INTERNATIONAL PACIFIC HALIBUT COMMISSION

Report on current and future Biological and Ecosystem Science Research activities

Agenda item: 4.1.1

IPHC-2025-SRB027-06

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

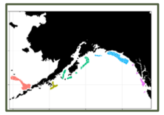
1. Migration and Population Dynamics

5-Yr Research Plan (2017-2021)

Multiple life-stage connectivity

Bering Sea

Gulf of Alaska



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

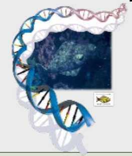
- NMFS trawl survey data
- Spatiotemporal model

→ Ontogenetic migration

Genetic samples of spawning aggregations

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
- Manuscript in preparation
- Stock composition: mixed stock analyses
- Development of an epigenetic clock for aging Pacific halibut

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

Development of an epigenetic clock for aging Pacific halibut

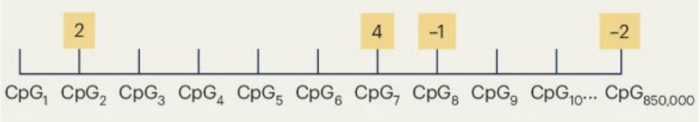
Objective: Develop a non-lethal genetic method for aging Pacific halibut using fin clips

- **Epigenetic clocks** are molecular ageing clocks: machine learning algorithms trained on epigenomic data from samples reflecting a wide range of ages.
- **Epigenetic clocks** use genome-wide DNA methylation features at cytosine-guanine (CpG) dinucleotide pairs in GC-rich regions of the genome (i.e. proportion of DNA molecules methylated at each CpG site for each individual) as input.

ID	Age	CpG_1	CpG_2	...	$CpG_{850,000}$
1	73	0.71	0.31		0.91
2	54	0.65	0.33		0.85
3	36	0.52	0.28		0.84
...					
10,000	64	0.68	0.30		0.95

Outcome: age
Predictors: CpG_1, CpG_2..., $CpG_{850,000}$

- **Age predicting models** (e.g. elastic net penalized regression models) rely on the weighed average of methylation across a subset of CpGs.



- **Test dataset** is used to validate and test the performance (e.g. Pearson correlation or median absolute error) of the epigenetic clock.

1. Migration and Population Dynamics

Development of an epigenetic clock for aging Pacific halibut

- Epigenetic clocks have been developed for a handful of fish species.

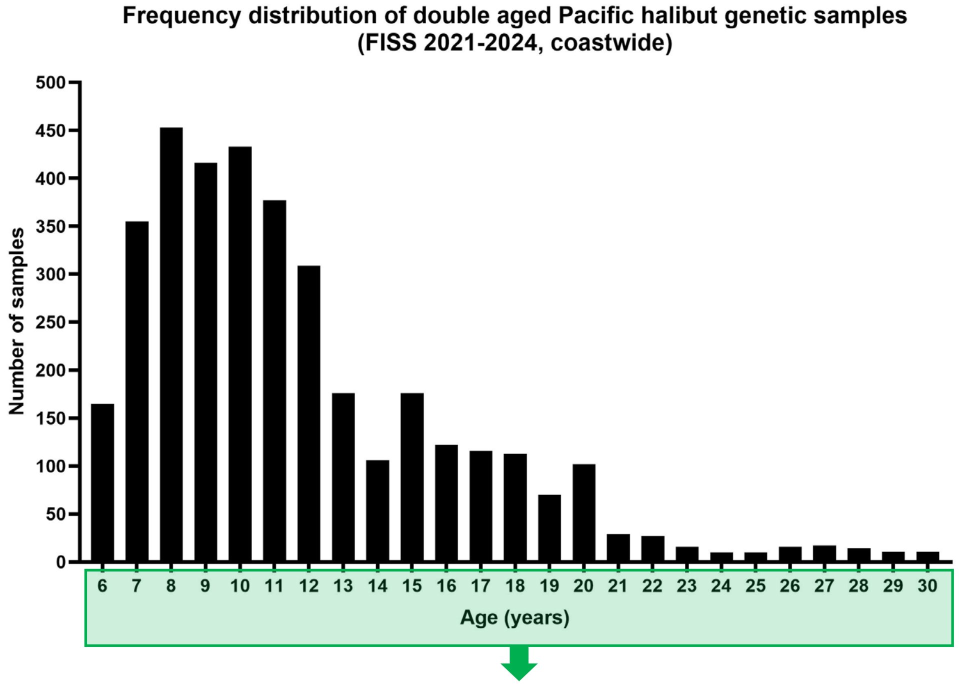
Species	Tissue	MAE	Correlation	# CpGs	Reference
Human	Multiple	3.6 years	0.96	353	Horvath, 2013
European Sea Bass	Muscle	2.15 years	0.82	48	Anastasiadi and Piferrer, 2020
Zebrafish	Fin	3.18 weeks	0.97	29	Mayne et al., 2020
Lungfish	Fin	0.86 years	0.98	31	Mayne et al., 2021
Murray cod, Mary River cod	Fin	0.34 years	0.92	26	Mayne et al., 2021
Red snapper	Muscle	-	0.99	199	Weber et al., 2022
Red grouper	Fin	-	0.99	49	Weber et al., 2022
Golden perch	Fin	74.5 days	0.96	49	Mayne et al., 2023
Blackvelly rosefish	Muscle, fin	1.62 years	0.98	316	Weber et al., 2024
Atlantic halibut	Fin	-	-	-	Ruzzante et al., in progress

- Recent estimates indicate a minimum of 220 aged tissue samples to minimize error rates (Mayne et al., 2021)

1. Migration and Population Dynamics

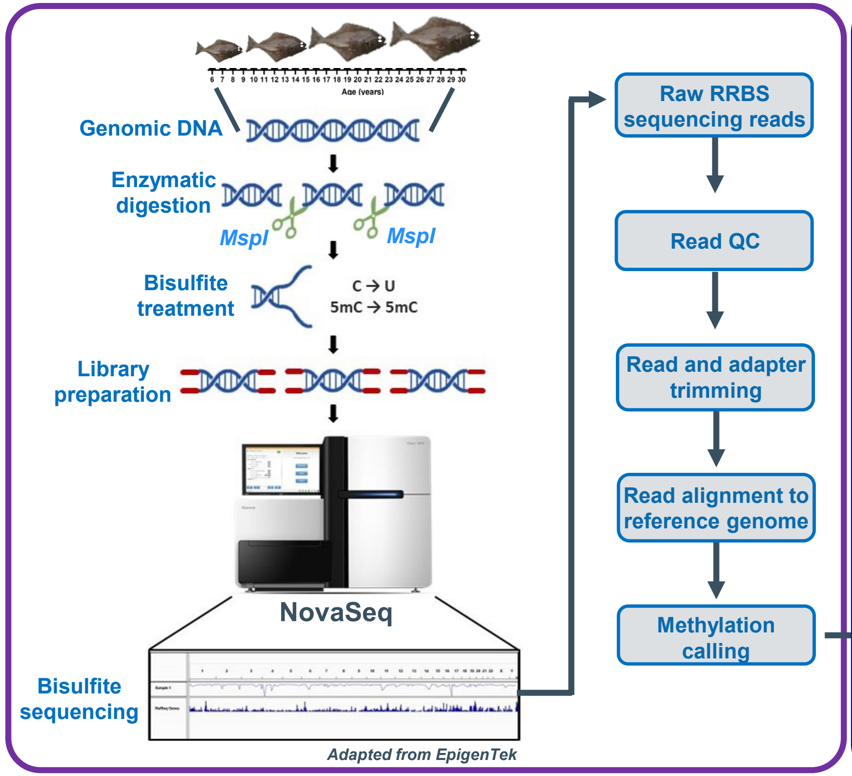
Development of an epigenetic clock for aging Pacific halibut

Sea Grant ALASKA
Project R/2024-05 (2025-2027)

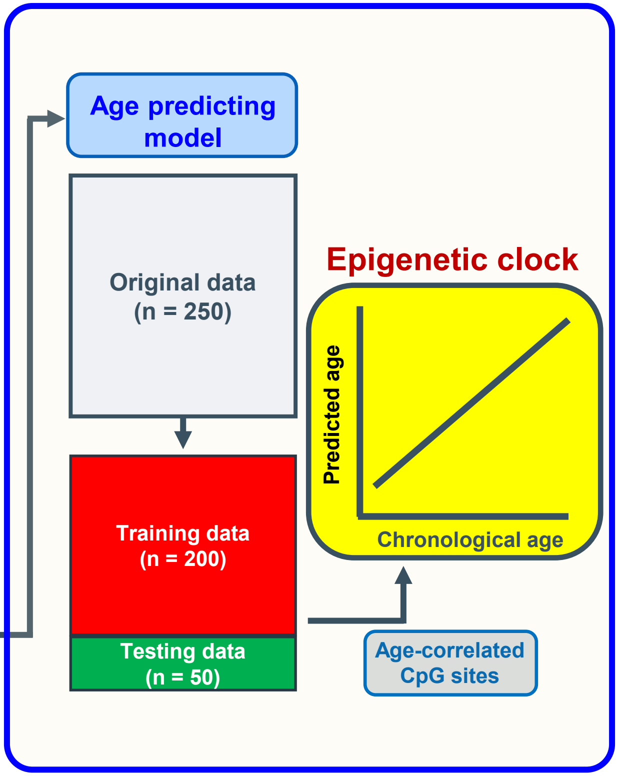


5♂ and 5♀/age from 6 to 30 years of age
N = 250 samples

Step 1: Reduced Representation Bisulfite Sequencing



Step 2: Predictive model

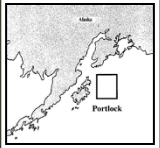


- DNA extracted from all 250 samples.
- Individual libraries constructed from 168 samples.
- First pair of pooled libraries submitted for sequencing.
- Bioinformatic pipeline for analysis established.

2. Reproduction

5-Yr Research Plan (2017-2021)	PIRM 2022-2026	Relevance for stock assessment

2017-2018 Field sample collection (central GOA)



30♀/ month

♀>90 cm FL

Seasonal characterization of reproductive development

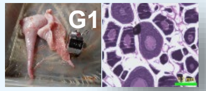
Histological samples → Characterization of oocyte stages → Classification of female developmental stages → Classification of reproductive phases → Appropriate timing of gonad collection in FISS

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

Research outcomes:
- In progress

2017-2022 Commercial landings

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

PIRM 2022-2026:
- Manuscript in preparation
- Fecundity assessment
- Male Reproductive Characterization
- Revise macroscopic staging criteria
- Sex-ratio monitoring

Relevance for stock assessment:
- Direct input into stock assessment for estimation of the stock-recruitment relationship
- Estimate annual reproductive output
- Revise time-series of historical and future maturity

Scale of female spawning biomass and reference point estimates

- Annual sex-ratio at age for the commercial fishery fit by the stock assessment

Reduce uncertainty in stock size and fishing intensity

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*

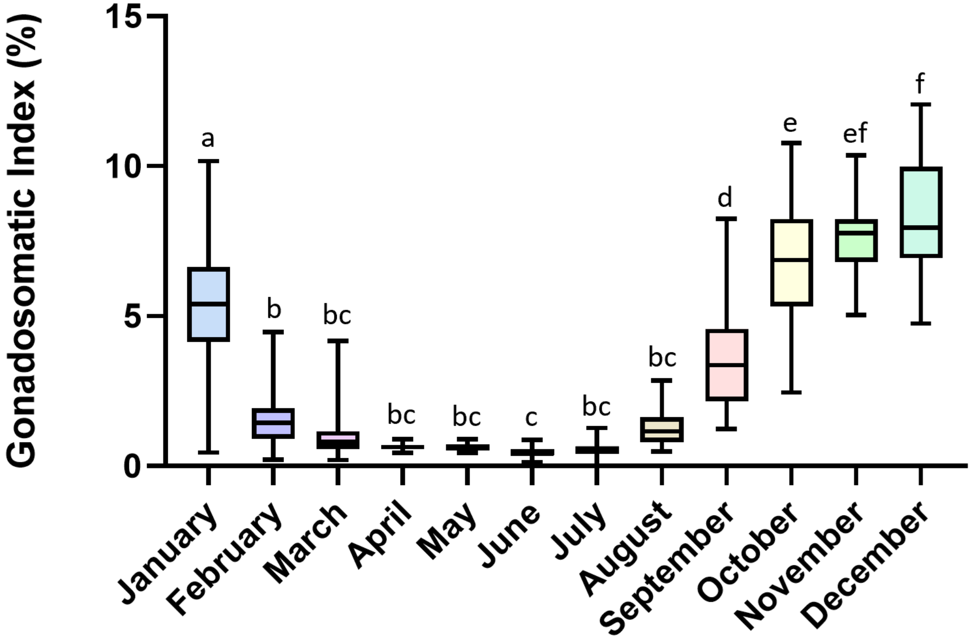
2. Reproduction

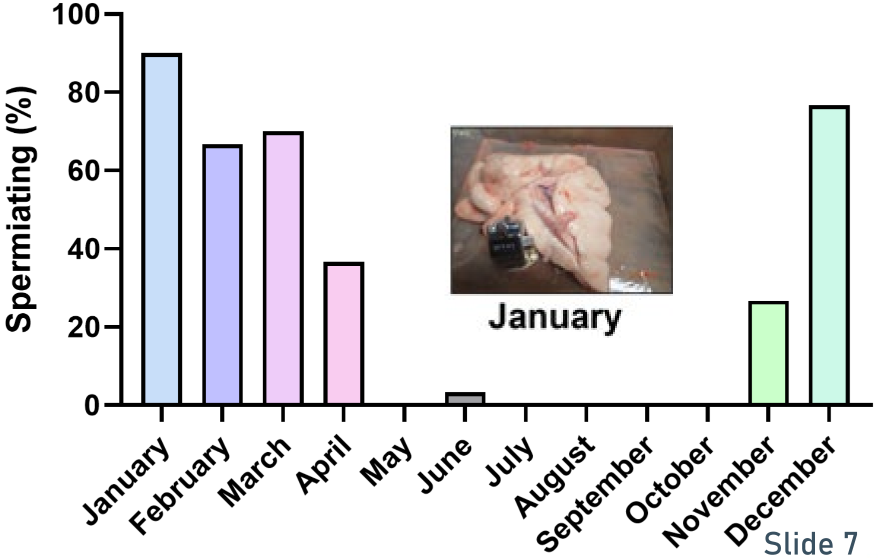
Male Reproductive Characterization

- Sample collection
  - Sept 2017 – Aug 2018, Portlock Region (Central Gulf of Alaska)
  - 30 males / month
  - ≥ 70 cm fork length

- Highest gonadosomatic index (GSI) values coincided with peak spawning for females (Dec – Jan)

- Sperm production detected November – April

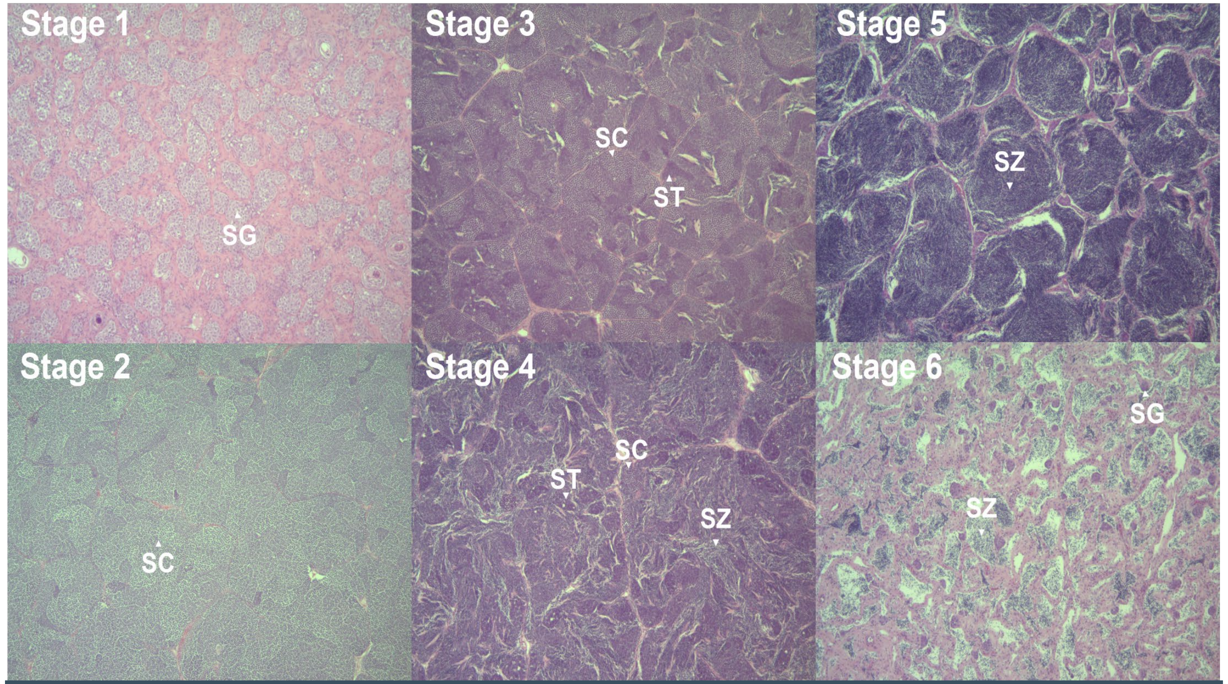




2. Reproduction

Male Reproductive Characterization

- Histology
  - Six stages of testicular development

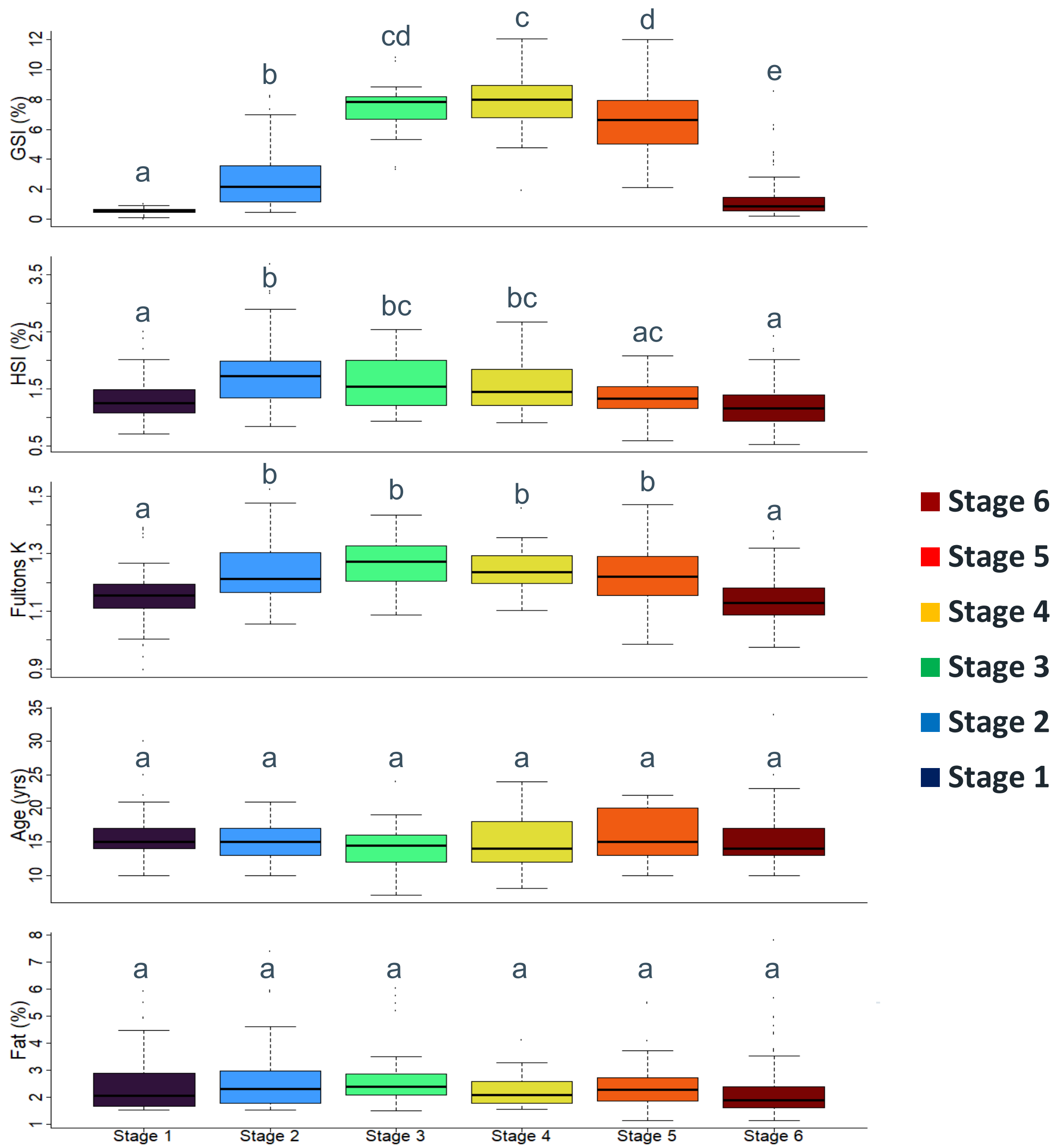


Stages	***Description***	***Cellular characteristics***
Stage 1	Early Spermatogenesis	Only spermatogonia (SG)
Stage 2	Mid Spermatogenesis	SG and spermatocytes (SC)
Stage 3	Mid-Late Spermatogenesis	SC and spermatids (ST)
Stage 4	Late Spermatogenesis	SC, ST and spermatozoa (SZ)
Stage 5	Spermiation	Testes full of mature SZ
Stage 6	Post-Spawning/Spent	Partially empty testes with residual SZ and SG clumps

2. Reproduction

Male Reproductive Characterization

- Histology
  Six defined stages of testicular development
- Annual reproductive cycle
  Spermatogenesis rapidly progressing from March to November, when spermiation begins
- Biological indicators by stage
  GSI, HSI, Fulton's K, Age, Fat %
- Next Steps
  Immature vs Mature classification



3. Growth

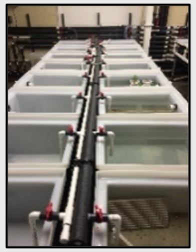
5-Yr Research Plan (2017-2021) | **(2022-2026)**

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
- Density manipulations
- Handling manipulations

Transcriptomic and proteomic profiling

- Temperature-responsive growth markers
- Density-responsive growth markers
- Handling-responsive growth markers

Validation studies

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

(2022-2026):
- Environmental influences on growth patterns
- Dietary influences on growth patterns and physiological condition

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. Manuscript accepted in *J. Exp. Biol.*

4. Mortality and Survival Assessment

5-Yr Research Plan (2017-2021) | **PIRM 2022-2026** | **Relevance for stock assessment**

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

Physiological condition assessment

Analysis of capture-related variables

Survival assessment by tagging

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

Research outcomes:
- Recreational DMR

Best handling practices in longline fishery

Best handling practices in recreational fishery

- Improved estimates of discard mortality
- Reduce potential bias in stock assessment results and management of mortality limits

Reduce unobserved mortality and its effect on stock 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

Manuscript in preparation

5. Fishing technology

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

Relevance for stock assessment

Summer 2023 pilot test

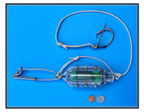
Investigate new methods for whale avoidance/deterrence to reduce whale depredation in the longline fishery

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* 2***41****: 106664*

5. Fishing technology

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

Reducing whale depredation by protecting longline catches

Second phase: Testing shuttle in the presence of depredators

- Objective: Further refine and characterize performance of the shuttle device in the presence of toothed whales in IPHC Regulatory Area 4A.
- Field study took place from 21-28 May 2025 from Dutch Harbor, AK on the F/V Oracle.
- 18 sets: 15 sets with shuttle and control catch paired comparisons (6 sets in the presence of orcas).
- Collected ~ 80 hours of underwater footage (~ 70 hr reviewed to date: 10/15 paired sets).




5. Fishing technology

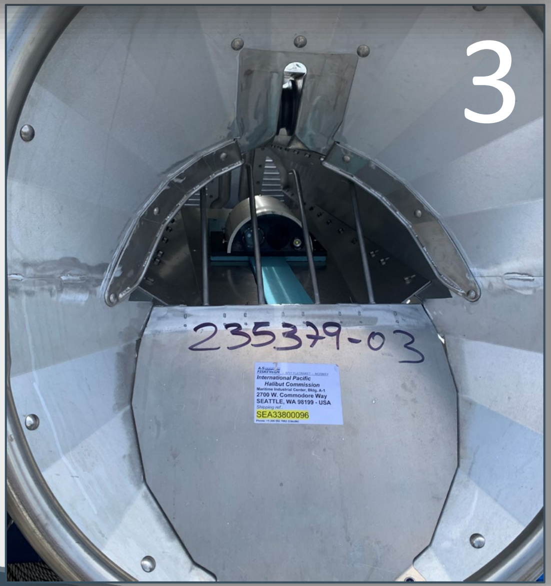
NOAA FISHERIES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

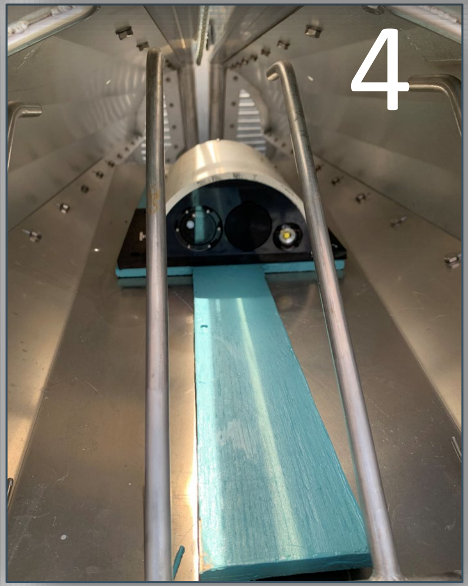
Bycatch Reduction Engineering Program
(BREP) NA23NMF4720414

Reducing whale depredation by protecting longline catches

Four Camera Systems

1. Long Line Cam (Control)
2. Shuttle External Cam
3. Shuttle Internal Forward Facing (towards entrance)
4. Rear Facing (towards keyhole)



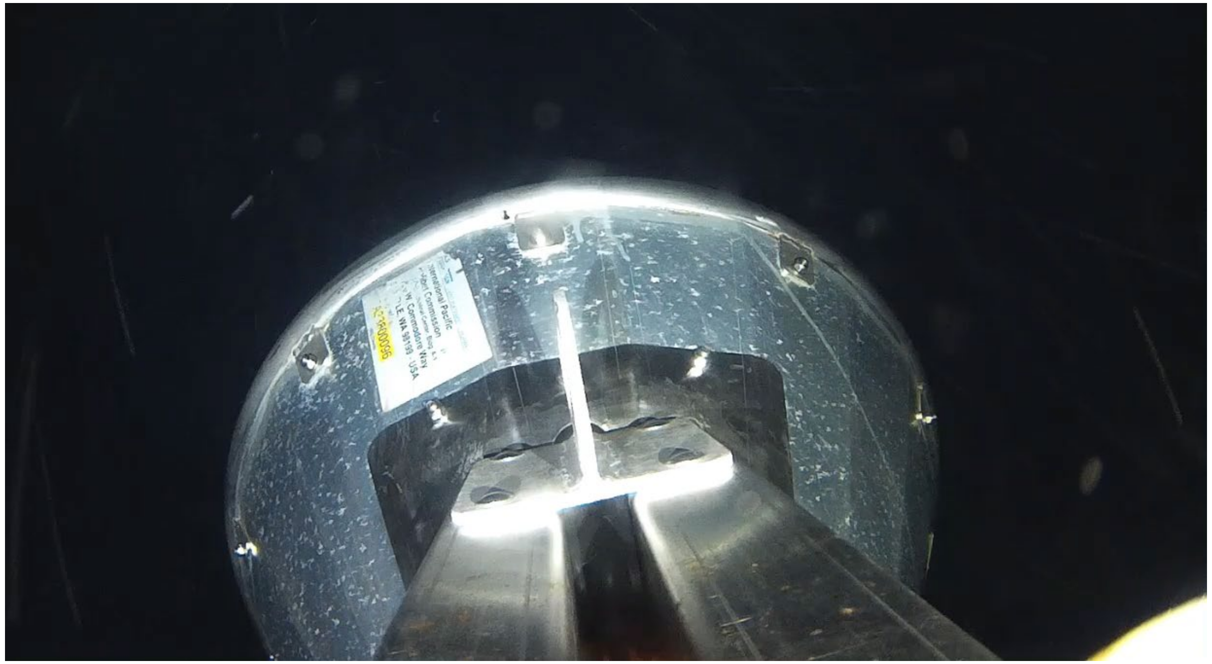


5. Fishing technology

Bycatch Reduction Engineering Program
(BREP) NA23NMF4720414

Reducing whale depredation by protecting longline catches

Exclusions



External Shuttle Camera

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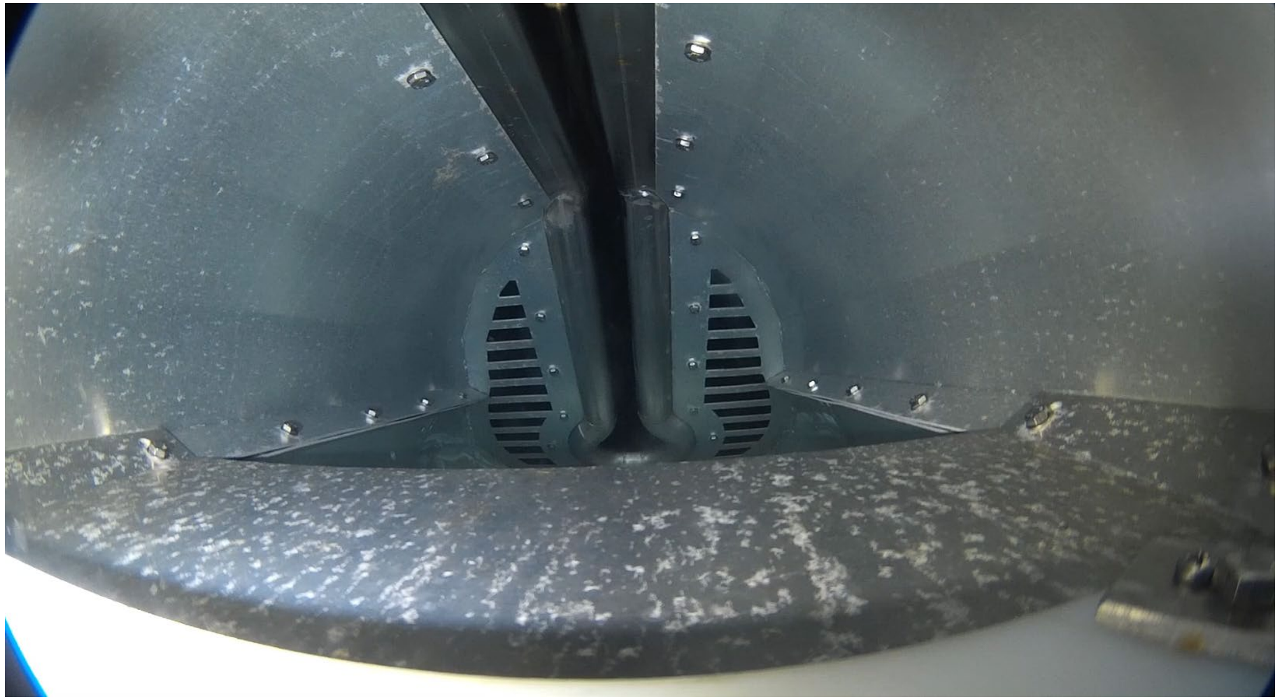
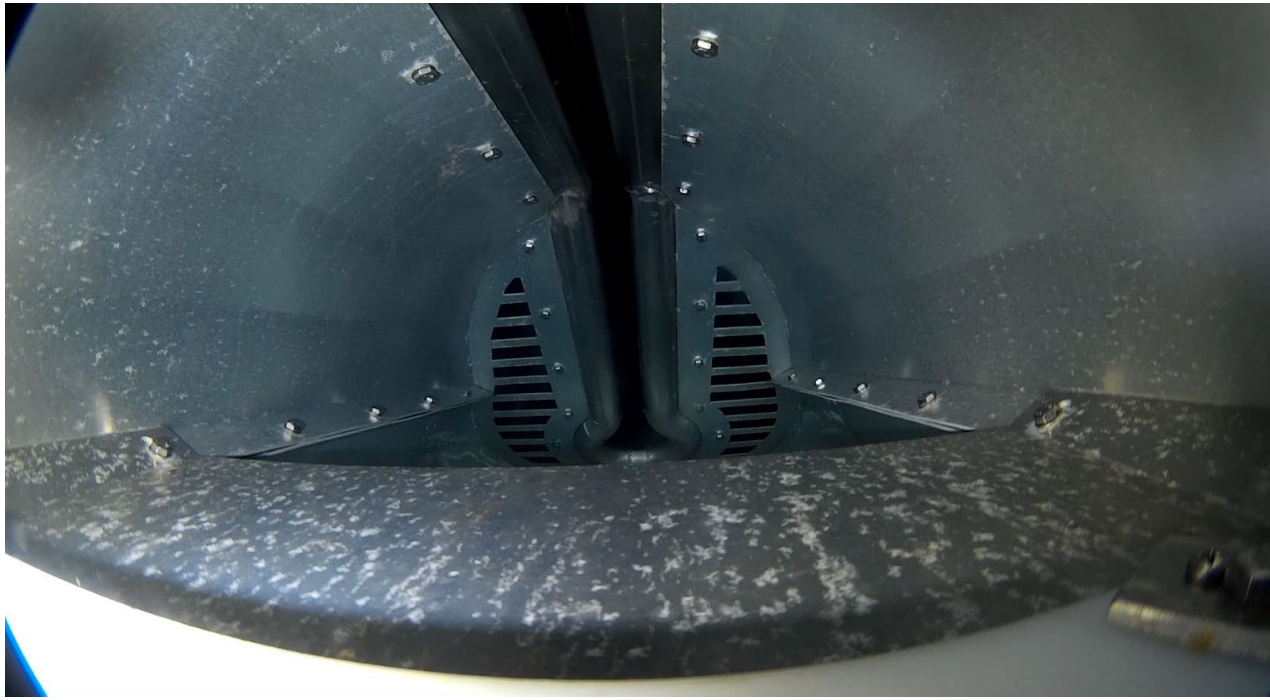
Bycatch Reduction Engineering Program
(BREP) NA23NMF4720414

Reducing whale depredation by protecting longline catches

Pass Throughs





Internal Rear Facing Camera

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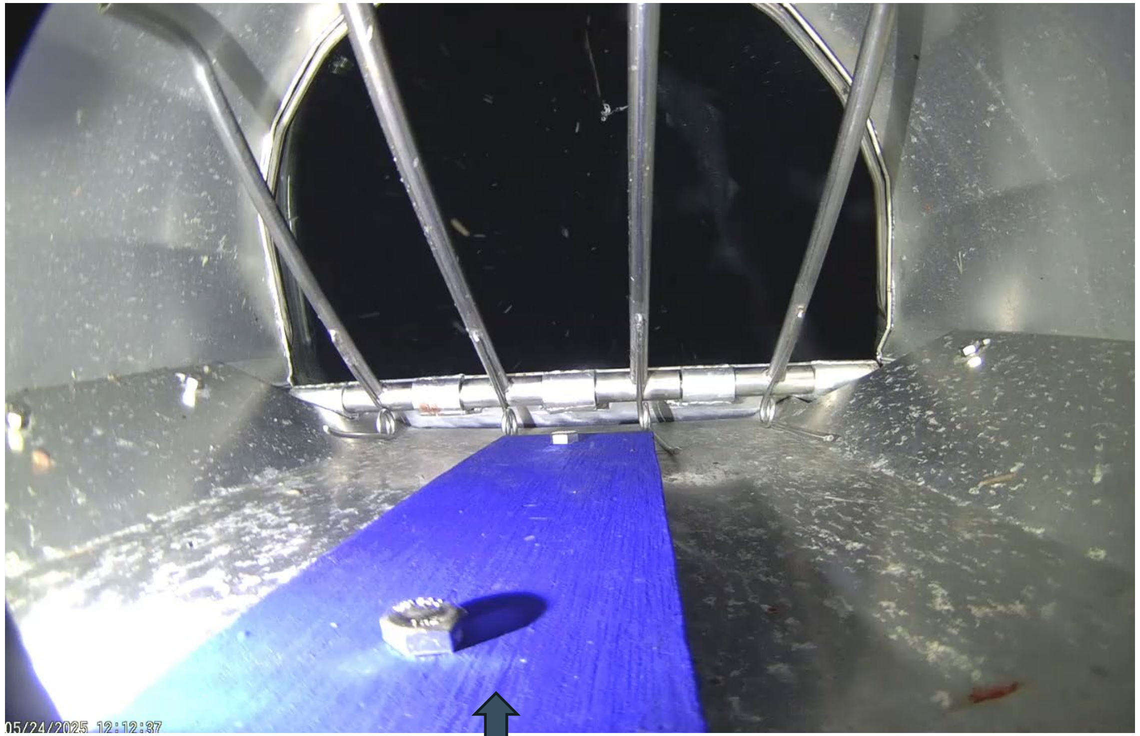
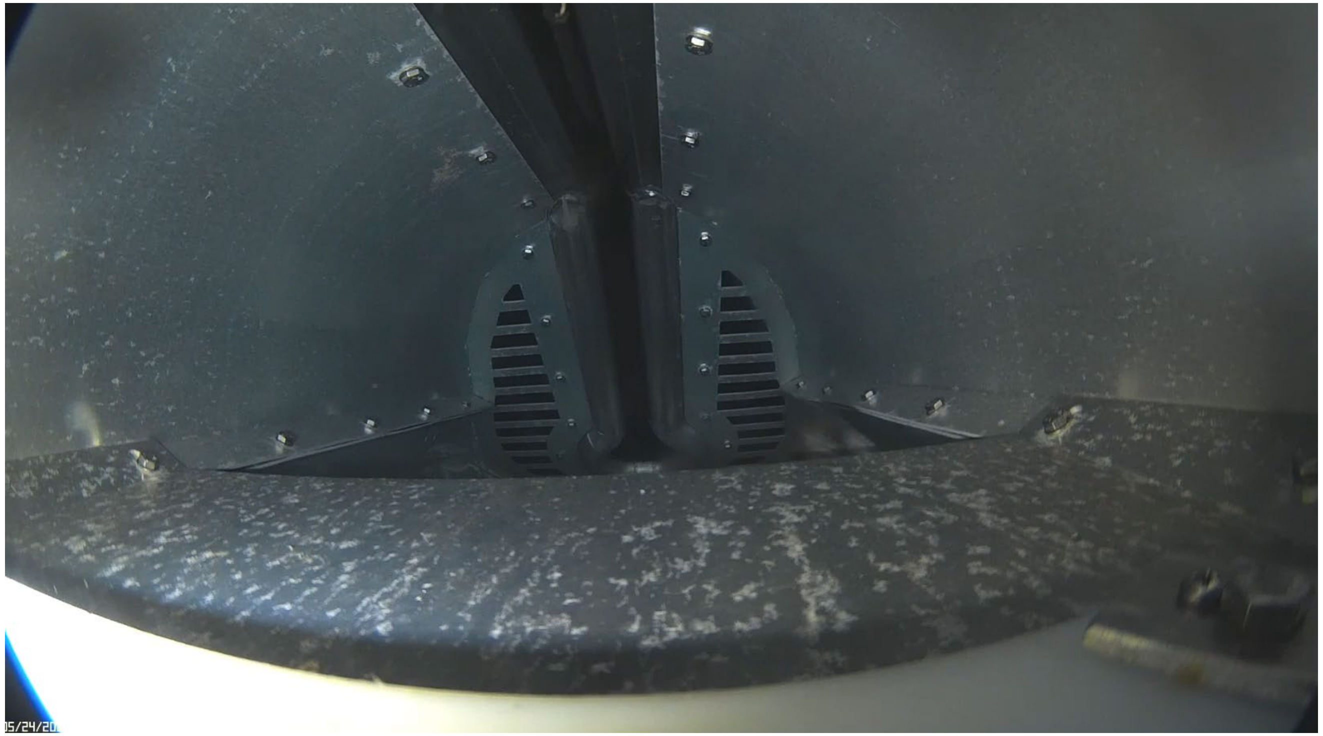
Bycatch Reduction Engineering Program
(BREP) NA23NMF4720414

Reducing whale depredation by protecting longline catches

Entrainments





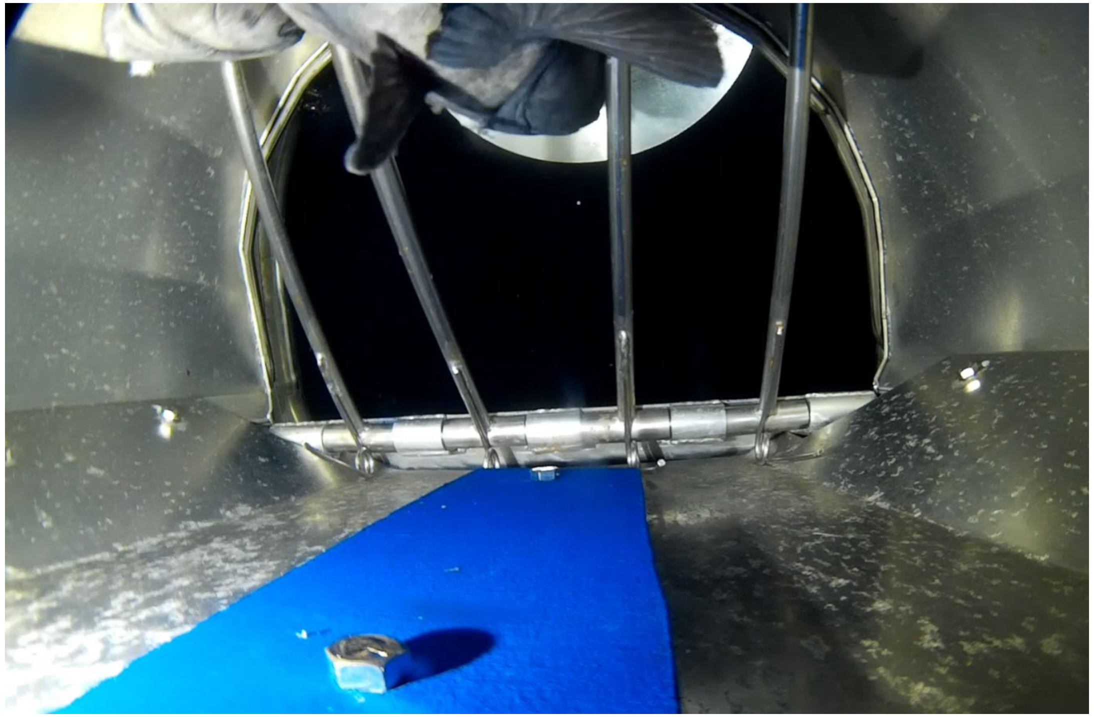
Internal Forward-Facing Camera

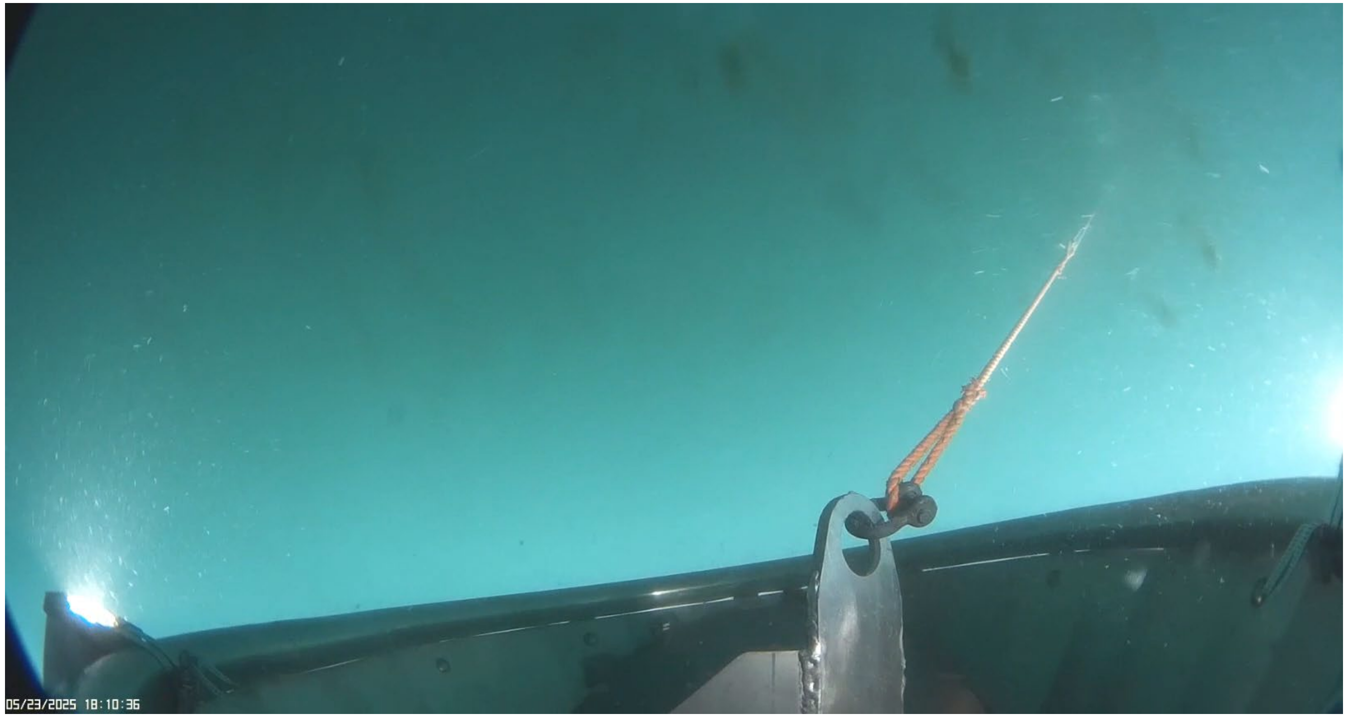
5. Fishing technology

Bycatch Reduction Engineering Program
(BREP) NA23NMF4720414

Reducing whale depredation by protecting longline catches

Escapes





5. Fishing technology

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

Reducing whale depredation by protecting longline catches

- Preliminary Results: Retention Trends from Camera

Common Name	Encountered	Excluded	Entered	Escaped	Passed Through	Entrained
Pacific halibut	89	1 (1.1%)	88	0	8 (9.1%)	80 (90.9%)
Sablefish	160	2 (1.3%)	158	45 (28.5%)	30 (19.0%)	83 (52.5%)
Pacific cod	124	3 (2.4%)	121	13 (10.7%)	6 (5.0%)	102 (84.3%)
Rockfish	16	7 (43.8%)	9	2 (22.2%)	1 (11.1%)	6 (66.7%)
Skate	18	3 (16.7%)	15	0	2 (13.3%)	13 (86.7%)

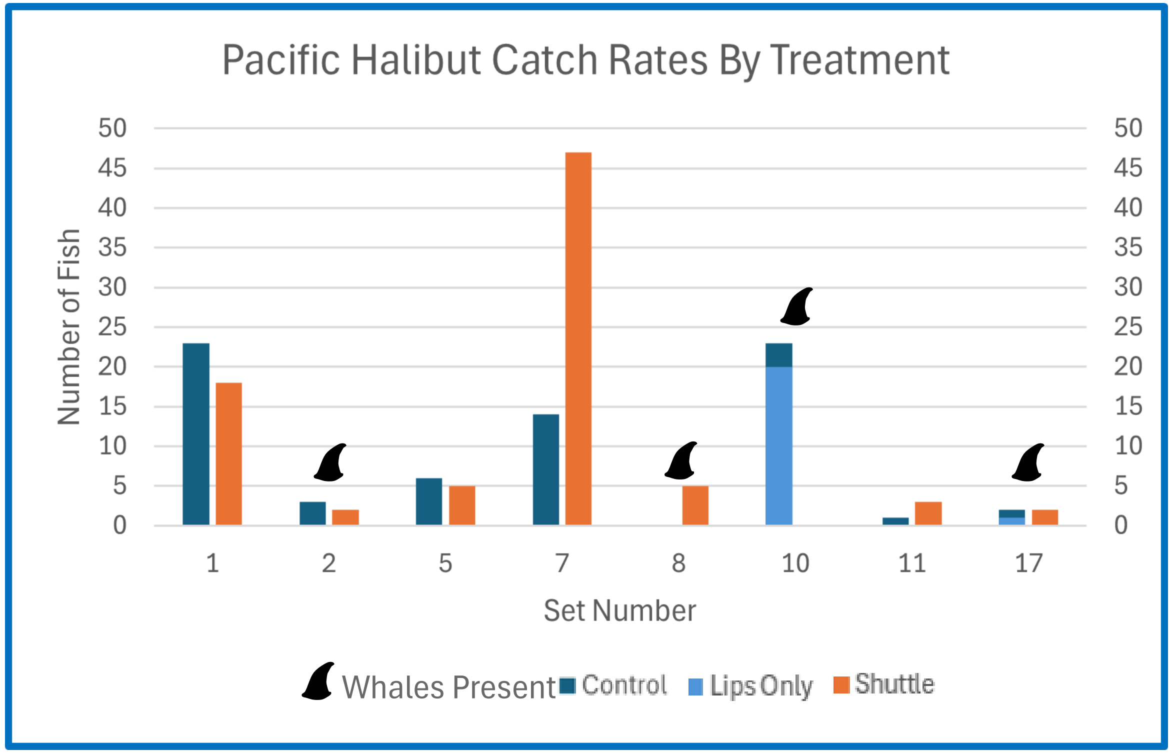
- 4,863 hook status observations recorded across all four cameras.
- Species morphology is primarily responsible for retention outcomes when encountering the shuttle.
- Retention rates can be improved with simple modifications.
- Captured rare footage of killer whales swimming around the groundline.

5. Fishing technology

Bycatch Reduction Engineering Program (BREP) NA23NMF4720414

Reducing whale depredation by protecting longline catches

- Preliminary Results: Treatment Catch Rates (Surface)



- Shuttle are capable of good retention.
  - Results variable between control and shuttle
- Uncontrollable factors confound results (crab pot snarls, species composition).

5. Fishing technology

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

Reducing whale depredation by protecting longline catches

Killer whales captured swimming around the groundline

5. Fishing technology

Conclusions

- Shuttle can be safely deployed and retrieved by vessels with a picking boom.
- Shuttle has good retention of Pacific halibut.
- Simple modifications should increase retention of smaller species (i.e. Pacific cod and Sablefish).
- Next steps to help foster this new tool to reduce impacts of whale depredation should be investigated and may include:
    - Regulation changes requiring full retention of all sizes of Pacific halibut.
    - Weaker gangions, softer hooks, or modified hooks considered to reduce hook removal damage.
    - Consider a collapsible design for safer stowage and transport.

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/