INTERNATIONAL PACIFIC HALIBUT COMMISSION

Biological and Ecosystem Science Research Plan: Update

Agenda Item 8

IPHC-2019-SRB015-08

Outline

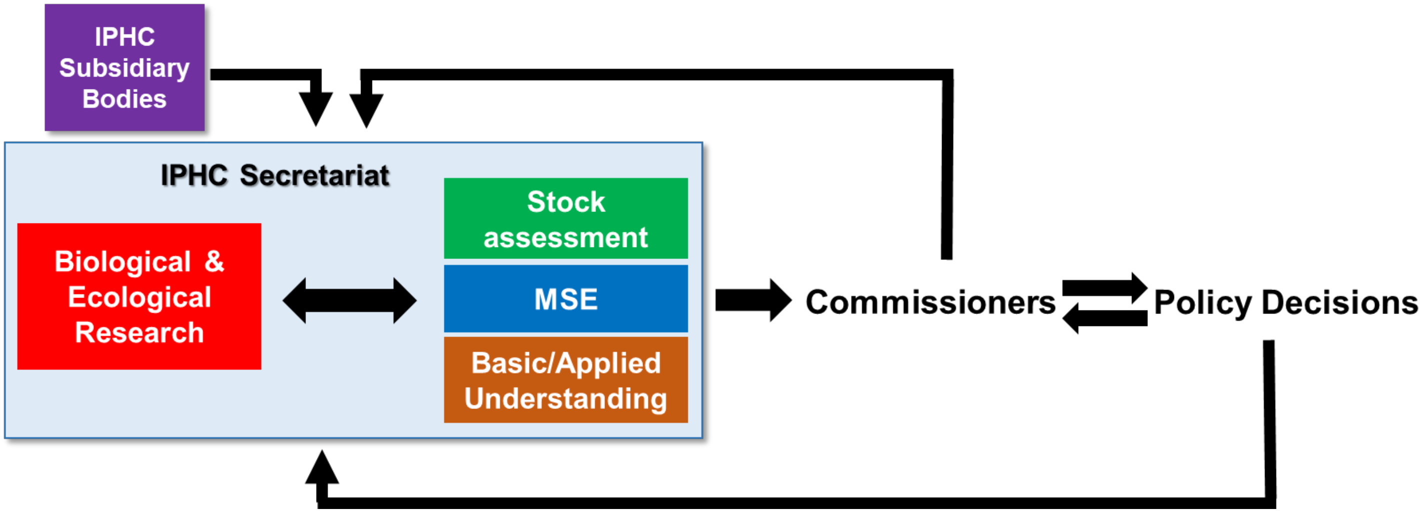
- Five-year research program and management implications
- Progress on ongoing research projects
- Externally-funded collaborative research

Five-year research program and management implications

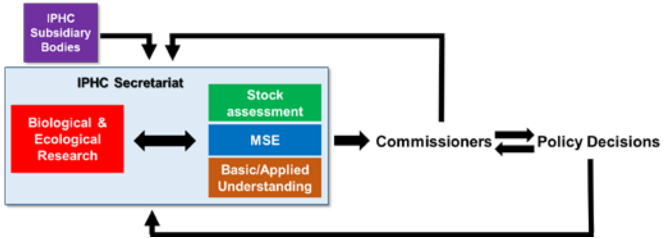
5-Year Biological and Ecosystem Science Research Plan

Primary Research Areas
Migration
Reproduction
Growth
DMRs and discard survival
Genetics and genomics

Integration of biological research, stock assessment, and policy



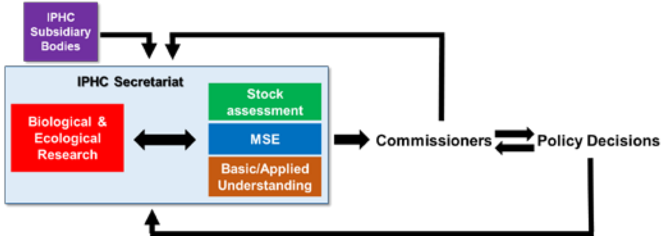
Integration of biological research, stock assessment, and policy



Biological research | Stock assessment | Stock assessment MSE

Research areas	*Research outcomes*	*Relevance for stock assessment*	*Inputs to stock assessment and MSE development*
Migration	**Larval distribution** **Juvenile and adult migratory behavior and distribution**	**Geographical selectivity** **Stock distribution**	**Information for structural choices** **Recruitment indices** **Migration pathways and rates** **Timing of migration**
Reproduction	**Sex ratio** **Spawning output** **Age at maturity**	**Spawning biomass scale and trend** **Stock productivity** **Recruitment variability**	**Sex ratio** **Maturity schedule** **Fecundity**
Growth	**Identification of growth patterns** **Environmental effects on growth** **Growth influence in size-at-age variation**	**Temporal and spatial variation in growth** **Yield calculations** **Effects of ecosystem conditions** **Effects of fishing**	**Predicted weight-at-age** **Mechanisms for changes in weight-at-age**
Discard Survival	**Bycatch survival estimates** **Discard mortality rate estimates**	**Scale and trend in mortality** **Scale and trend in productivity**	**Bycatch and discard mortality estimates** **Variability in bycatch and uncertainty in discard mortality estimates**
Genetics and Genomics	**Genetic structure of the population** **Sequencing of the Pacific halibut genome**	**Spatial dynamics** **Management units**	**Information for structural choices**

Integration of biological research, stock assessment, and policy



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Migration	Larval distribution Juvenile and adult migratory behavior and distribution	Geographical selectivity Stock distribution	Information for structural choices Recruitment indices Migration pathways and rates Timing of migration
Reproduction	Sex ratio Spawning output	Spawning biomass scale and trend Stock productivity	Sex ratio Maturity schedule ecundity
Growth			d weight-at-age hanges in weight-at-age
Discard Survival			ard mortality estimates and uncertainty in discard ity estimates
Genetics and Genomics	Sequencing of the Pacific halibut genome	Management units	nformation for structural choices

Sex ratio of commercial landings

Spawning biomass scale and trend
INPUT: Sex ratio at age

Operating Model
INPUT: Sex ratio at age

Integration of biological research, stock assessment, and policy: timelines

Research Area		2018	2019	2020	2021	2022
Migration	Larval distribution	Data analysis	Data synthesis; SA MSE	Sample collection; Data analysis	Data synthesis	
	Adult and juvenile migration	Tagging; Data analysis	Tagging; Data synthesis	SA MSE; Tagging; Data analysis	Data synthesis; SA MSE	Tagging; Data analysis; Data synthesis

SRB request for new position:
Life History Modeler

Progress on ongoing research projects

1. Migration and distribution

Projects:

1. Larval and early juvenile dispersal

2. Late juvenile migration

3. Tail pattern recognition

2. Reproduction

3. Growth

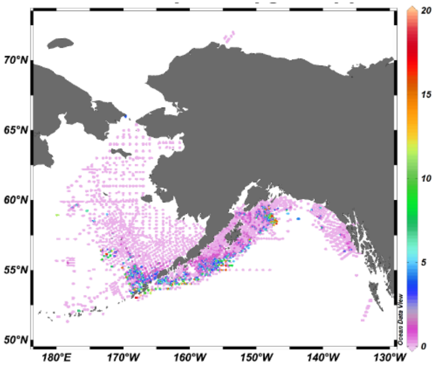
4. Discard Mortality

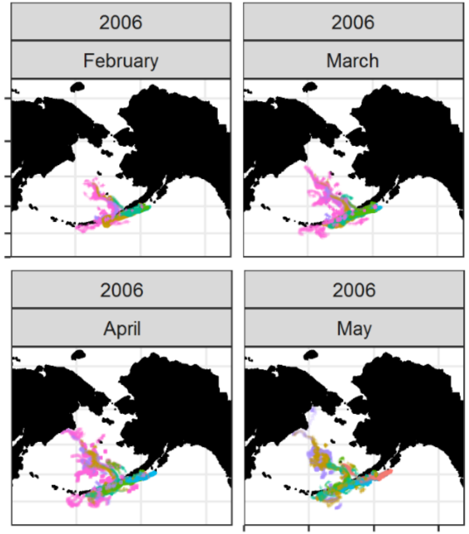
5. Genetics and genomics

1. Migration and Distribution

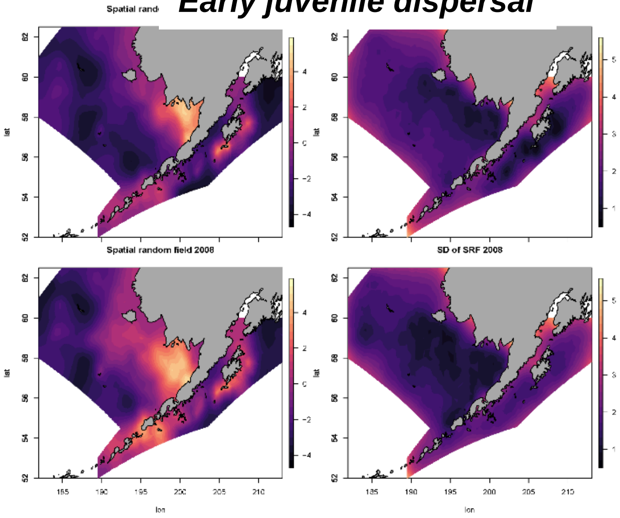
1. Larval and early juvenile dispersal

- Contribution of spawning grounds to settlement grounds
- Connectivity of ocean basins
- Environmental effects on larval distribution
- Collaboration with NOAA/EcoFOCI
- Dispersal of young fish post-settlement



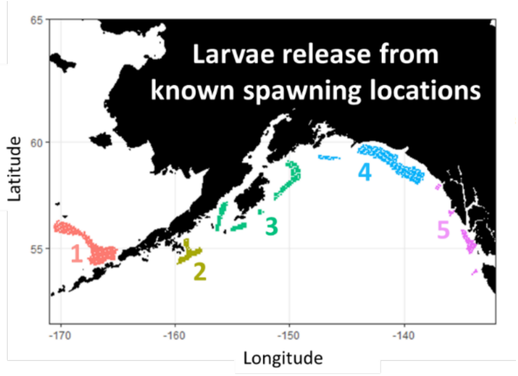


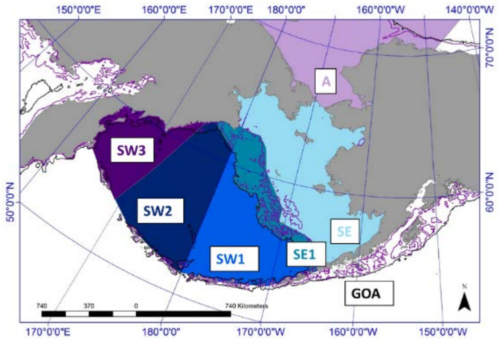
Early juvenile dispersal

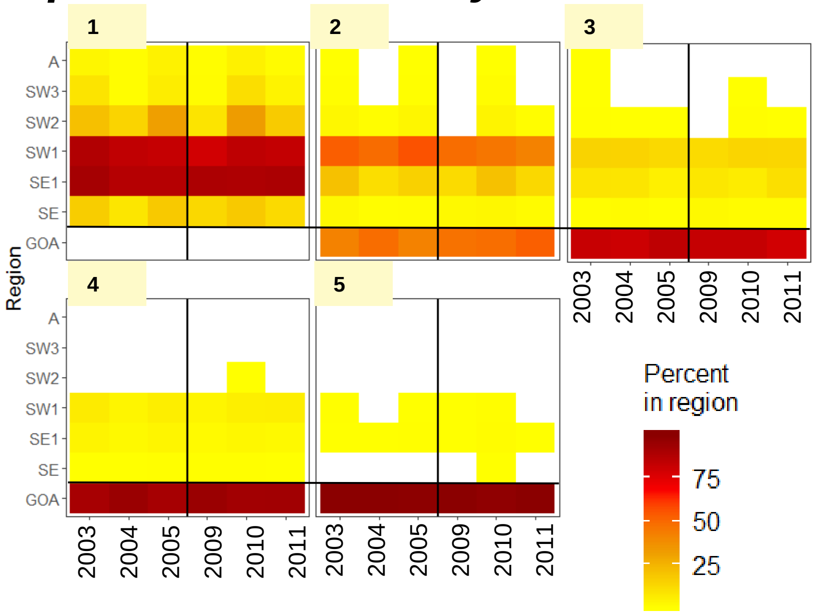


1. Migration and Distribution

1. Larval and early juvenile dispersal: connectivity between GOA and BS







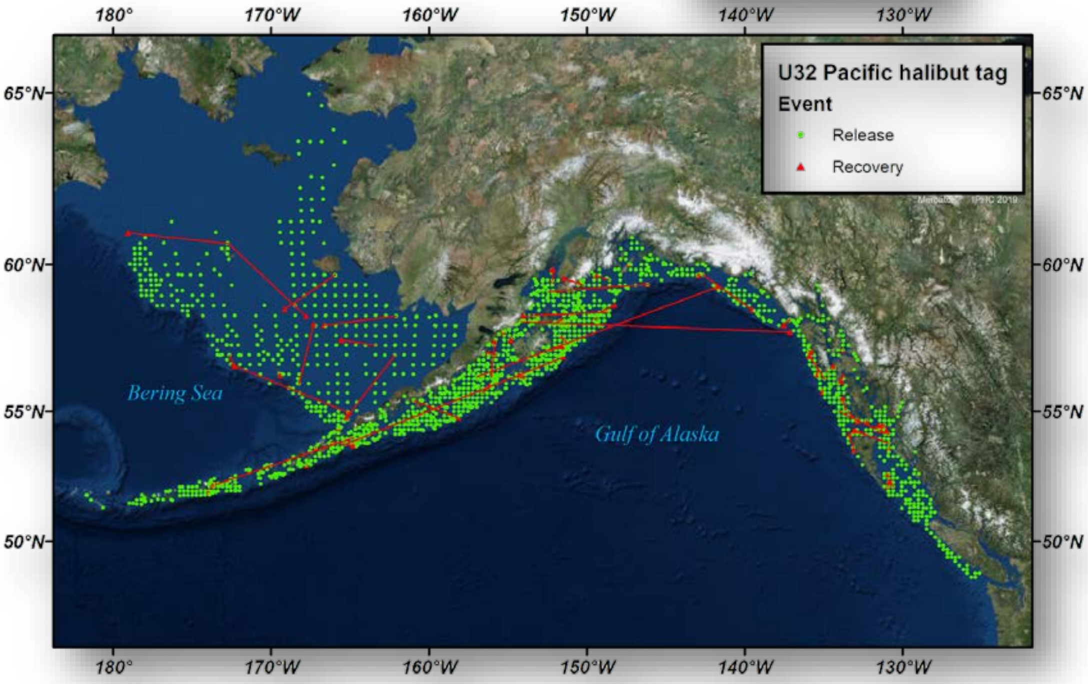
Although there are inter-annual dispersal differences, there are no obvious differences between warm and cold regimes

1. Migration and Distribution

2. Late juvenile dispersal: wire tagging of U32 fish

Since 2015:

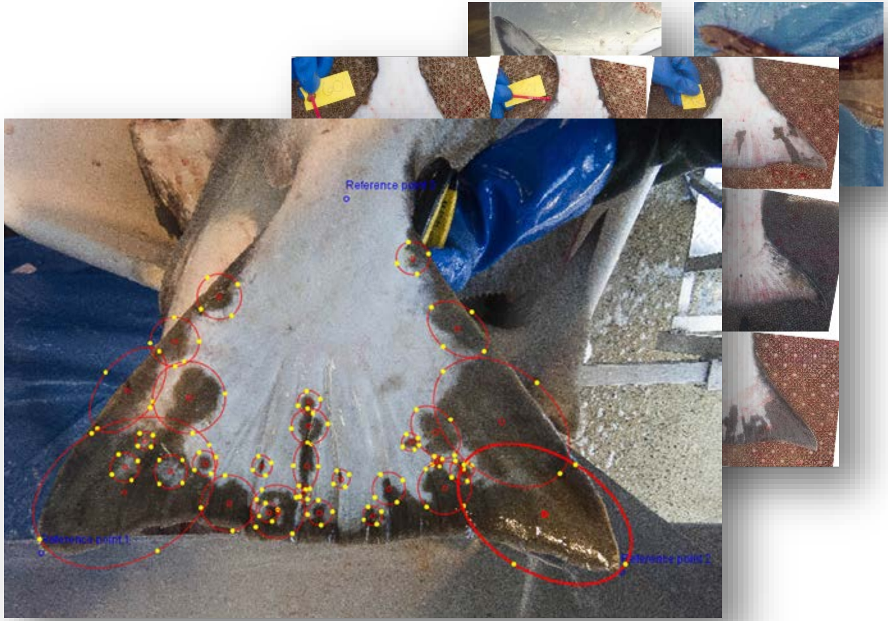
- **10,770 U32 fish wire tagged in FISS and NMFS Trawl Survey**
- **110 recoveries**



1. Migration and Distribution

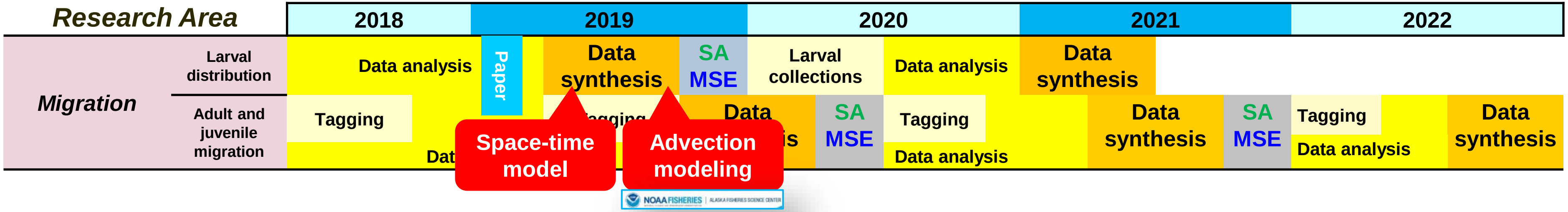
3. Tail pattern recognition

Objective: Use natural markings to identify individuals over time and inform on movement patterns and growth



- Blind side of tail is preferable for imaging
- Spots and patterns appear to be unique
- Markings could be used to identify individuals with image recognition software
- Future could integrate into vessel/shoreside electronic monitoring (EM) or recreational fisher applications
- To date, 882 U32 Pacific halibut photographed and wire tagged as part of this project
- To date, 7 tags recovered with tail pictures

1. Migration: timeline and integration with stock assessment, and MSE



- **Larval distribution and connectivity**

2. Reproduction



Projects:

1. ***Identification of sex in the commercial landings***

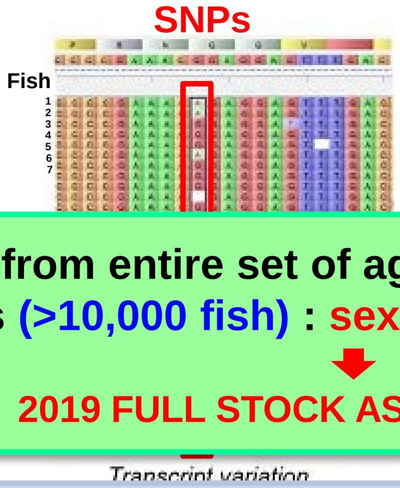
2. ***Full characterization of the annual reproductive cycle to improve current estimates of maturity***

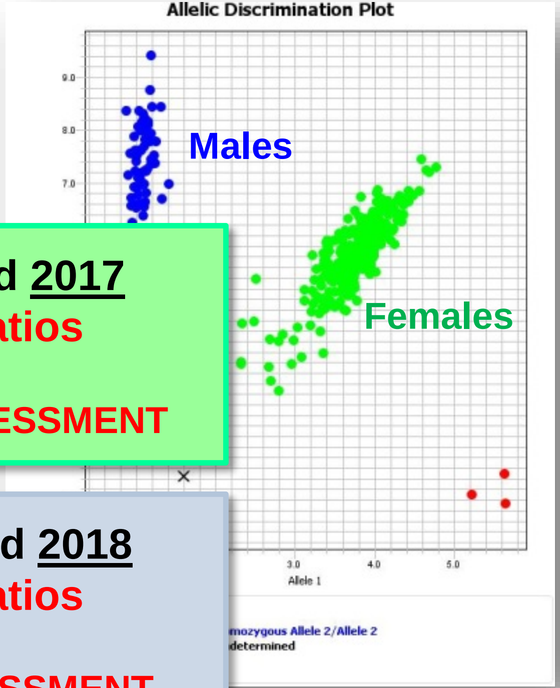
2. Reproduction

1. Identification of sex in the commercial landings

To generate sex-ratio data for use in assessment and policy analysis

Application of genetic techniques (SNPs)





- **Completed**: **Fin clips from entire set of aged <u>2017</u> commercial samples (>10,000 fish) : sex ratios**

  2019 FULL STOCK ASSESSMENT

- **In Progress**: **Fin clips from entire set of aged <u>2018</u> commercial samples (>10,000 fish) : sex ratios**

  2020 STOCK ASSESSMENT

2. Reproduction

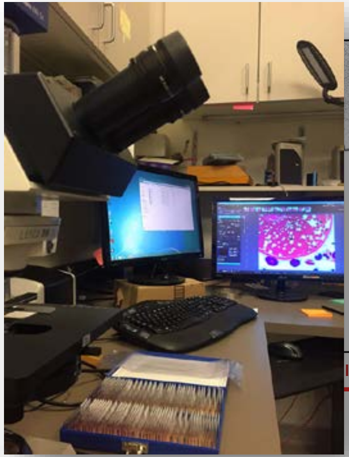
2. Full characterization of the annual reproductive cycle

Objective: **Revise maturity estimates for male and female Pacific halibut**

Annual reproductive cycle

Gonadal growth	Maturation	Spawning

- **Histological assessment of gonadal development**
- **Reproductive hormones in the blood**
- **Activation of the endocrine reproductive axis (pituitary and gonads)**
- **Energy levels (fat content/hepatosomatic index)**
- **Revised scoring criteria of maturity stages by macroscopic observations in the field**



Deliverables:

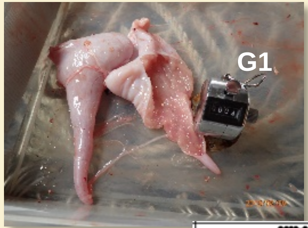
- **Accurate staging of reproductive status**
- **Updated maturity-at-age estimates**
- **Estimates of skipped-spawning**

2. Reproduction

2. Full characterization of the annual reproductive cycle

Objective: Revise maturity estimates for male and female Pacific halibut

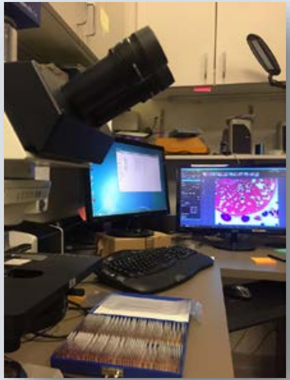
Macroscopic maturity staging (*visual assessment*)



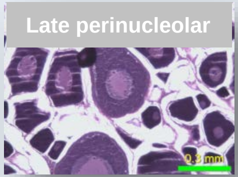
Maturity Stage
- 1 immature
- 2 maturing
- 3 ripe
- 4 resting

vs

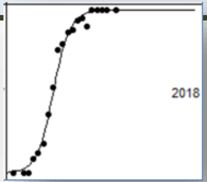
Microscopic maturity staging (*histological assessment*)



Ovarian histology
⬇
Oocyte stage classification
⬇
Maturity staging

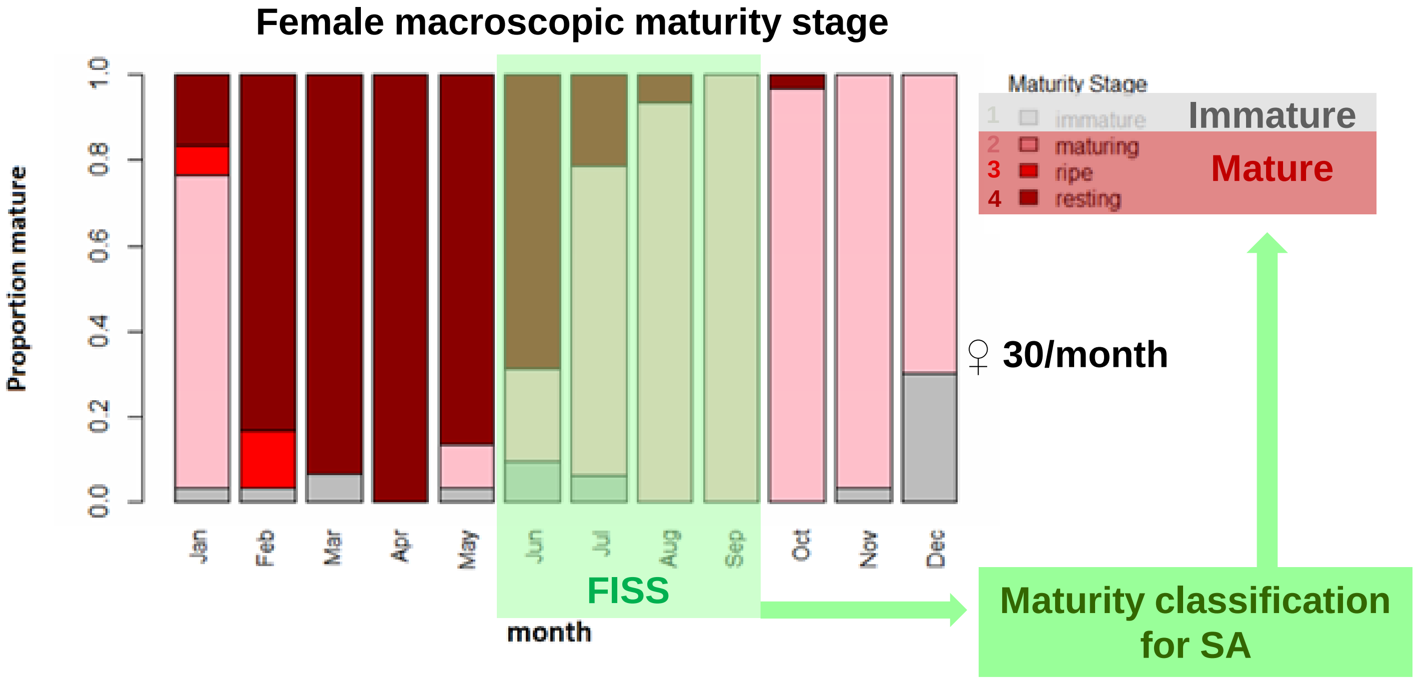


- Maturity ogives
- Maturity estimates



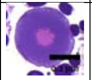
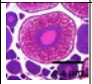
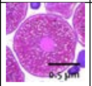
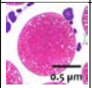
2. Reproduction

Macroscopic maturity staging



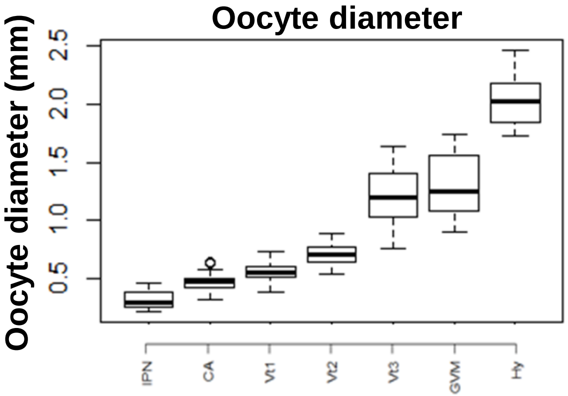
2. Reproduction

Microscopic maturity staging: Oocyte stage classification by histology

	Female Pacific Halibut Histology Stages	Stage photo	Microscopic visual characteristics	Quantitative characteristics
Primary Growth (PG)	**Early perinucleolus (ePN)** 1		Oocytes are small often angular and compact with a single large nucleolus. Cytoplasm stains dark purple.	N = 0
	Late perinucleolus (lPN) 2		Oocytes are larger and rounder than ePN, cytoplasm stains lighter purple, and nucleoli develop.	N* = 4 Diameter range** 0.22-0.46 Mean diameter*** = 0.32
Vitellogenic	**Cortical alveolus (CA)** 3		First cortical alveoli appear as white stain in the periphery of the oocyte.	N = 41 Diameter range 0.32-0.64 Mean diameter = 0.46
	Early-vitellogenic (Vtg1) 4		Yolk globules first appear and stain pink at the periphery of the oocyte and fill inwards occupying up to 1/3 of the cytoplasm.	N = 110 Diameter range 0.39-0.73 Mean diameter = 0.56
	Mid-vitellogenic (Vtg2) 5		Yolk globules transition from only the periphery (outer 1/3 as in Vt1) of the ooplasm and fill inwards to the nucleus.	N = 59 Diameter range 0.54-0.89 Mean diameter = 0.71
	Late-vitellogenic (Vtg3) 6		Yolk globules become larger as they begin to fuse and completely fill the ooplasm, making contact with the central nucleus.	N = 69 Diameter range 0.76-1.63 Mean diameter = 1.21
Post-vitellogenic	**Germinal vesicle migration (GVM)** 7		The nucleus begins to migrate to the edge of the cell wall through a cytoplasm fully filled with yolk globules.	N = 59 Diameter range 0.90-1.74 Mean diameter = 1.30
	Germinal vesicle breakdown (GVBD) 8		Nucleus is no longer visible and yolk globules coalesce into dark pink stained yolk masses.	N = 0
Hydration	**Hydration (Hy)** 9		Yolk coalesces into a central mass in the cell occupying over 50% of the area. Oocyte is still within the follicle wall.	N = 14 Diameter range 1.73-2.46 Mean diameter = 2.03

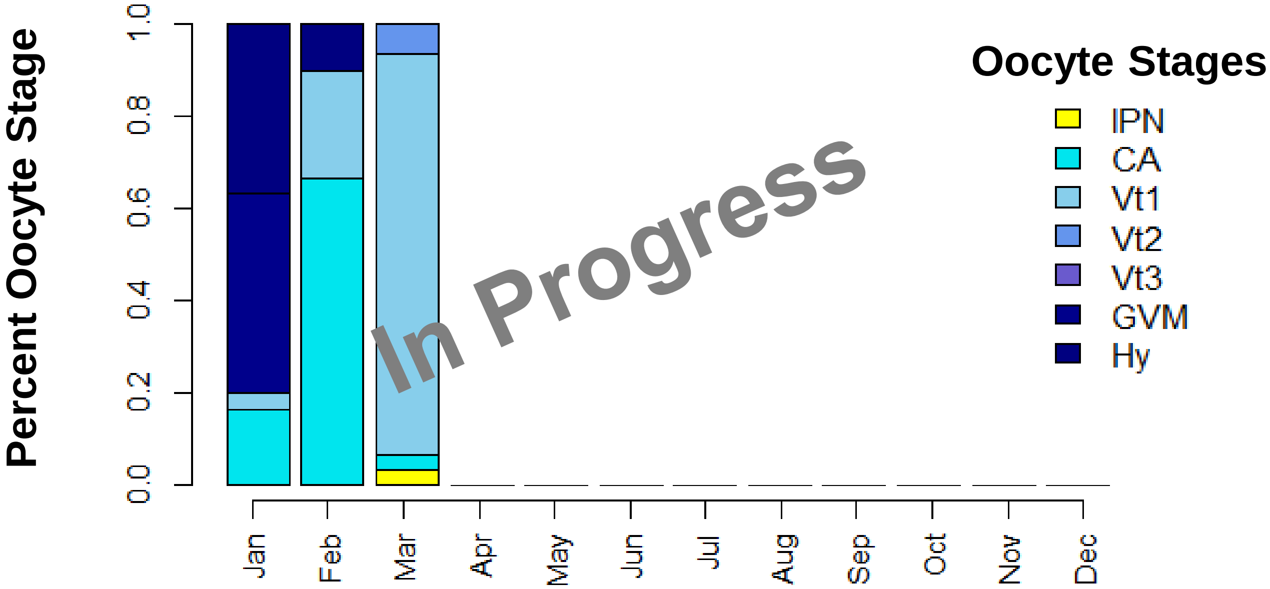
Oocyte stages:

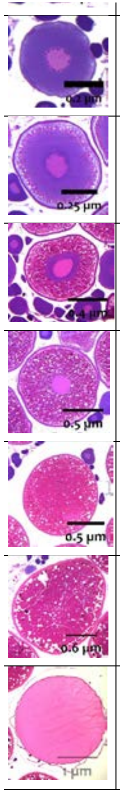
1. Early perinucleolus (ePN)
2. Late Perinucleolus (lPN)
3. Cortical alveolus (CA)
4. Early vitellogenic (Vt1)
5. Mid vitellogenic (Vt2)
6. Late vitellogenic (Vt3)
7. Germinal vesicle migration (GVM)
8. Germinal vesicle breakdown (GVBD)
9. Hydration



2. Reproduction

Microscopic maturity staging: based on histological oocyte stages





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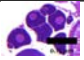
Primary Growth (PG)	**Early perinucleolus (ePN)** 1		Oocytes are small often angular and compact with a single large nucleolus. Cytoplasm stains dark purple.	N = 0
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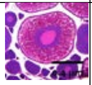
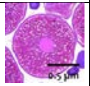
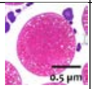
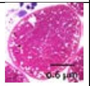
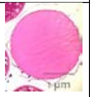
	Mid-vitellogenic (Vtg2) 5		Yolk globules transition from only the periphery (outer 1/3 as in Vt1) of the ooplasm and fill inwards to the nucleus.	N = 59 Diameter range 0.54-0.89 Mean diameter = 0.71
	Late-vitellogenic (Vtg3) 6		Yolk globules become larger as they begin to fuse and completely fill the ooplasm, making contact with the central nucleus.	N = 69 Diameter range 0.76-1.63 Mean diameter = 1.21
Post-vitellogenic	**Germinal vesicle migration (GVM)** 7		The nucleus begins to migrate to the edge of the cell wall through a cytoplasm fully filled with yolk globules.	N = 59 Diameter range 0.90-1.74 Mean diameter = 1.30
	Germinal vesicle breakdown (GVBD) 8		Nucleus is no longer visible and yolk globules coalesce into dark pink stained yolk masses.	N = 0
Hydration	**Hydration (Hy)** 9		Yolk coalesces into a central mass in the cell occupying over 50% of the area. Oocyte is still within the follicle wall.	N = 14 Diameter range 1.73-2.46 Mean diameter = 2.03

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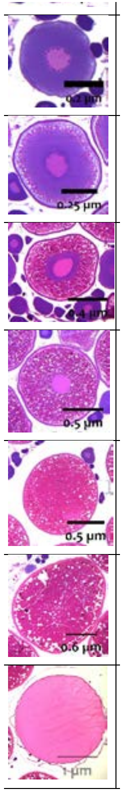
5. Mid vitellogenic (Vt2)
6. Late vitellogenic (Vt3)
7. Germinal vesicle migration (GVM)
8. Germinal vesicle breakdown (GVBD)
9. Hydration

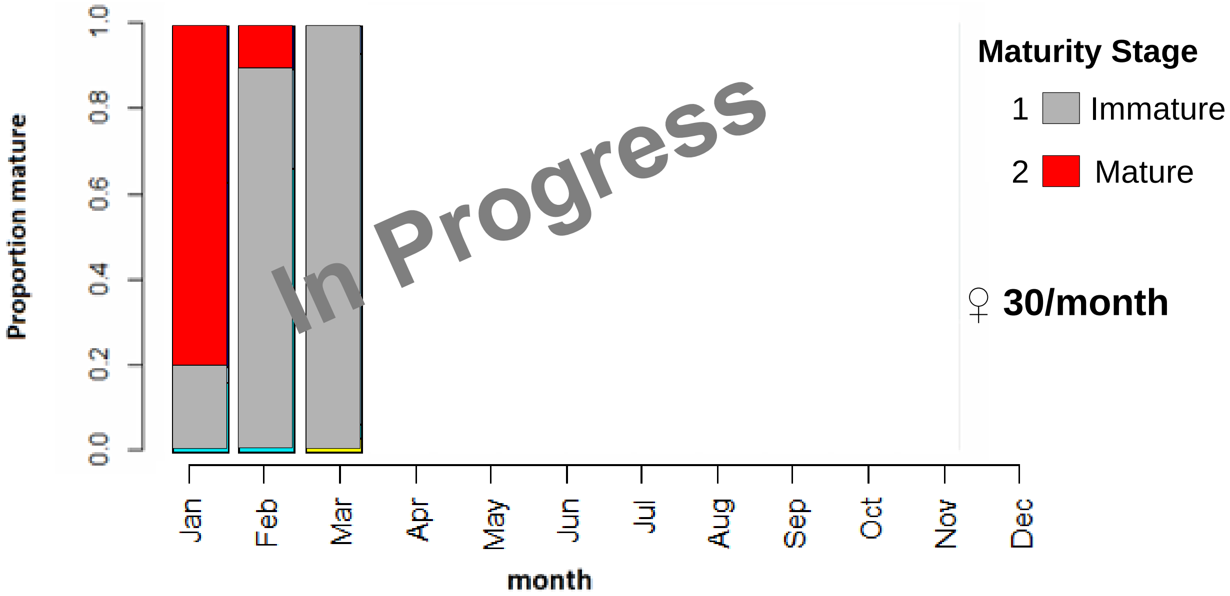
Maturity classification:

1. Immature (e.g. Oocyte stages 1-5)
2. Mature (e.g. Oocyte stages 6-9)

2. Reproduction

Macroscopic maturity staging





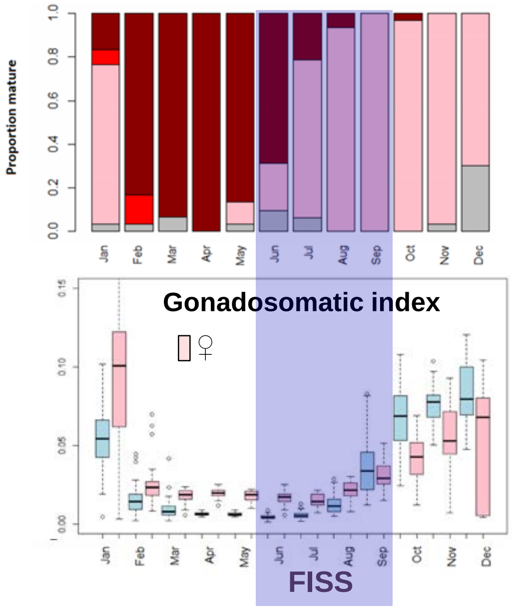
2. Reproduction

Female maturity information available from one region: Portlock

FISS dates:
2019: 26 May - 22 Sept
2018: 28 May - 15 Sept

- **Full annual collection (2018)**

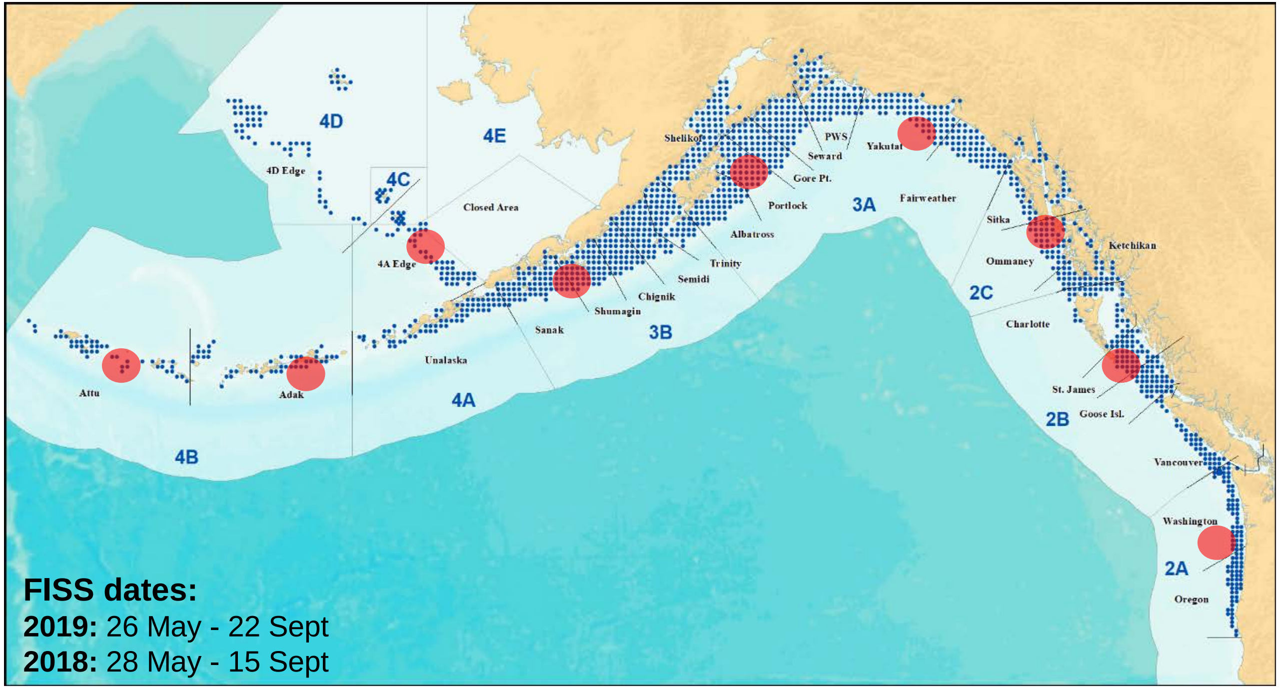
Macroscopic maturity staging (♀)



- **Interannual collection June 2017, 2018, 2019**

2. Reproduction

Spatial analysis of maturity



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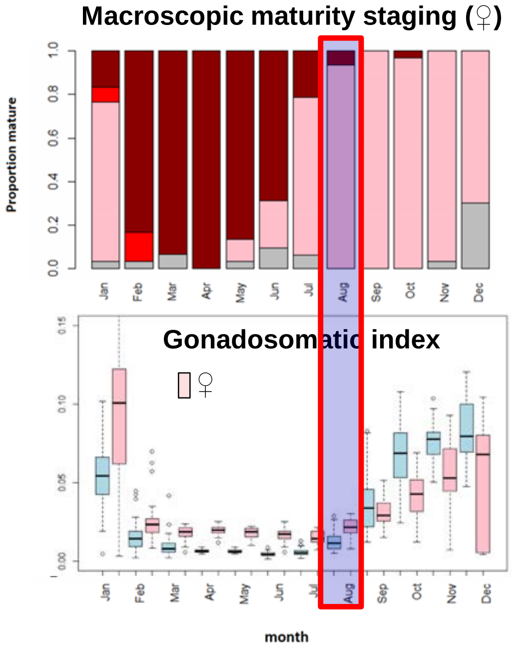
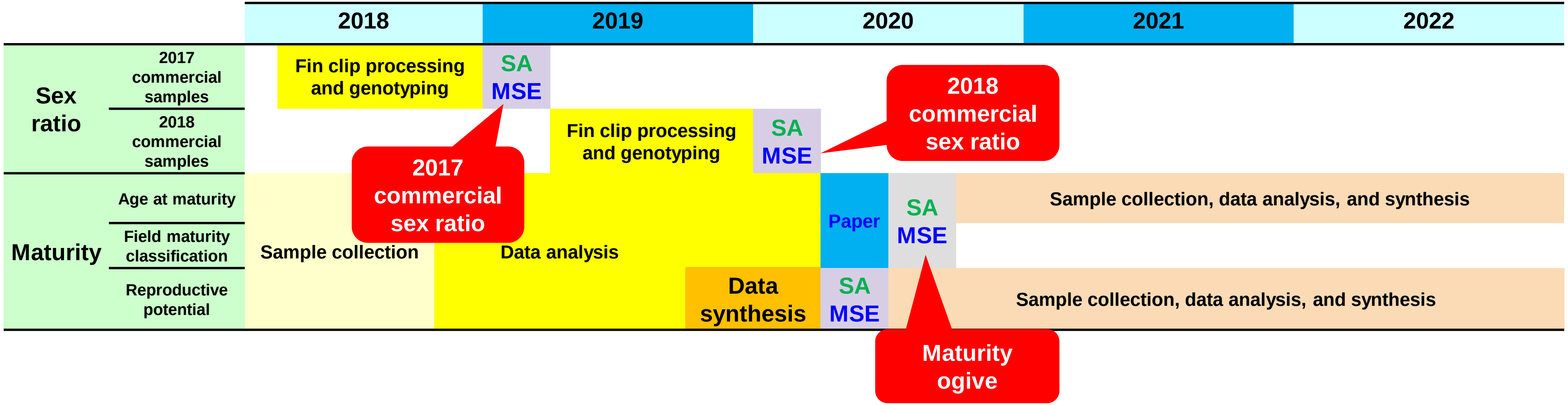


- **August collection in FISS**

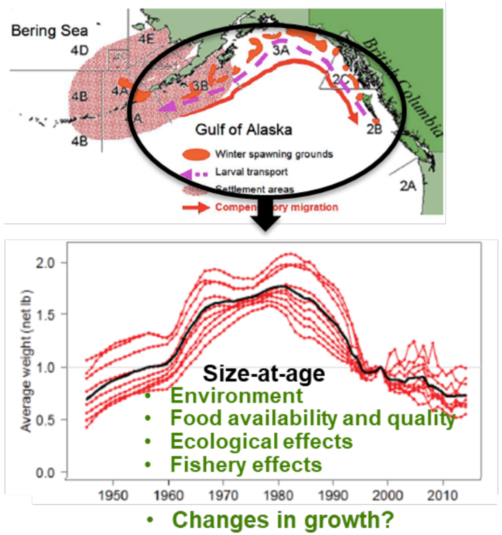
2. Reproduction: timeline and integration with stock assessment, and MSE



3. Growth

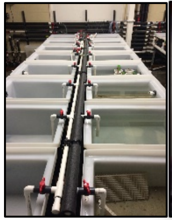
Projects:

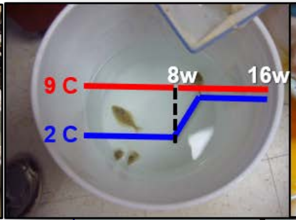
1. ***Identification and validation of physiological markers for growth***
2. ***Evaluation of growth patterns in the Pacific halibut population and possible effects of environmental variability***

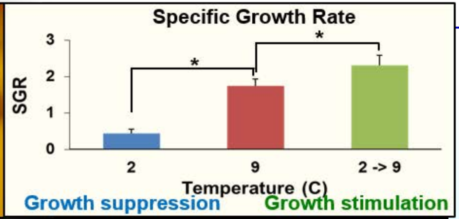


3. Growth

1. Identification and validation of physiological markers for growth







White muscle:

- **Transcriptomics**
- **Proteomics**
- **Stable isotopes**

Temperature | **Population Density** | **Dominance** | **Capture Stress**

Effects on transcriptome and proteome

MUSCLE

LIVER

BIOCHEMICAL AND MOLECULAR GROWTH RESPONSES

Identification of physiological growth markers

Application to field studies

IPHC / AFSC-NOAA (Newport, OR)

Dr. Josep Planas (PI)

Dr. Thomas Hurst

NPRB Grant 1704 (2017-2019)

3. Growth

Physiological growth markers → Application to field studies

2. Validation of physiological growth markers for adult Pacific halibut

- 44 adult Pacific halibut in captivity in Seward, AK (collaboration with Alaska Pacific University)
- Establishment of different growth rates through dietary manipulation
- Validation of physiological growth markers to infer growth patterns (slow versus fast growth) in adult Pacific halibut

3. Growth

Physiological growth markers → **Application to field studies**

3. Evaluation of growth patterns in the Pacific halibut population

Age-matched skeletal muscle samples collected in the NMFS trawl survey (2016 – 2018) from 3 size categories:

<40 cm FL

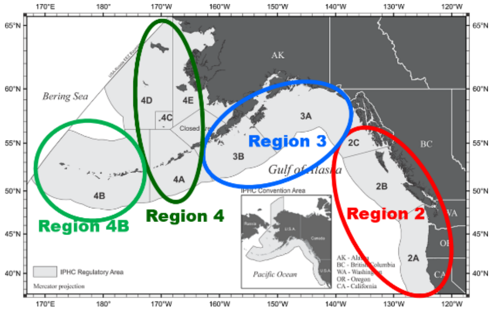
40-60 cm FL

60-80 cm FL

Slow growth rate?

Fast growth rate?

– **Regional monitoring of growth patterns**



3. Growth: timeline and integration with stock assessment, and MSE

		2018	2019	2020	2021	2022
Growth	Identification of growth markers	Data analysis and marker validation	Paper			
	Direct temperature effects on growth	Sample processing and data collection	Data analysis	Data synthesis	SA MSE	
	Growth pattern evaluation	Sample collection	Sample processing	Data analysis		Sample collection, data analysis, and synthesis
	Thermal growth history	Tagging		collection		

- Temperature– dependent growth
- Productivity

4. Discard mortality rates and survival assessment

Projects:

1. Improve DMR estimations in the directed longline fishery

NOAA FISHERIES Saltonstall – Kennedy Grant NA17NMF4270240 ALASKA PACIFIC UNIVERSITY

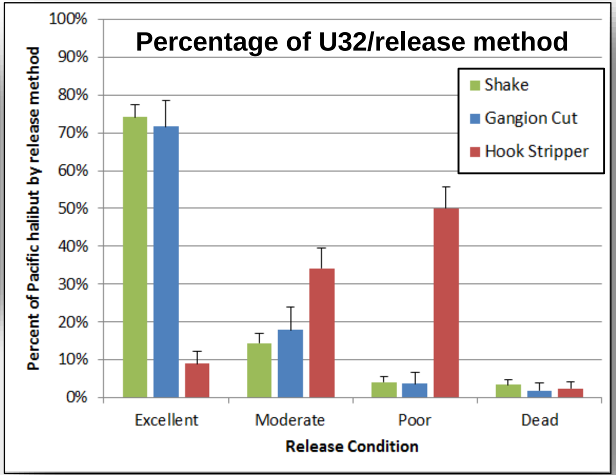
2. Estimate DMRs in the guided recreational fishery

NFWF National Fish and Wildlife Foundation UNIVERSITY OF ALASKA FAIRBANKS ALASKA PACIFIC UNIVERSITY Alaska Charter Association

4. DMRs and survival assessment

1. <u>Directed longline fishery</u>: A. Relationship between handling practices and injury levels and physiological condition of released Pacific halibut

– Assessed *injuries* associated with release techniques (careful shake, gangion cut, hook stripping).



– *Physiological condition* of released fish

- Condition factor indices

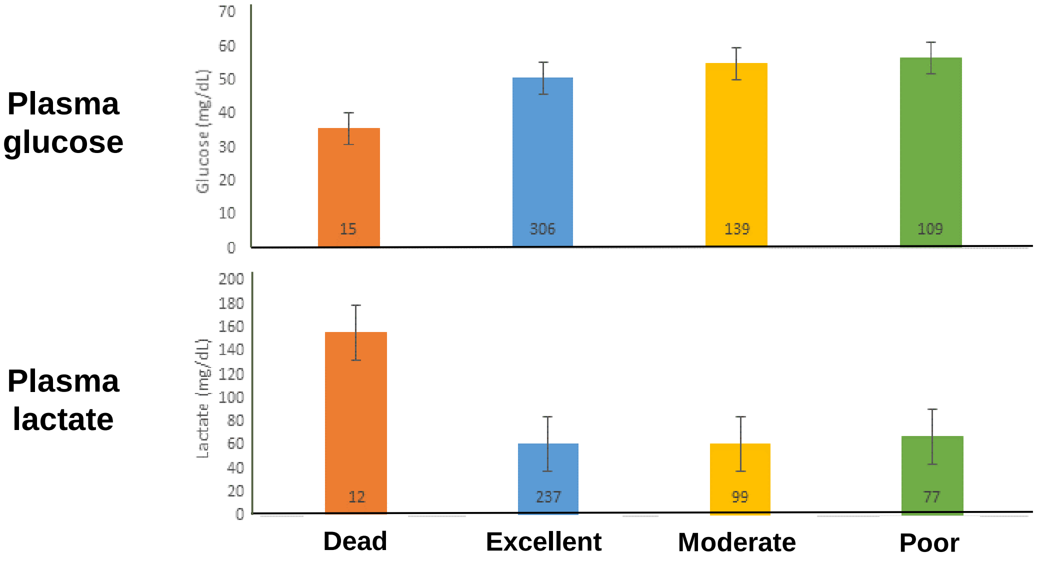
– *Capture conditions*

Blood stress indicators:
- ✓ Glucose
- ✓ Lactate
- Cortisol

4. DMRs and survival assessment

1. <u>Directed longline fishery</u>: A. Relationship between handling practices and injury levels and physiological condition of released Pacific halibut

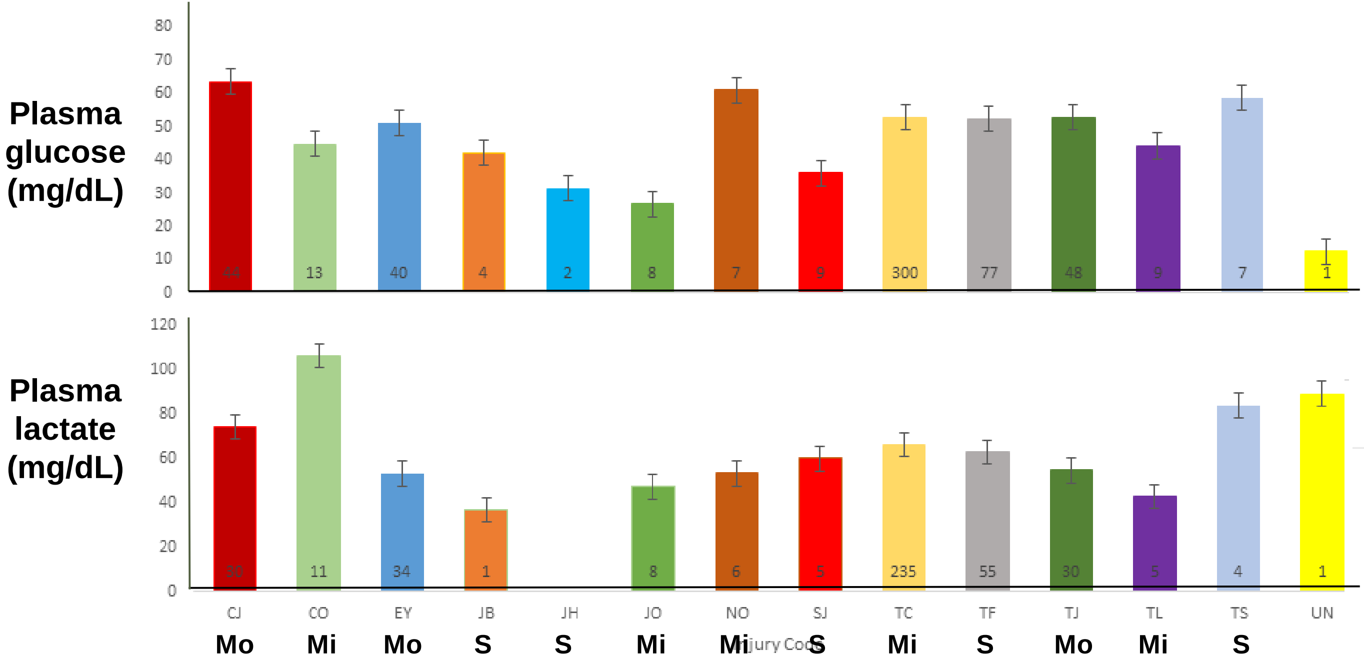
– ***Physiological condition*** **of released Fish: Blood stress indicators by <u>release condition</u>**



4. DMRs and survival assessment

1. <u>Directed longline fishery</u>: A. Relationship between ***handling practices*** *and* ***injury levels*** *and* ***physiological condition*** *of released Pacific halibut*

– ***Physiological condition*** **of released Fish: Blood stress indicators by <u>injury code</u>**



Severity	Code	Description
Minor Mi	NO	No apparent injury.
	CO	Cheek only (not through skin).
	JO	Jaw only (but not clear through the jaw).
	TL	Torn lip (skin covering external portion of jaw), cheek not punctured.
	TC	Torn cheek, small hole through cheek only.
Moderate Mo	TJ	Torn jaw, either side. Little or no tearing in cheek.
	CJ	Cheek and jaw. Tear in cheek extending through jaw.
	EY	Hook penetrated eye.
Severe S	TF	Torn face. Torn though cheek and jaw, like above, but large flap of side o head is ripped/missing.
	SJ	Split jaw. Lower jaw is split laterally.
	JB	Jig body. Fish snagged by hook somewhere on body other than head.
	JH	Jig head. Fish snagged by hook in the head (not through mouth).
	TS	Torn snout. Upper jaw is split laterally, usually tearing through the snout well.
Unknown	UN	Injury unknown or unrecorded.

4. DMRs and survival assessment

2. *Guided recreational fishery: Estimation of DMRs*

– Project initiated in 2019

Objectives:

2019

1. Collect information on hook types and sizes and handling practices

2020

2. Investigate the relationship between gear types and capture conditions and size composition of captured fish
3. Injury profiles and physiological stress levels of captured fish
4. Assessment of mortality of discarded fish

NFWF National Fish and Wildlife Foundation

UAF University of Alaska Fairbanks · Alaska Pacific University · ACA Alaska Charter Association

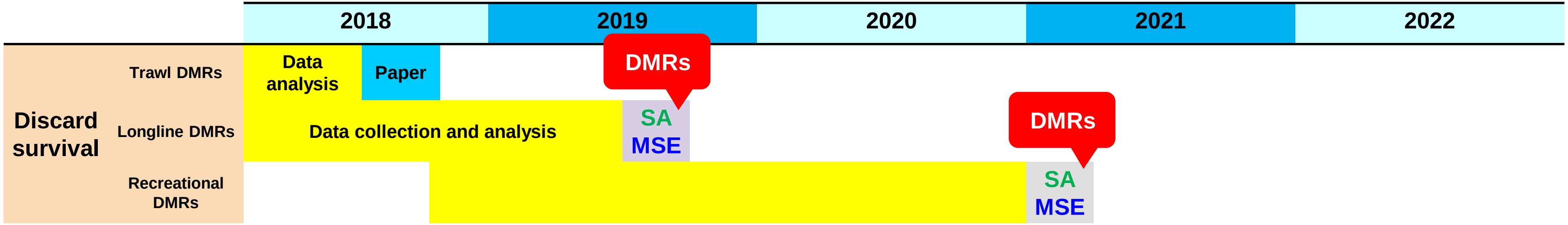
Sport charter

Captured Pacific halibut

Hook injury assessment

Tagging with sPATs

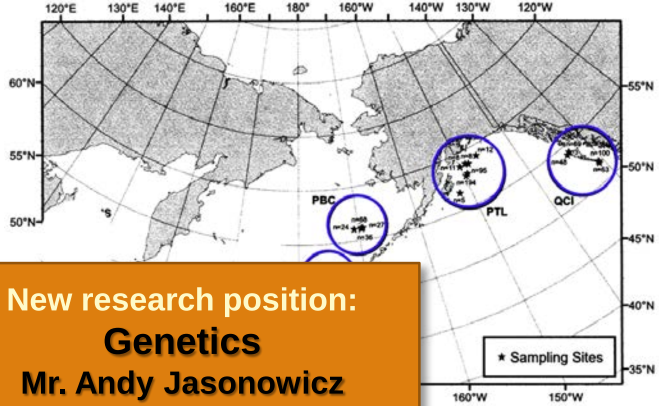
4. DMRs: timeline and integration with stock assessment, and MSE



5. Genetics and Genomics

Projects:

1. Genetic structure of the Pacific halibut population and distribution



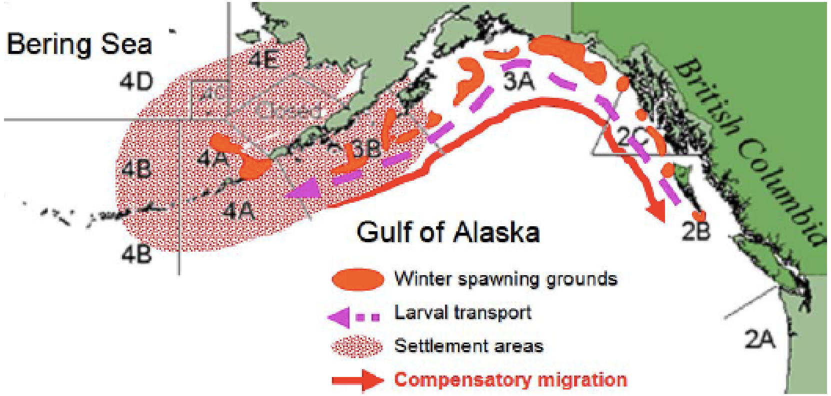
2. Genome sequencing

New research position:
Genetics
Mr. Andy Jasonowicz
1 yr- contract
8/26/2019-8/25/2020

- **Genomic DNA sequenced from one Pacific h**
- **Conducted first genome assembly:**
  - **Full genome sequenced. Genome size: 700 Mb**
  - **Non-continuous genome sequence.**
- **Additional sequencing is being conducted to complete assembly.**

INRA 70 Years SCIENCE & IMPACT

Incorporation of genetics into migration-related research

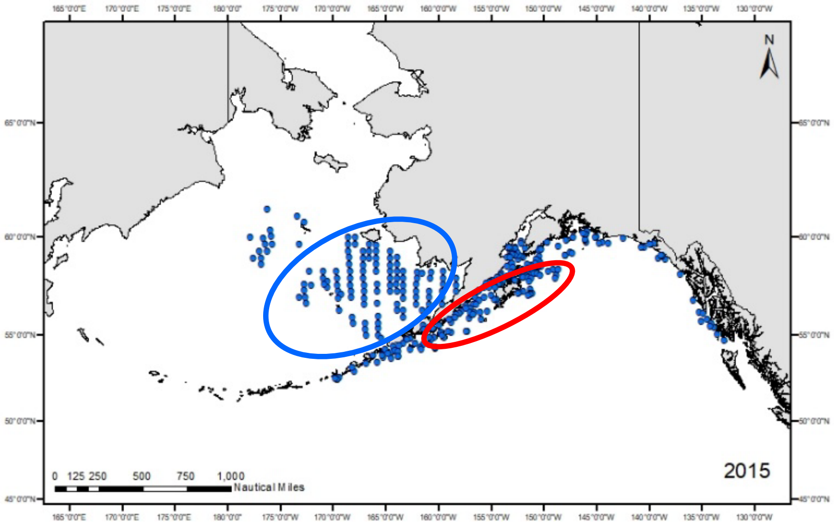


Future projects:

- Genetic variability among juvenile Pacific halibut in the Bering Sea and Gulf of Alaska
- Identification of potential genetic signatures of origin (spawning groups)
- Genetic structure of the Pacific halibut population

Incorporation of genetics into migration-related research

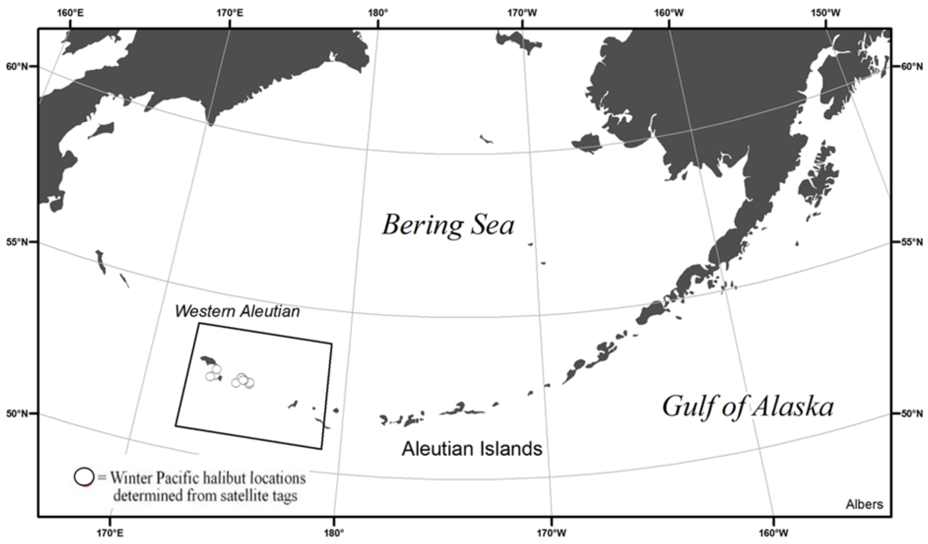
- **Genetic variability among juvenile Pacific halibut in the Bering Sea and Gulf of Alaska**



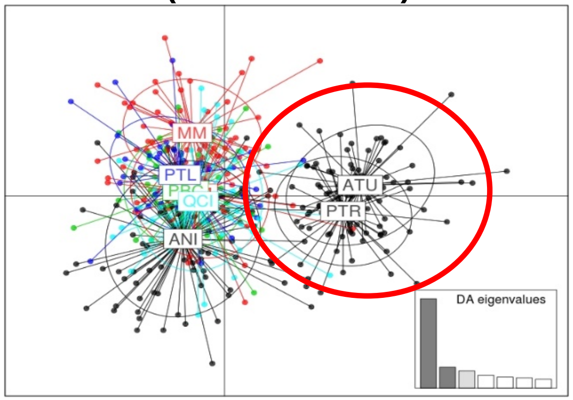
Aim: Evaluate potential genetic variability among BS and GOA juvenile Pacific halibut that could be indicative of potential contribution from different sources (spawning groups) and ocean basin differences

Incorporation of genetics into migration-related research

- Genetic structure of the Pacific halibut population: Part 1 – East vs West Aleutian Is.



Drinan et al., 2016. *J. Fish Biol.* (microsatellites)

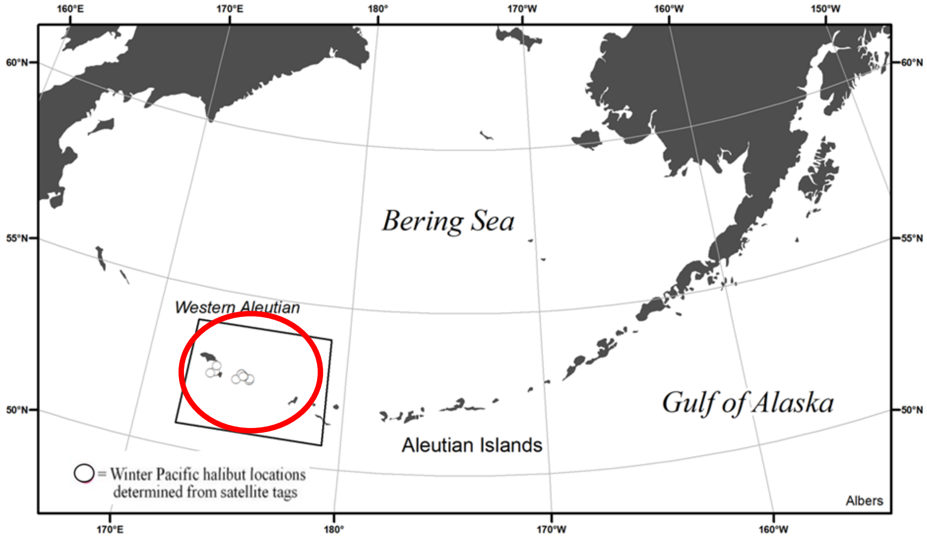


Subtle genetic differences in fish from the Western Aleutian Islands (Reg. Area 4B)

Caviat: Summer samples compared to winter (spawning) samples

Incorporation of genetics into migration-related research

- **Genetic structure of the Pacific halibut population: Part 1 – East vs West Aleutian Is.**

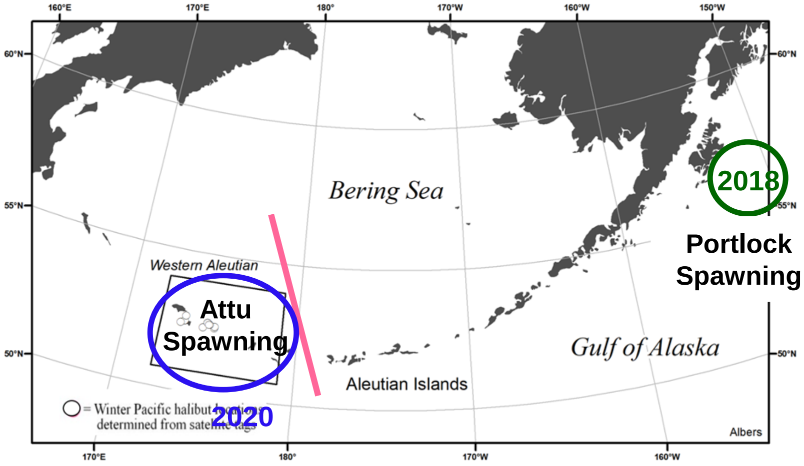


<u>Aim</u>: Establish potential genetic differences between Eastern and Western Aleutian Islands

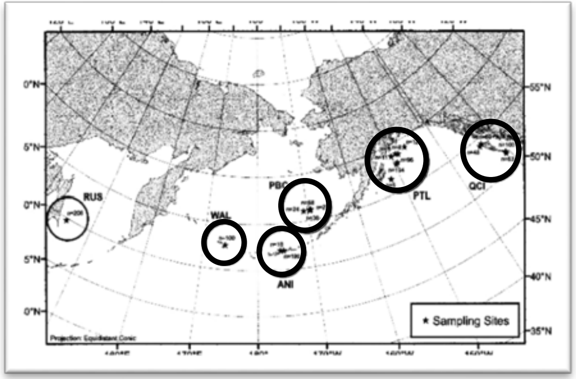
1. **Collect winter genetic samples (winter 2020)**
2. **Conduct genetic analyses**

Incorporation of genetics into migration-related research

- **Genetic structure of the Pacific halibut population: Part 2 – Identification of potential genetic signatures of origin (baseline signals): new spawning groups)**



Aim: Establish genetic baselines from known spawning groups to assist in assignment studies and in studies revisiting the genetic population structure coastwide



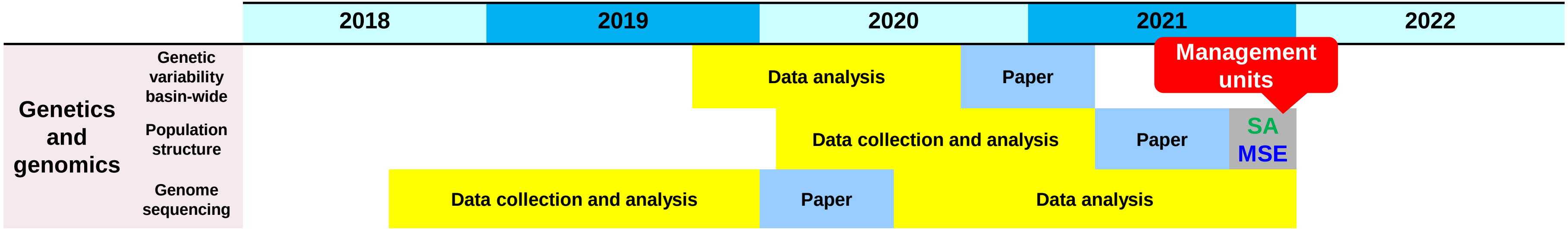
Aim: Revised population structure

Genetic analyses using:

New samples (**2018**, **2020**)

Old samples (early 2000s)

5. Genetics and genomics: timeline and integration with stock assessment, and MSE



Outline

INTERNATIONAL PACIFIC HALIBUT COMMISSION

- Five-year research plan and management implications
- Progress on ongoing research projects
- **Externally-funded collaborative research**

Externally-funded collaborative research

Project #	Grant agency	Project name	PI	Partners	IPHC Budget ($US)	Management implications	Grant period
1	Saltonstall-Kennedy NOAA	**Improving discard mortality rate estimates in the Pacific halibut by integrating handling practices, physiological condition and post-release survival (*Award No. NA17NMF4270240*)**	IPHC	Alaska Pacific University	$286,121	Discard estimates	September 2017 – August 2019
2	North Pacific Research Board	**Somatic growth processes in the Pacific halibut (*Hippoglossus stenolepis*) and their response to temperature, density and stress manipulation effects (*NPRB Award No. 1704*)**	IPHC	AFSC-NOAA-Newport, OR	$131,891	Changes in biomass/size-at-age	September 2017 – February 2020
3	Bycatch Reduction Engineering Program - NOAA	**Adapting towed array hydrophones to support information sharing networks to reduce interactions between sperm whales and longline gear in Alaska**	ALFA	IPHC, University of Alaska Southeast, AFSC-NOAA	-	Whale Depredation	September 2018 – August 2019
4	Bycatch Reduction Engineering Program - NOAA	**Use of LEDs to reduce Pacific halibut catches before trawl entrainment**	PSMFC	IPHC, NMFS	$1,750	Bycatch reduction	September 2018 – August 2019
5	National Fish and Wildlife Foundation	**Discard mortality rate characterization in the Pacific halibut recreational fishery (*NFWF Award No. 61484*)**	IPHC	UA Fairbanks, APU, Grey Light Fisheries, Alaska Charter Association	$98,901	Discard estimates	2019-2020
				Total awarded ($)	**$518,663**		

Other collaborative research

Project #	Partners	Topic of collaboration
1	**Agencies from contracting parties** (NOAA-Fisheries, DFO, PHMA, PSMFC, ADEC)	**Collaborative research and data collection in IPHC FISS**
2	**Industry**	• **Collaborative research with trawl fishery and with Pacific halibut directed (longline) and recreational fisheries on discard mortality rate.** • **Collaborative research with Pacific halibut directed fishery on (1) sex marking at sea and (2) incidence of chalky halibut.**
3	**North Pacific Fisheries Management Council**	**Joint research priority list NPFMC-IPHC (last updated in 2018)**
4	**Scientific partners** 1. **Contracting parties: US** (AFSC-NOAA Fisheries, NWFSC-NOAA Fisheries, University of Washington, University of Alaska Fairbanks, Alaska Pacific University) 2. **Contracting parties: Canada** (Simon Fraser University, Dalhousie University) 3. **International: France** (INRA)	**Scientific collaborative research on various topics (genomics, genetics, migration, ecosystem studies, etc)**

INTERNATIONAL PACIFIC

HALIBUT COMMISSION