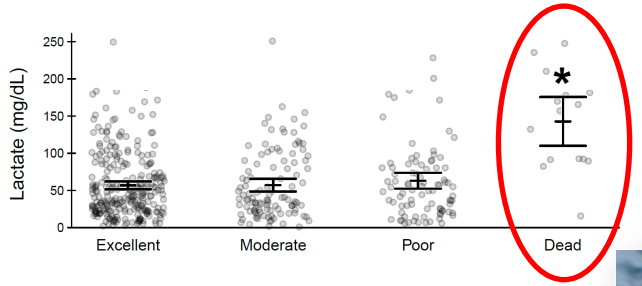
3. Mortality and Survival Assessment

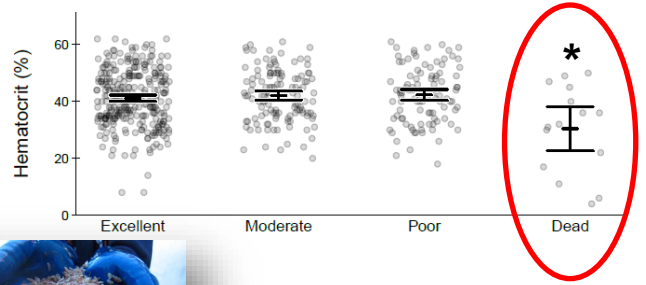
Characterization of discards in the directed longline fishery

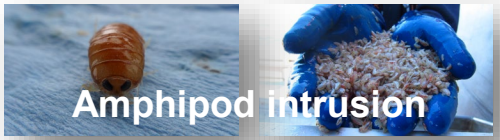
Stress Indicators in the Blood









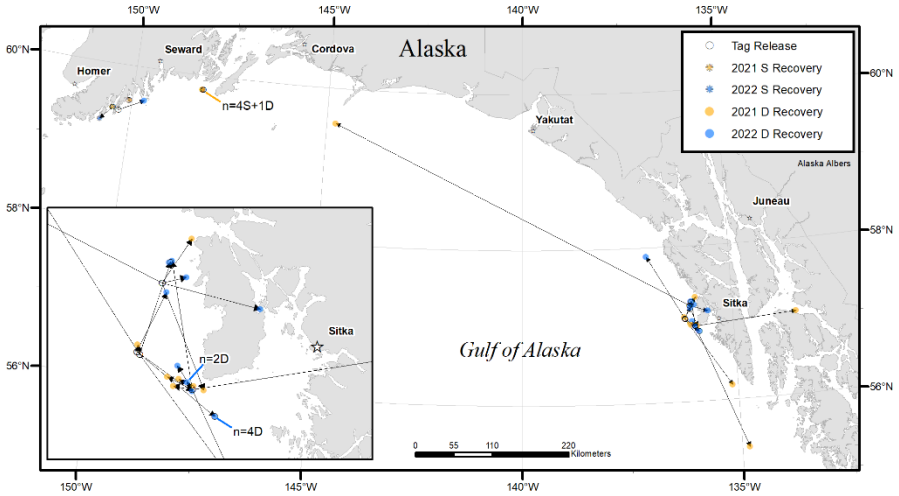


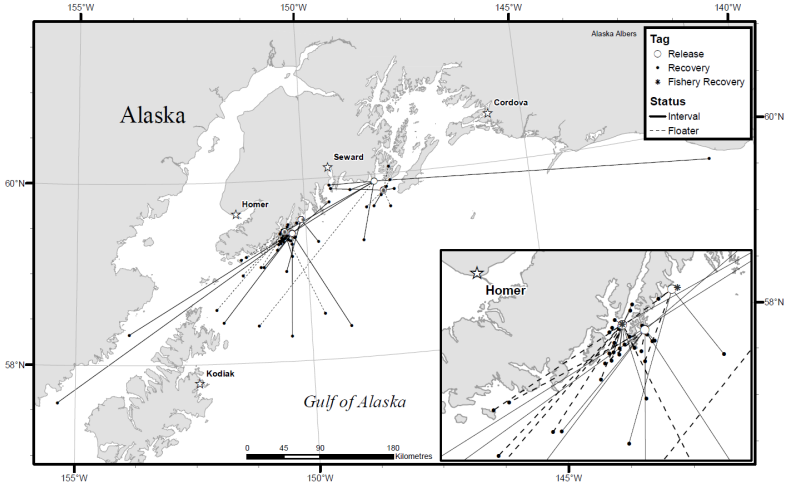
3. Mortality and Survival Assessment

DMRs in the guided recreational fishery

Tag types:

- Wire = 281 (all viabilities) – 32 recovered to date





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

4. Fishing technology

Bycatch Reduction Engineering Program
(BREP) NA21NMF4720534

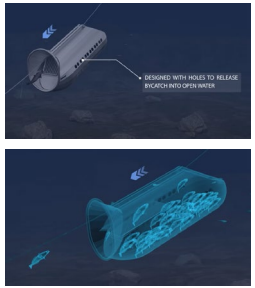
Reducing whale depredation by protecting longline catches

Field testing of catch protection devices: Newport, OR, 23-29 May 2023

Tested selected devices (1. Enclosed Shuttles / 2. Branchline Shrouds) for:

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

Shuttle



4. Fishing technology

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

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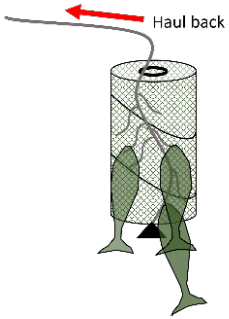
Shroud



Current externally-funded collaborative research

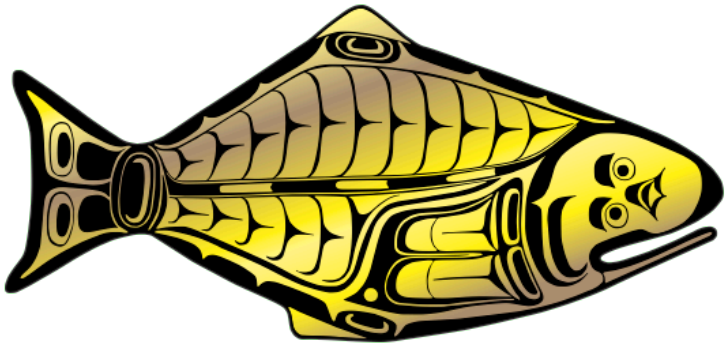
Project #	Grant agency	Project name	PI	Partners	IPHC Budget ($US)	Management implications	Grant period
1	Bycatch Reduction Engineering Program-NOAA	Gear-based approaches to catch protection as a means for minimizing whale depredation in longline fisheries (NOAA Award Number NA21NMF4720534)	IPHC	Deep Sea Fishermen's Union, Alaska Fisheries Science Center-NOAA, industry representatives	$99,700	Whale depredation	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 Fisheries	$193,685	Stock structure	1 December 2021 – 31 January 2024
Total awarded ($)					**$293,385**		

Recommendation

That the SRB:

- **NOTE** paper IPHC-2023-SRB022-09 which outlines progress on biological and ecological research contemplated in the IPHC's 5-year Program of Integrated Research and Monitoring (2022-26).

INTERNATIONAL PACIFIC



HALIBUT COMMISSION