INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC 5-year Biological and Ecosystem Science Research Program

Agenda Item 6.2
IPHC-2020-RAB021-05

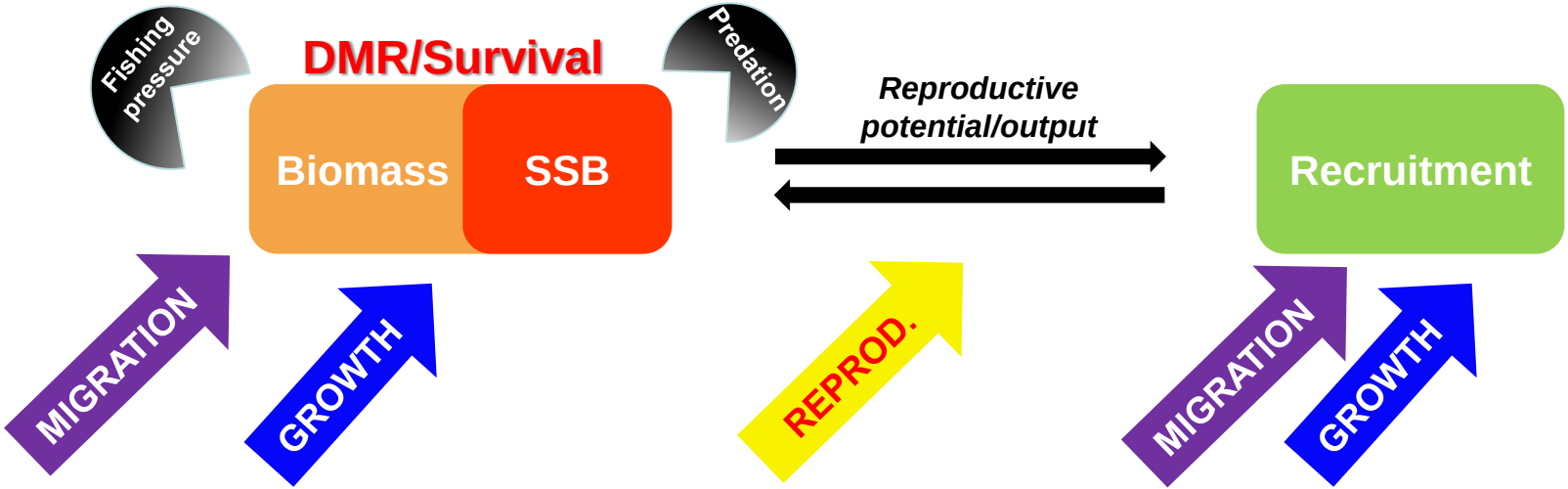
Description of IPHC research activities

1. **Overview of IPHC 5-year Biological and Ecosystem Sciences Research Plan (2017-2021)**
2. **Updates on specific topics: whale depredation and chalky Pacific halibut**
3. **Core research streams: Updates for key ongoing research activities (Project leaders)**
   - **Migration***: Migratory behaviour and distribution of Pacific halibut* (L. Sadorus, J. Forsberg, T. Loher)
   - **Reproduction***:*
     - *Reproductive assessment of the Pacific halibut population* (J. Planas)
     - *Application of genotyping techniques to determine the sex ratio commercial landings* (A. Simeon)
   - **Growth***: Factors affecting somatic growth in juvenile Pacific halibut* (J. Planas)
   - ***Discard mortality rates:*** *Discard mortality rates and post-release survival in the Pacific halibut fisheries* (C. Dykstra)
   - **Genetics and genomics**: Application of genetics and genomics to improve our knowledge on population structure and distribution (A. Jasonowicz)

Primary research activities at IPHC

Primary objectives

- Identify and address *critical knowledge gaps* in the biology of Pacific halibut
- Understand the influence of *environmental conditions* on Pacific halibut biology
- Apply resulting knowledge to reduce *uncertainty* in current stock assessment models

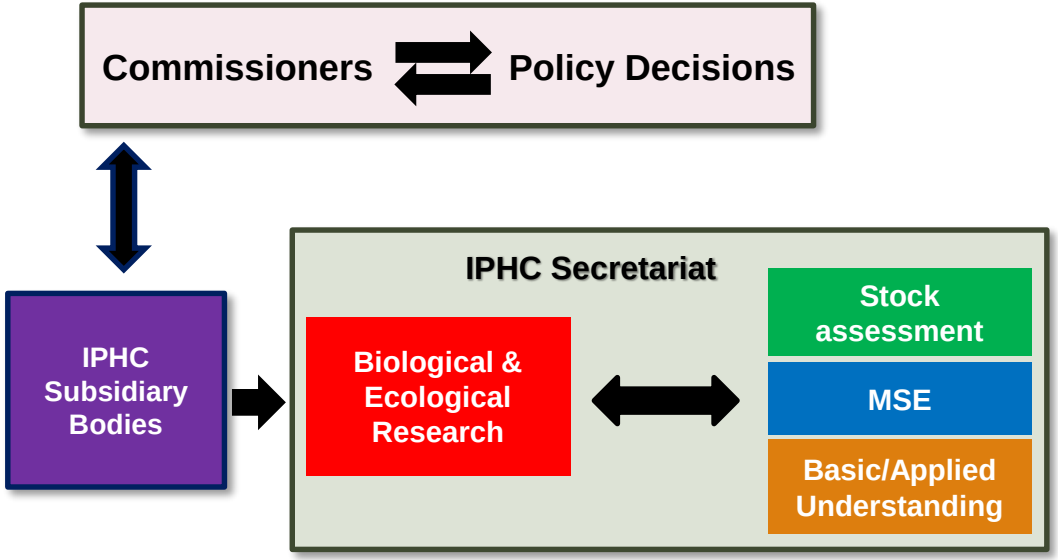


Five-year research plan and management implications

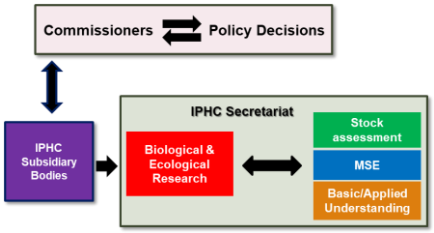
5-Year Biological and Ecosystem Science Research Plan

Primary Research Areas	*Main Objectives*	*Management implications*
Migration	Improve understanding of migration throughout all life stages (larval, juvenile, adult feeding and reproductive migrations)	Stock distribution, regional management
Reproduction	Information on sex ratios of commercial landings and improved maturity estimates	Female stock spawning biomass
Growth	Improve understanding of factors responsible for changes in size-at-age and development of tools for monitoring growth and physiological condition	Biomass estimates
DMRs and discard survival	Improve estimates of DMRs in the directed longline and guided recreational fisheries	Discard mortality estimates
Genetics and genomics	Improve understanding of the genetic structure of the population and create genomic tools (genome)	Stock distribution, local adaptation

Integration of biological research, stock assessment, and policy

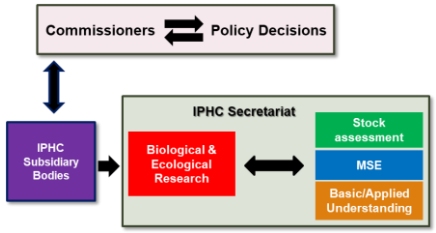


Integration of biological research, stock assessment, and policy



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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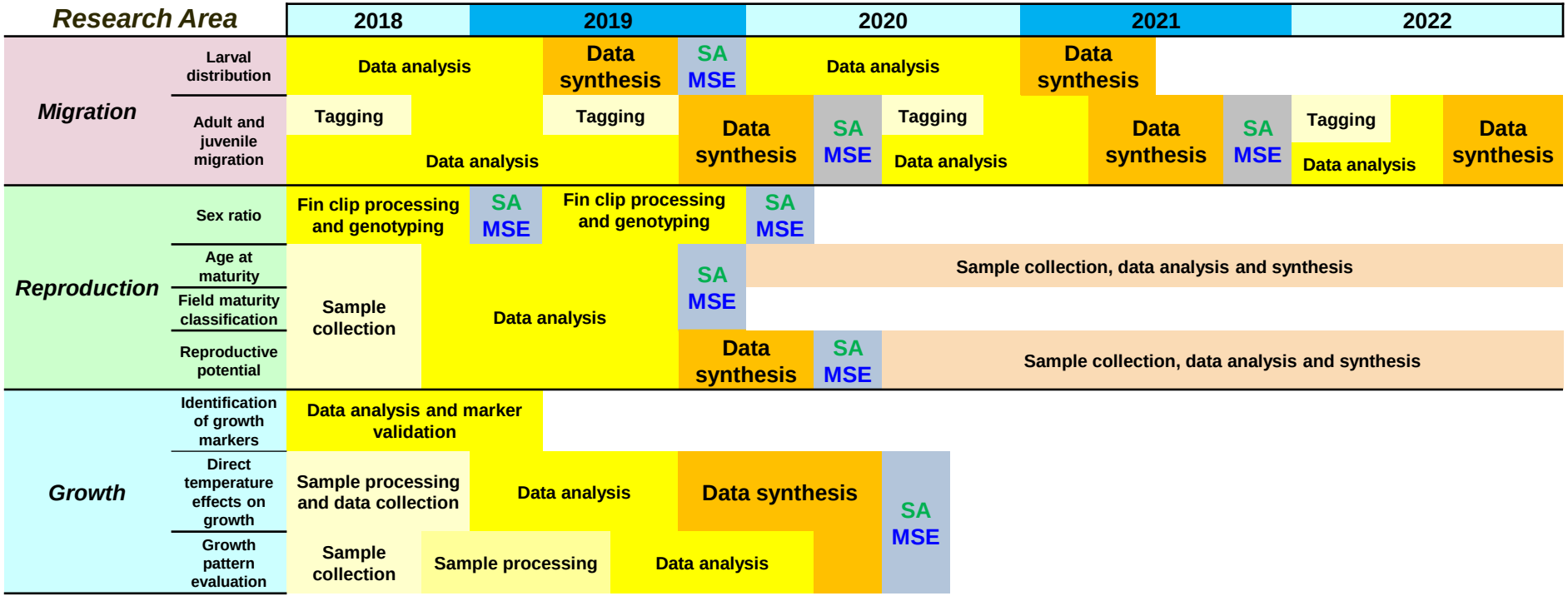
Sex ratio of commercial landings

→ **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



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3. Core research streams: Updates for key ongoing research activities (Project lea

- **Action Item 6.1.1: Whale depredation (Claude Dykstra)**
- **Action Item 6.1.2: Chalky Pacific halibut (Lauri Sadorus)**

- J. Forsberg, T. Loher)
- **Reproduction:**
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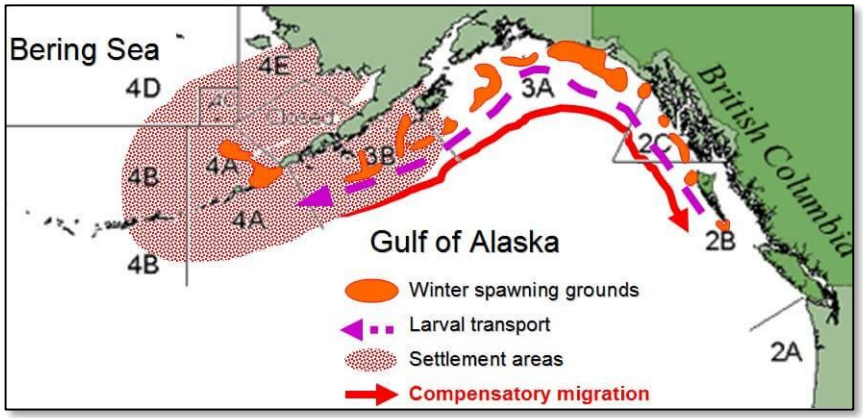
Updates for key ongoing research activities

1. Migration and distribution

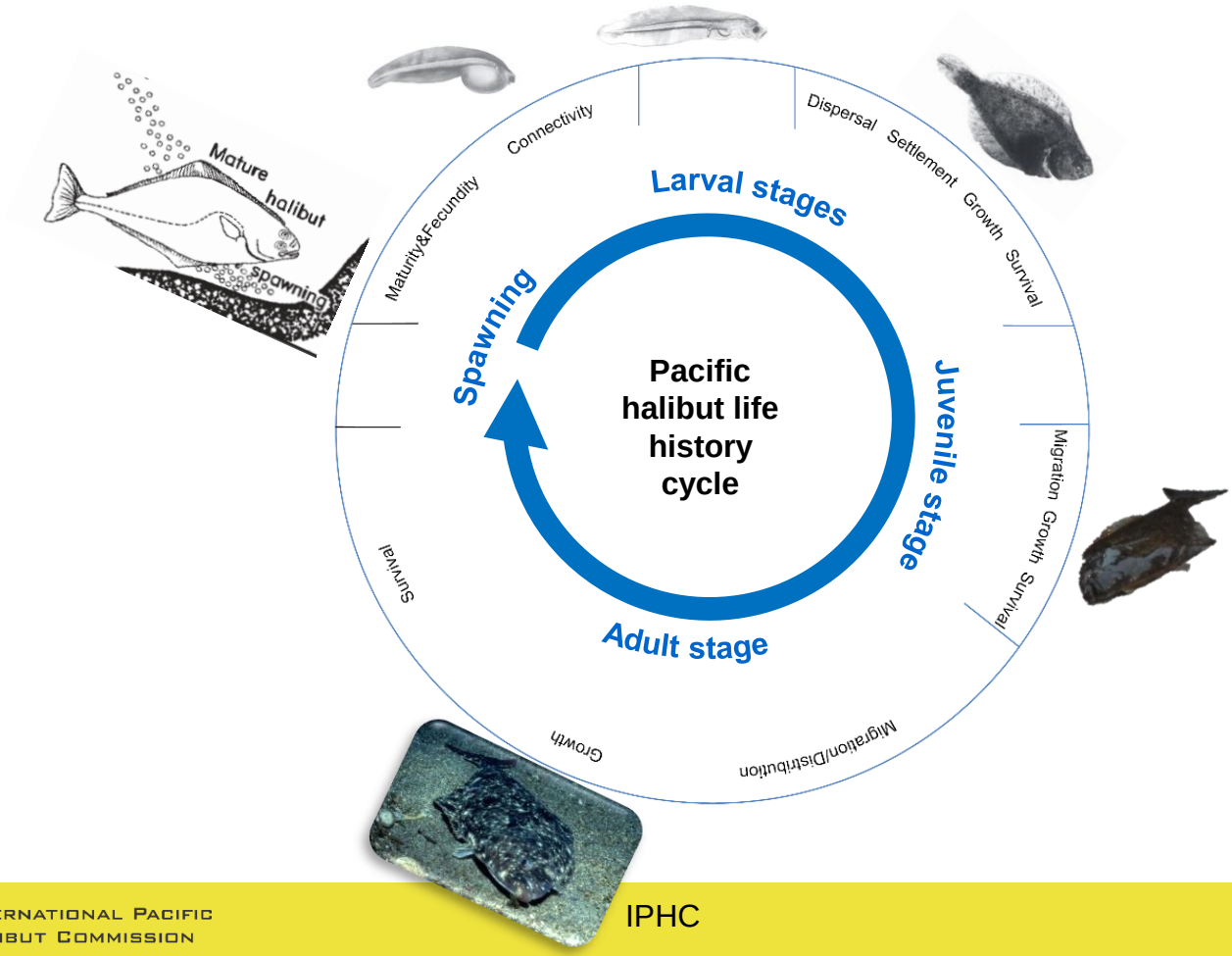
Projects:

1. Larval and early juvenile dispersal

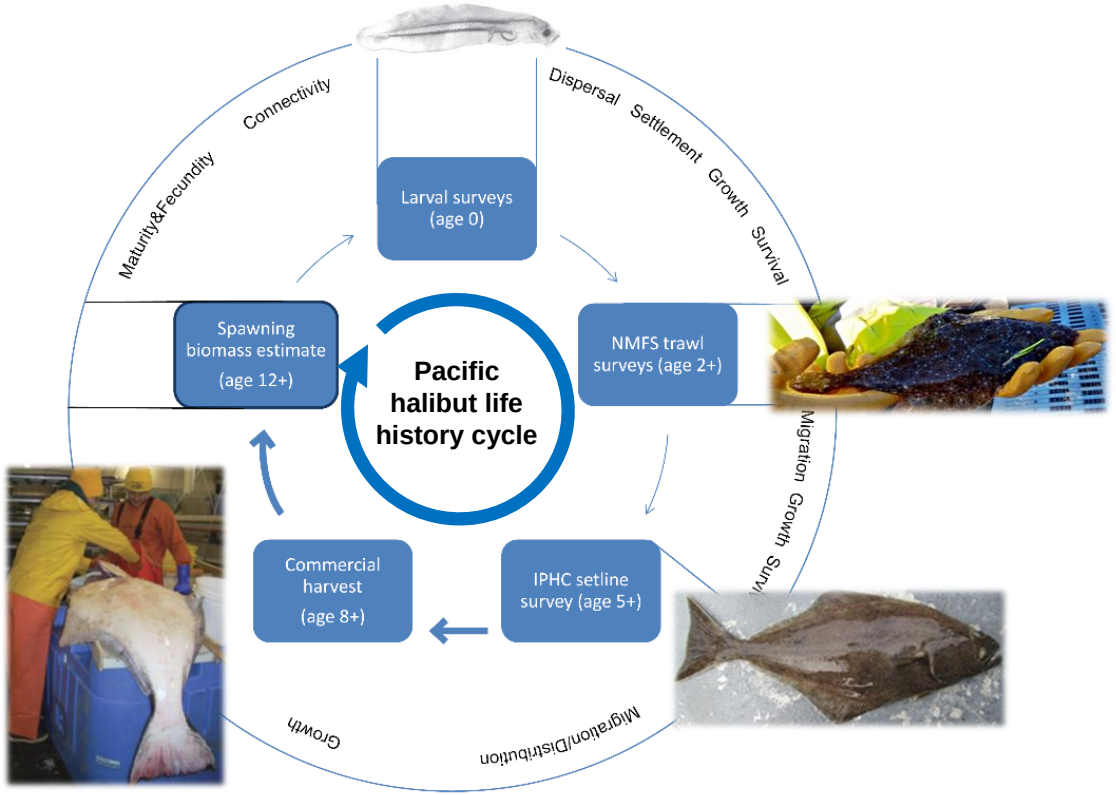
2. Late juvenile and adult migration



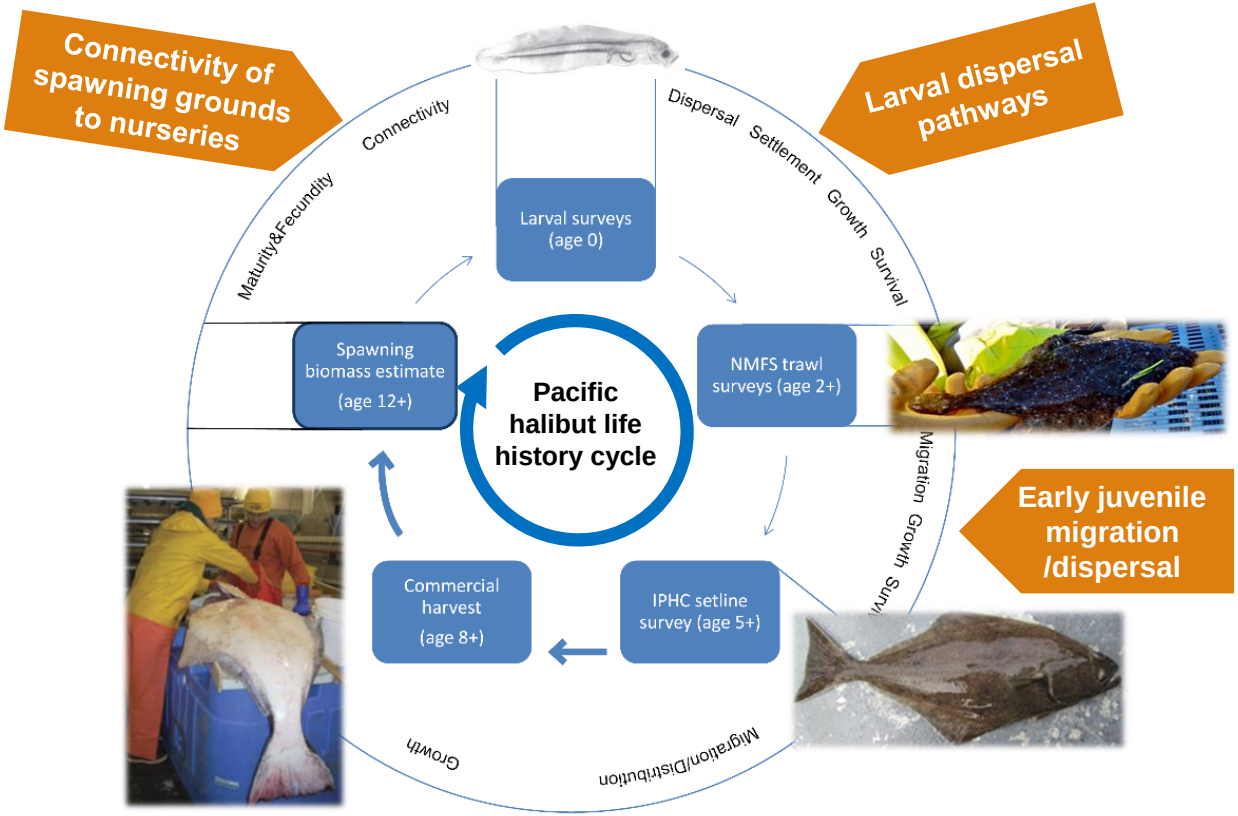
Migration and distribution – Conceptual model



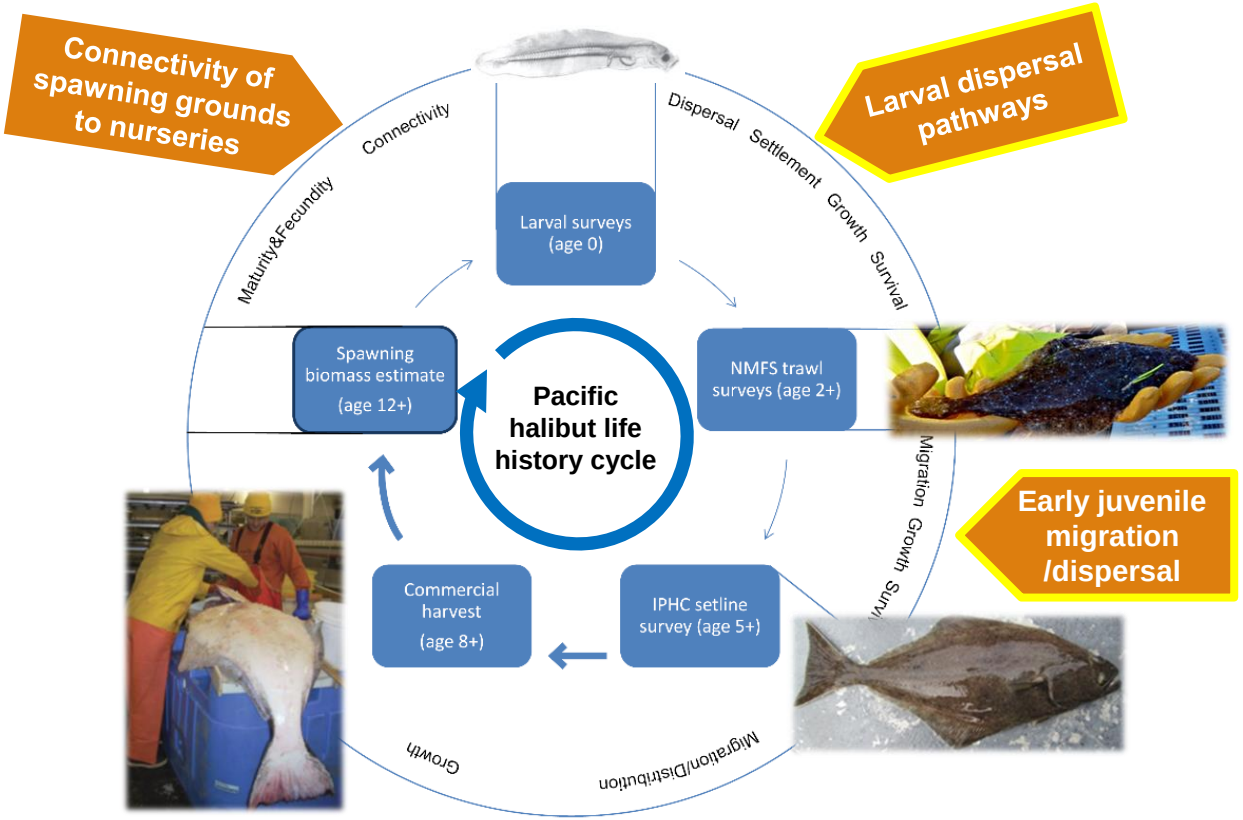
Migration and distribution: ID data sets



Migration and distribution: ID important gaps in knowledge



Migration and distribution: important gaps in knowledge

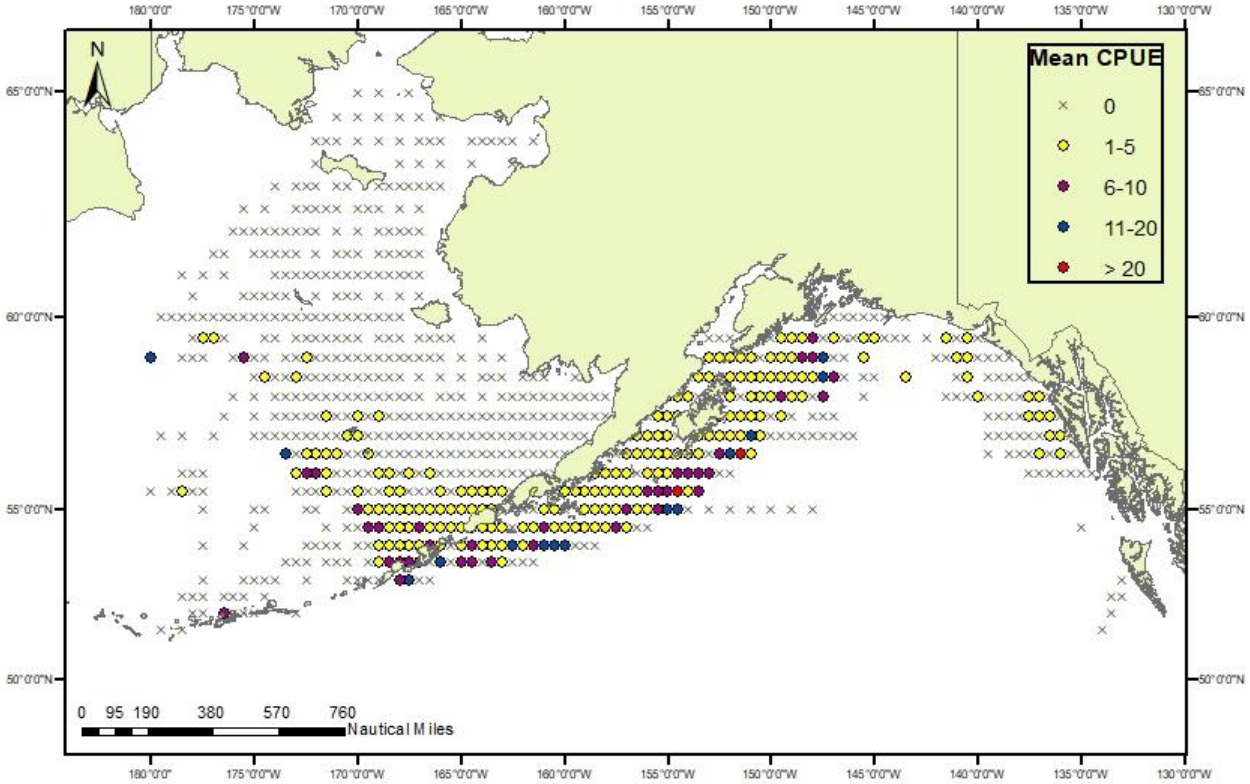


Larval and early juvenile dispersal

- **Collaborative project with NOAA/EcoFOCI**
- **Primary goals:**
  - **Establish degree of connectivity between and within ocean basins**
  - **Identify large-scale environmental effects on larval distribution**
- **Dispersal/counter-migration of young fish post-settlement**

- **Project complete and being prepared for publication:**
  Sadorus, L. L., Goldstein, E., Webster, R. A., Stockhausen, W. T., Planas, J. V., and Duffy-Anderson, J. In prep. Multiple life-stage connectivity of Pacific halibut (*Hippoglossus stenolepis*) across the Bering Sea and Gulf of Alaska

Larval dispersal

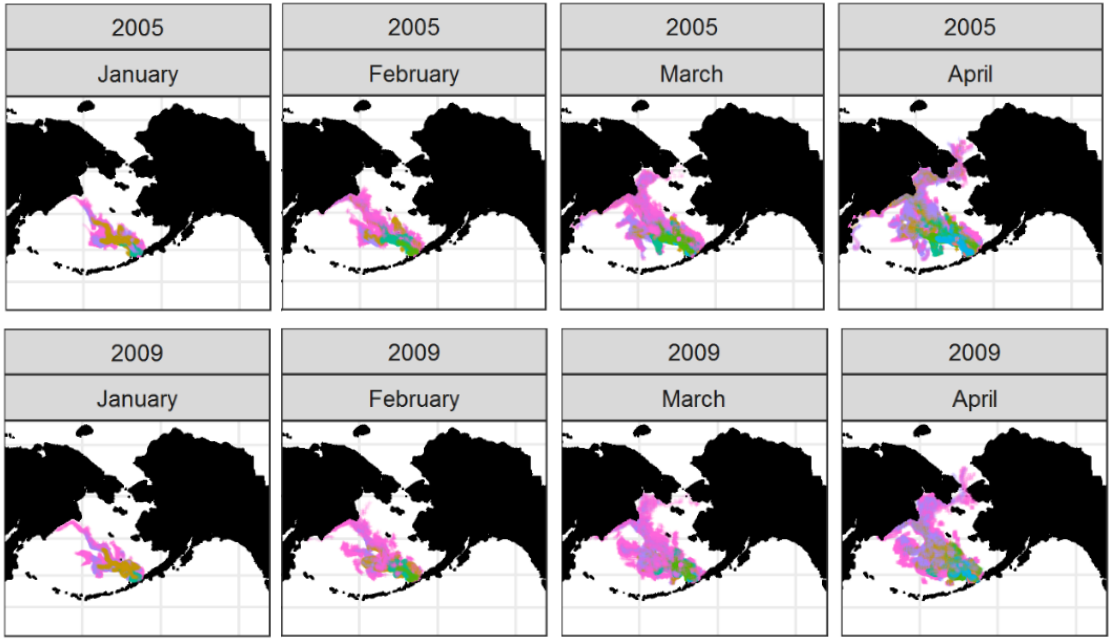


- NOAA Icthyoplankton surveys: 1972-2015
- Mean CPUE within 0.5 degree blocks

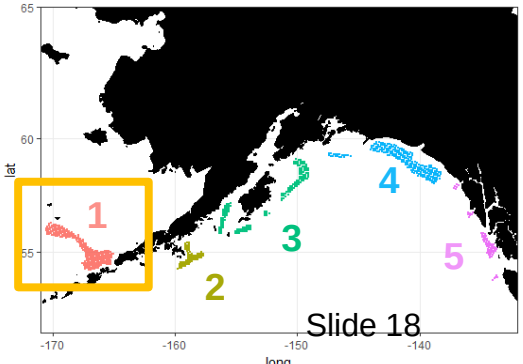
Spawn region 1

Spawn month

October
November
December
January
February
March
April



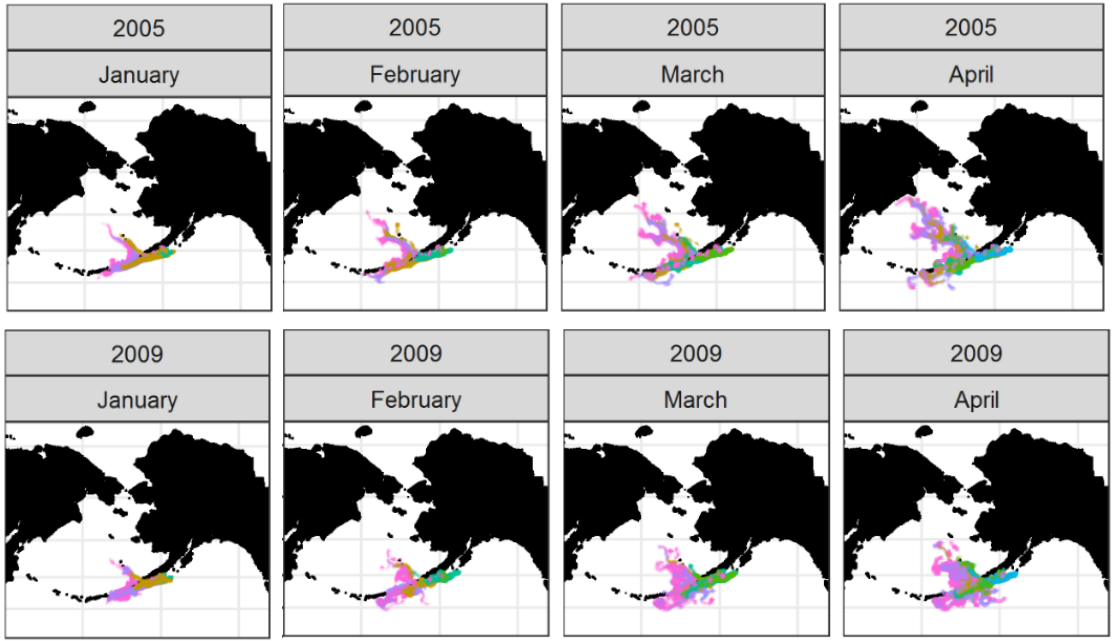
- 100% retained in the Bering Sea
- Strong connectivity between E and W Bering Sea
- Connectivity to Chukchi Sea



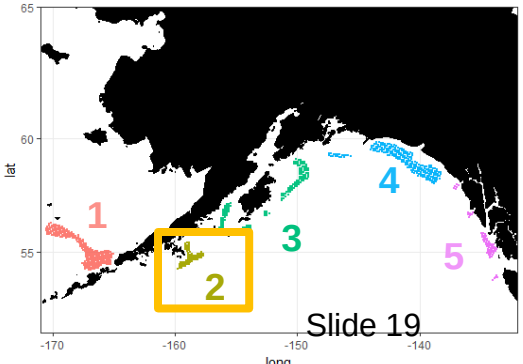
Spawn region 2

Spawn month

October
November
December
January
February
March
April



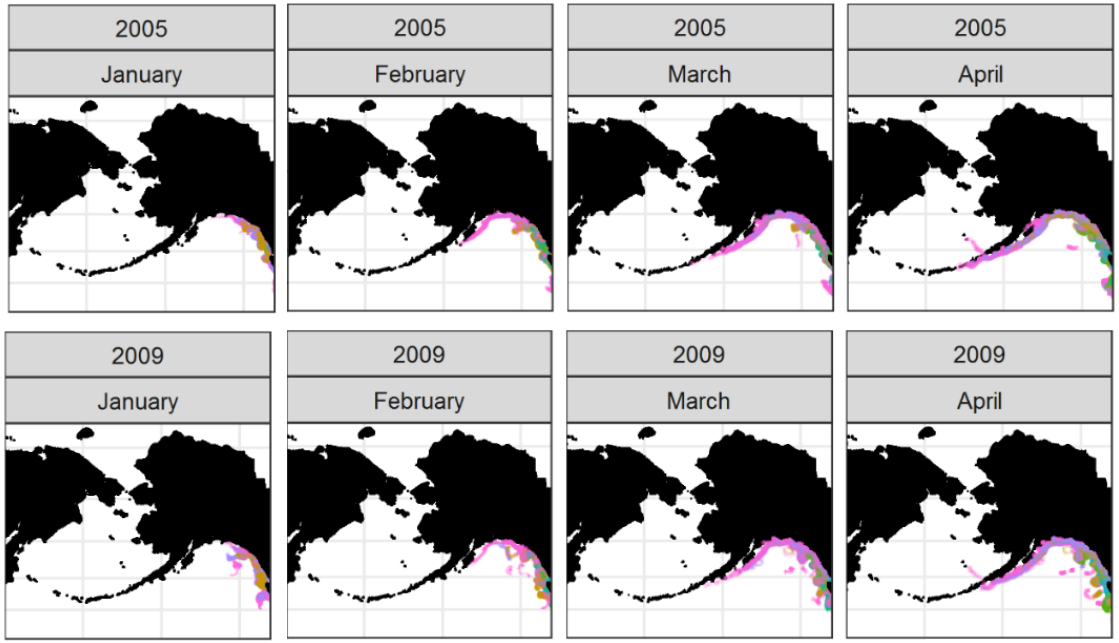
- 53-58% arrival in the BS
- Strong connectivity between basins



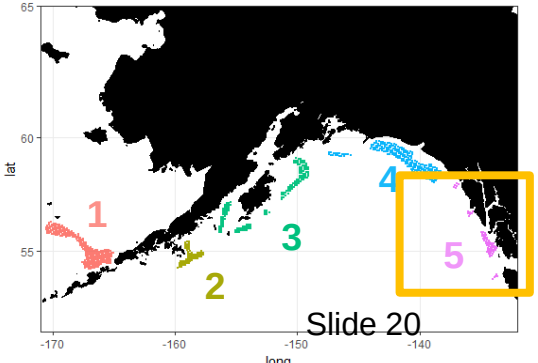
Spawn region 5

Spawn month

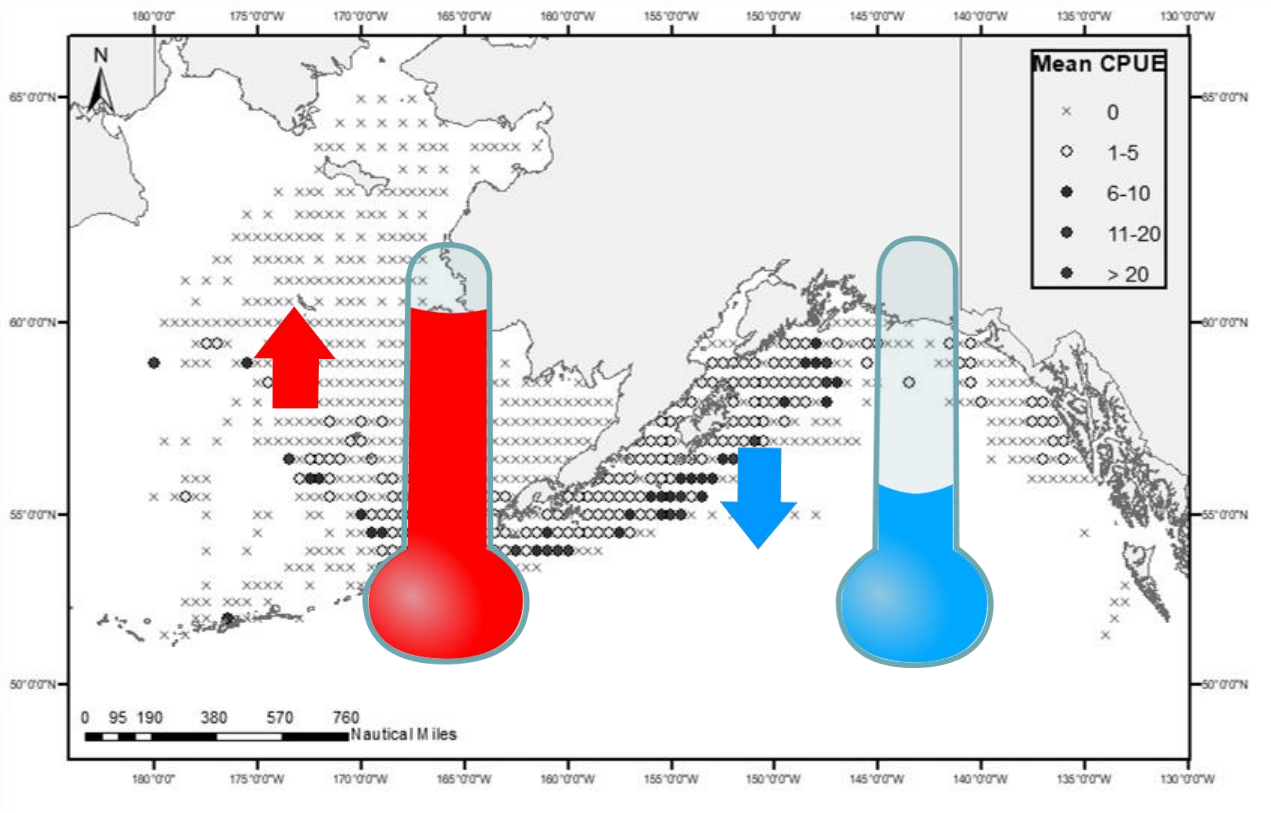
October
November
December
January
February
March
April



- <1% arrival in the BS from the GOA
- Strong connectivity between E GOA and W GOA



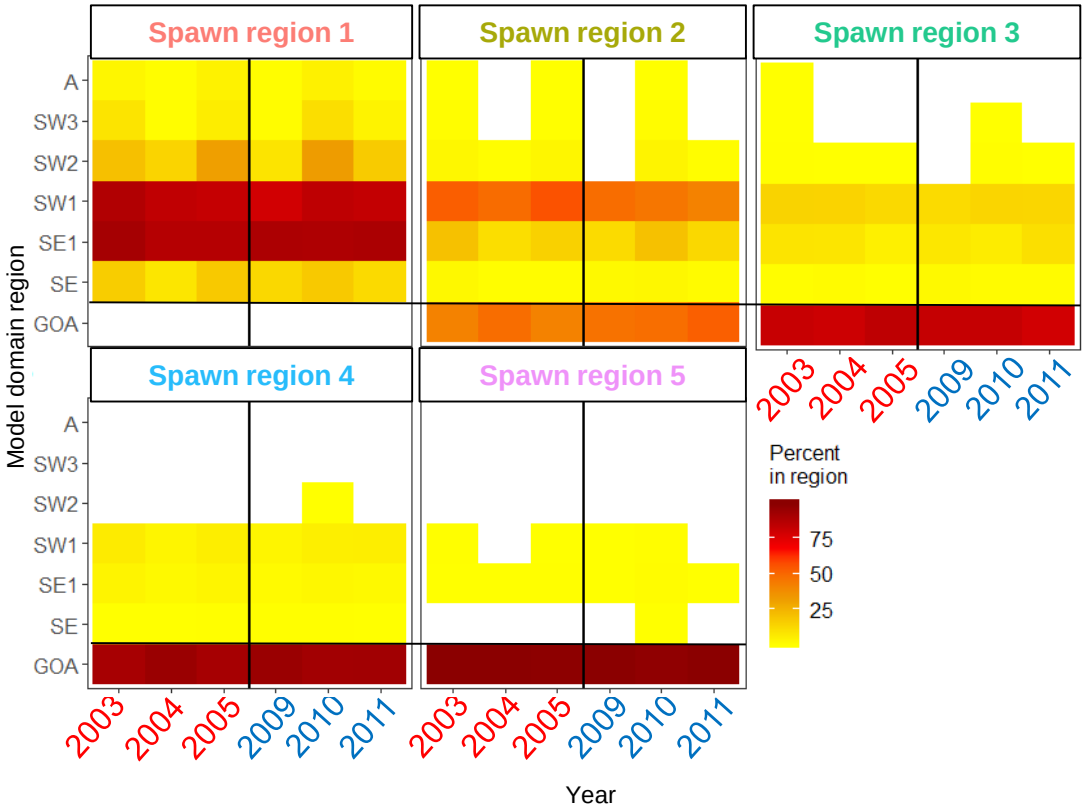
Environmental differences

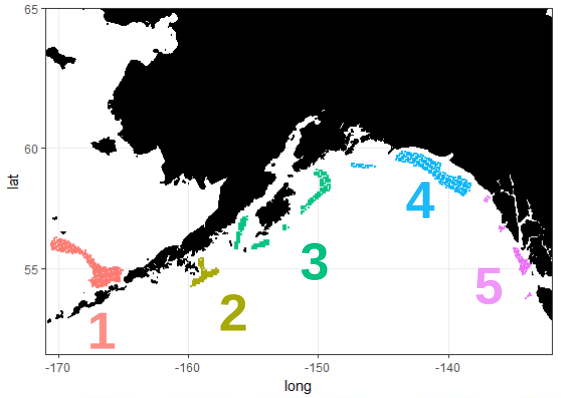


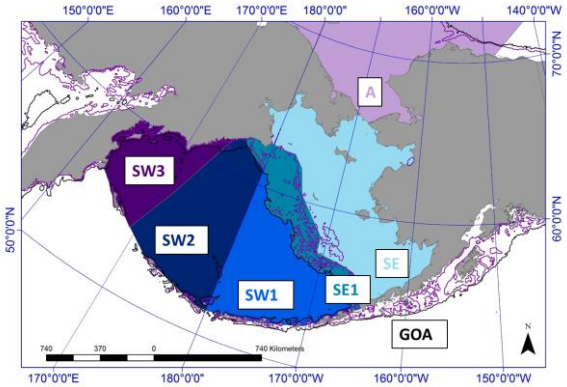
Warm vs Cold years

2003	2009
2004	2010
2005	2011

Potential advection pathways

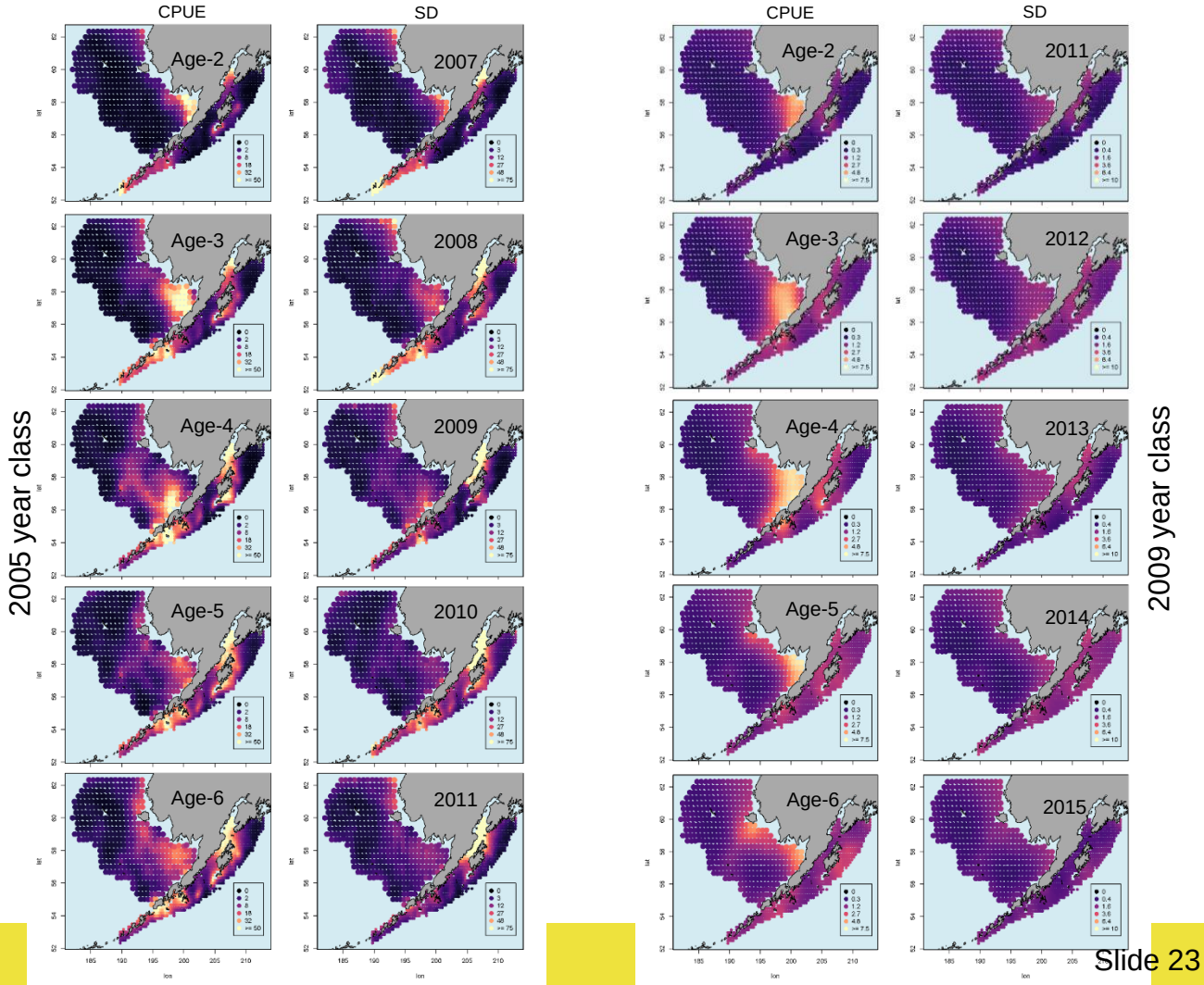






Model domain regions

Juvenile dispersal



Larval and early juvenile dispersal:
Overarching conclusions

There is a strong circular, life-history dependent connection for Pacific halibut between and within the Gulf of Alaska and Bering Sea

Migration and Distribution

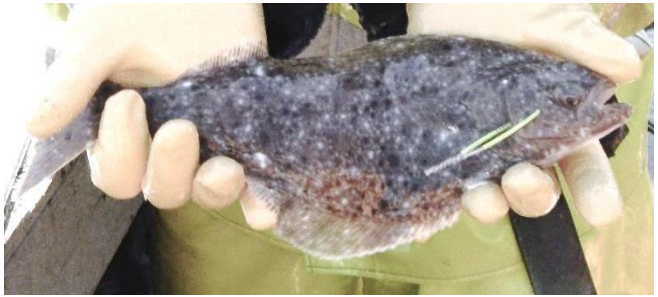
2. Late juvenile and adult dispersal: wire tagging of U32 fish

- **Most recent juvenile tagging studies were in the 1980s**
- **Goal of gaining more information on movement and growth of juvenile halibut**
- **NMFS trawl survey encounters mostly U32 halibut**

Migration and Distribution

2. Late juvenile and adult dispersal: wire tagging of U32 fish

- **Pilot tagging on NMFS trawl survey in BS and GOA in 2015**
- **Catch randomly split 50/50 into tagging and otolith sample**
- **2015 all viable fish in tag sample tagged**
- **2016-2019 only U32 fish tagged**
- **Smallest fish tagged = 16 cm**



Migration and Distribution

2. Late juvenile and adult dispersal: wire tagging of U32 fish

- **Expanded to U32 fish on IPHC setline survey (FISS) in 2016 (Area 4D only)**
- **Expanded to all areas of FISS in 2017**
- **Target of 500 tags released per IPHC Regulatory Area**
- **Tagging rate set by area, subsample of U32 fish not being sampled for otoliths**

Migration and Distribution

2. Late juvenile and adult dispersal: wire tagging of U32 fish

Wire tag types used since 2015

Tail pattern project tags →

Migration and Distribution

2. Late juvenile and adult dispersal: wire tagging of U32 fish

U32 Pacific halibut releases by year and area

	IPHC Regulatory Area								NMFS Region			
Year	**2A** *	**2B**	**2C**	**3A**	**3B**	**4A**	**4B**	**4D**	**BS**	**GOA**	**AI**	**Total**
2015									432	1418		**1850**
2016								169	424		170	**763**
2017		290	407	341	332	312	244		756	714		**3396**
2018	34	346	228	496	320	357			768		148	**2697**
2019				54					885	821		**1760**
Total	**34**	**636**	**635**	**891**	**652**	**669**	**244**	**169**	**3265**	**2953**	**318**	**10466**

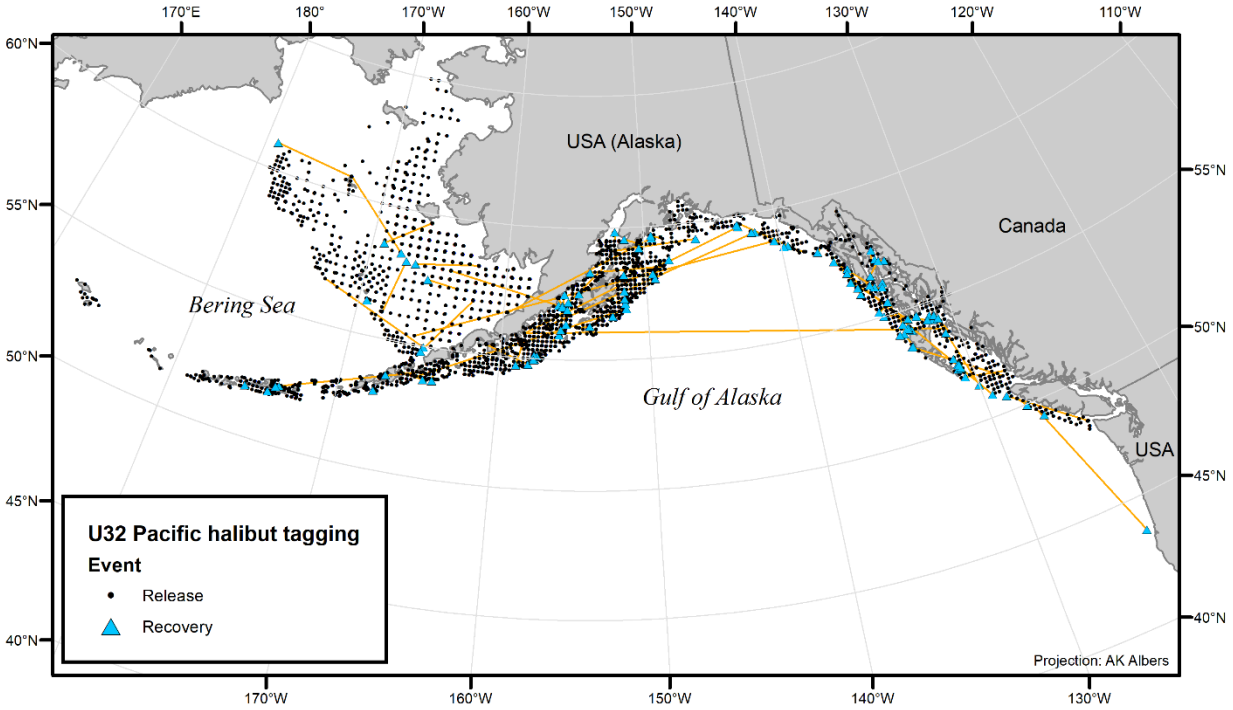
*2A U32s released on Makah Cibud/circle hook study
FISS tagging scaled back in 2019 as weights at sea introduced

Migration and Distribution

2. Late juvenile and adult dispersal: wire tagging of U32 fish

Since 2015:

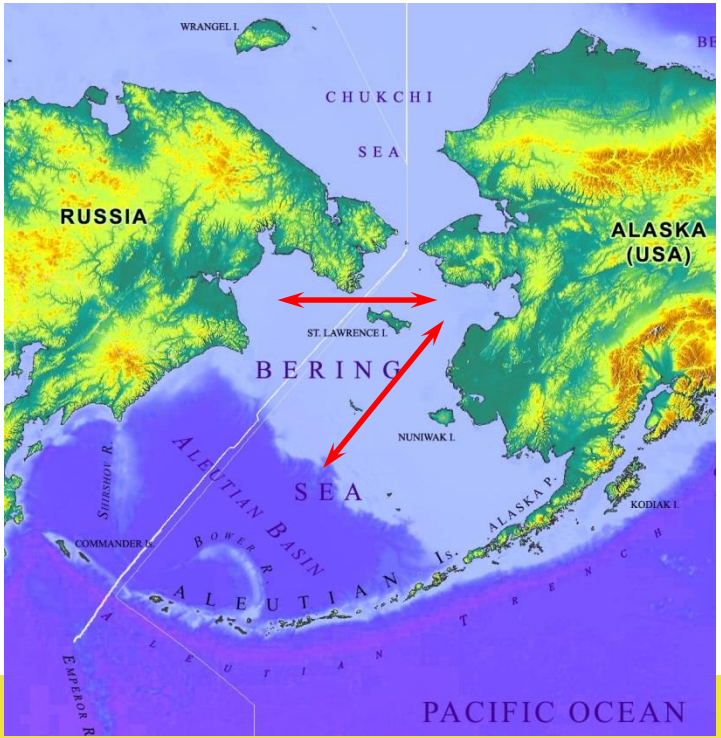
- **10,466 U32 fish wire tagged**
- **134 recoveries**
- **Continue in 2020**



Northern Bering Sea (NBS) migration

- Investigation of connectivity between outer and inner shelf; and between the Eastern and Western Bering Sea

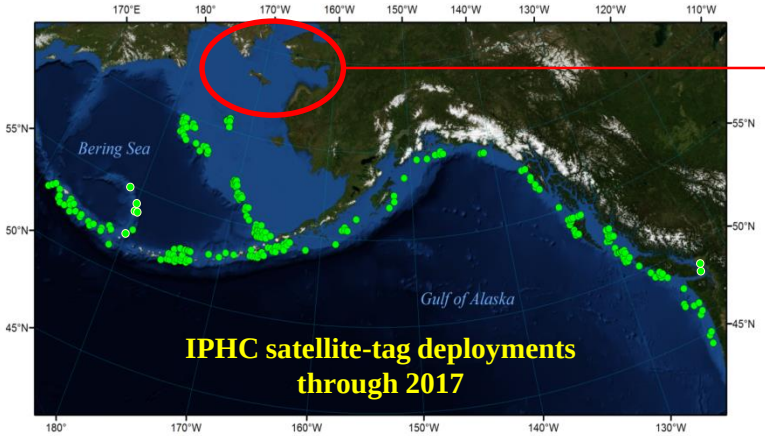
  - Coordinated and funded through the Norton Sound Economic Development Corporation (NSEDC)
  - Graduate student support via a UAF Rasmuson (RFRC) Fellowship: Mr. Austin Flanigan (MSc)
  - Initiated in 2019 and projected to continue through at least 2021

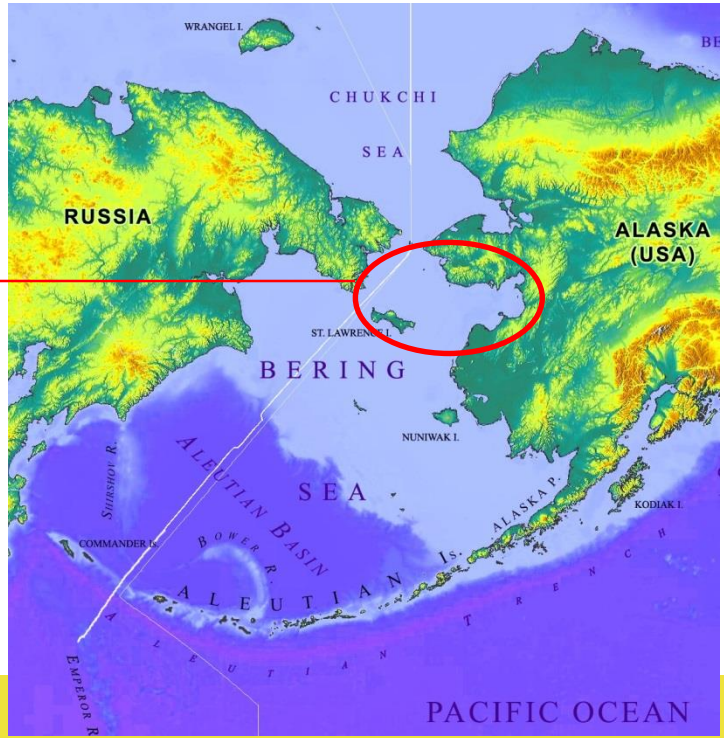


Northern Bering Sea (NBS) migration

- Inspired by increasing prevalence of cod and Pacific halibut in Norton Sound and around St. Lawrence Island

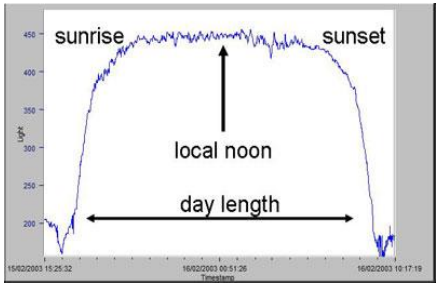
- Links to IPHC's history of Bering Sea tagging, in which the Northern Bering Sea has received little attention



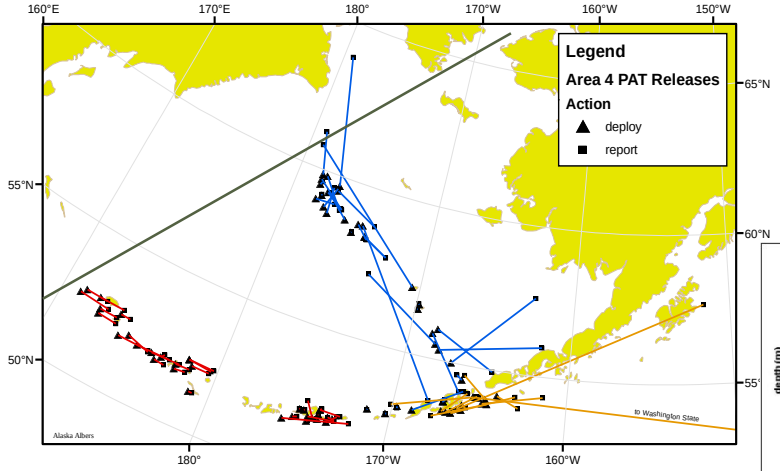


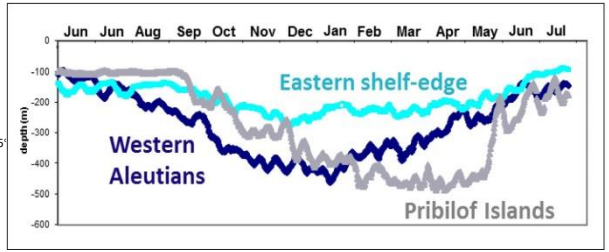
Northern Bering Sea (NBS) migration

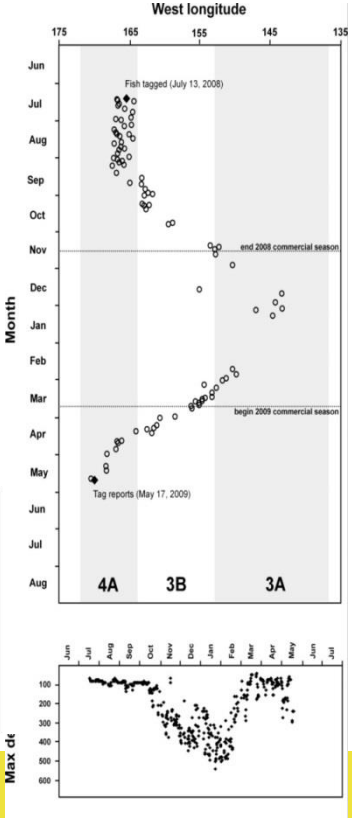
- Deployment of Pop-up Archival Transmitting (PAT) tags



Graphic: Tag-a-Giant Foundation







Northern Bering Sea (NBS) migration

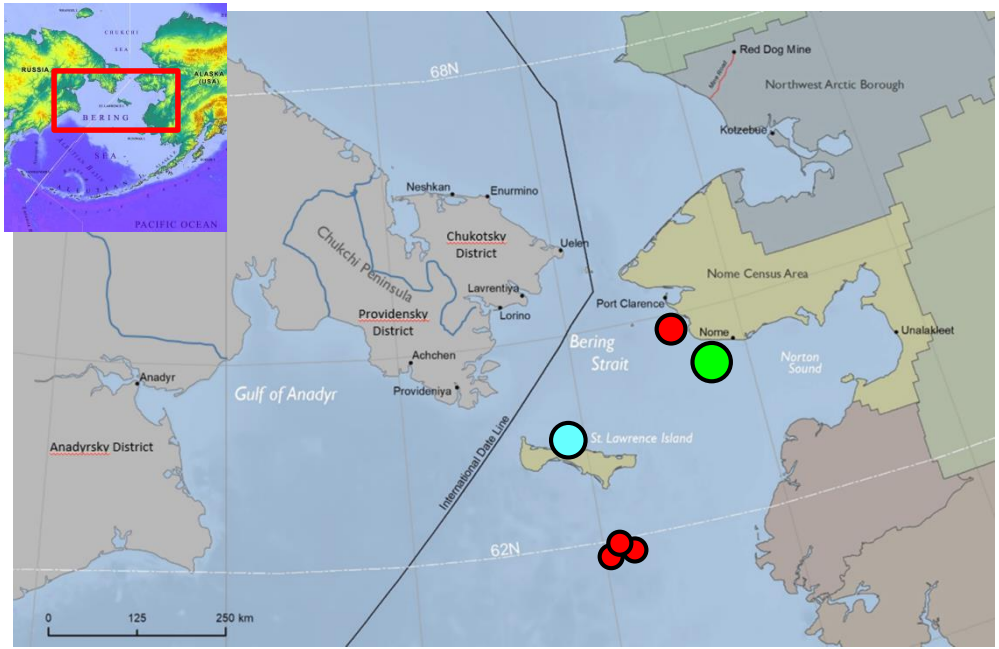
- Deployment of Pop-up Archival Transmitting (PAT) tags

  - 44 tags deployed in 2019 in three groups:

Shelf (n=5) *(NMFS trawl)*

Norton Sound (n=24) *(Nome)*

St. Lawrence (n=15) *(Savoonga)*



Map image from: *Knapp and Kryukov (2020) Economies of the Bering Strait Region (Springer Verlag)*

Northern Bering Sea (NBS) migration

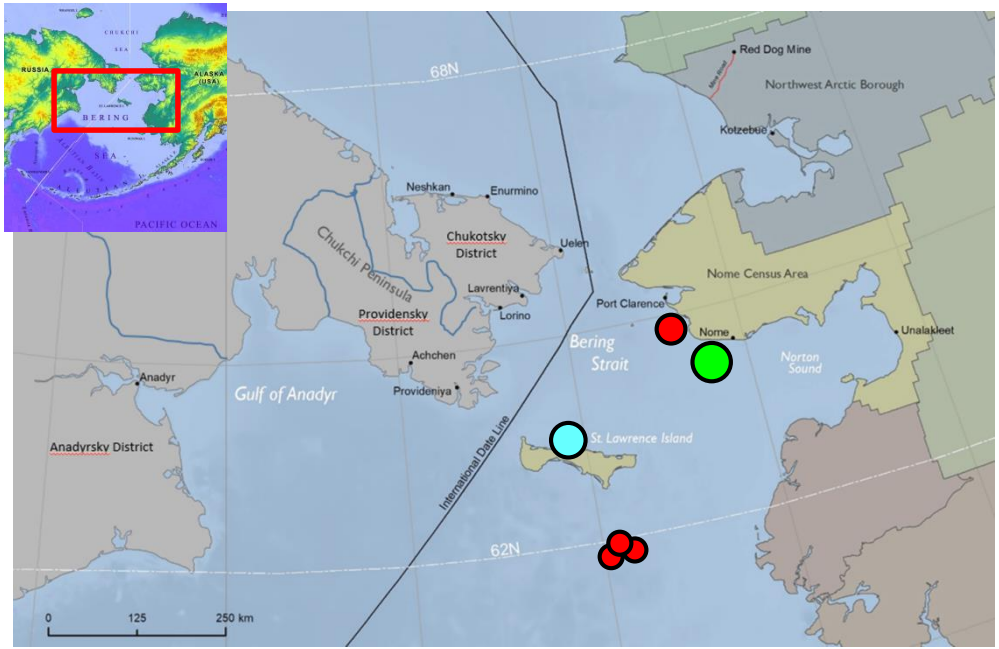
- Deployment of Pop-up Archival Transmitting (PAT) tags

  - 44 tags deployed in 2019
  - Programmed to report in three “waves”:

January 2020 (n=19)

Summer 2020 (n=15)

Summer 2021 (n=10)



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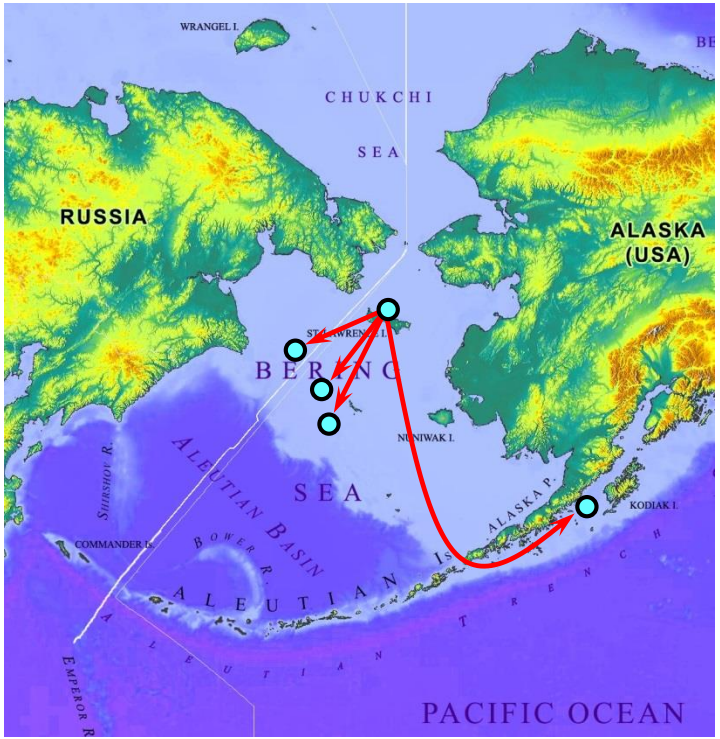
Northern Bering Sea (NBS) migration

- Tags began reporting in August
  - (14) after 30-62 days at liberty
  - (4) on January 15-16, as scheduled
  - Leaving (10) tags that are “missing”



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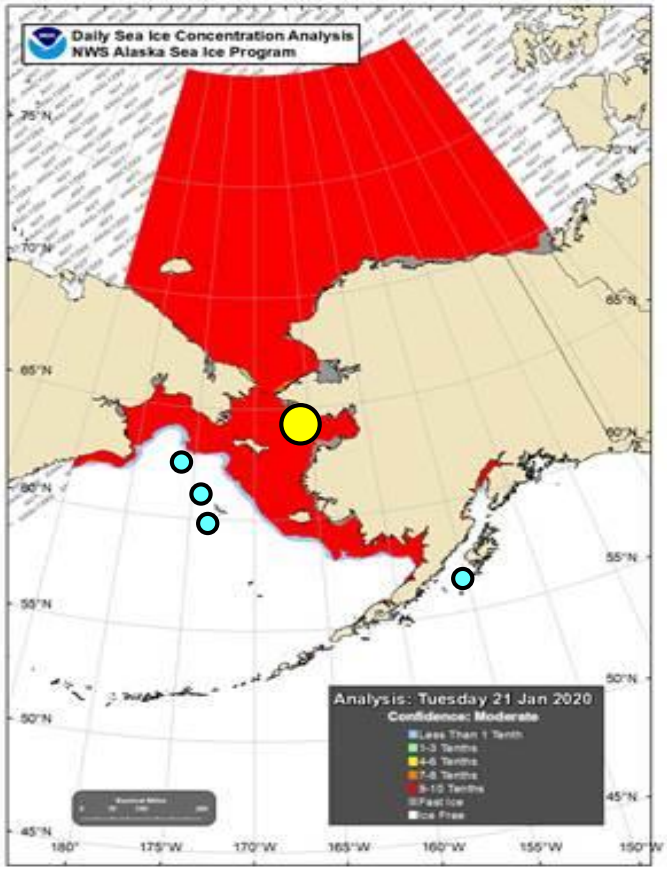
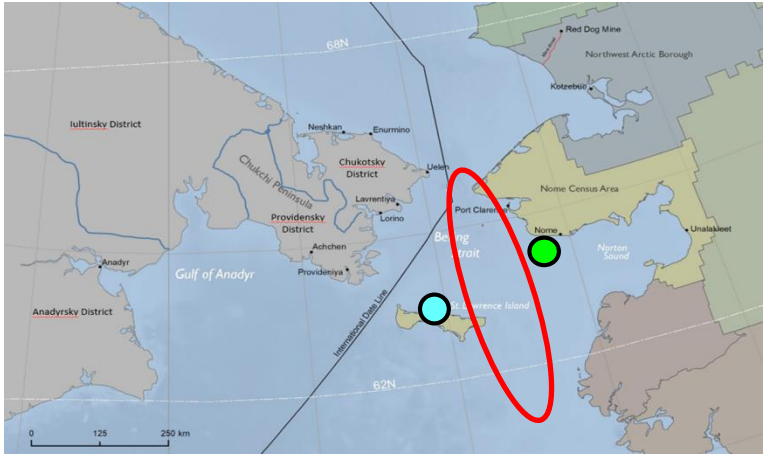


Northern Bering Sea (NBS) migration

- Deployments will continue in 2020
  - NSEDC buying all tags and covering all logistical costs
  - UAF Grad Student funded for two years
  - (62) tags: (12) “leftovers” from 2019; plus an additional (50) in production
  - Working with NMFS researchers to coordinate tagging of cod and halibut at the same location(s) simultaneously



Map image from: *Knapp and Kryukov (2020) Economies of the Bering Strait Region (Springer Verlag)*

Migration and Distribution

East-West North Pacific connectivity: developing international collaborations

W2: FIS Workshop
Integrating biological research, fisheries science and management of Pacific halibut and other widely distributed fish species across the North Pacific in the face of climate and environmental variability

Co-sponsors: IPHC

Duration:
1 day

Convenors:
Josep Planas, *corresponding*
(International Pacific Halibut Commission - IPHC)
Gordon Kruse
(University of Alaska Fairbanks, USA)
Chris Rooper (DFO, Canada)
Roman Novikov
(Kamchatka Research Institute of Fisheries and Oceanography, Russia)
Naoki Tojo
(Hokkaido University, Japan)

Invited Speakers:
Janet Duffy-Anderson (NOAA, USA)
Mark Lomeli (PSMFC, USA)
David Wilson (IPHC)

2. Reproduction

Projects:

1. Sex ratio of the commercial landings

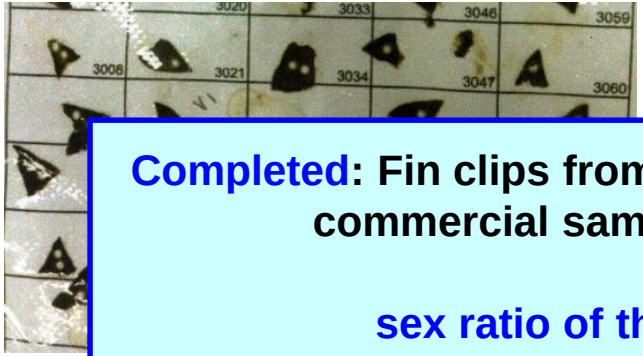
2. Full characterization of the annual reproductive cycle to improve current estimates of maturity

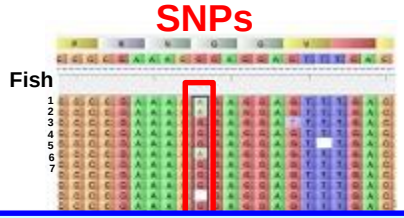
Reproduction

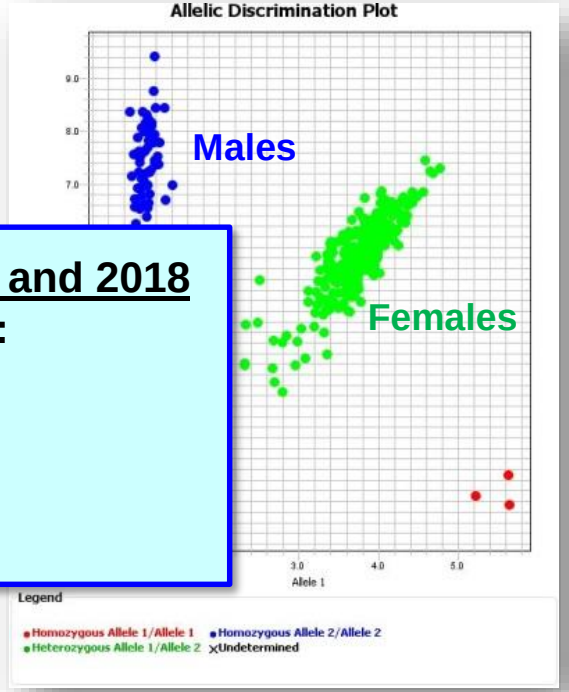
1. Identification of sex in the commercial landings

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 2017 and 2018 commercial samples (>10,000 fish/year) :

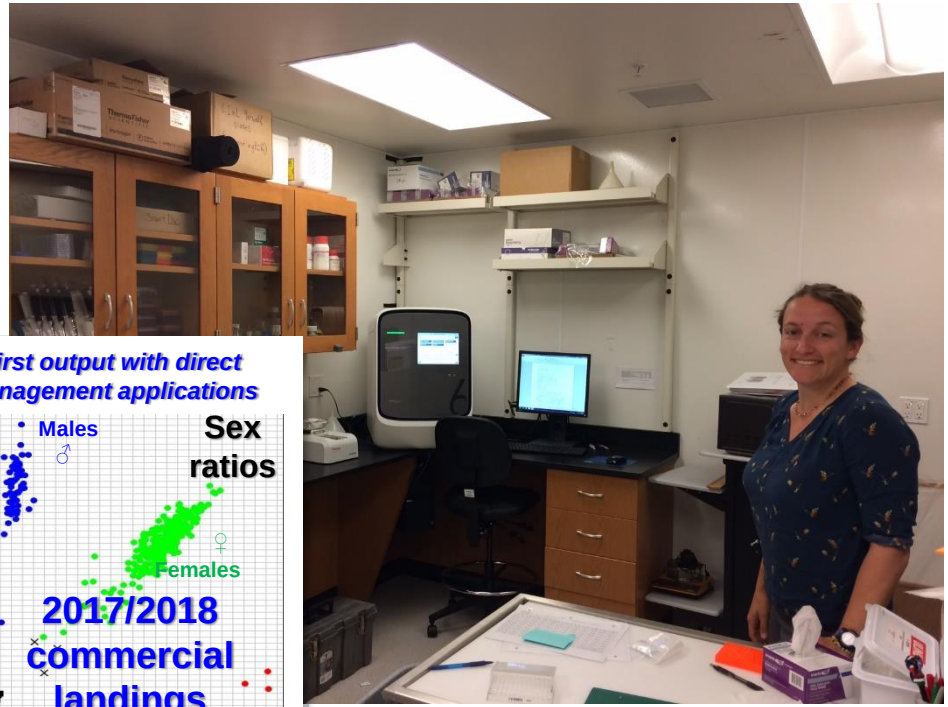
↓

sex ratio of the commercial fishery

↓

2019 FINAL STOCK ASSESSMENT

Biological laboratory at IPHC: established in 2018



- **Laboratory technician**: *Ms. Anna Simeon*
  - Full time; 04/2018 - 03/2020
  - Salary co-financed by NPRB

- **Current lab capabilities**:
  - Nucleic acid extraction and quantification
  - Genotyping

  → Sex ratios/ genetics/ migration
  - Gene expression → Growth/reproduction
  - Blood metabolite and hormone determinations
  - Staff and student training

  → Discard survival/ reproduction

- Alaska Pacific University MSc Student: Ms. Teresa Fish
- 2019 IPHC Intern: Ms. Kennedy Bolstad
- High school Senior Project: Mr. David King

Reproduction

2. Full characterization of the annual reproductive cycle

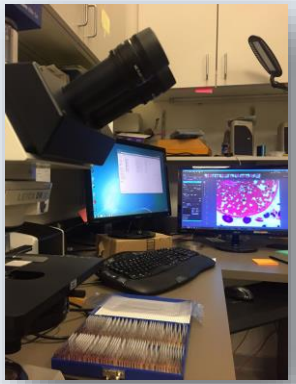
Objective: Revise maturity estimates for female Pacific halibut

Macroscopic maturity staging (*visual assessment*)

Maturity Stage
1 immature
2 maturing
3 ripe
4 resting

vs

Microscopic maturity staging (*histological assessment*)



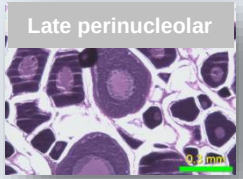
Ovarian histology

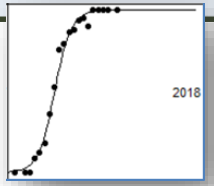
⬇

Oocyte stage classification

⬇

Maturity staging

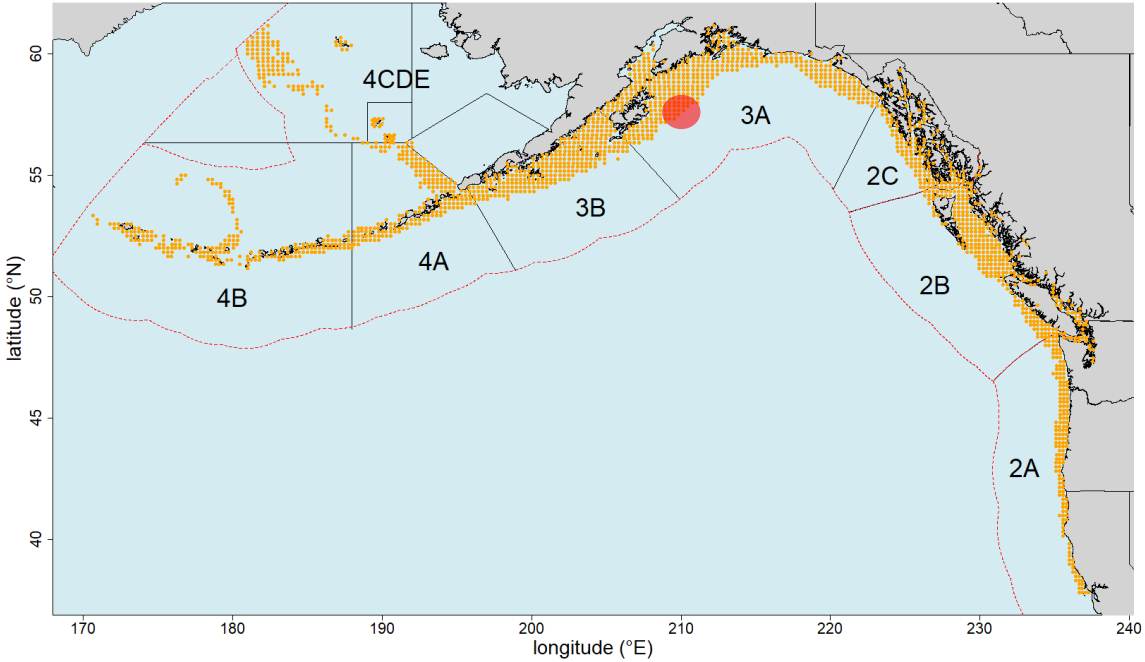




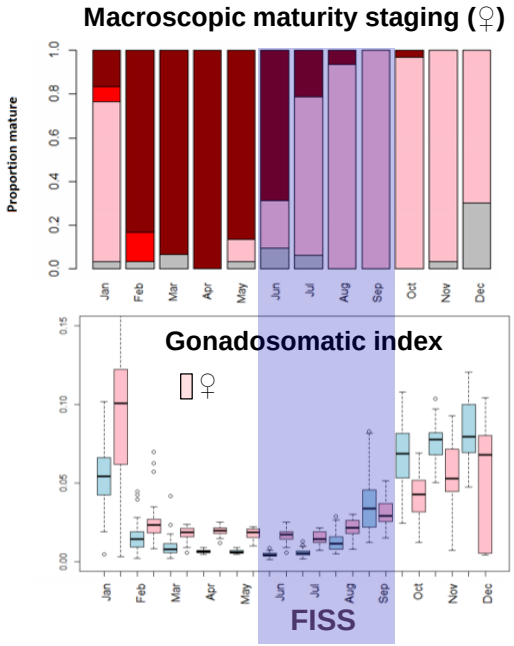
- Maturity ogives
- Maturity estimates

Reproduction

Female maturity information available from one region: Portlock



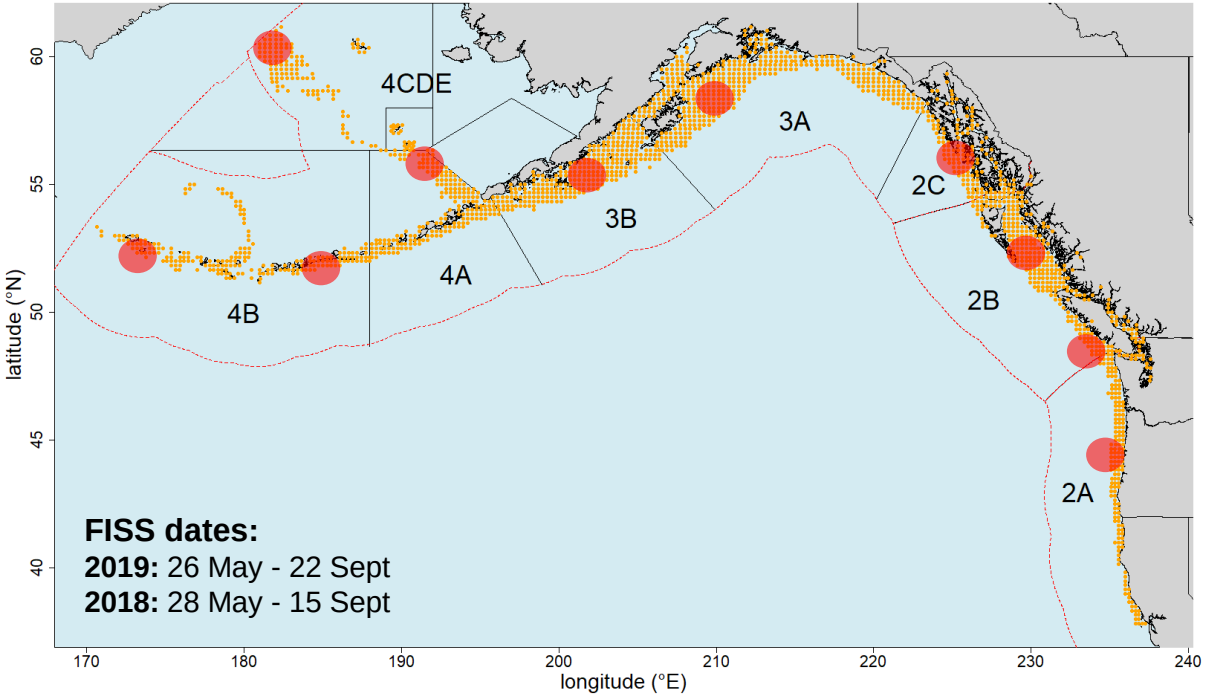
- **Full annual collection (2018)**

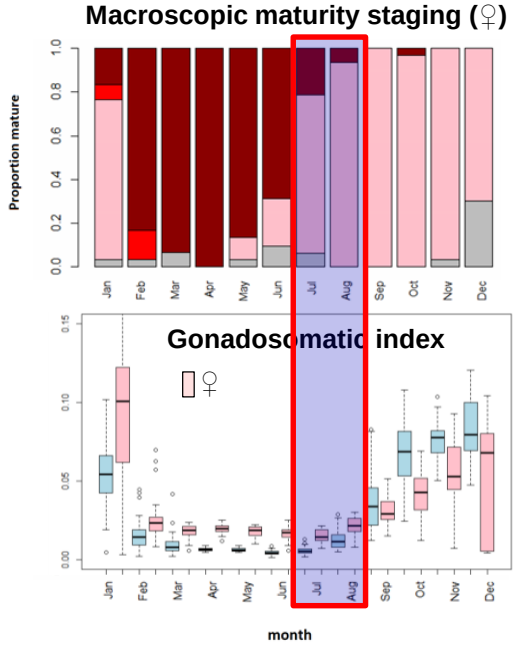


- **Interannual collection June 2017, 2018, 2019**

Reproduction

Proposed research: Spatial analysis of maturity



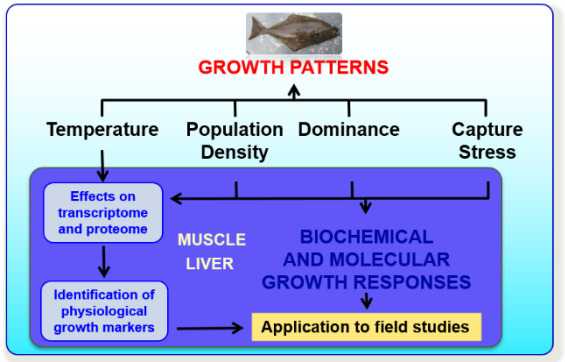


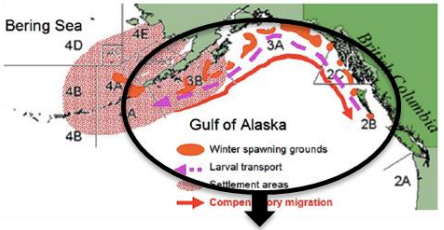
- **July-August collection in FISS**

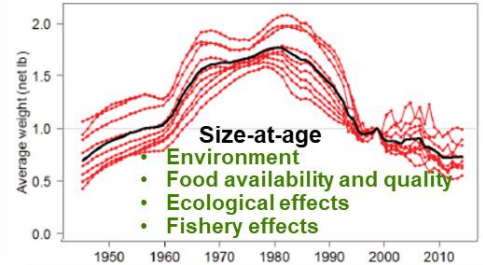
3. Growth

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***







• **Changes in growth?**

NPRB Grant 1704 (2017-2020)

Dr. Thomas Hurst

Growth

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

2. 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:

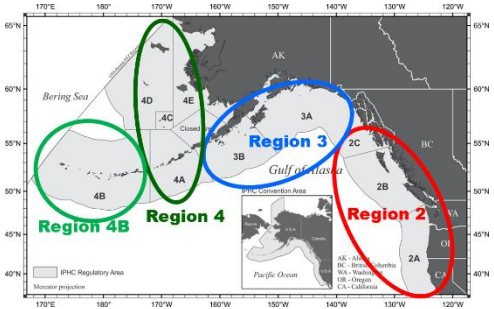
<40 cm FL

40-60 cm FL

60-80 cm FL

Characterization of physiological growth markers in muscle samples from age-matched individuals

3. Regional monitorization of growth patterns



4. Discard mortality rates and survival assessment

Projects:

Provide direct estimations of DMRs in:

1. Directed longline fishery

2. Guided recreational fishery

Saltonstall – Kennedy Grant NA17NMF4270240

NOAA FISHERIES

ALASKA PACIFIC UNIVERSITY

Physiological predictors of survival

NFWF **National Fish and Wildlife Foundation**

UAF UNIVERSITY OF ALASKA FAIRBANKS

ALASKA PACIFIC UNIVERSITY

ACA Alaska Charter Association

DMRs and survival assessment

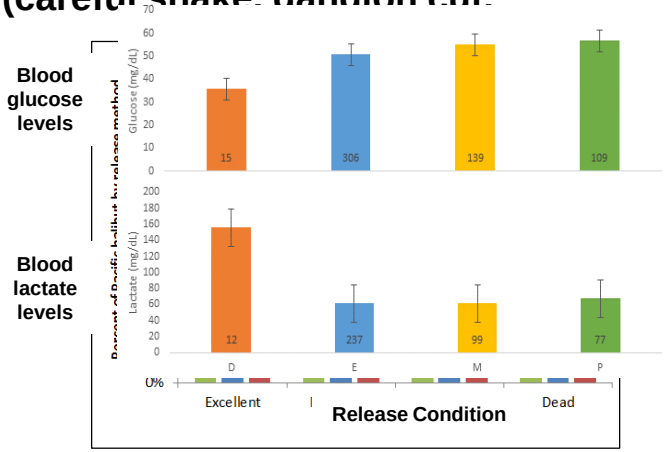
1. *Directed longline fishery:*

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**

a) Condition factor indices



– ***Capture conditions***

- Time

- Water temperature loggers

- Fish temperature

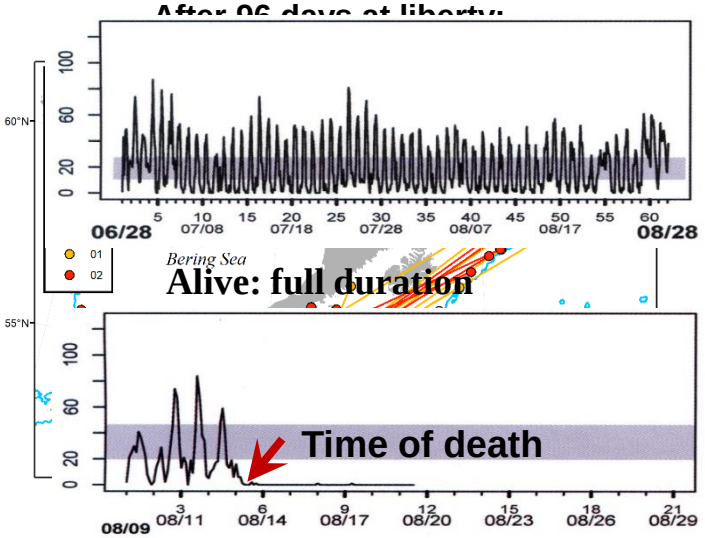
Stress indicators:
- ✓ Glucose
- ✓ Lactate
- ✓ Cortisol

DMRs and Survival Assessment

B. Relationship between physiological condition post-capture and survival post-release as assessed by tagging

- **Accelerometer tags (n=79): only fish in excellent condition**
- **Wire tags (n=1,048): including all handling practices and release conditions**

Results: 4% mortality



DMRs and Survival Assessment

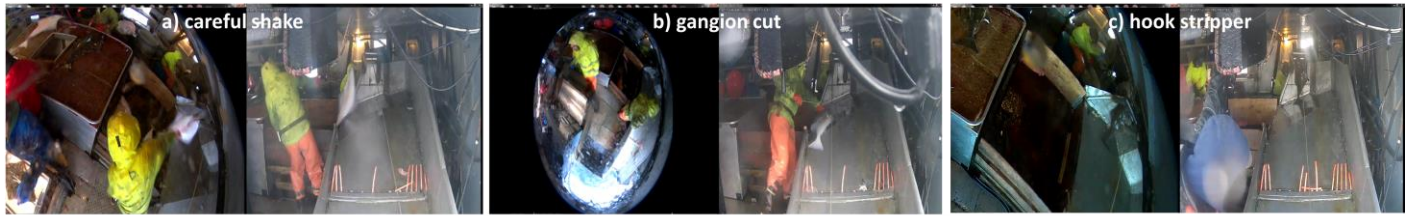
C. Applicability of electronic monitoring (EM) in DMR estimation

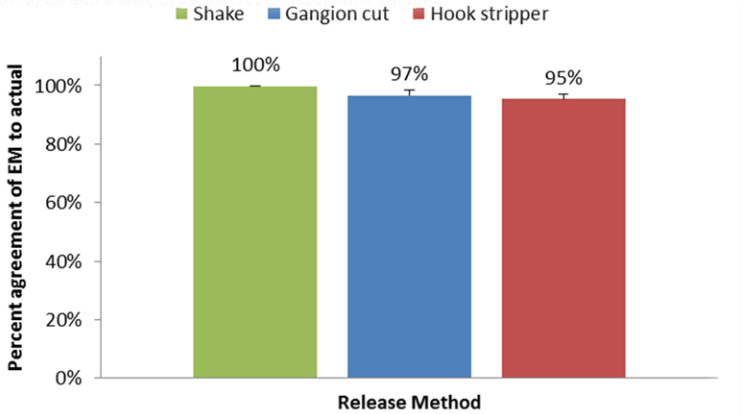
- **Deployed EM system on a longline vessel**
- **Video recorded fish handling events during capture**
- **This will allow us to determine injury profile by release method**

DMRs and Survival Assessment

C. Applicability of EM in DMR estimation

– **Results: Comparison of EM-determined release method to the actual**





DMRs and survival assessment

2. *Guided recreational fishery: Estimation of DMRs*

– **Project initiated in 2019**

Objectives:

2019

1. **Collect information on gear types and sizes and handling practices: Completed**

2020

2. **Investigate the relationship between gear types and handling practices and size composition on captured/released fish**
3. **Injury profiles and physiological stress levels of captured/released fish**
4. **Assessment of mortality of discarded fish**

Sport charter

Captured Pacific halibut

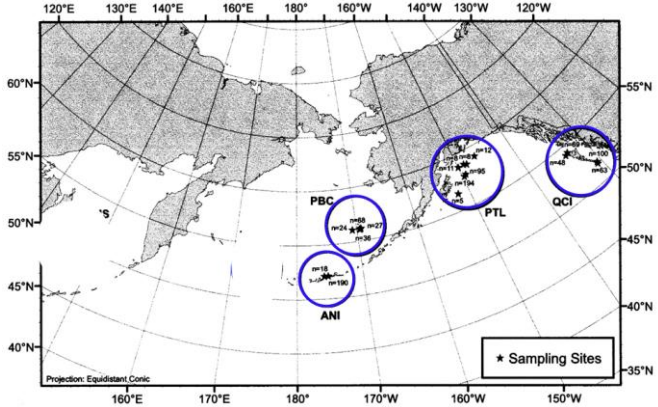
Hook injury assessment

Tagging with sPATs

5. Genetics and Genomics

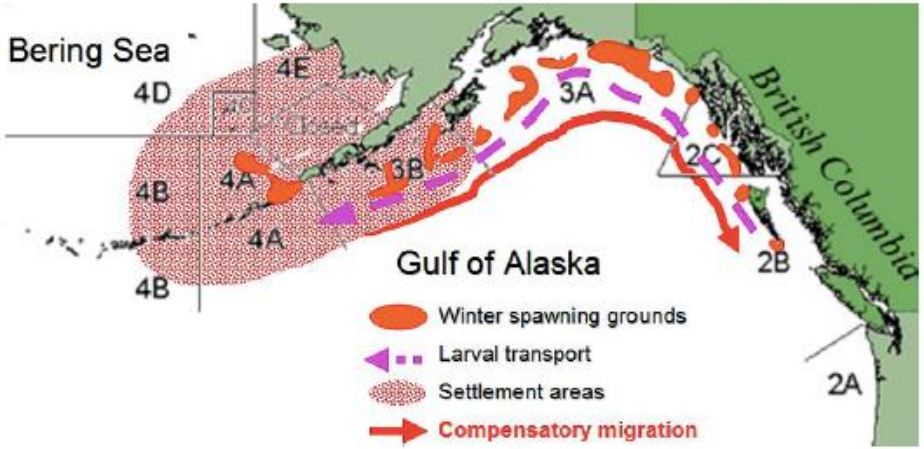
Projects:

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

Incorporate Genetics Into Migration-related Research



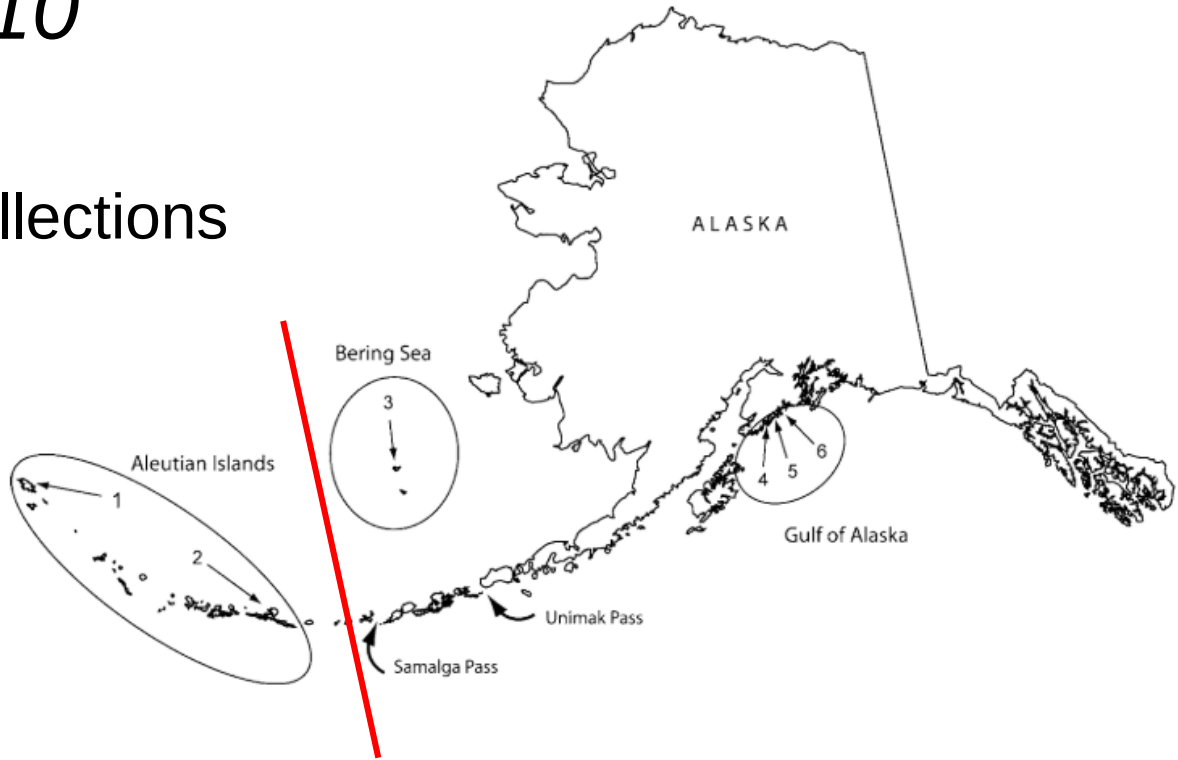
A. Identification of potential genetic signatures of origin or spawning groups to revise population structure
B. Analysis of genetic population structure in IPHC Regulatory Area 4B
C. Analysis of genetic variability among juvenile Pacific halibut in the Bering Sea and the Gulf of Alaska

Previous Genetic Studies

Nielsen et al. 2010

- 9 microsatellite loci
- Summer sample collections

	Aleutian Islands	Bering Sea
Bering Sea	**0.0082***	
Gulf of Alaska	**0.0069***	-0.0016



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.

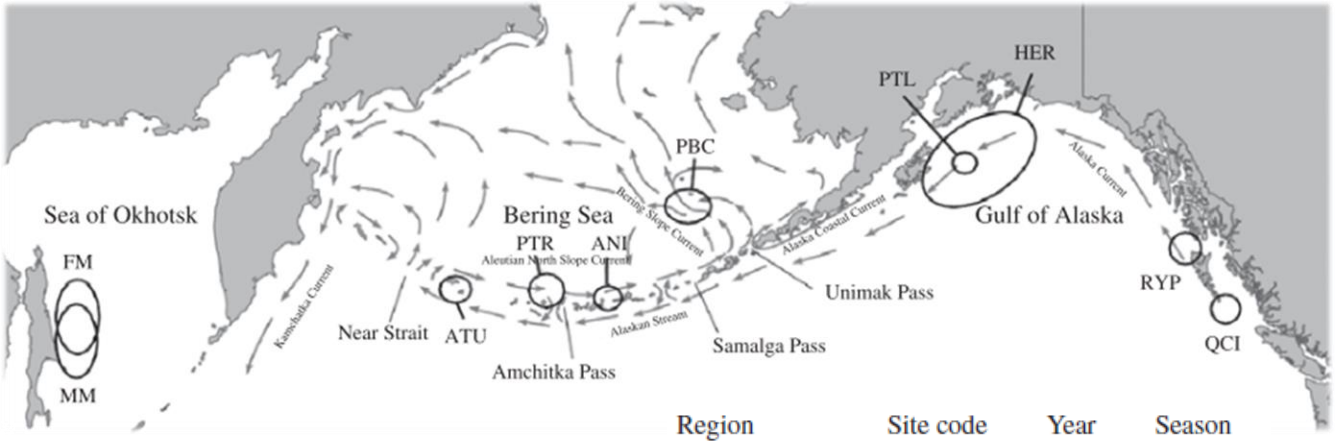
Previous Genetic Studies

Drinan et al. 2016

2 Datasets

Dataset 1
9 microsatellite loci
828 samples

Dataset 2
46 microsatellite loci
435 samples



Region	Site code	Year	Season
Haida Gwaii	RYP	1998–99	Winter
	QCI	2004	Winter
Gulf of Alaska	HER	1998–99	Winter
	PTL	2004	Winter
Aleutian Islands	PTR	2003	Summer
	ANI	2007	Winter
	ATU	2003	Summer
Bering Sea	PBC	2004	Winter
Sea of Okhotsk	FM	1995	Summer
	MM	1995	Summer

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.

Previous Genetic Studies

Drinan et al. 2016

- No Structure in Neutral Dataset
- Evidence of structure in 4B
  - Attu and Petrel vs. rest of stock.

Region	Site code	Year	Season
Haida Gwaii	RYP	1998–99	Winter
	QCI	2004	Winter
Gulf of Alaska	HER	1998–99	Winter
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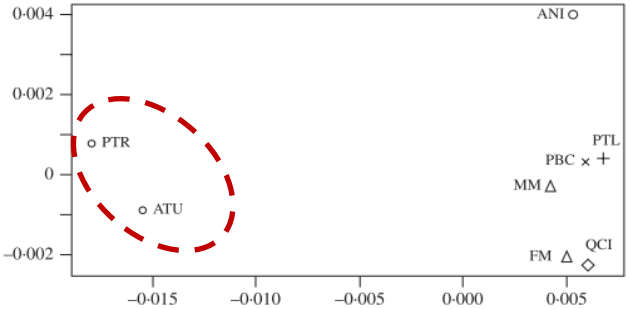
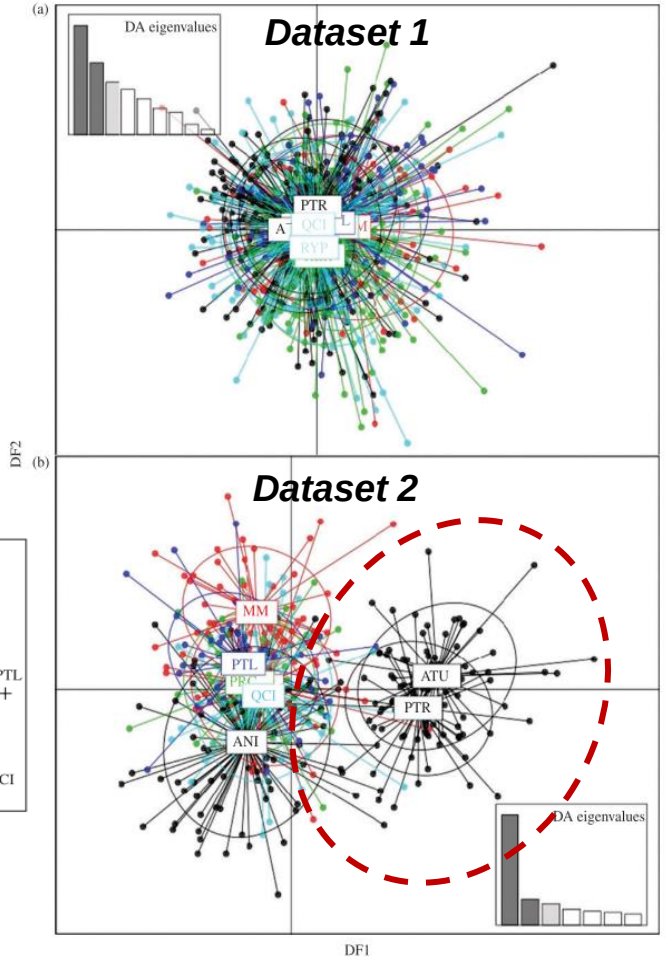




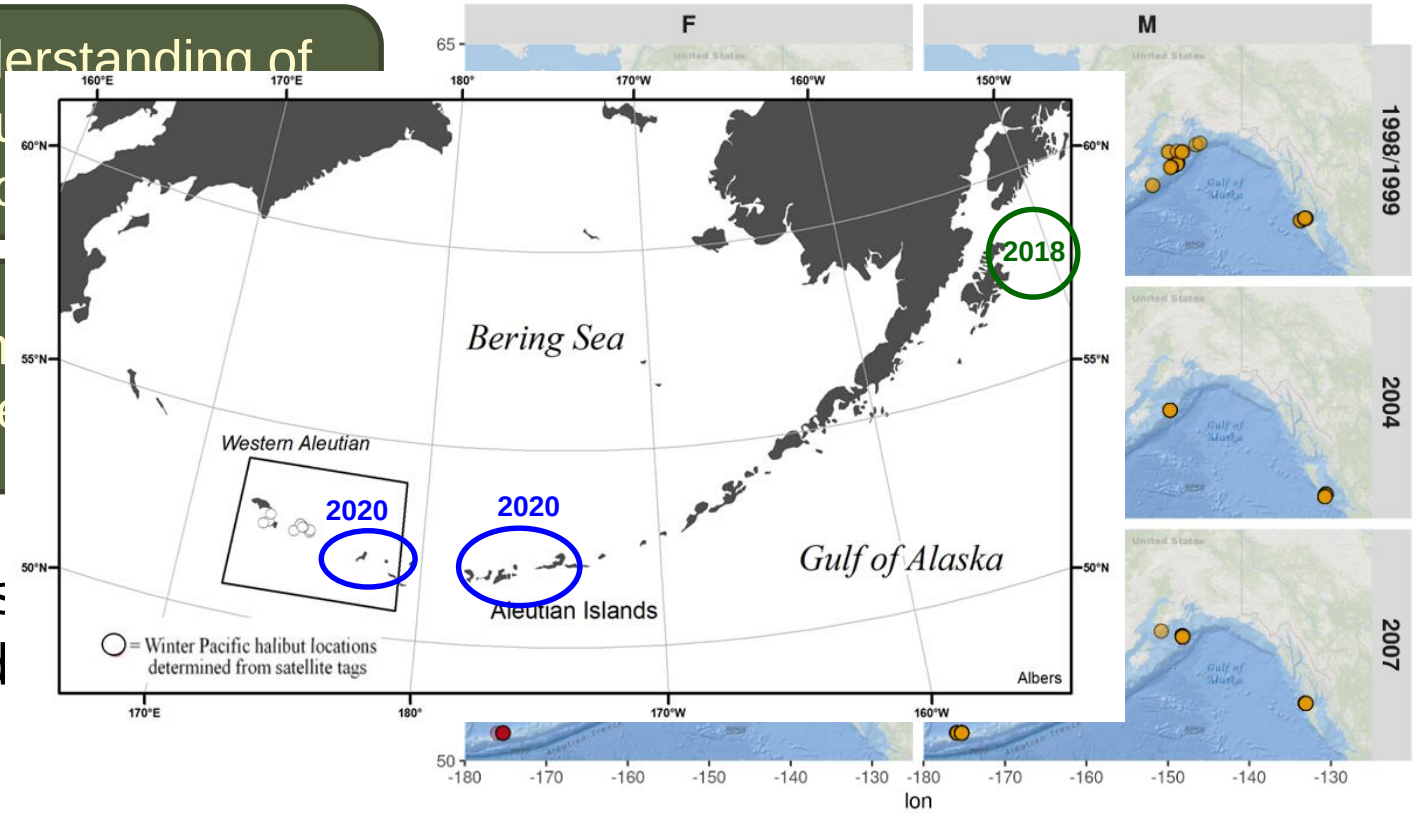
Drinan, D. P., H. M. Galindo, T. Loher, and L. Hauser. 2016. Subtle genetic population structure in Pacific halibut *Hippoglossus stenolepis*. Journal of Fish Biology 89(6):2571–2594.

Genetic Structure of Pacific Halibut

A. Revise understanding of population stru signatures of

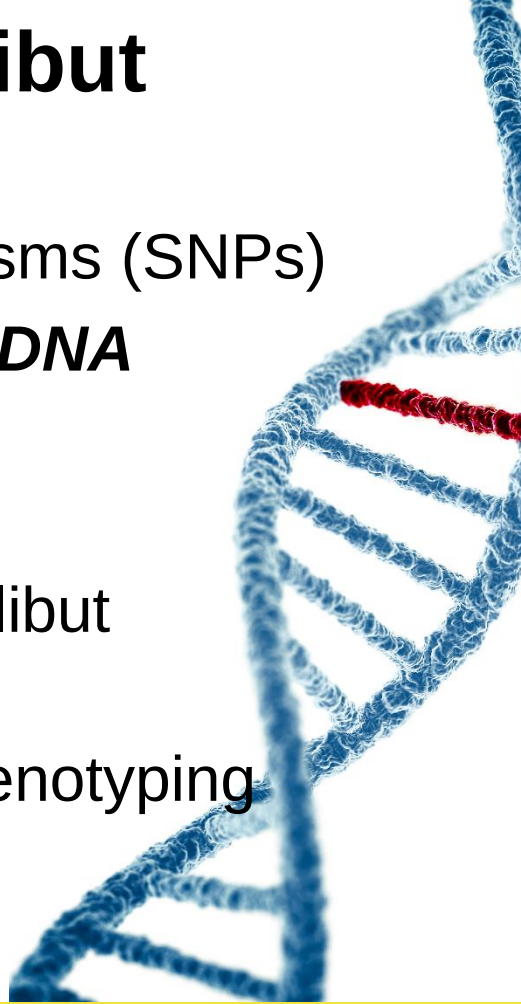
B. Structure in Regulatory Are

Utilize s collected



Genetic Structure of Pacific Halibut

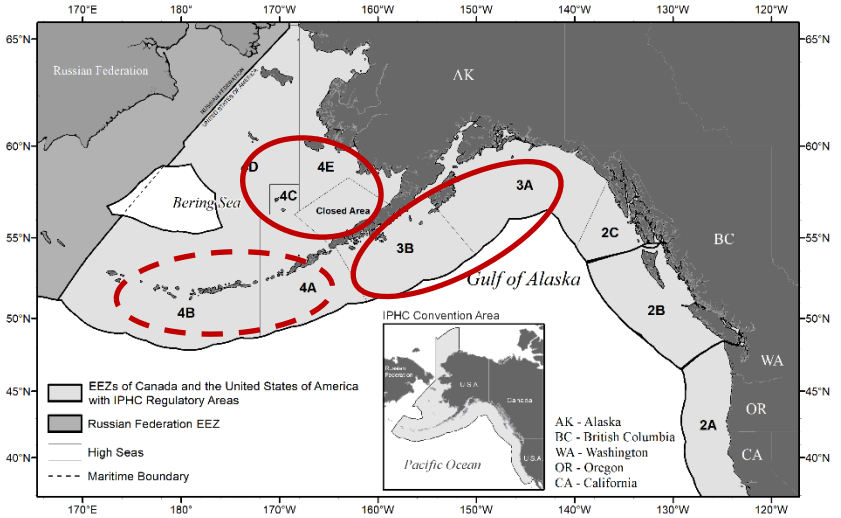
- Whole genome resequencing
  - ~millions of **S**ingle **N**ucleotide **P**olymorphisms (SNPs)
    - ***SNP = single base-pair difference in DNA sequence***
  - ~50 individuals per collection (~600 total)
  - First use of recently sequenced Pacific halibut genome (24 chromosomes)
  - Develop SNP panel for high-throughput genotyping



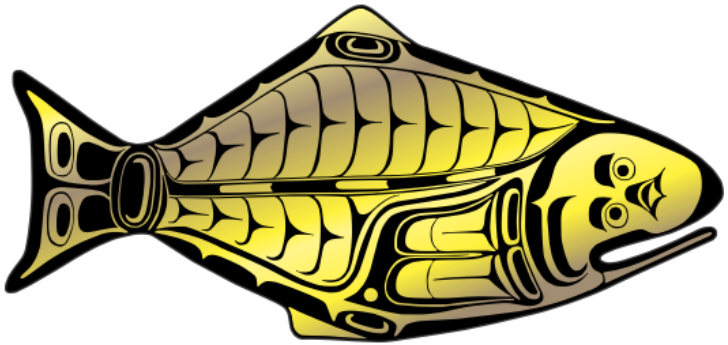
Genetic Variability of Juvenile Pacific Halibut

- Fin clips collected during NMFS trawl surveys
  - Gulf of Alaska (2015, 2017, 2020)
  - Bering Sea (2015-2019)
  - *Aleutian Islands (2016, 2018, 2020)*

Potential application of high-throughput SNP panel



INTERNATIONAL PACIFIC



HALIBUT COMMISSION