INTERNATIONAL PACIFIC

HALIBUT COMMISSION

Migration and population genetics research at IPHC

(T. Loher, L. Sadorus, J. Planas)

Agenda item 8.3
IPHC-2019-SRB014-09

SRB request

IPHC–2018–SRB013–R

36. The SRB **NOTED** that the IPHC Secretariat is following up on the SRB suggestion to hire a life history modeller and that this action is subject to broader IPHC budgetary considerations.

7.1 Biological research updates

37. The SRB **NOTED** paper IPHC-2018-SRB013-07 which provided an update on the progress of the Biological and Ecosystem Science research program.

38. The SRB **AGREED** that the primary biological research activities at the IPHC should continue to follow Commission objectives, and are identified and described in the 5-Year Research Plan for the period 2017-21, including focusing on studies of migration, reproduction, growth, discard mortality and genetics.

39. The SRB **NOTED** that the biological research activities should help to define hypotheses associated with processes that affect plausible states of nature for the assessment and MSE process (e.g. climate effects on growth and recruitment).

40. The SRB **NOTED** that the IPHC Secretariat has been responsive in focusing research outcomes to management objectives required for stock assessment and MSE work, and that this work is leading to peer-reviewed journal publications.

41. The SRB **REQUESTED** that specific research topics, analysis and results be addressed in depth at subsequent SRB meetings, and that at SRB014, a presentation focused on population genetics and migration as they relate to the stock assessment and MSE work be provided. For example, how does this work identify alternative hypotheses for movement and population structure that can be considered in the MSE process and the stock assessment.

Outline

1) **Structure and Frameworks for recent connectivity research**
2) **Summary of major Findings from that work**
3) **A Model for project selection**
   - Identification of products and deliverables
   - Quantification of research plans
4) **Some Topics of current interest**
5) **Incorporation of genetics into migration-related research**

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Research Program Structure

***Circa* 2002, we developed an integrated research program that was structured around Scale-dependent Processes and their relationship to Management Structure**

… that can be nested into three Temporal Scales relative to life history:

A) Large-scale = multigenerational / population-level

- Long-term; cumulative ontogenic

B) Meso-scale = intragenerational / cohort-level

- Ontogenic

C) Fine-scale = intrannual / individual-based

- Diurnal, sub-diurnal, seasonal

Research Program Structure

***Circa* 2002, we developed an integrated research program that was structured around Scale-dependent Processes and their relationship to Management Structure**

… and developed under two Overarching Frameworks:

1) **Applied Fisheries Science**
   - That is, seeking to produce results that will lead to *specific* **management actions**

2) **Theoretical Ecology**
   - Producing parameters leading to the **better understanding** of population function in general terms

Framework #1: Applied Science

Scale-dependent Processes and Management Actions

A) Large-scale: intergenerational / population-level

- How is the stock structurally organized, from a population-level perspective?
- Vaguely: Does this match our underlying management design?
- Specifically: Would we need additional Regulatory Areas to accurately encompass all functional population components?

For example, if Area 4B is composed of two genetically-distinct subpopulations, should we create a new Reg Area west of Amchitka?

Framework #1: Applied Science

Scale-dependent Processes and Management Actions

B) Meso-scale: intragenerational / cohort-level

- Spatial recruitment patterns: where do “our” fish come from?
- Vaguely: To what degree does fishing mortality in one Area affect other(s)?
- Specifically: Exactly *how* “wrong” is it to apply a region’s U32 trawl-bycatch mortality to its directed longline yield, when we “know” that those fish would not have stayed in that region? That is, where is that lost yield truly being felt?

Framework #1: Applied Science

Scale-dependent Processes and Management Actions

C) Fine-scale: intrannual / individual-based

- How does individual fish behavior interact with harvest strategy?
- Vaguely: Does seasonal migration redistribute fish in ways in which we do not understand?
- Specifically: To what extent does the distribution of fish as surveyed during summer (i.e., that which we simply call "stock distribution") reflect regional mean abundance integrated over nine- (or twelve-) month fishing seasons?

That is, if we're looking to achieve a relatively constant SPR among all regulatory areas within a Biological Region, how far from our target(s) might we be (by Area) "knowing" that the fish are unlikely to be where we surveyed them if they're harvested prior to May or after September?

Framework #1: Applied Science

Scale-dependent Processes and Management Actions

C) Fine-scale: intrannual / individual-based

- How does individual fish behavior interact with assessment?
- Vaguely: How do foraging dynamics affect indices of abundance?
- Specifically: To what extent does fish behavior introduce biases into the relationship between CPUE and true abundance?

For example, seeing as survey CPUE is a more direct an index of feeding motivation than of abundance *per se* … and feeding motivation in fishes tends to be highly influenced by water temperature … does a given CPUE imply the same thing (read: catch limit) in the Bering Sea as in Canada? Or, are we missing some critical "adjustment factors"?

Framework #2: Theoretical Ecology

Generate data for the construction, parameterization, and validation of age- and sex-specific spatial-distribution models

- The ecological equivalent of spatially-explicit assessment models
  - but numerical abundance estimation is not necessarily required; relative abundance or simple spatial coverage are valid goals

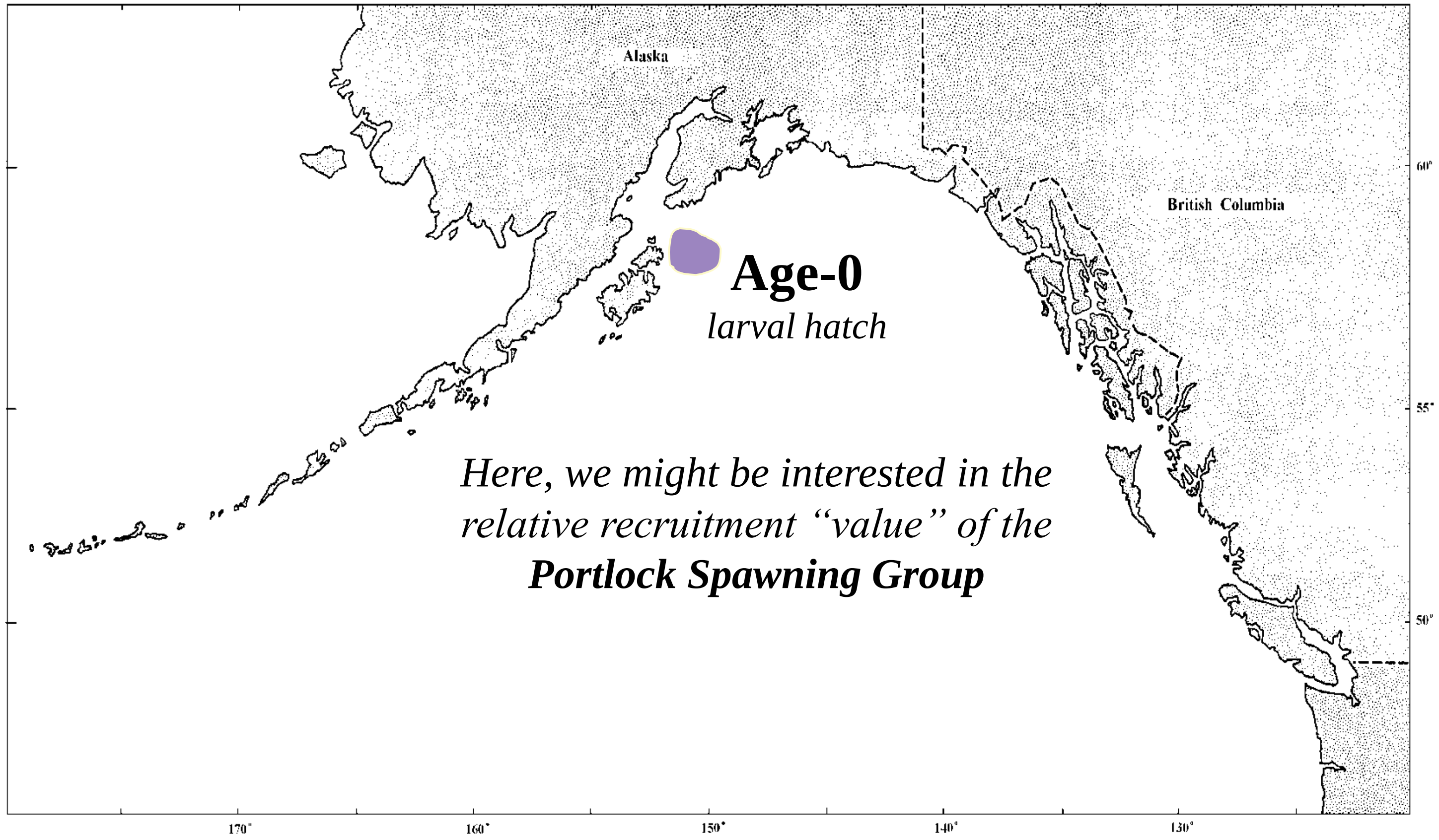
- Often referred to as “metapopulation modeling”
  - except, not really … because extinction-recolonization dynamics are not the focus

- More appropriately: a form of “landscape ecology modelling”

Framework #2: Theoretical Ecology

Generate data for the construction, parameterization, and validation of age- and sex-specific spatial-distribution models

- Example: spatial progression of a distinct source population



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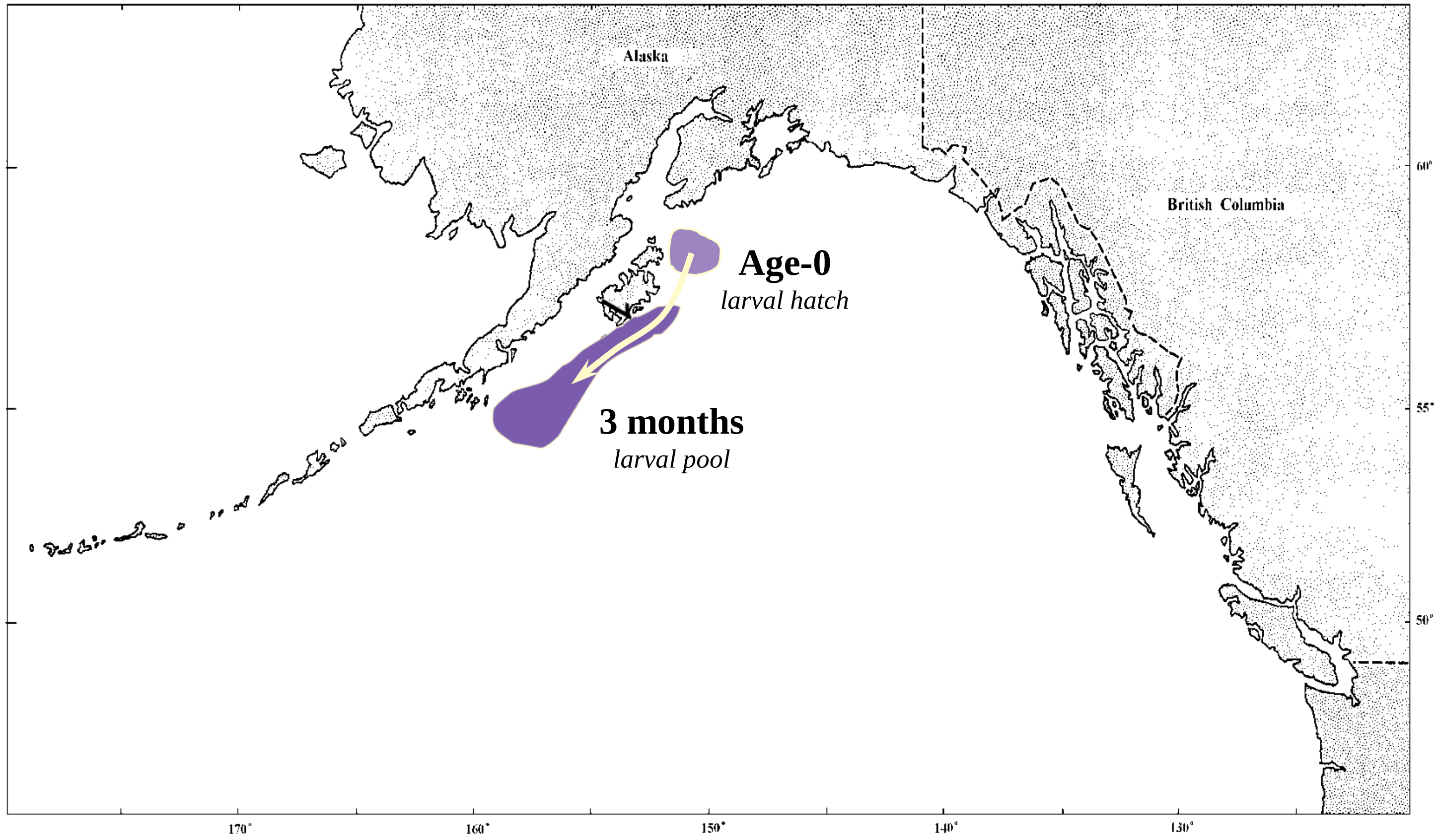

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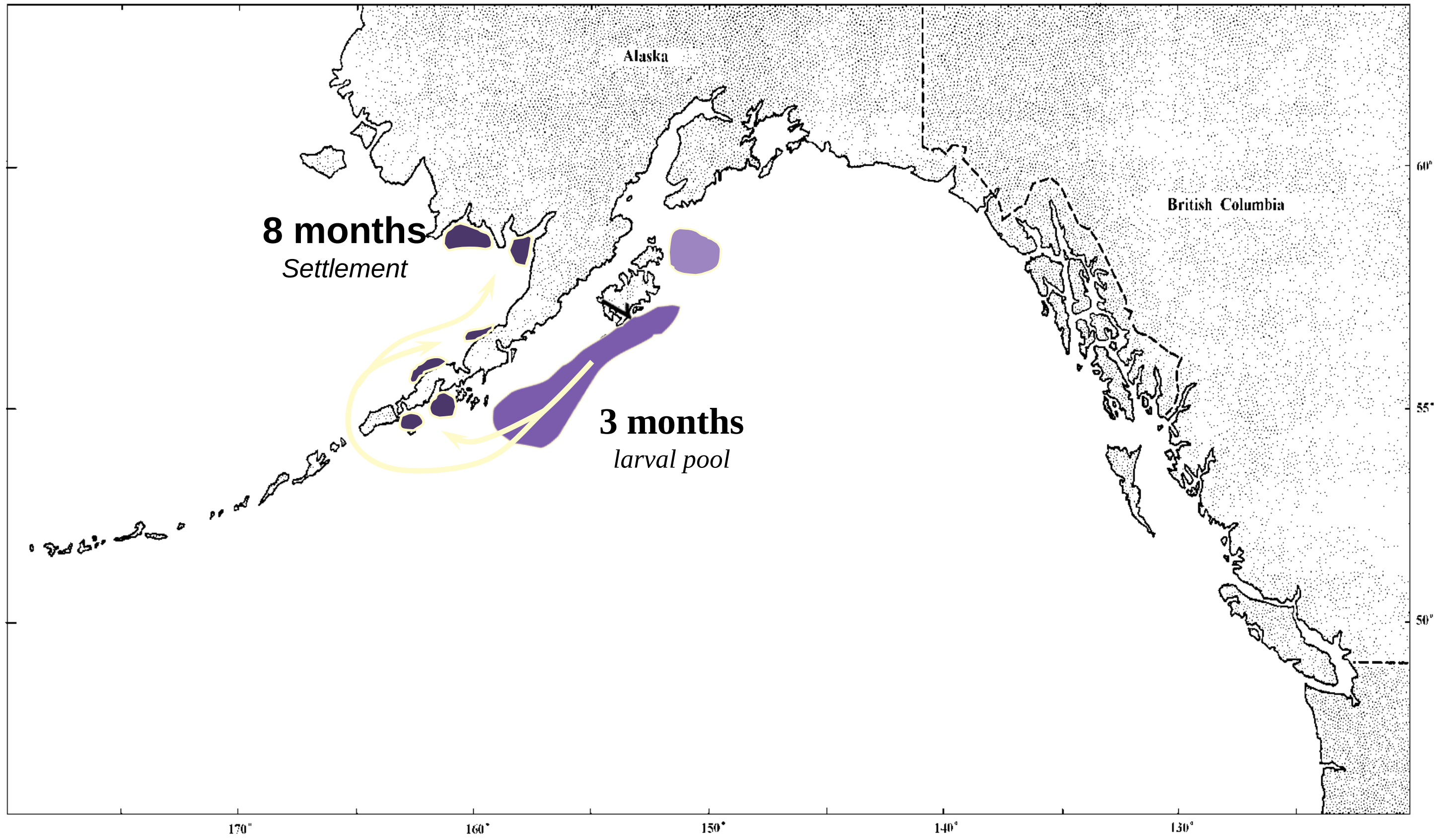

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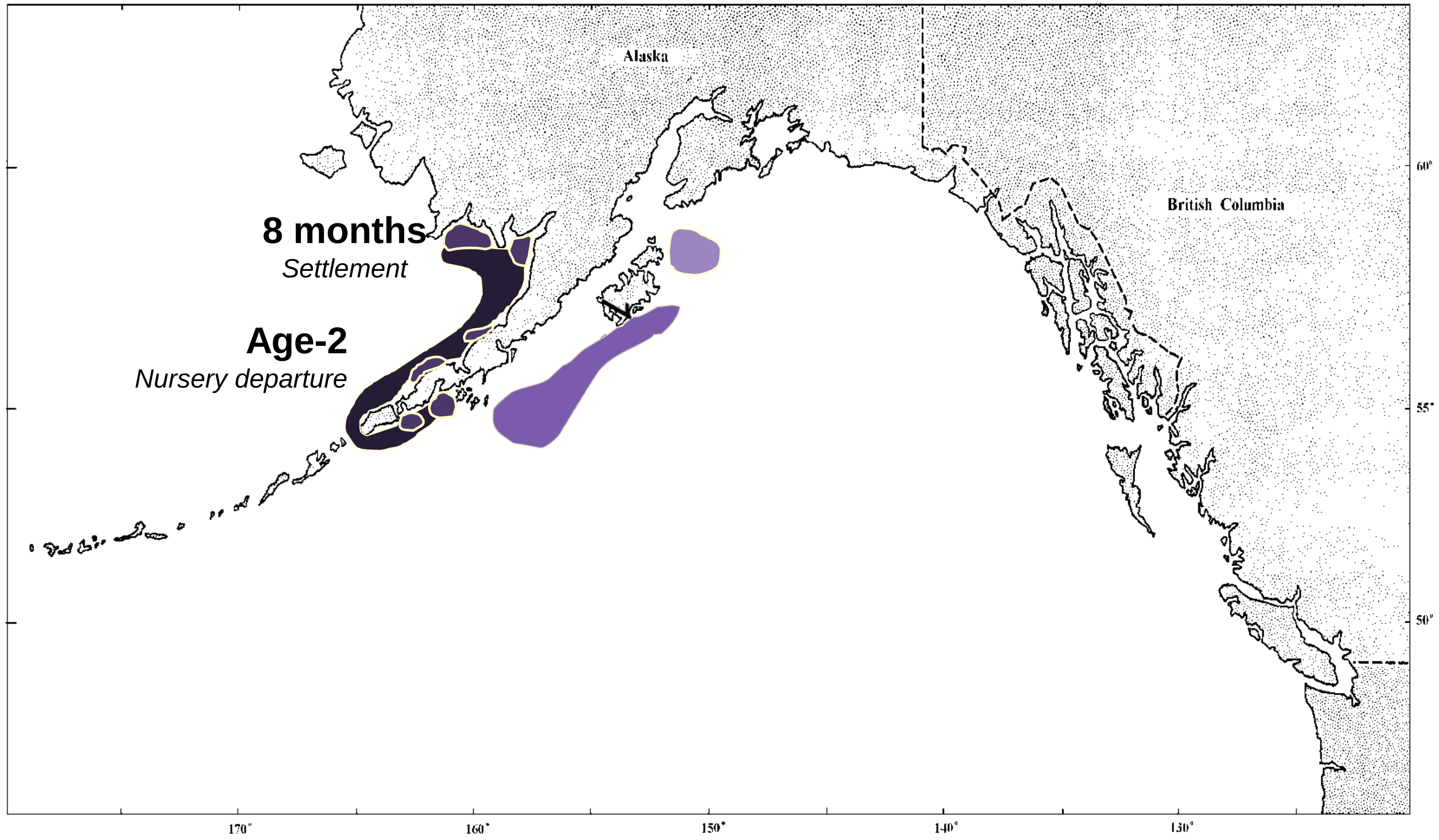

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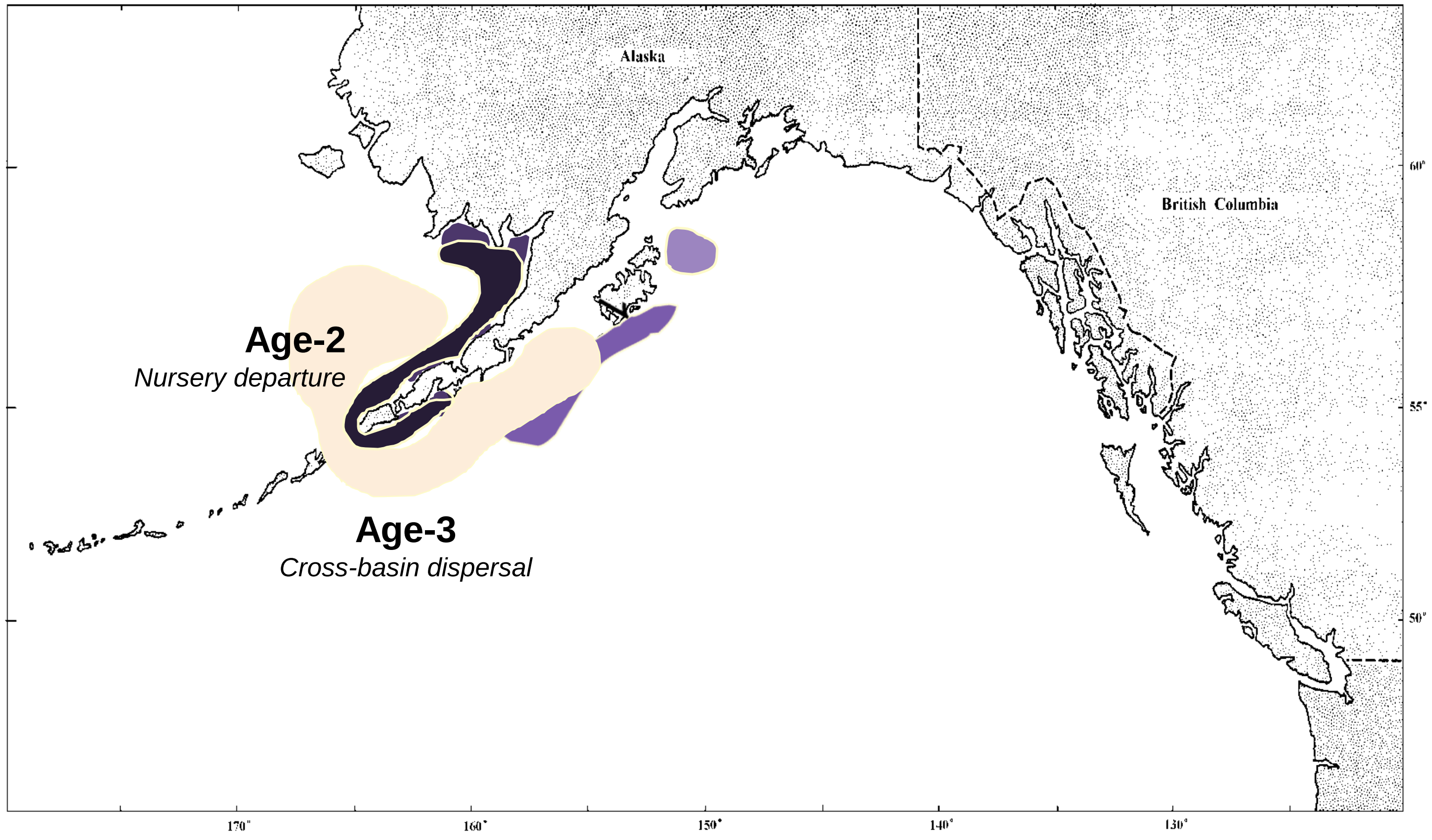

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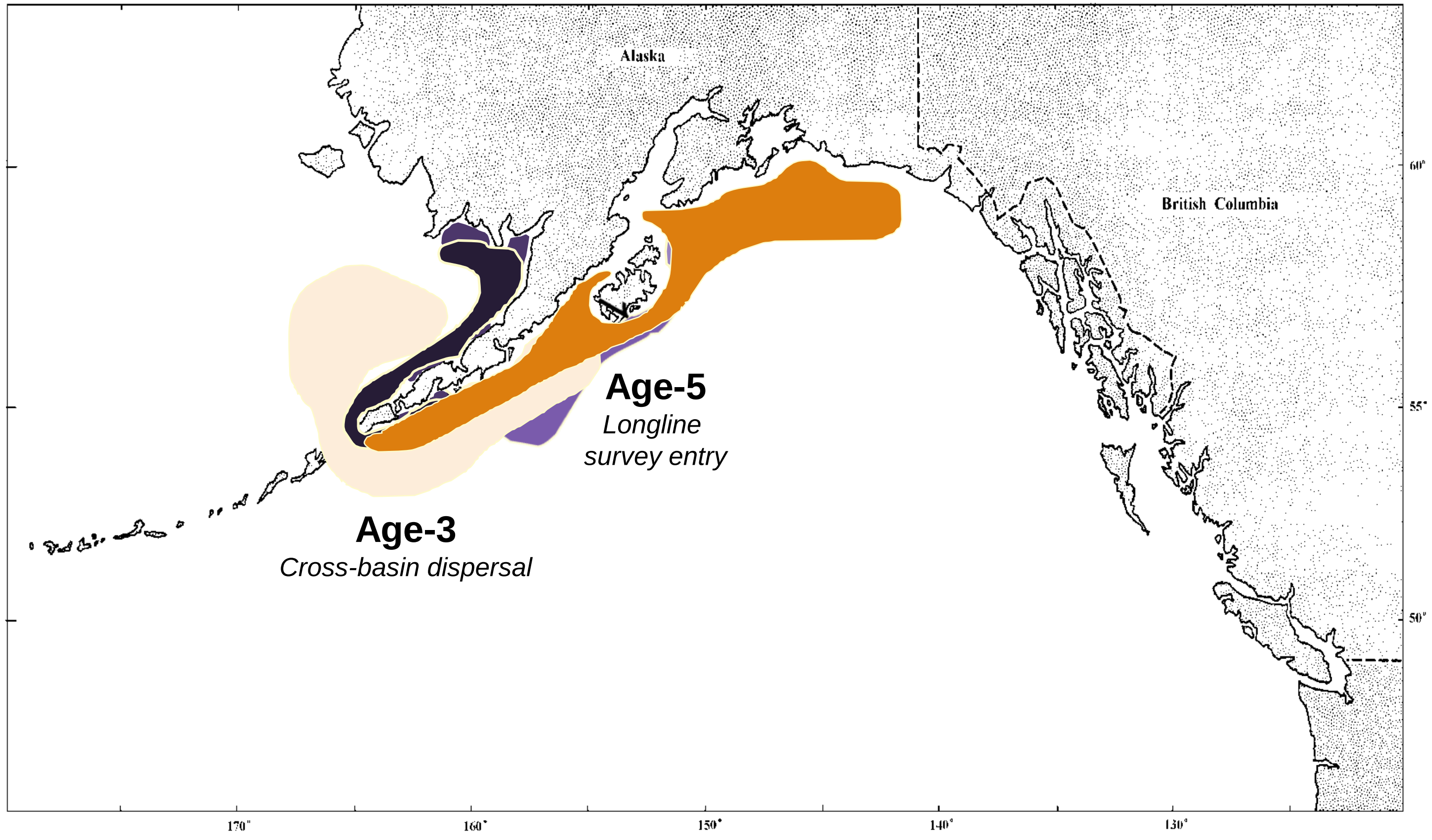

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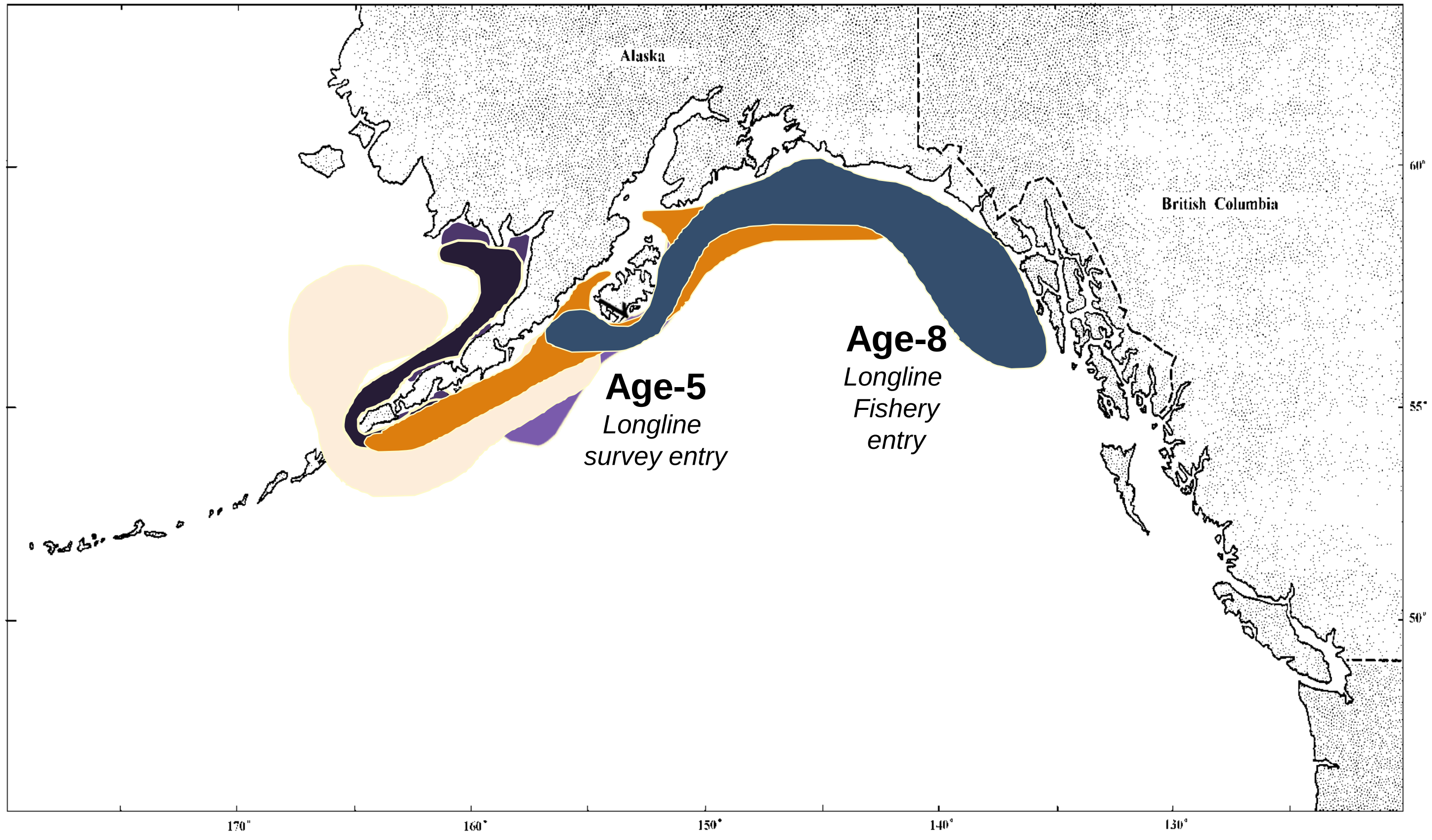

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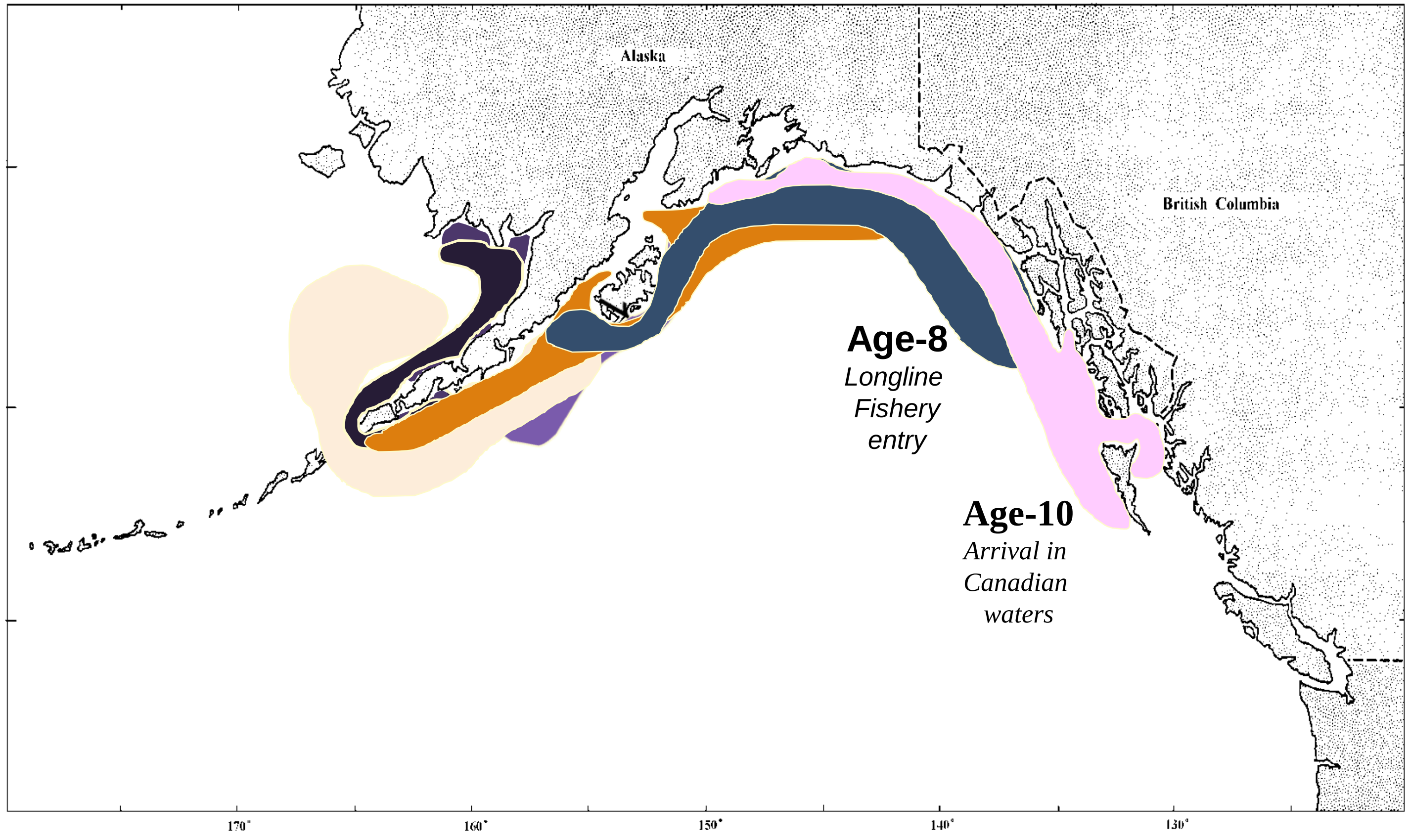

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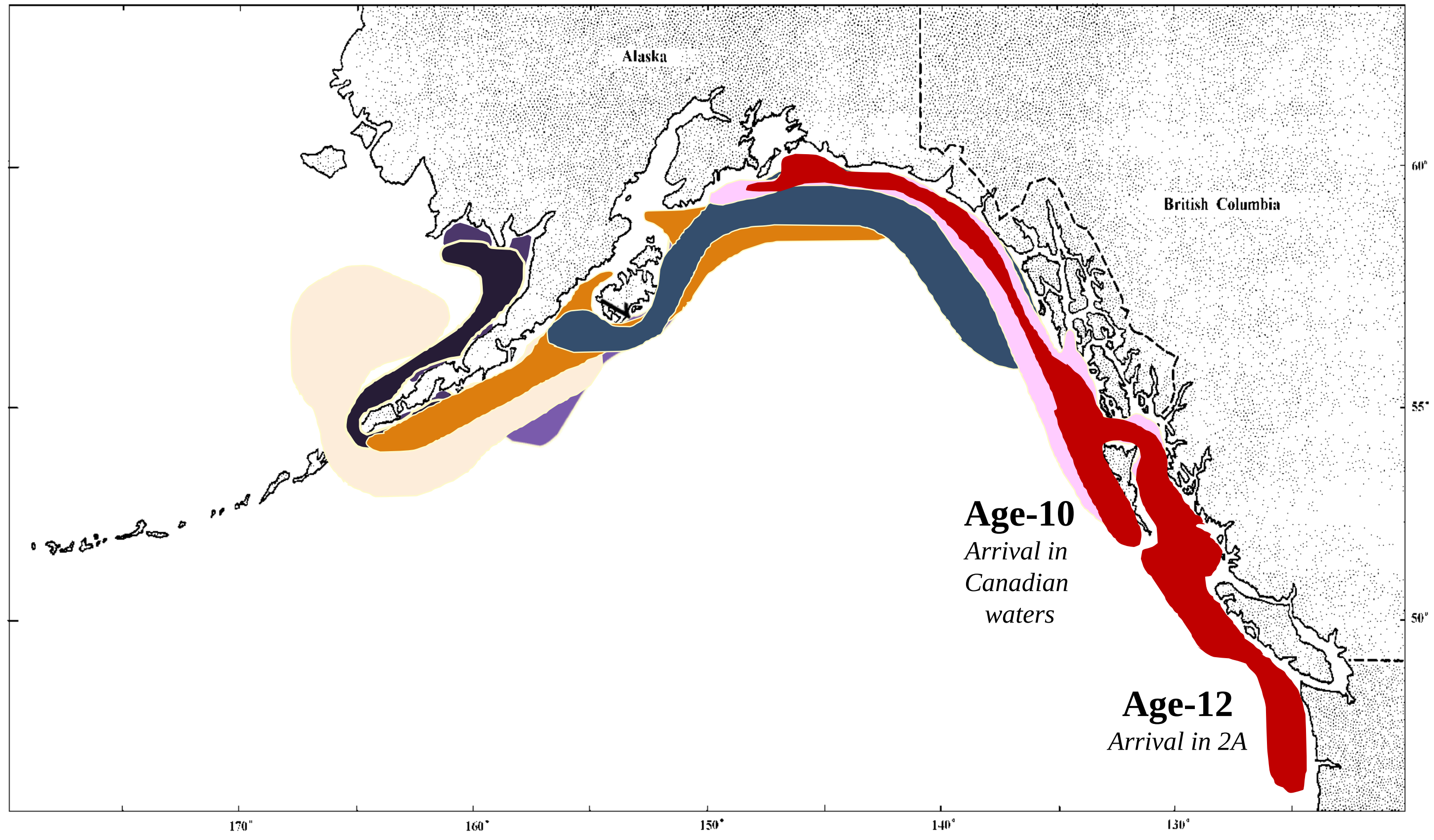

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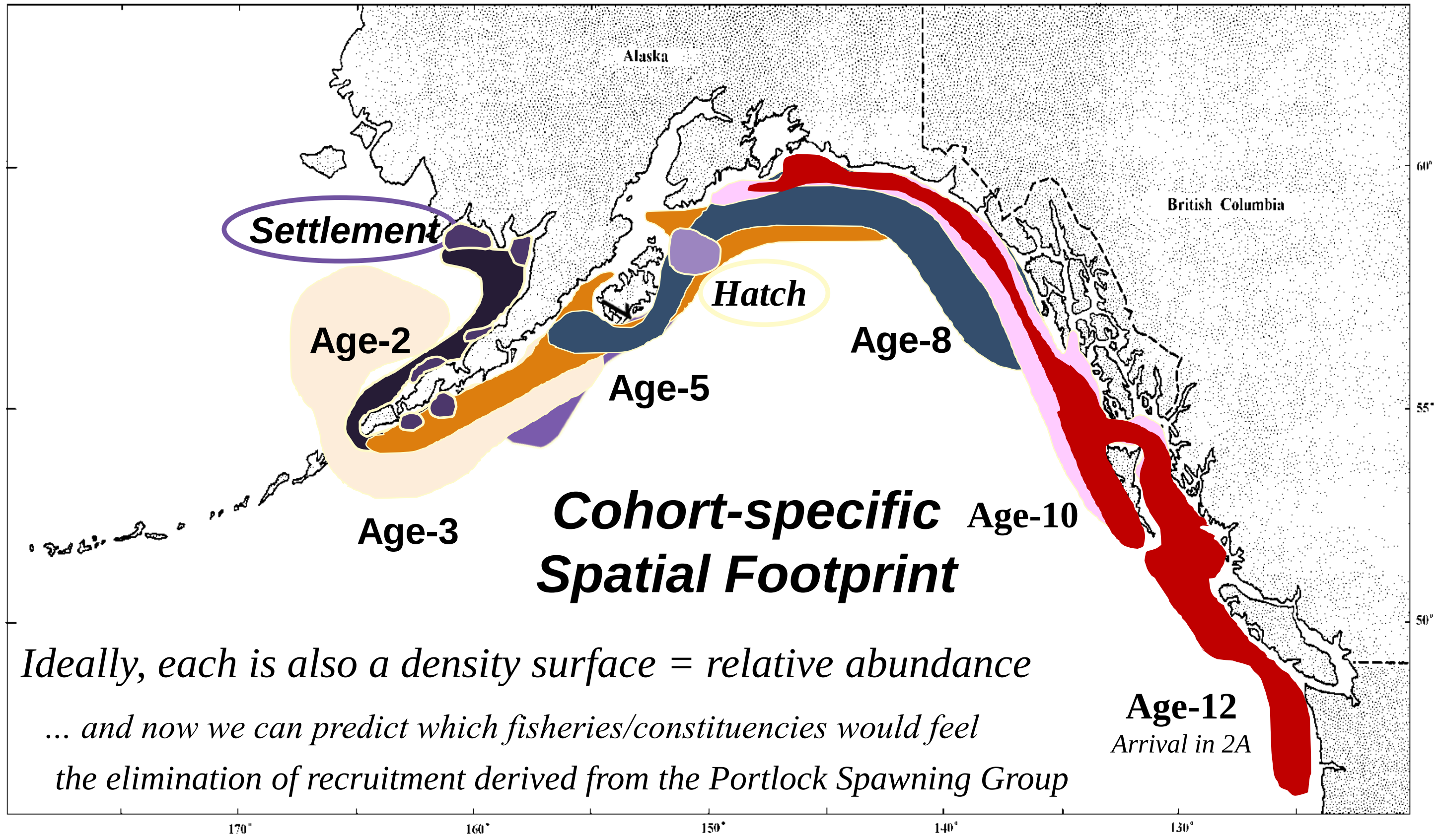

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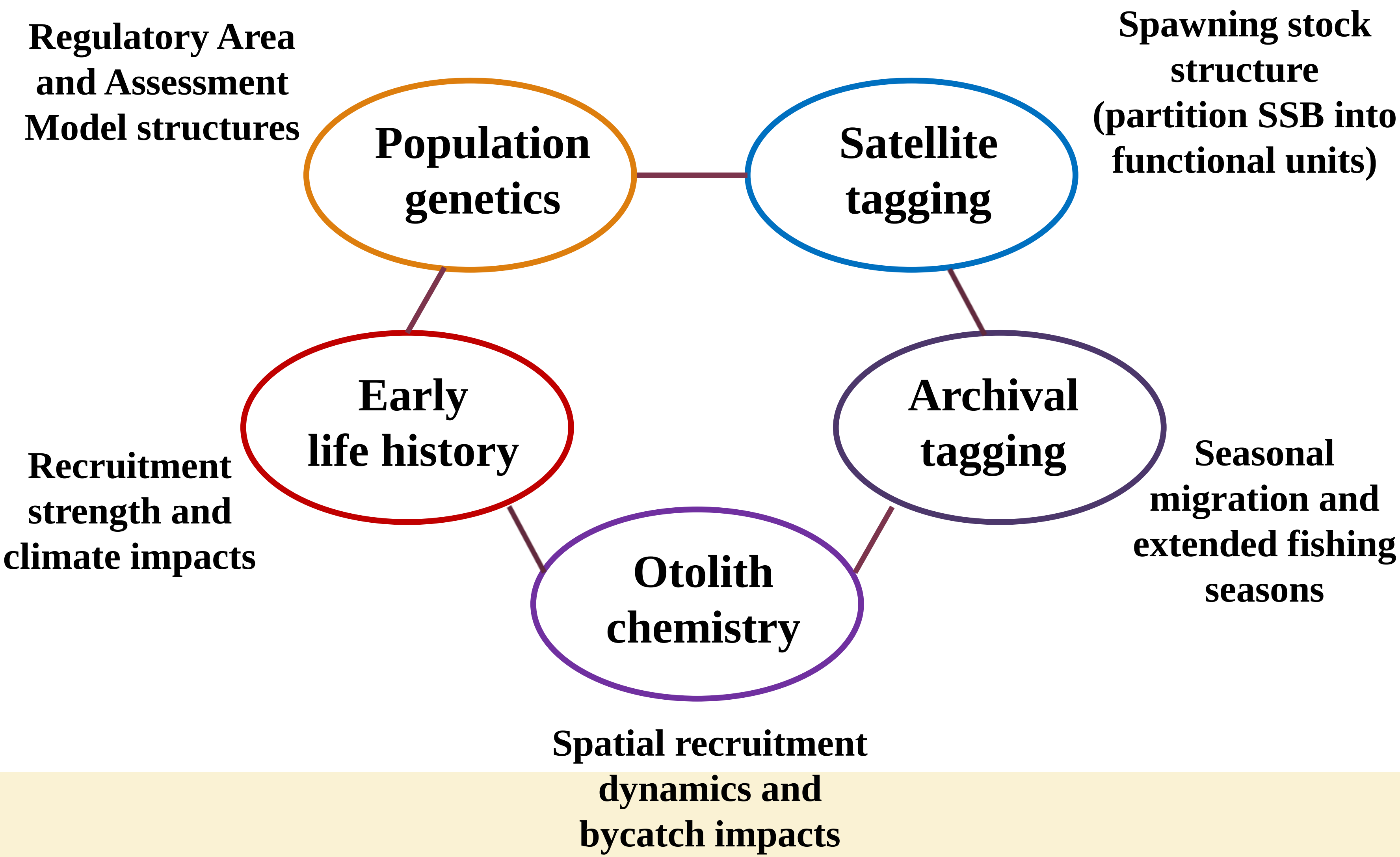
The Integrated Research Design



Some major findings

From coastwide deployment of 67,436 PIT tags (2001-2009)

Pre-dated the Integrate Design and was not intended for this context

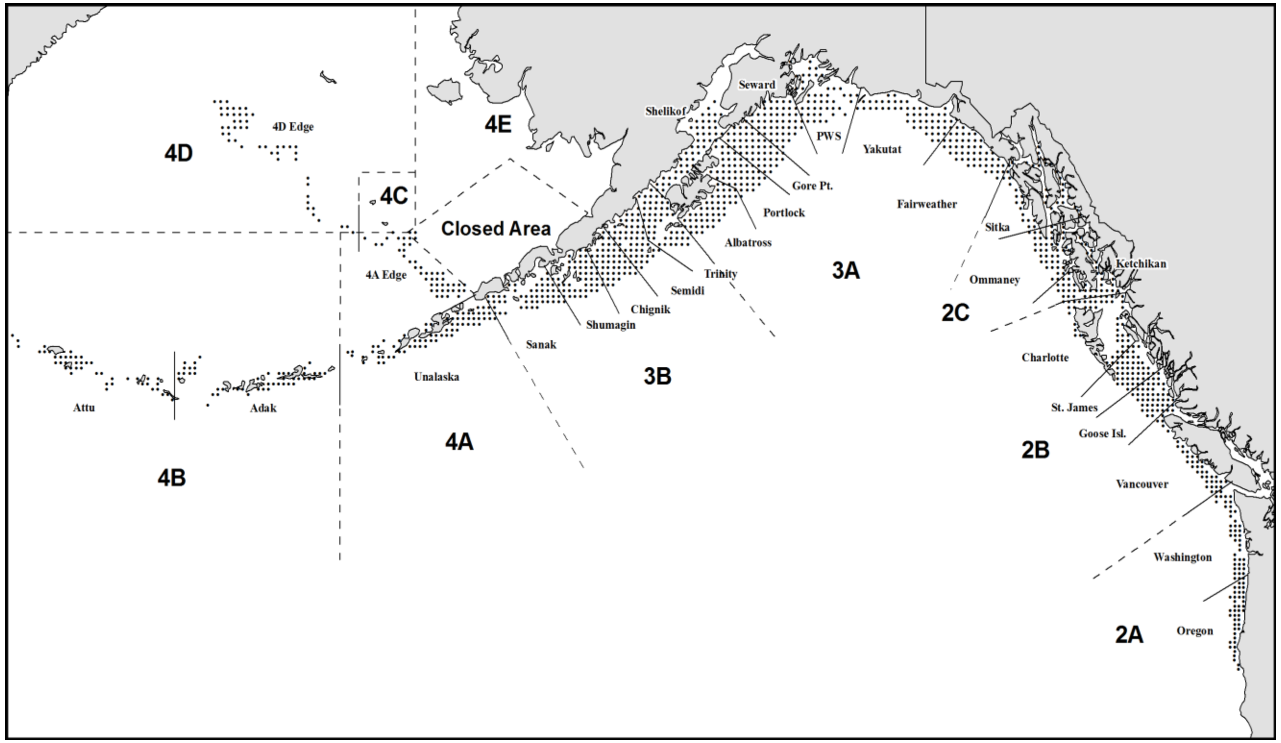
- Preparations began in 2000 and had nothing to do with connectivity: rather, designed for mortality (F, M) and abundance estimation

  - Unexpectedly low tag-recovery rates in some areas led to questionable estimates of fishing mortality

- However, the resultant data were highly amenable to migration analysis

Some major findings

From coastwide deployment of 67,436 PIT tags (2001-2009)

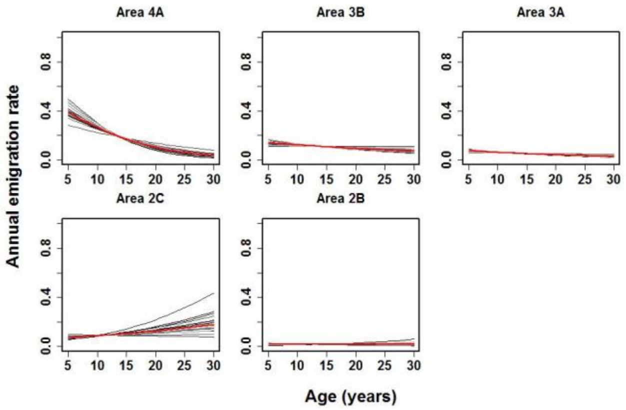


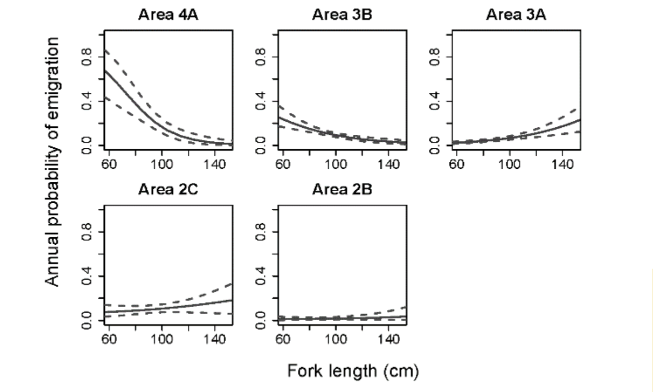
Recovered via an extensive portside commercial-harvest recovery program

Some major findings

From coastwide deployment of 67,436 PIT tags (2001-2009)

Movement rates of 032 fish modelled as functions of length and age …





… and tabulated Area-to-Area

Estimated annual migration rates for 100 cm fish from PIT tags 2003-2009 (Webster *et al*. 2013).

Area in yr i	**Area in yr i+1**				
	4A	**3B**	**3A**	**2C**	**2B**
4A	**0.833**	0.041	0.093	0.013	0.019
3B	0.002	**0.907**	0.084	0.004	0.003
3A	0.000	0.059	**0.934**	0.003	0.004
2C	0.000	0.000	0.025	**0.895**	0.080
2B	0.006	0.000	0.002	0.008	**0.984**

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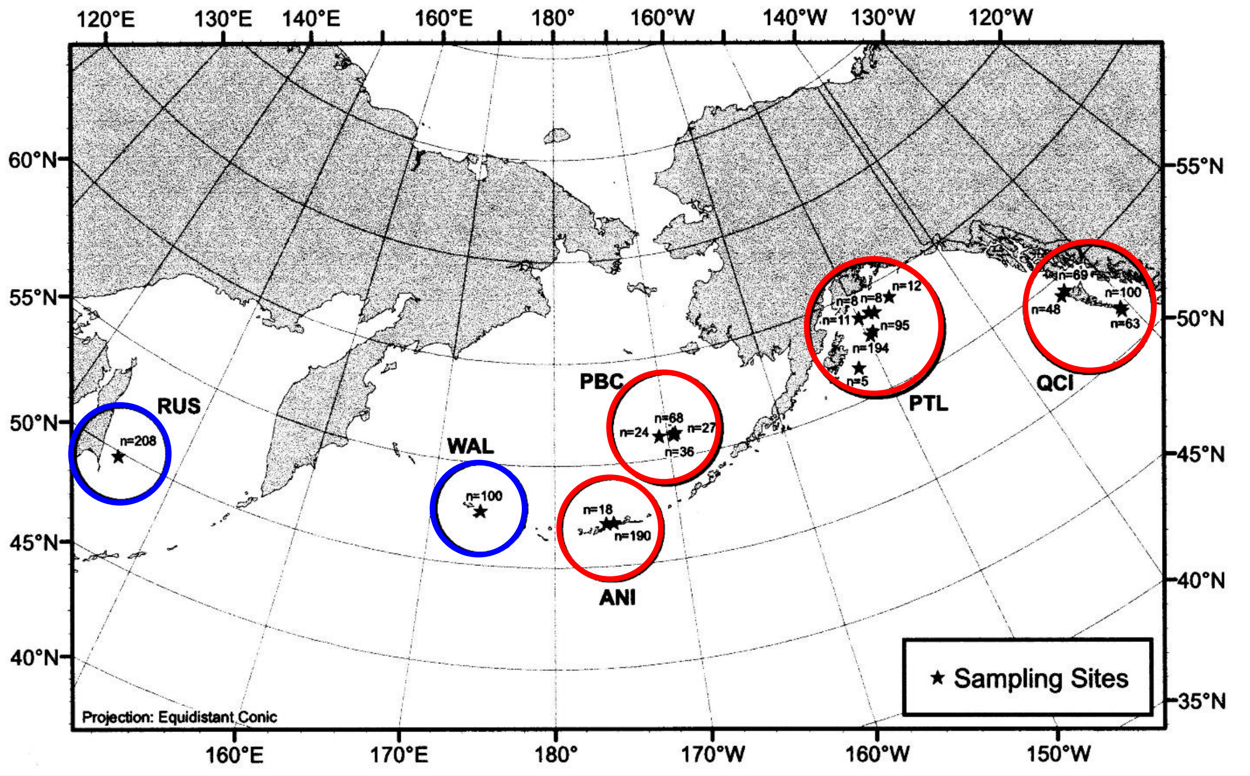
Some major findings

From Population genetic analyses (1998-2017)

- (968) mature fish sampled at winter spawning grounds from British Columbia to the eastern Aleutian Islands; plus (308) summer-collected samples from the western Aleutians and Russia



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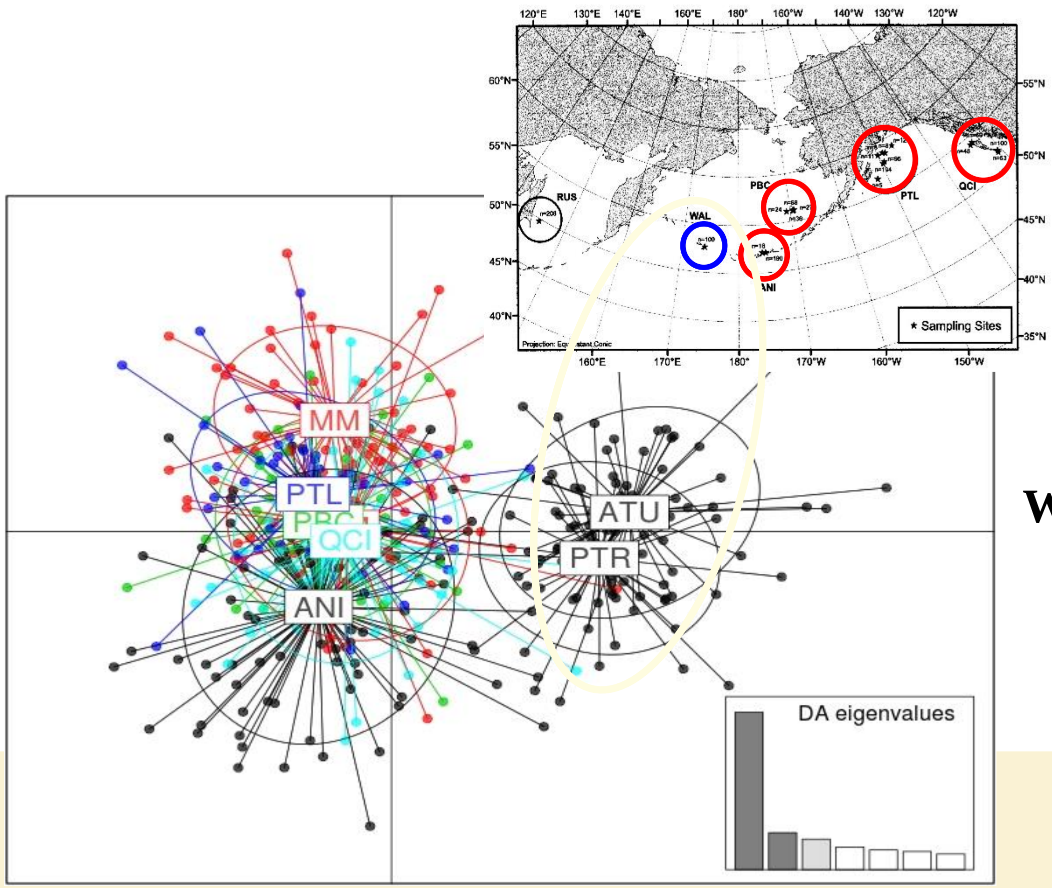
Some major findings

From Population genetic analyses (1998-2017)

- Analyses based on 61 microsatellite loci
    - 23 anonymous loci and 38 Expressed Sequence Tags (ESTs)



Evidence of Western Aleutian isolation

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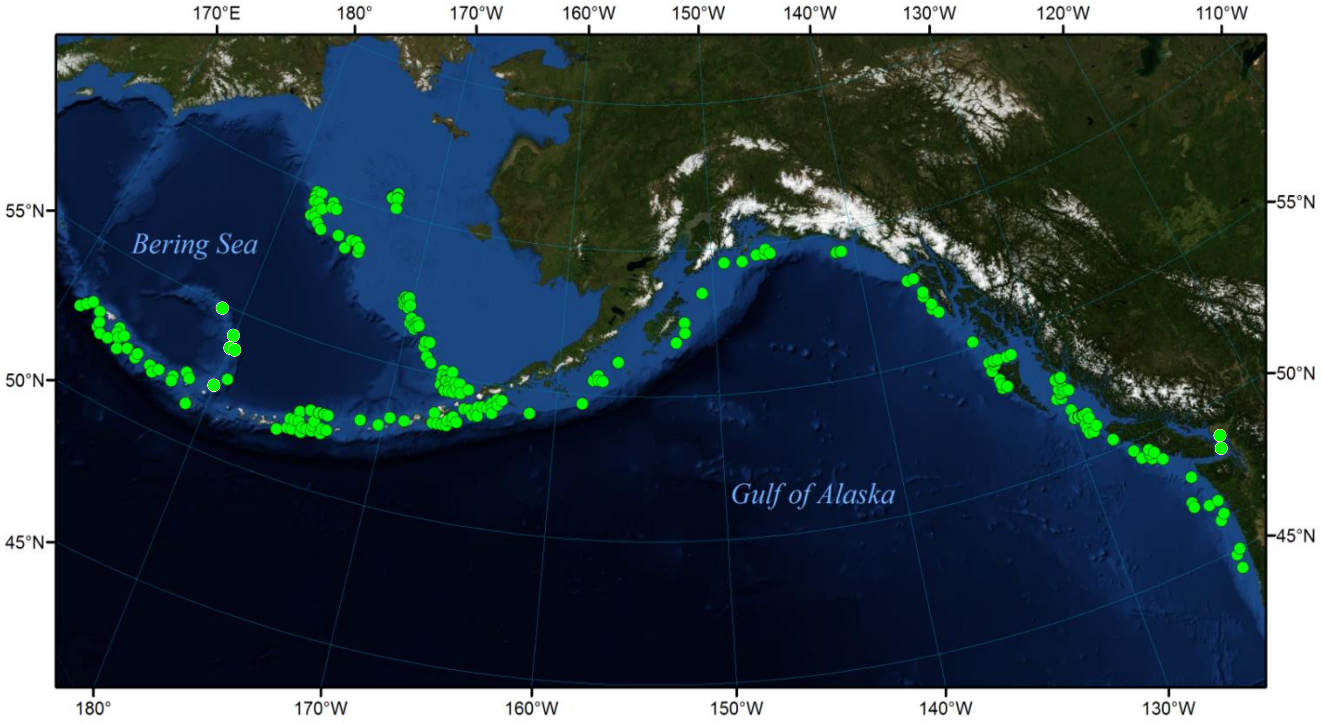
Some major findings

From 401 summer-deployed PAT tags (2002-2017)

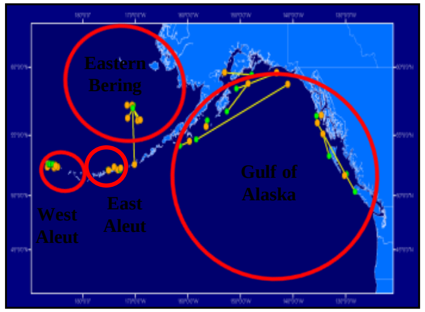


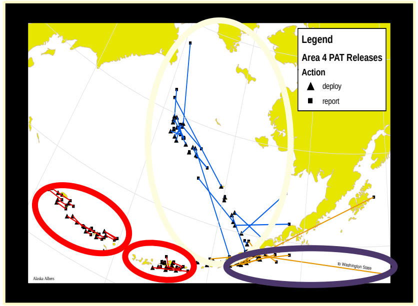
Programmed as a mixture of winter reporting for spawning locations …
… and summer reporting of site fidelity and regional mixing

Some major findings

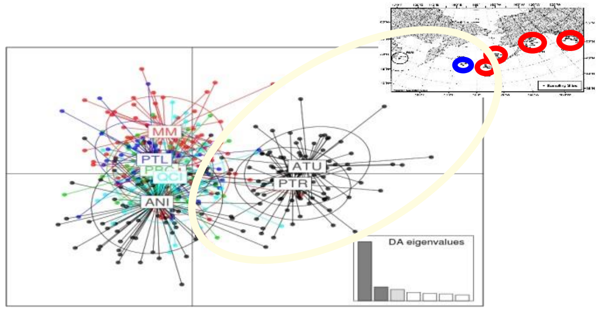
From 401 summer-deployed PAT tags (2002-2017)

Indication of basin-scale spawning stock structure with West Aleutian isolation…

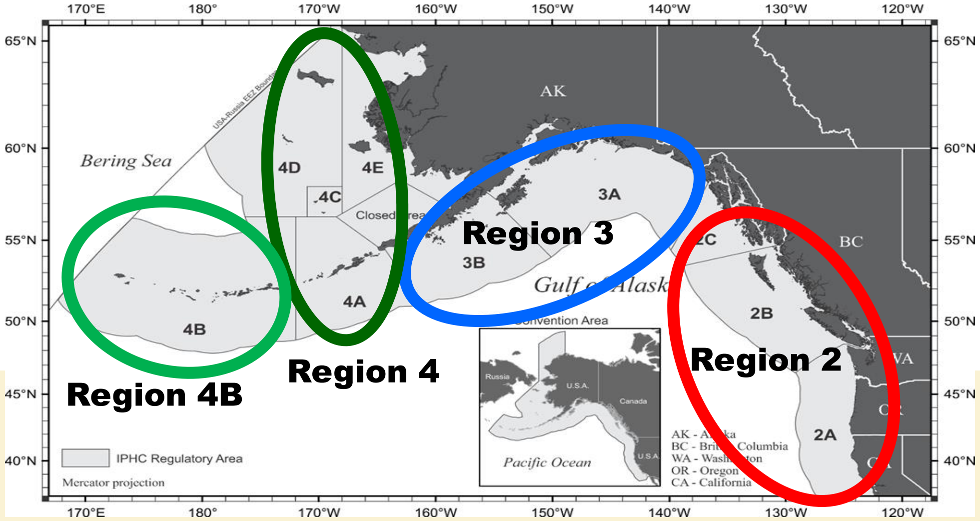




… consistent with population-genetic analyses



Supporting our move towards metrics within Biological Regions



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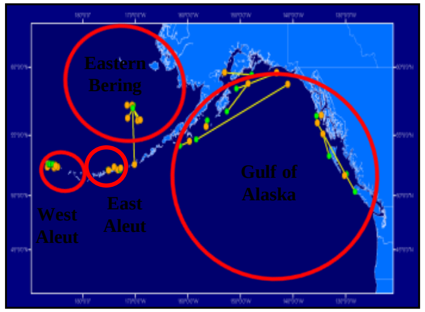
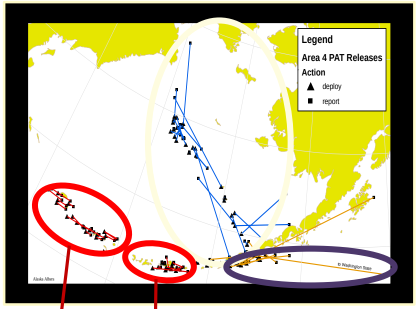
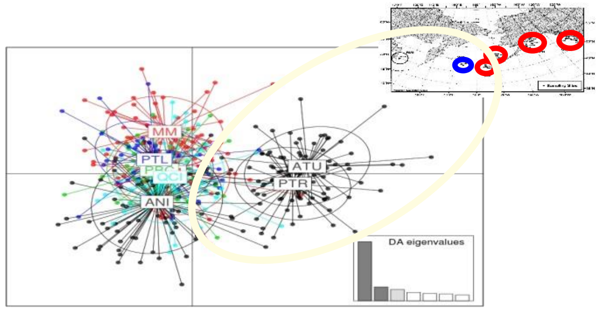
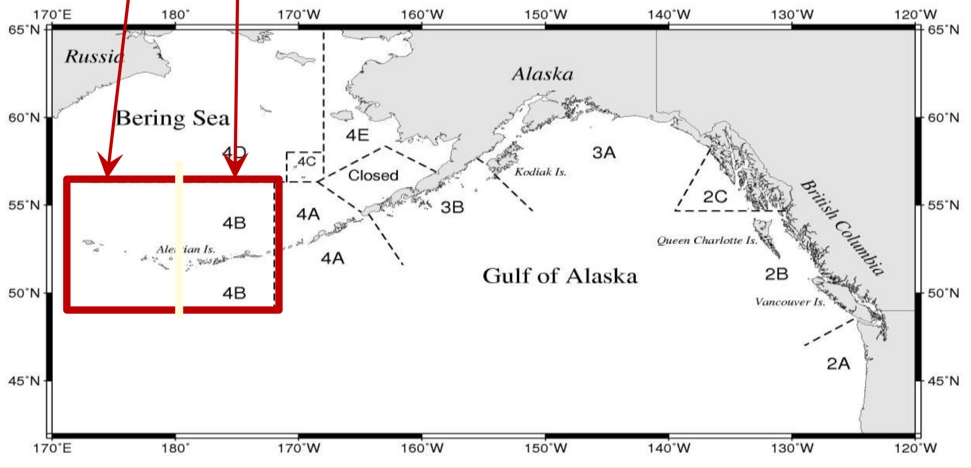






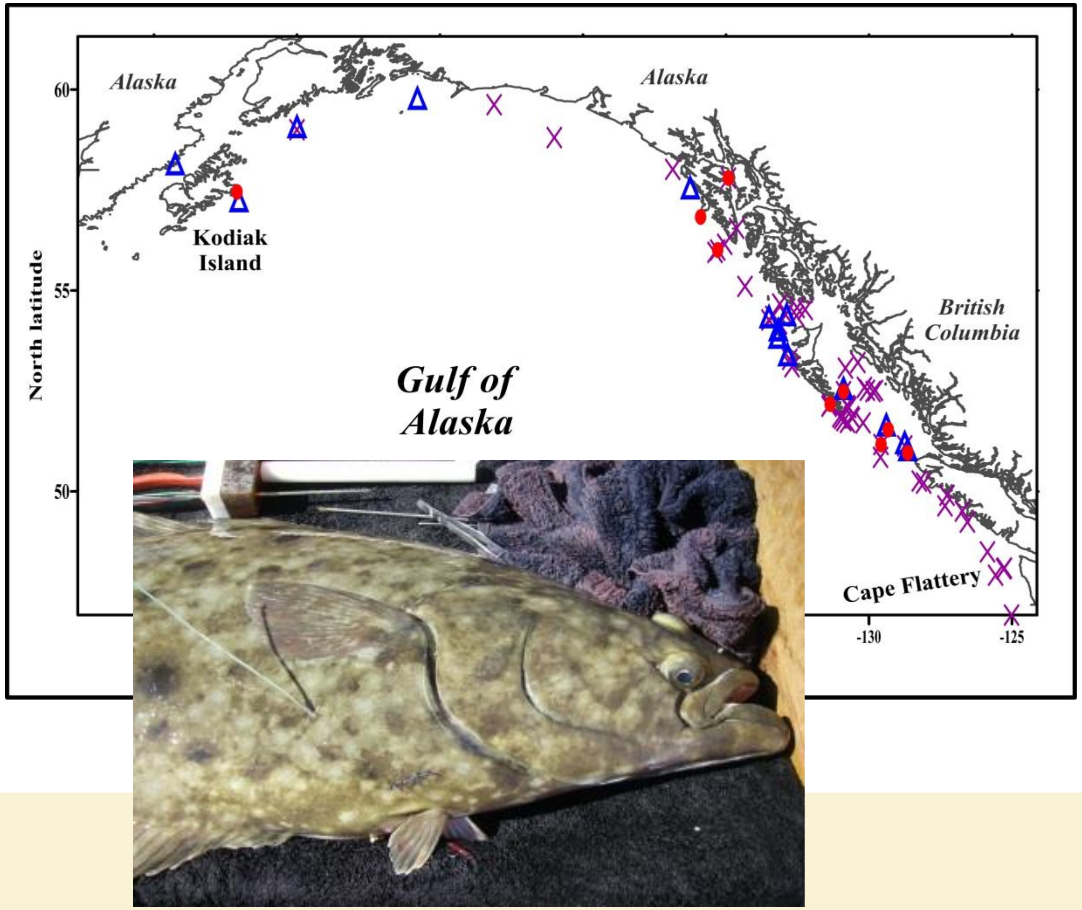
But, suggesting that Area 4B represents two discrete population components



Some major findings

From seasonal analysis of archival depth data (2002-2009)

- Using archival tag data to quantify group-level seasonal migration



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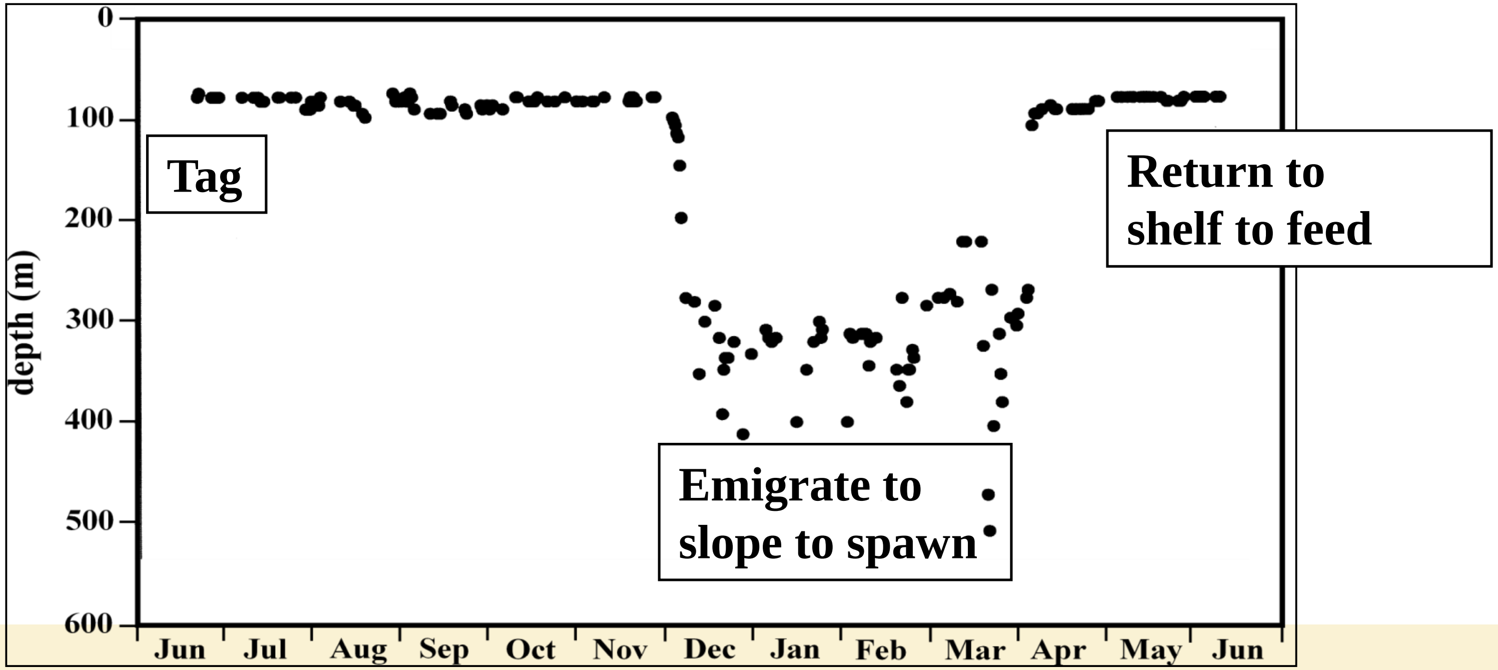
Ability to define seasons from the perspective of the fish



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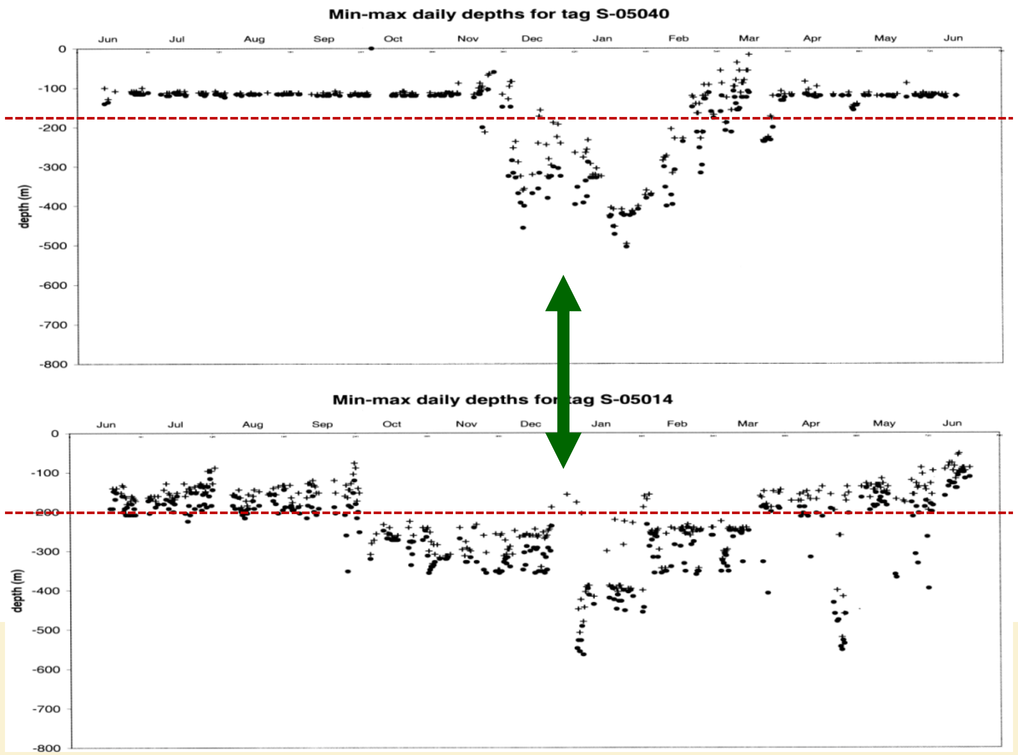
Aggregate data to characterize average annual habitat use:



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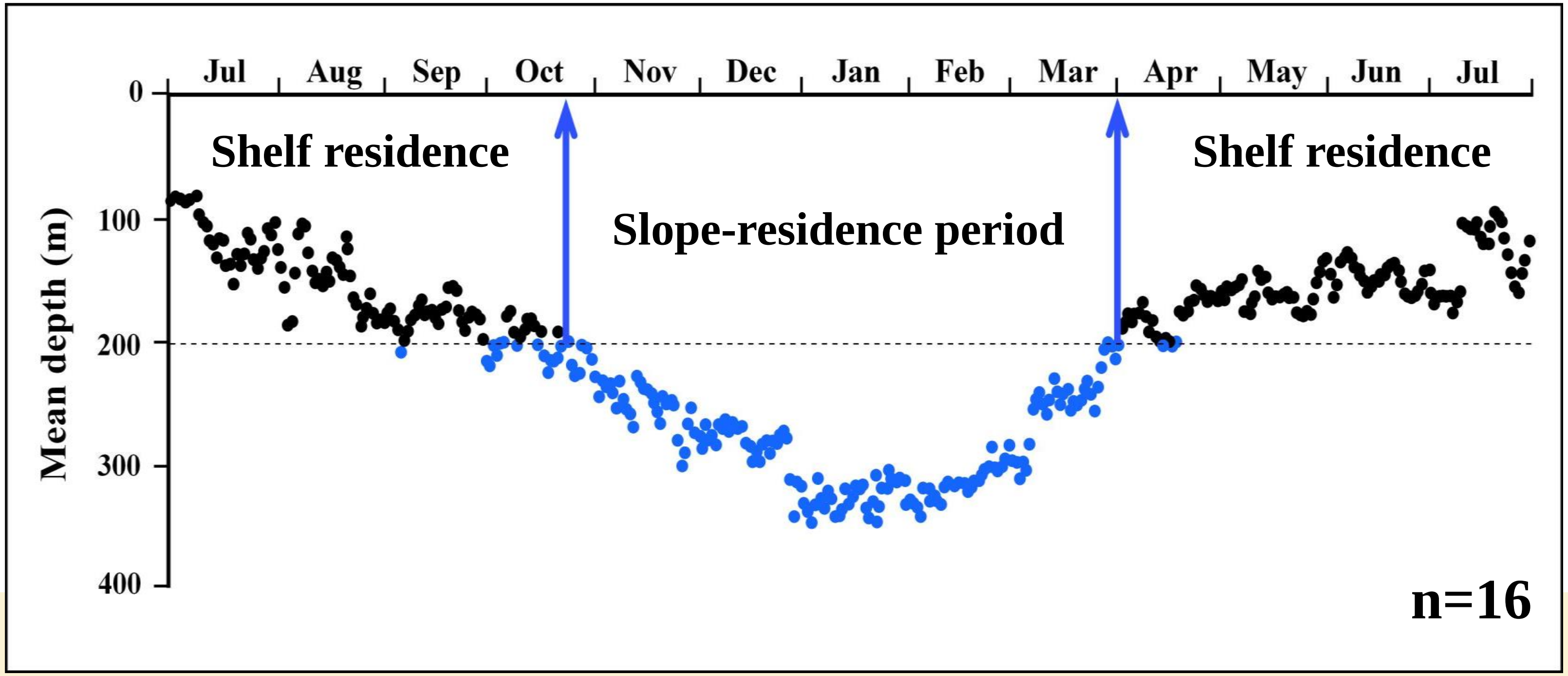

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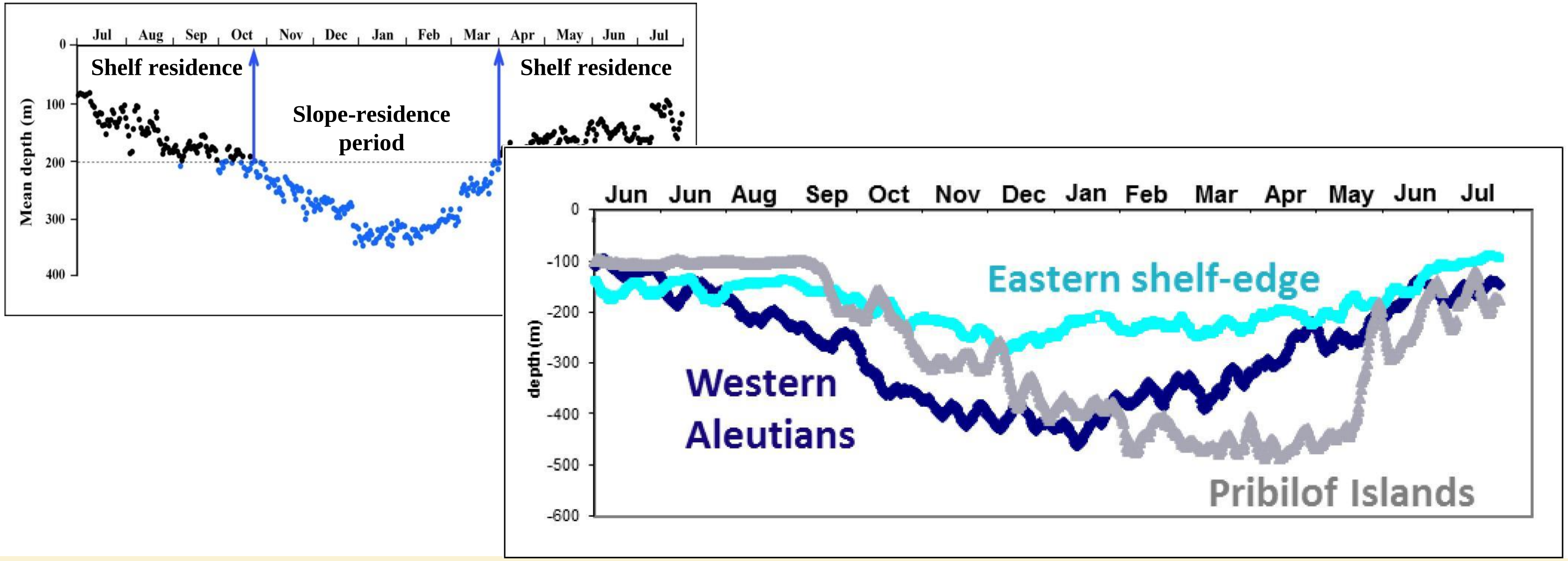

Noting evidence of regional variance …

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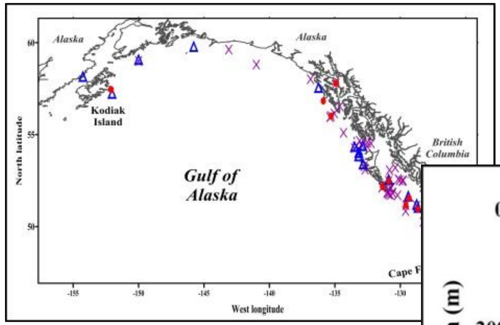
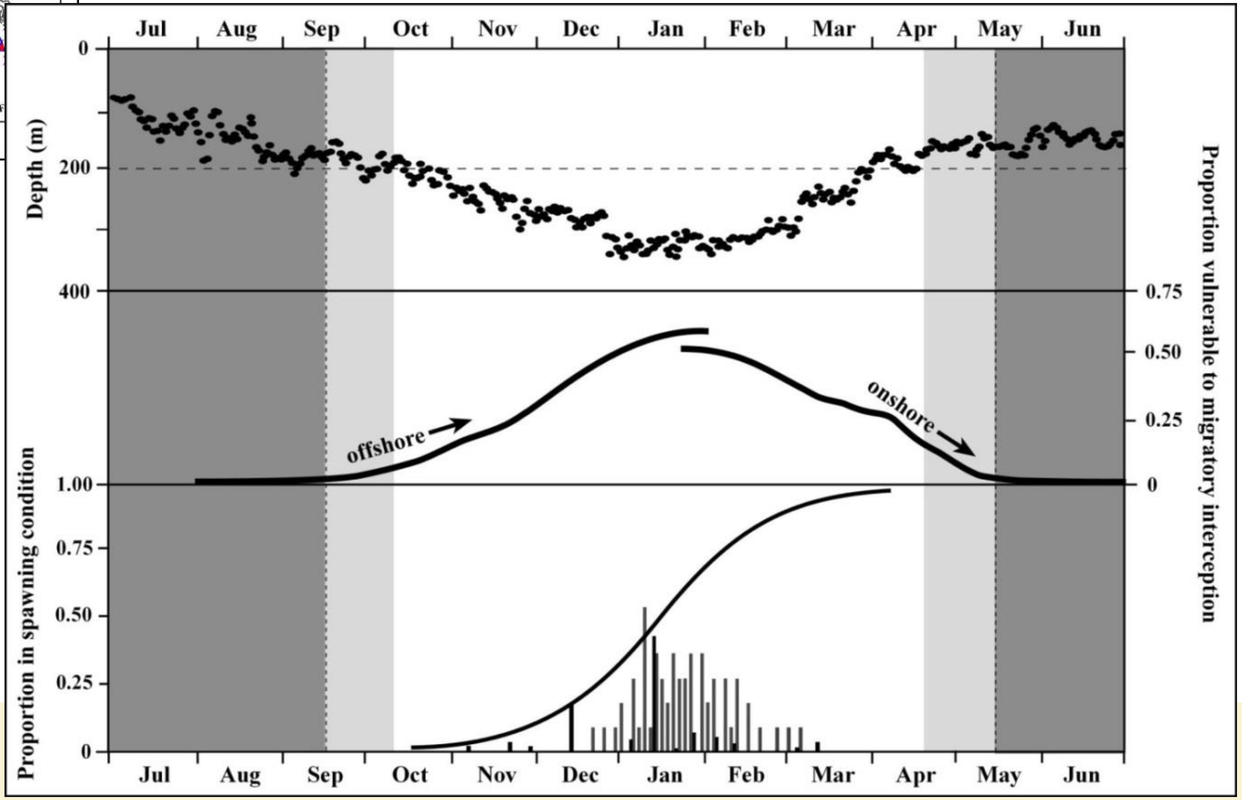
Some major findings

From seasonal analysis of archival depth data (2002-2009)



Integrated metrics to describe habitat use and spatial redistribution

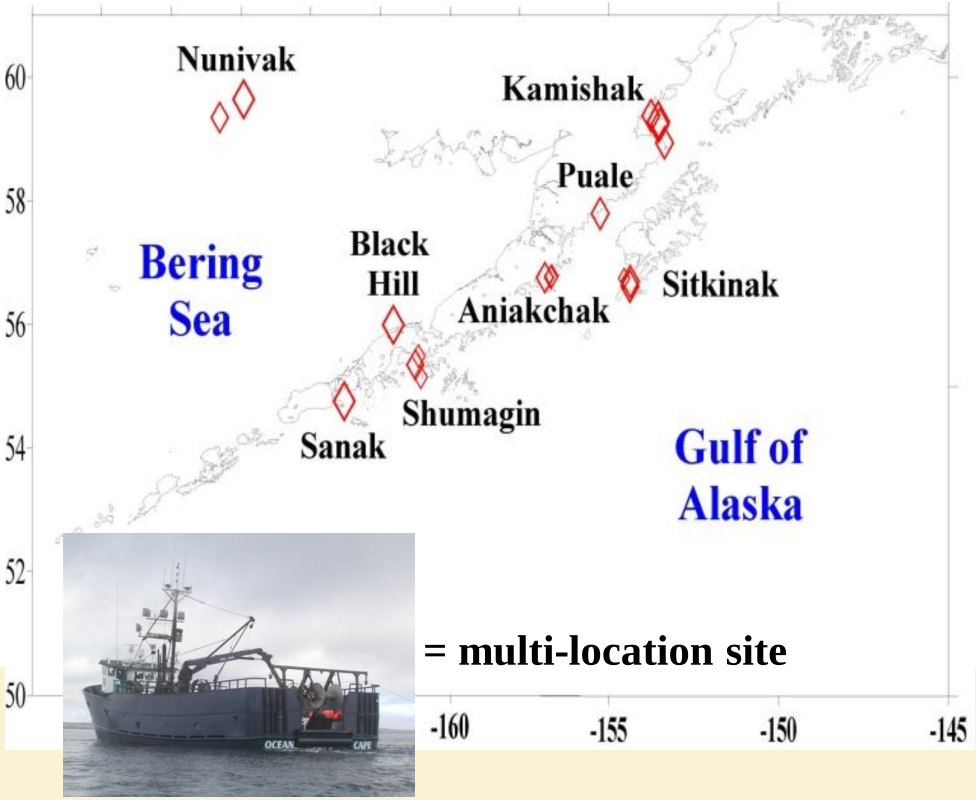


Some major findings

From analyses of otolith microchemistry (2002-2007)

- Looking for *spatially-trended* patterns allowing for source identifications not prone to assigning fish from unsampled locations to those sampled

Relied on fish from NMFS trawl surveys



= multi-location site

- **From 16 locations representing 8 sites, from west-central GOA to the southeast Bering Sea**
- **Spatial coverage of ~2300 km of coastline**

Some major findings

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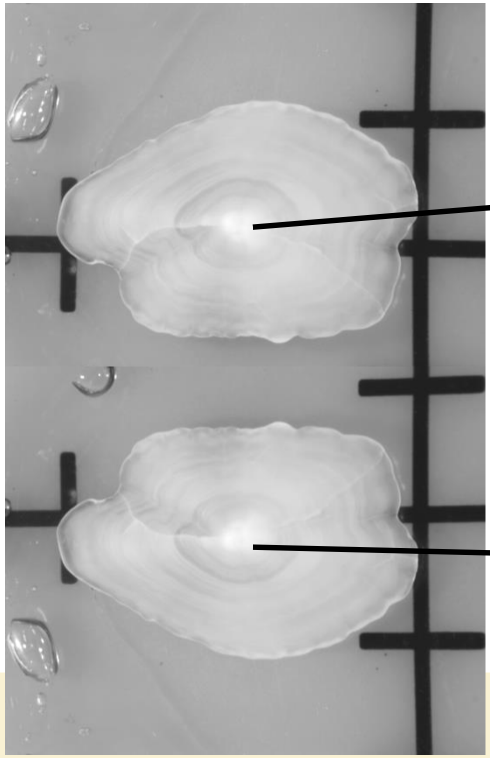
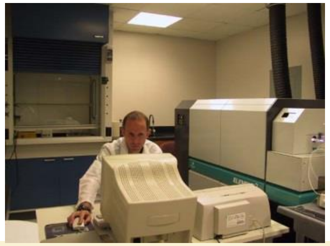


Right otolith: stable isotope ratios

Ratio Mass Spectrometry

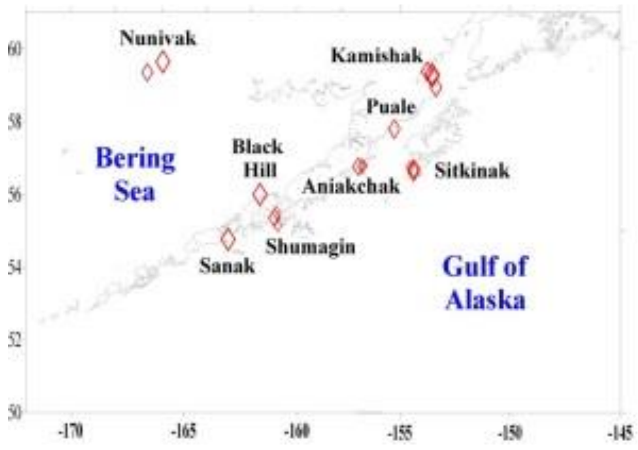


Inductively-Coupled Plasma Mass Spectrometry (IC-PMS)

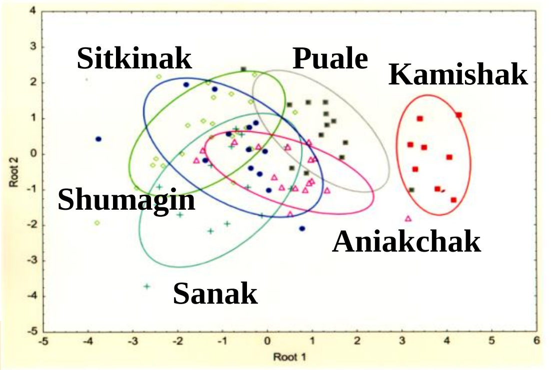
Left otolith: trace metals

Some major findings

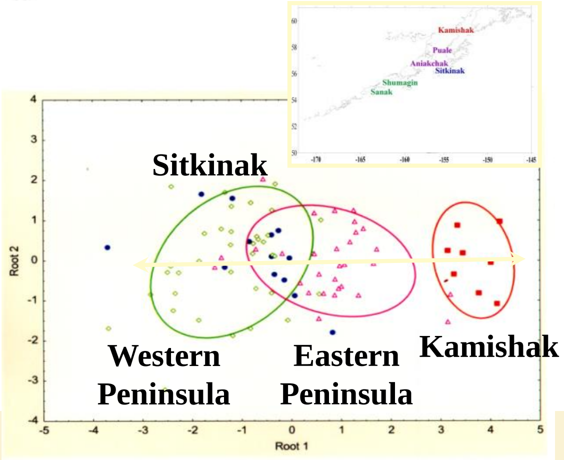
From analyses of otolith microchemistry (2002-2007)



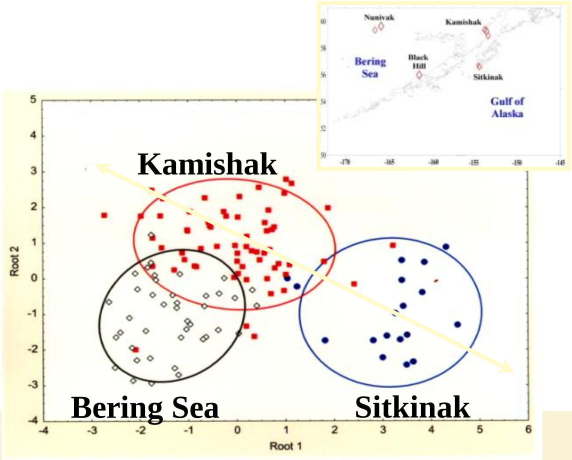
Suggesting that regional origin for individual fish *might* be distinguishable and robust



Local = muddled



GOA Regional = E-W trend



Basin-scale = Bering offset

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Some major findings

From larval dispersal modelling **(2015-2019)**

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Pacific halibut connectivity: Gulf of Alaska & Bering Sea

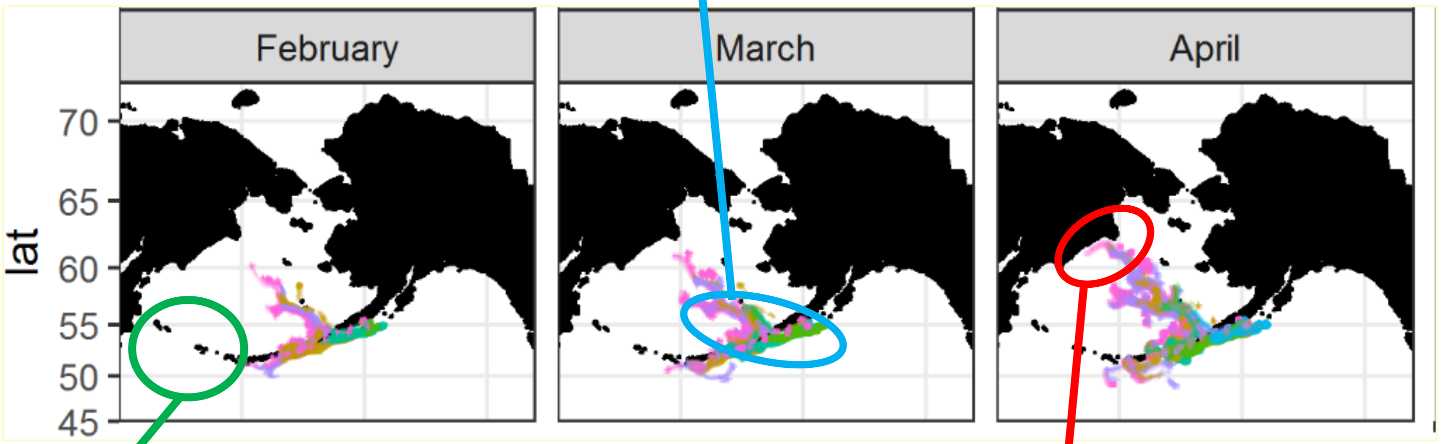
From larval dispersal modelling (2015-2019)

- IPHC and NOAA EcoFOCI cooperative project

International Pacific Halibut Commission   EcoFOCI Ecosystems & Fisheries-Oceanography Coordinated Investigations

- Nearing completion: final results and draft manuscript expected 2019

Cross-basin larval delivery that connects the Gulf of Alaska and eastern Bering Sea …



…western Aleutian isolation

… a mechanism for connectivity between eastern Pacific spawning stock and Russian coastal nurseries

Pacific halibut connectivity: Gulf of Alaska & Bering Sea

From larval dispersal modelling (2015-2019)

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INTERNATIONAL PACIFIC HALIBUT COMMISSION   EcoFOCI Ecosystems & Fisheries-Oceanography Coordinated Investigations

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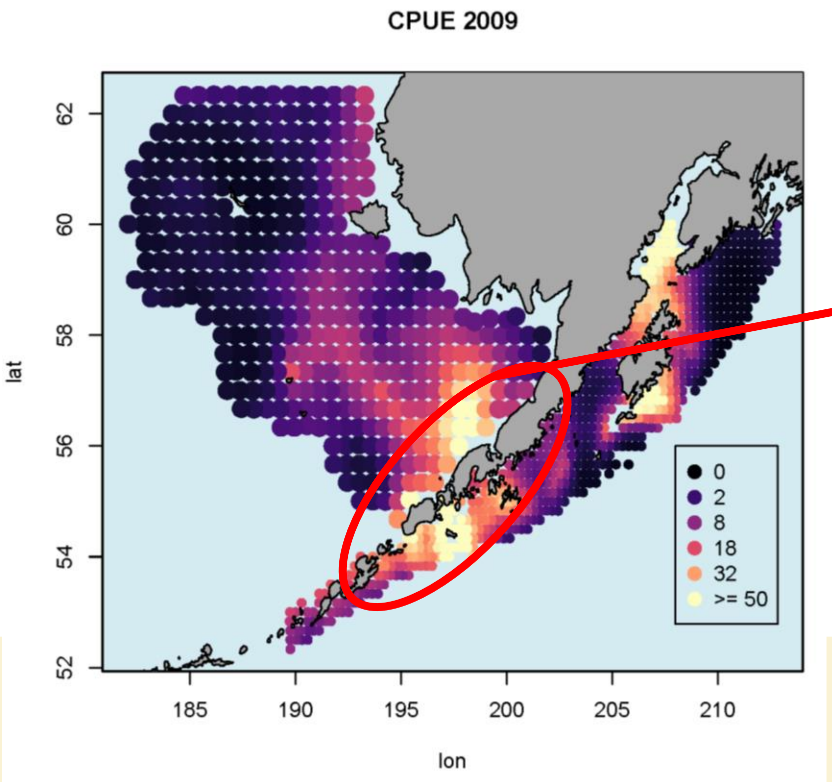
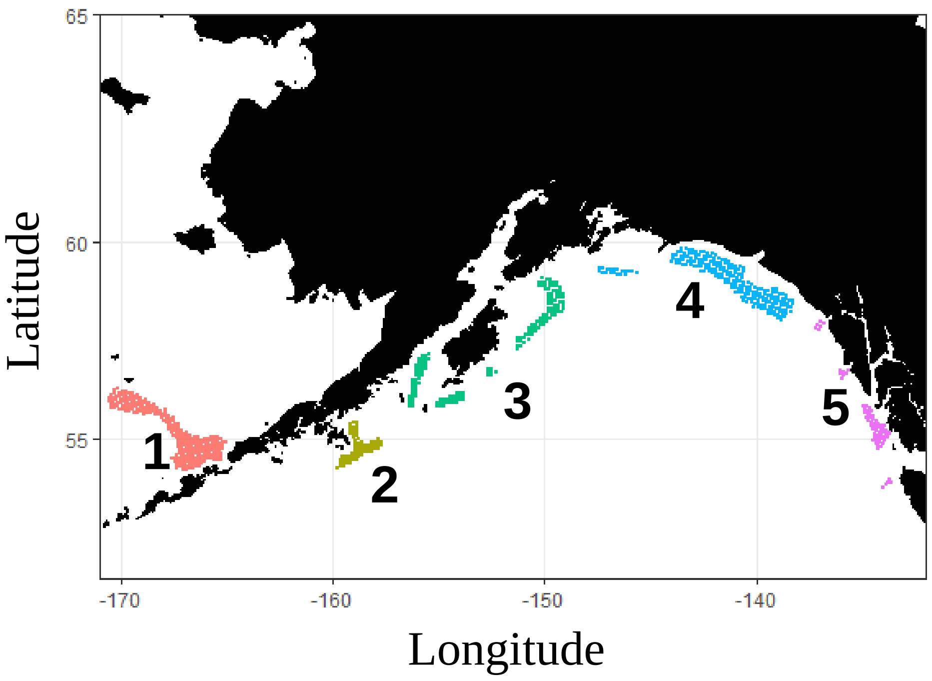


… and connectivity between basins of young fish actively migrating away from the settlement grounds

Pacific halibut connectivity: Gulf of Alaska & Bering Sea

From larval dispersal modelling **(2015-2019)**

Individual-based Biophysical Model +
Oceanographic model (ROMS NEP6) + Pacific halibut larval traits



Warm years – stronger year classes

2003
2004
2005

Cold years – weaker year classes

2009
2010
2011

Do dispersal patterns correlate with environmental regimes?

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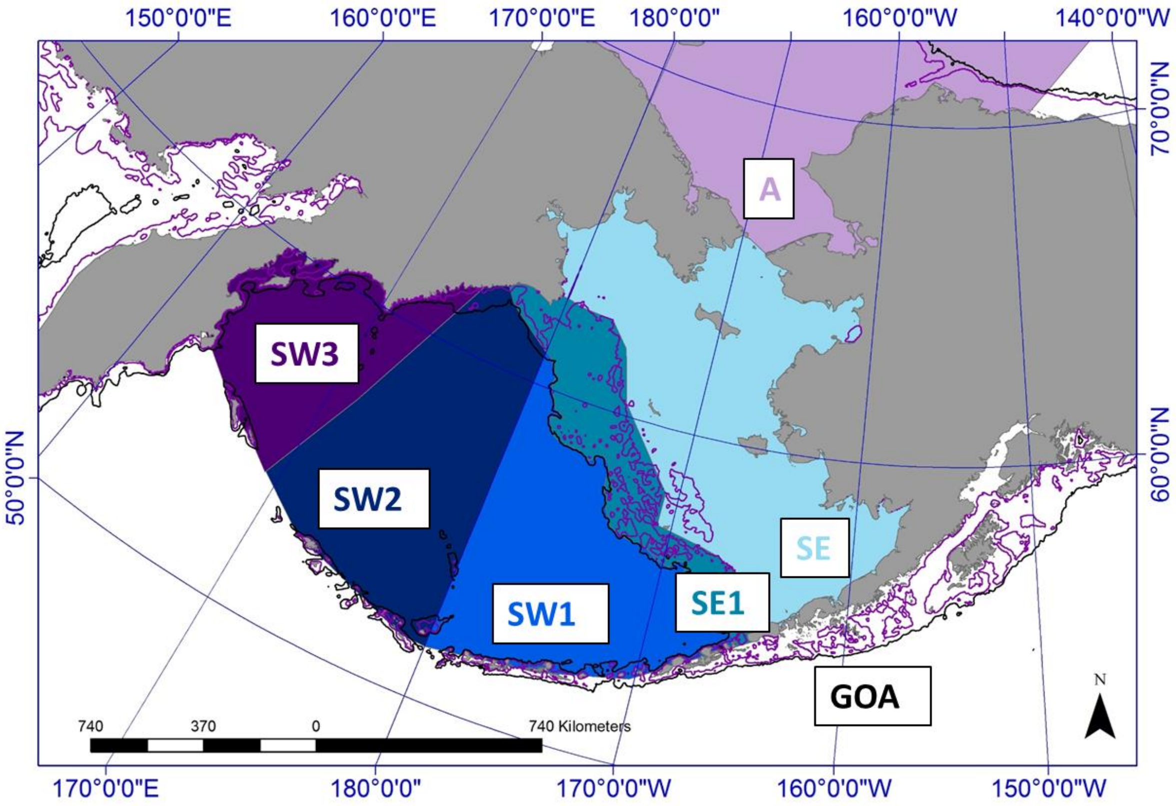
Pacific halibut connectivity: Gulf of Alaska & Bering Sea

Key questions

- Are there environmentally driven differences in dispersal?
- To what degree does the GOA spawning stock contribute to the Bering Sea settled population?



Divided the model domain into 7 regions:

GOA
SE
SE1
SW1
SW2
SW3
A

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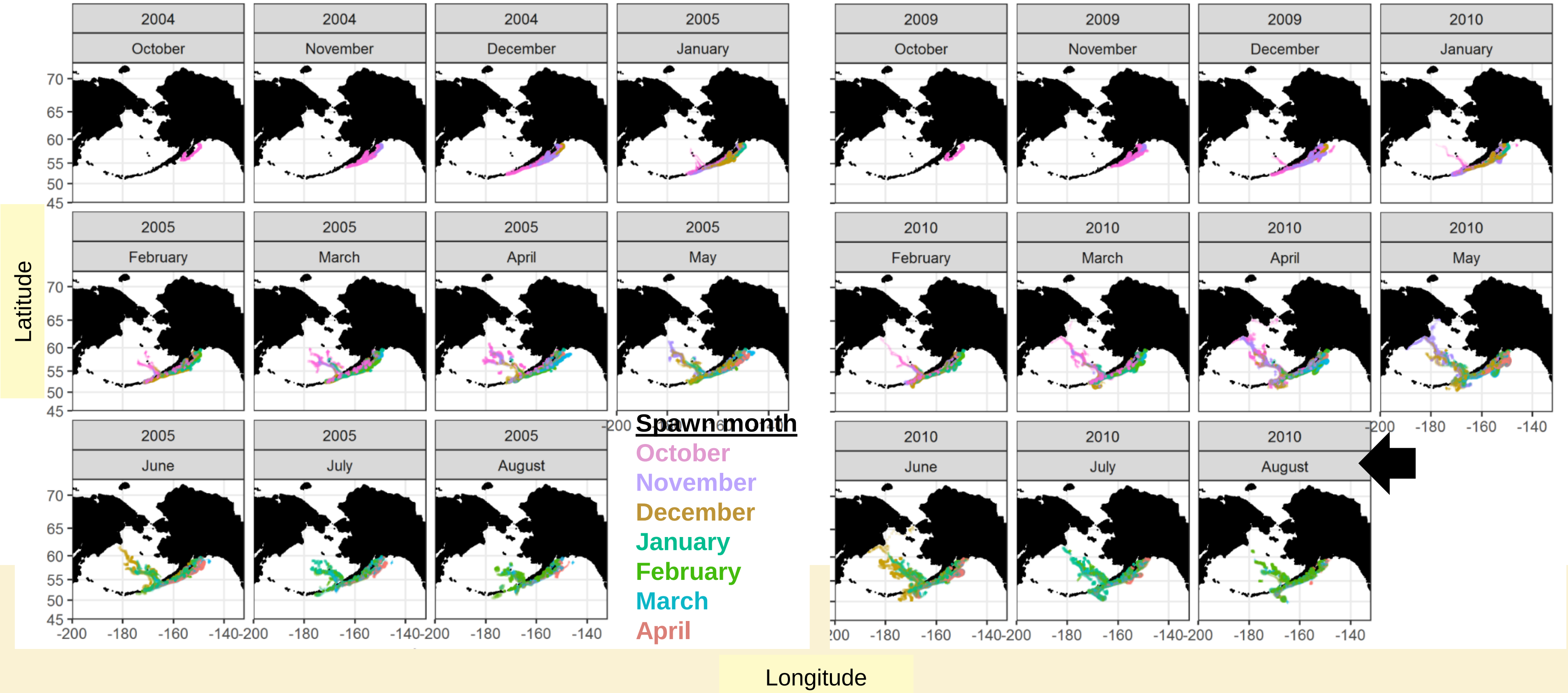
Pacific halibut connectivity: Gulf of Alaska & Bering Sea

Example output from larval migration model: Spawning region 3

2005 year class **2010 year class**



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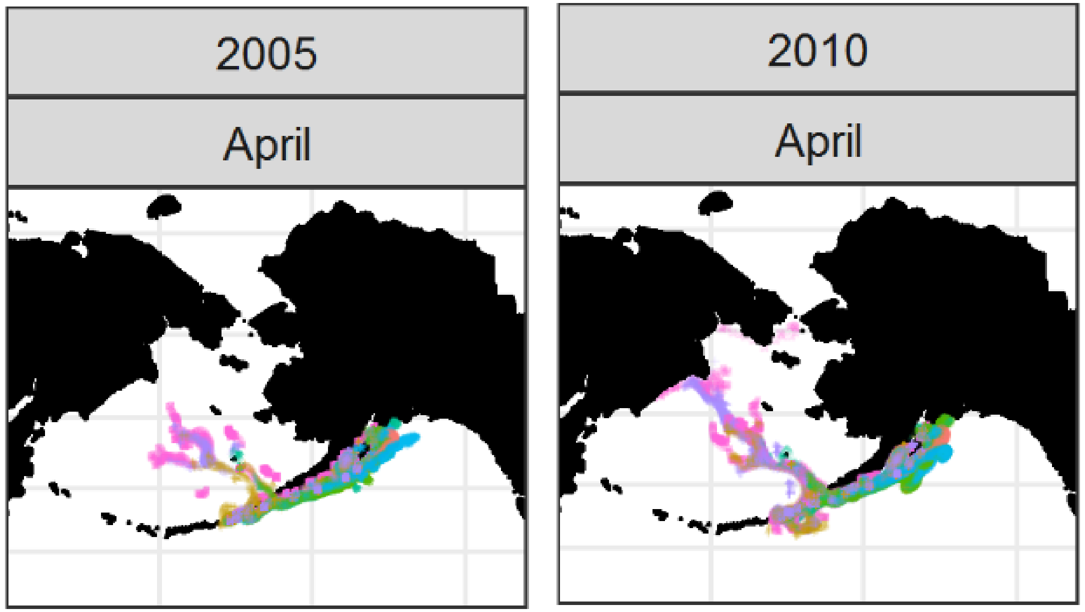
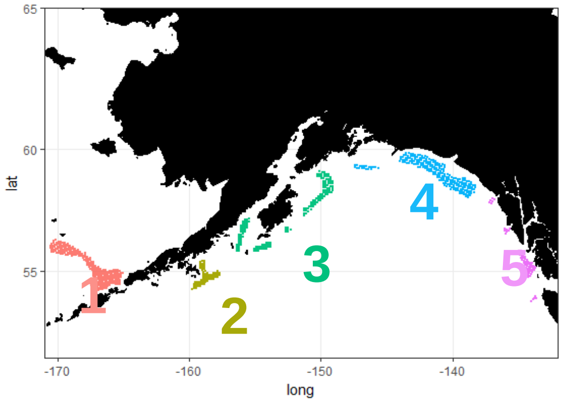
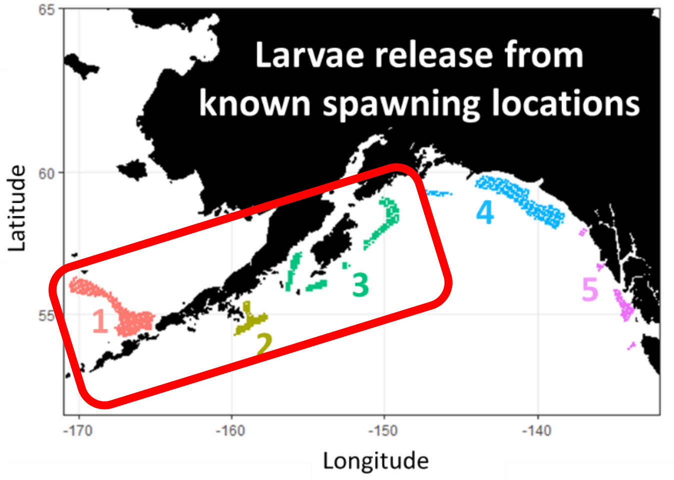
Pacific halibut connectivity: Gulf of Alaska & Bering Sea

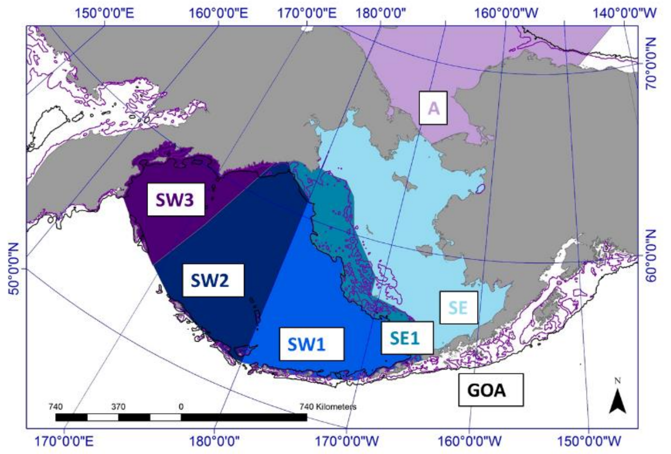
- Modeling shows inter-annual differences in northward transport

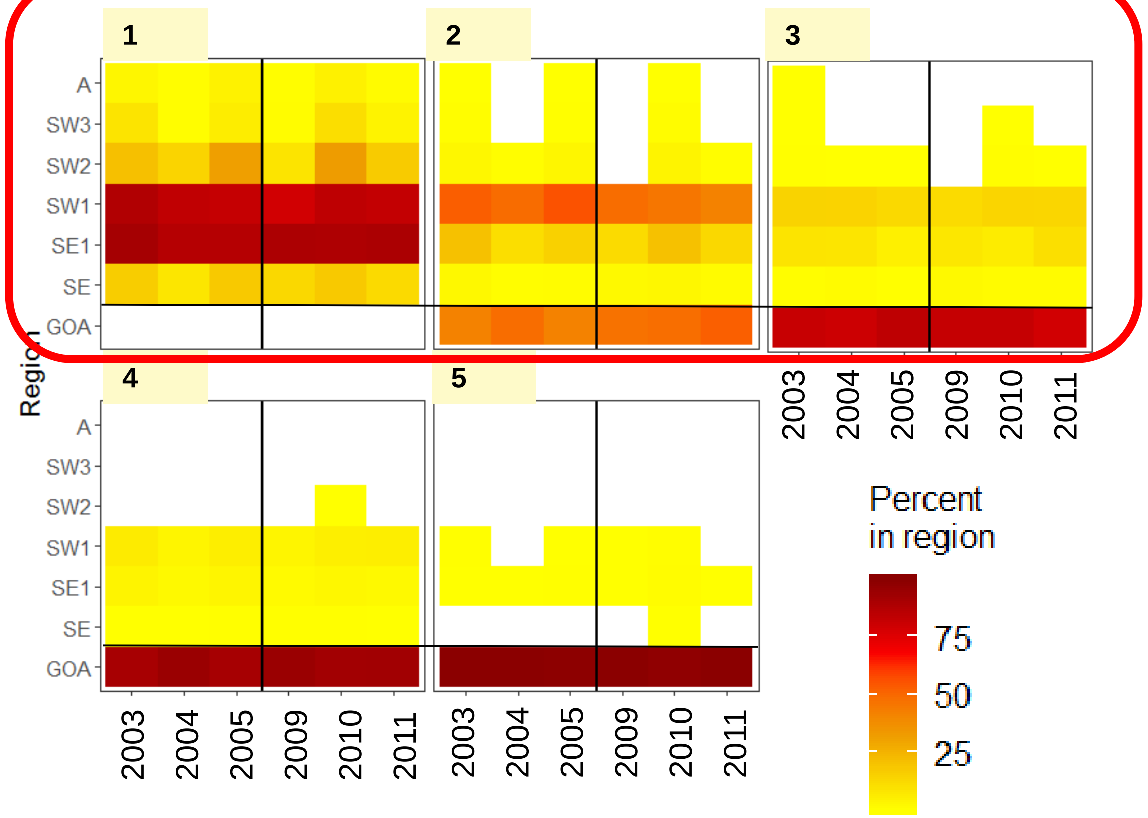




Pacific halibut connectivity: Gulf of Alaska & Bering Sea







Spawn regions 1, 2, and 3 contribute to Bering Sea settlement population

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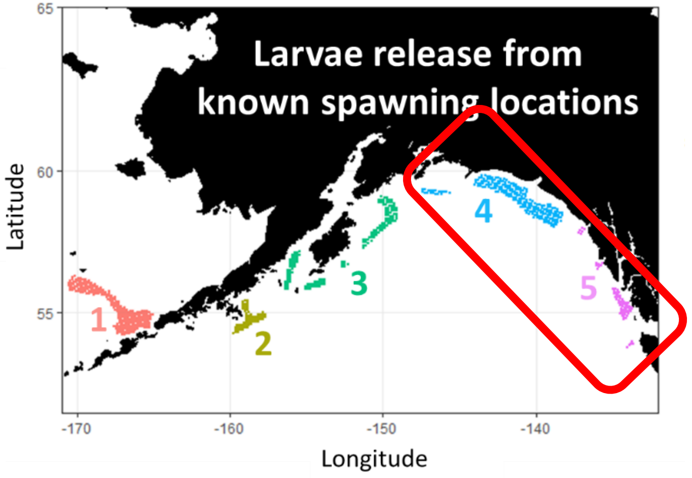
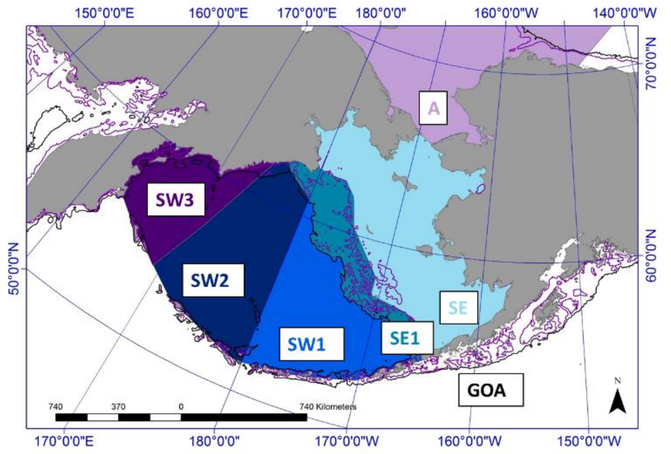
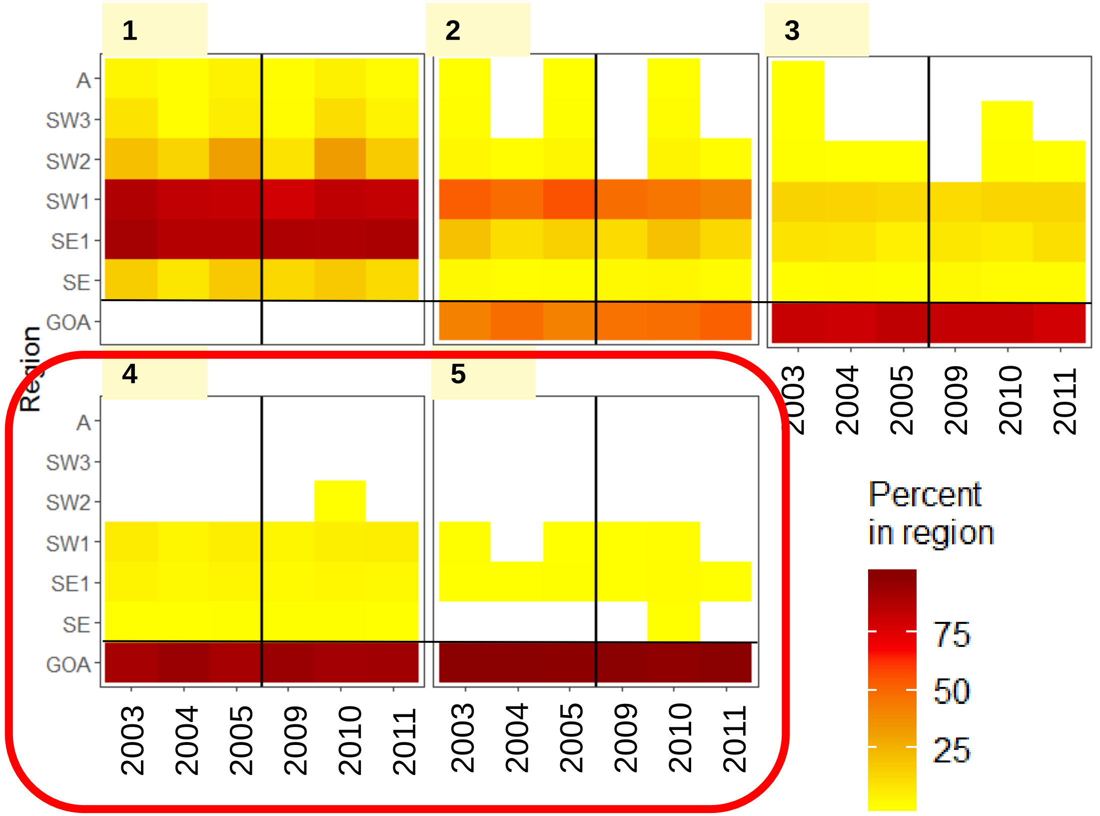
Pacific halibut connectivity: Gulf of Alaska & Bering Sea

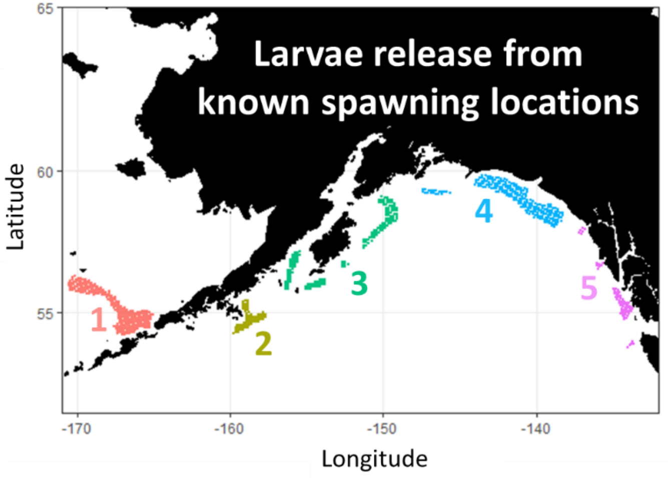


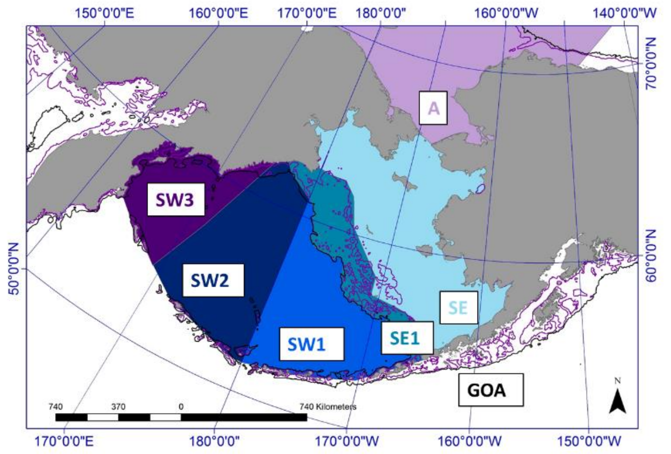


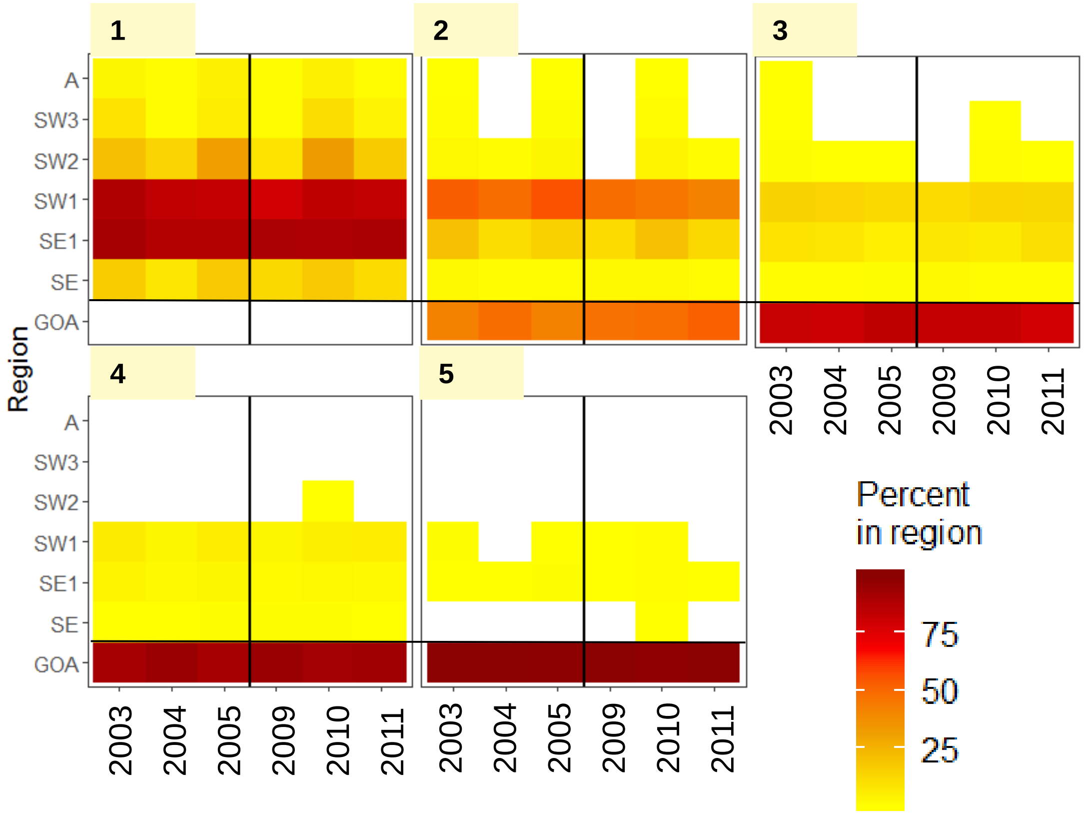


Spawn regions 4 and 5 contribute primarily to the Gulf of Alaska settlement population

Pacific halibut connectivity: Gulf of Alaska & Bering Sea







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

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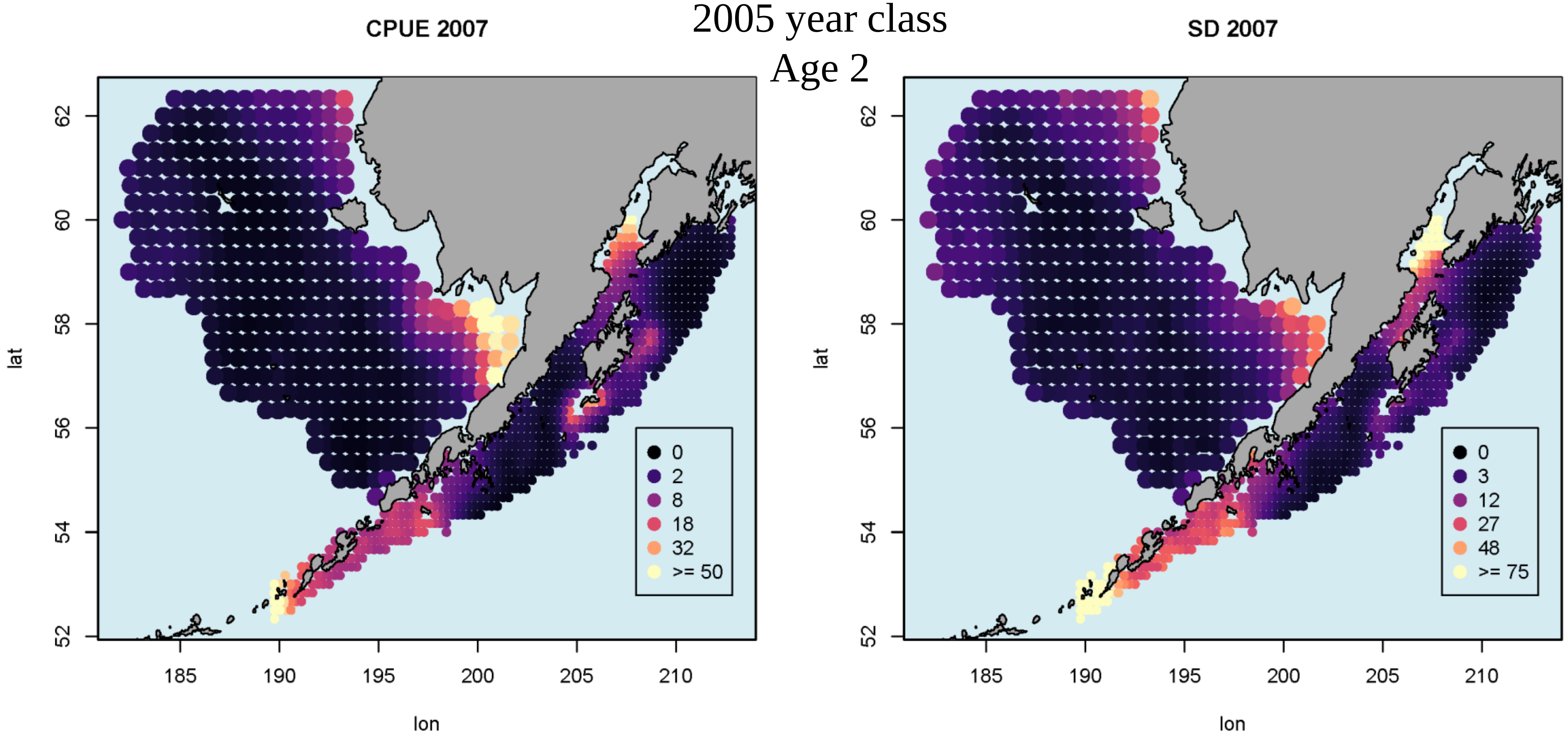
Pacific halibut connectivity: Gulf of Alaska & Bering Sea

And the story continues…

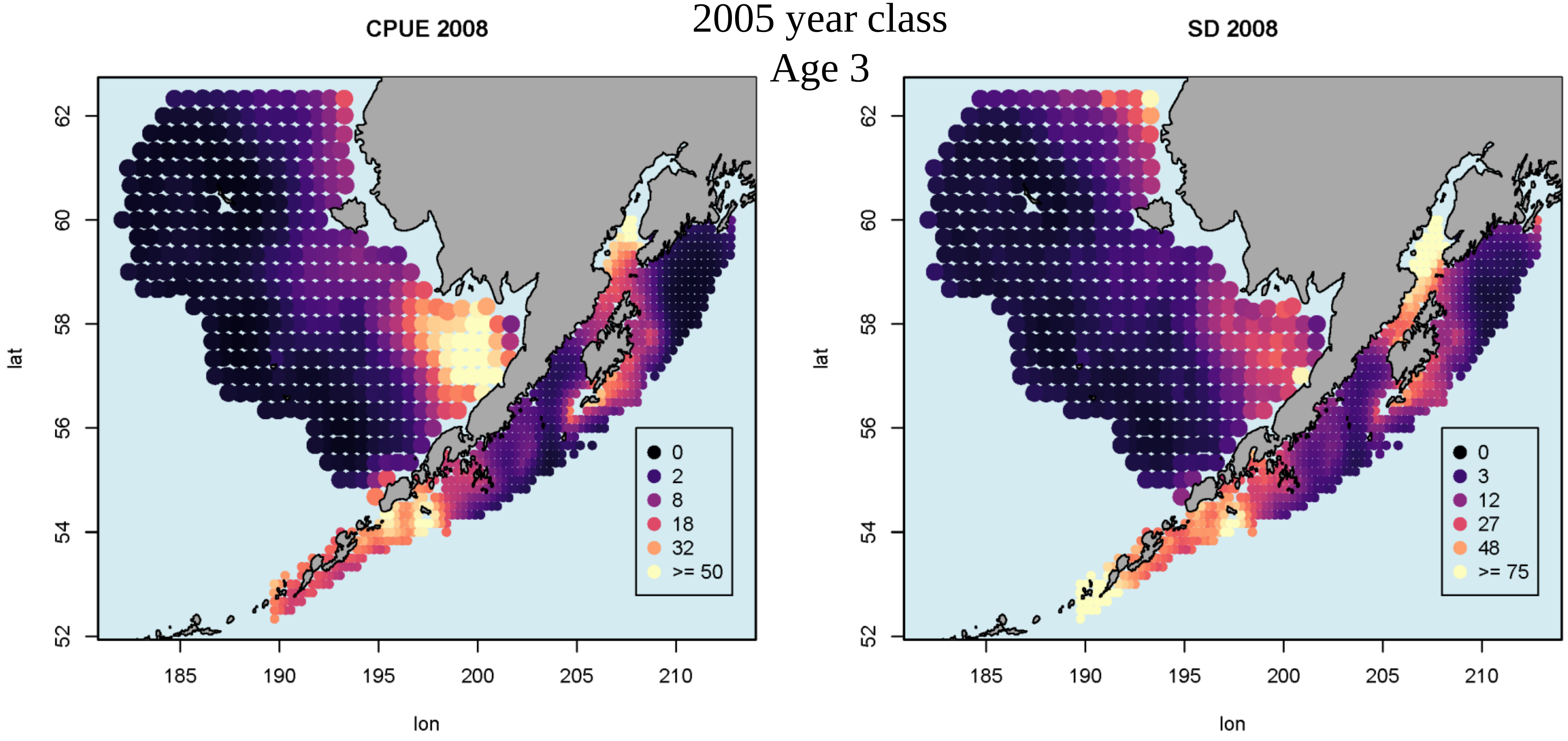
2005 year class
Age 2



Using the IPHC Spatial Model to map the distribution of a cohort
Example output of the 2005 year class

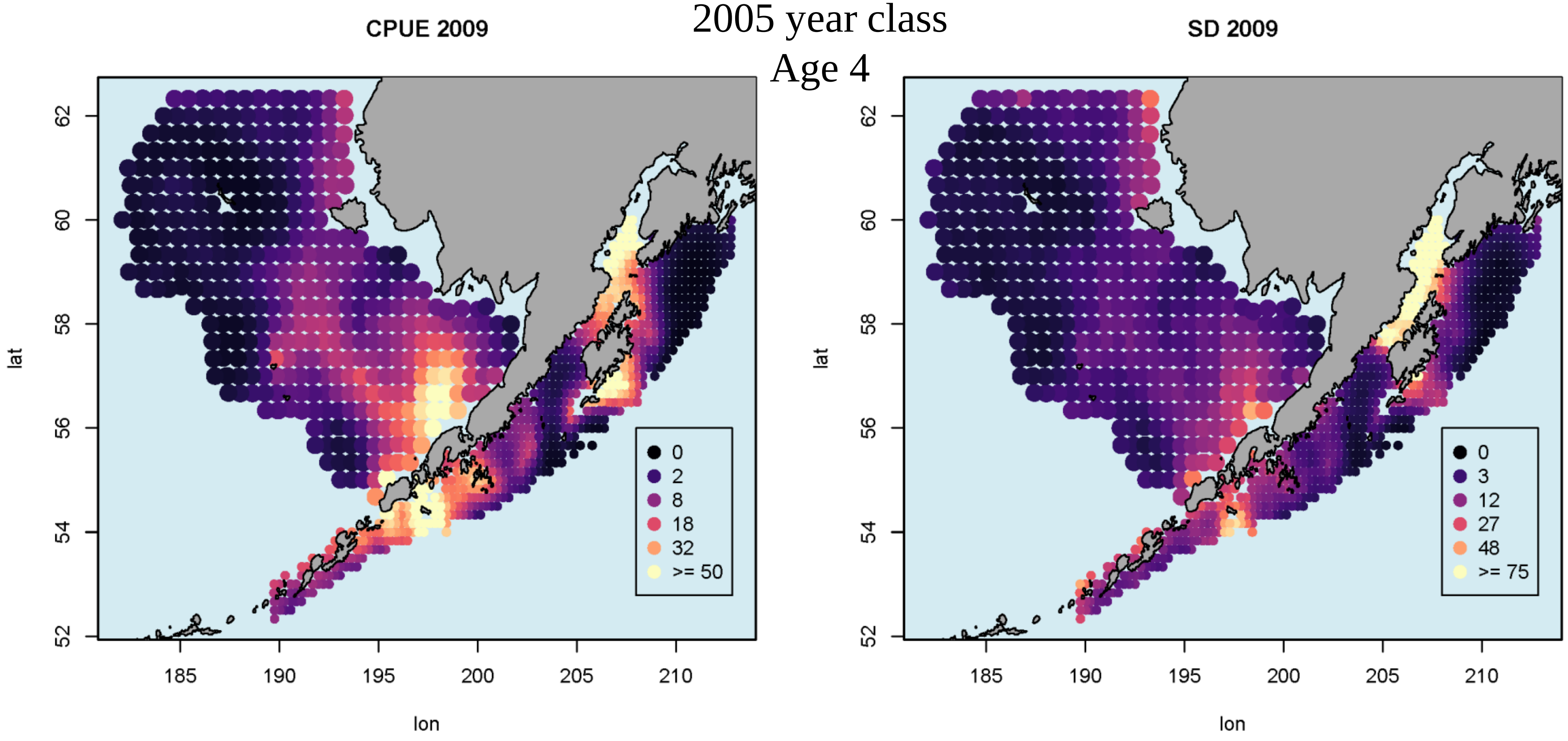
Pacific halibut connectivity: Gulf of Alaska & Bering Sea

2005 year class
Age 3



Pacific halibut connectivity: Gulf of Alaska & Bering Sea

2005 year class
Age 4



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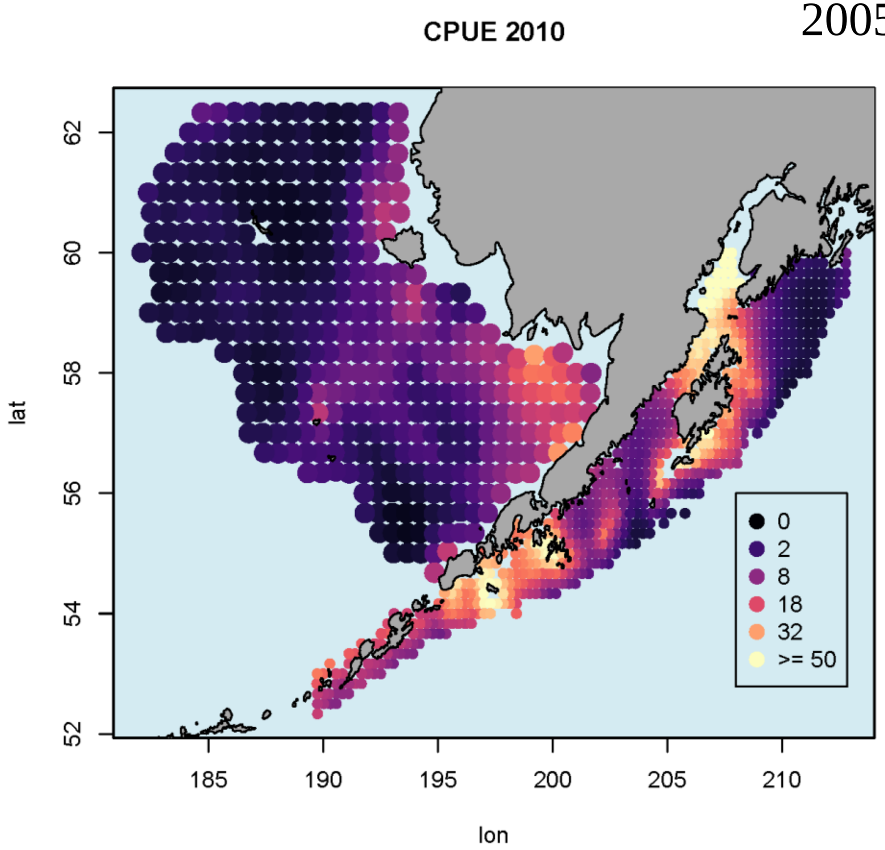
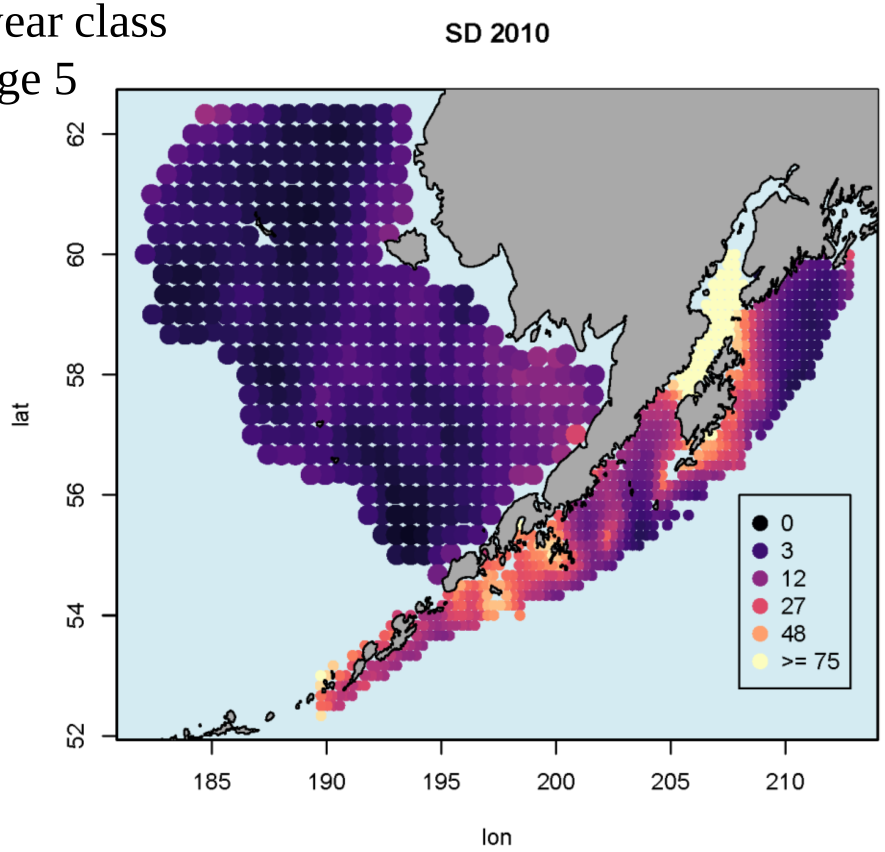
Pacific halibut connectivity: Gulf of Alaska & Bering Sea

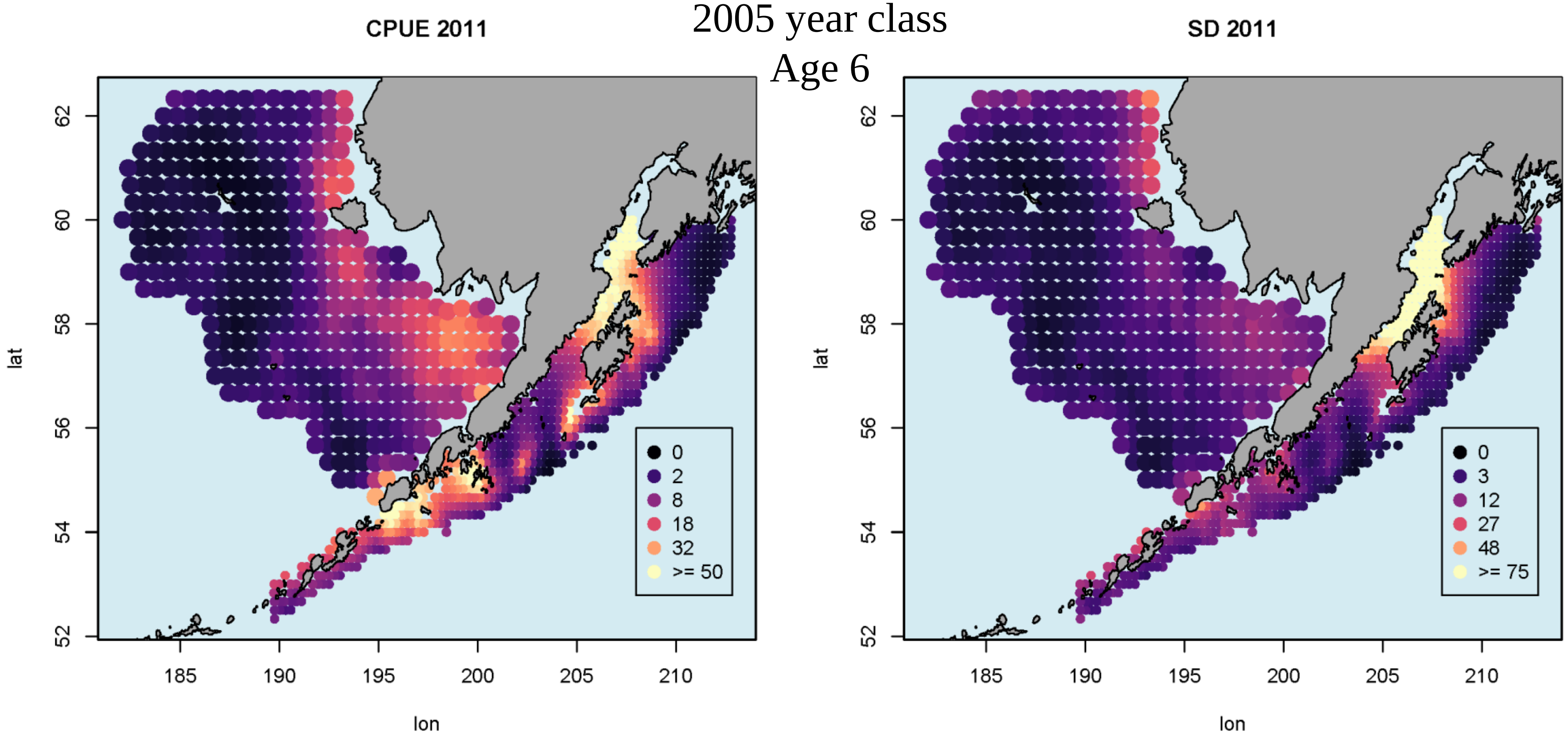
2005 year class
Age 5





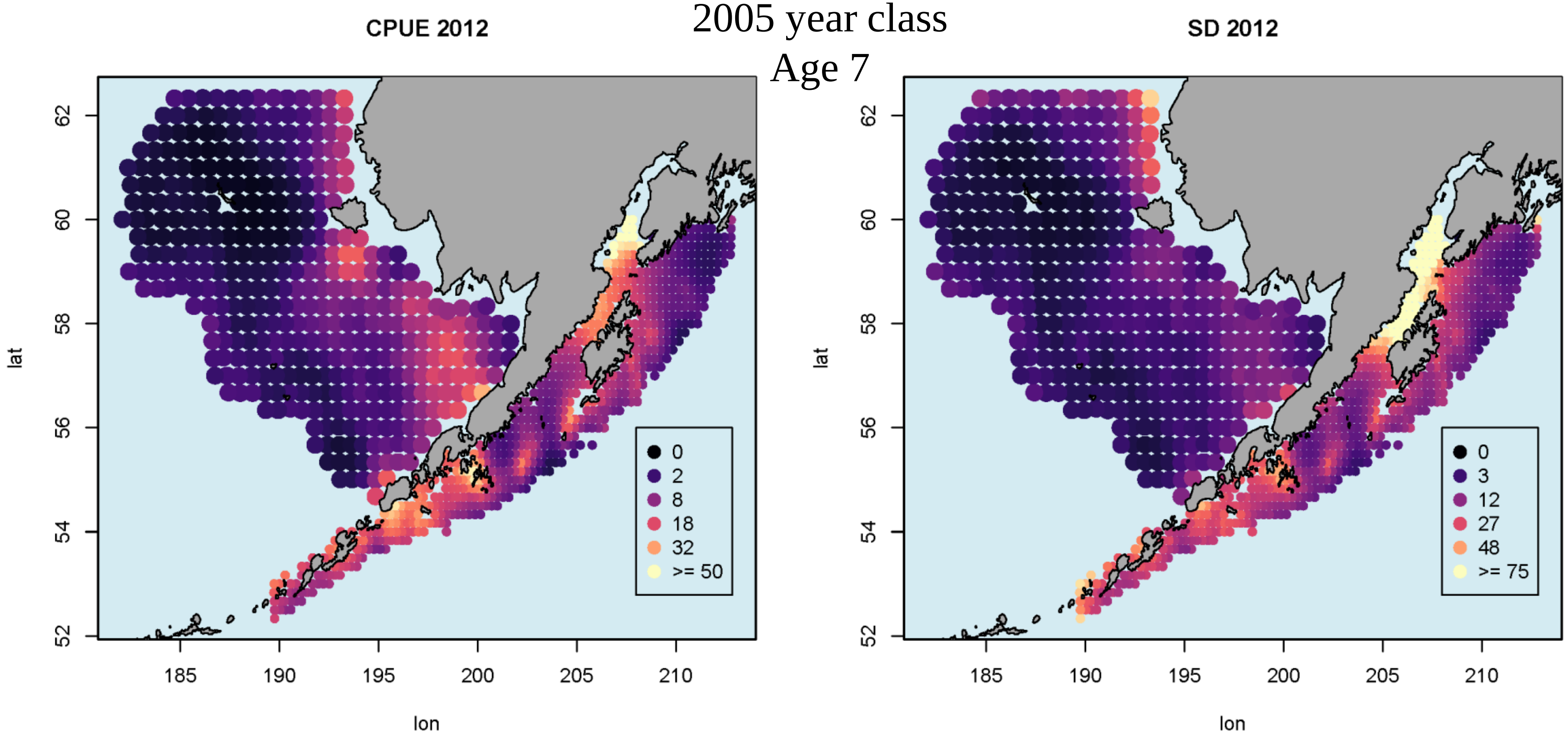
Pacific halibut connectivity: Gulf of Alaska & Bering Sea

2005 year class
Age 6



Pacific halibut connectivity: Gulf of Alaska & Bering Sea

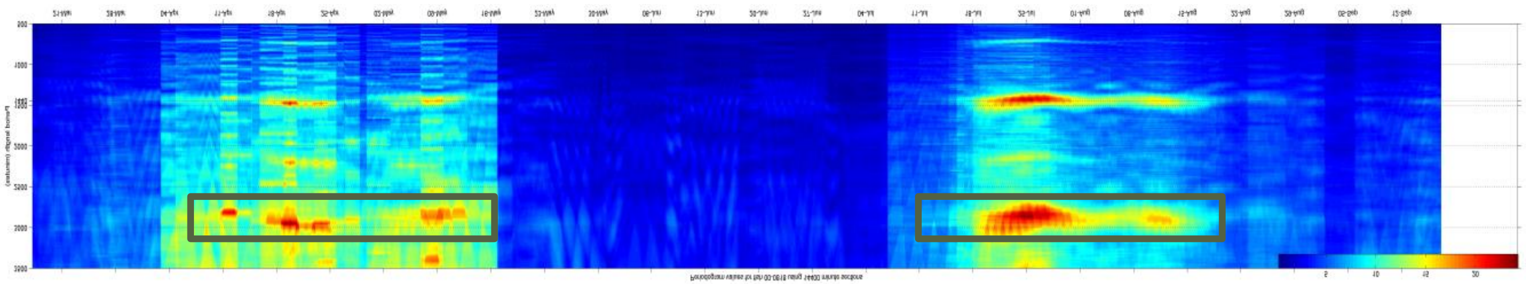
2005 year class
Age 7

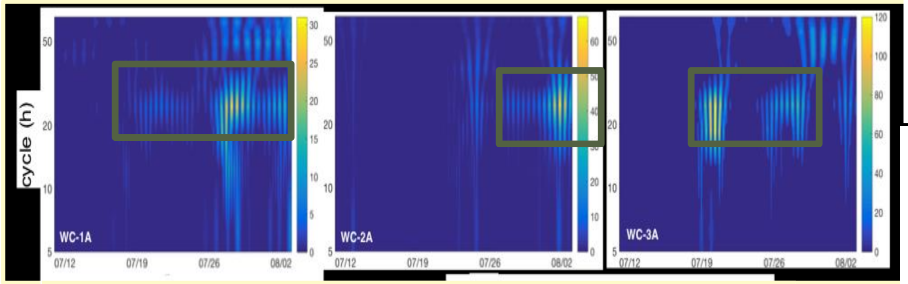


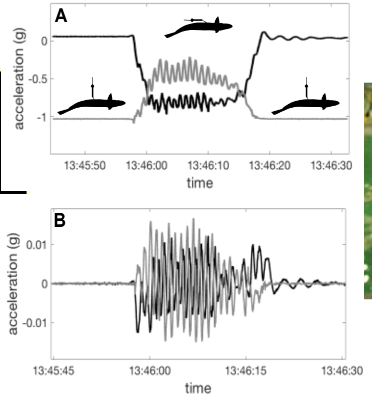
Results suggest active migration of young fish from the Bering Sea to the Gulf of Alaska counter to larval dispersal

Some major findings

From fine-scale analysis of depth and accelerometry (2012-2015)



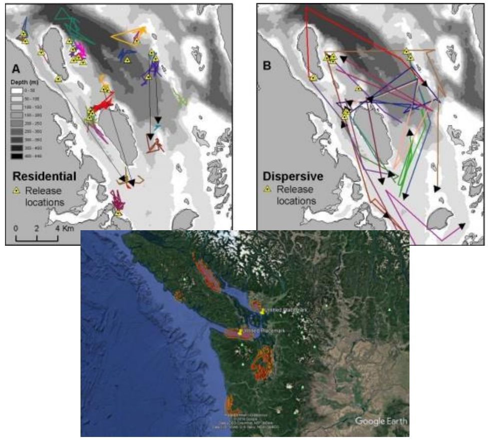


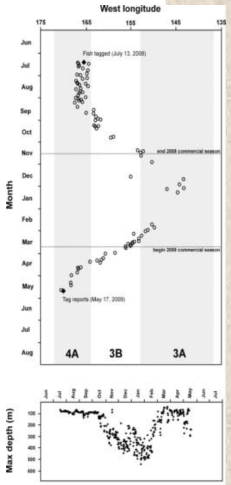


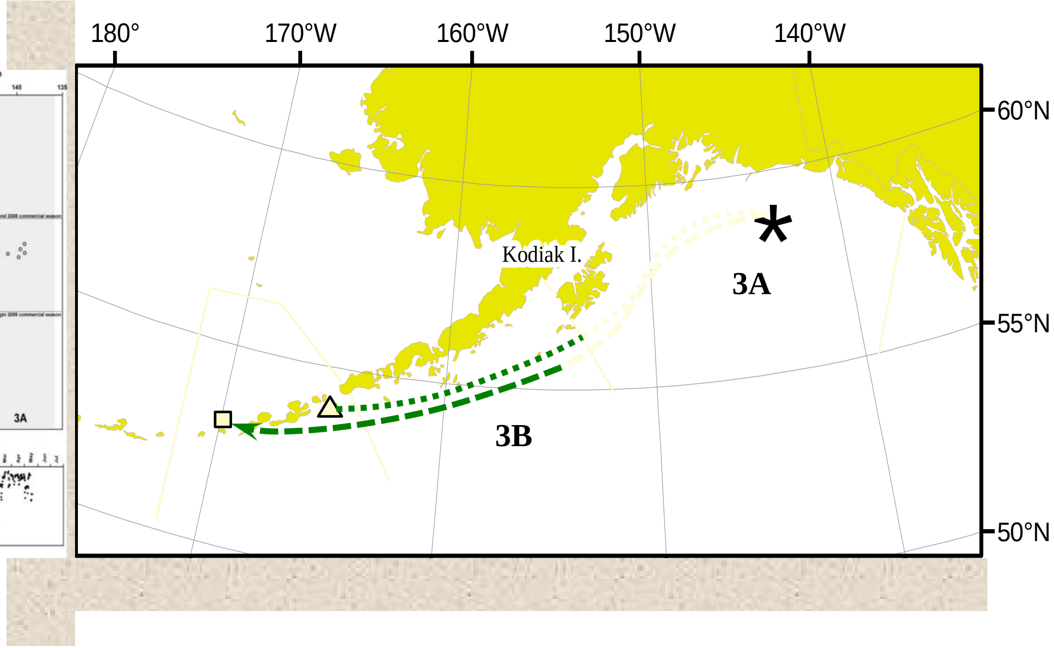
Quantification of diurnal and tidal activity, swimming speed, and *in situ* growth rates

Some major findings

From refinements of Hidden Markov Modelling (2014-2019)







A statistically-based method for tracking movements and modelling distributions

So, where do we go from here?

Philosophies of research planning

Ultimately, research planning and project selection can be viewed to exist along a continuum of planning horizons

- Using historical IPHC connectivity projects as an example:

Multi-decadal scale ⟷ **Annual scale**

Most of what we do falls somewhere in the middle

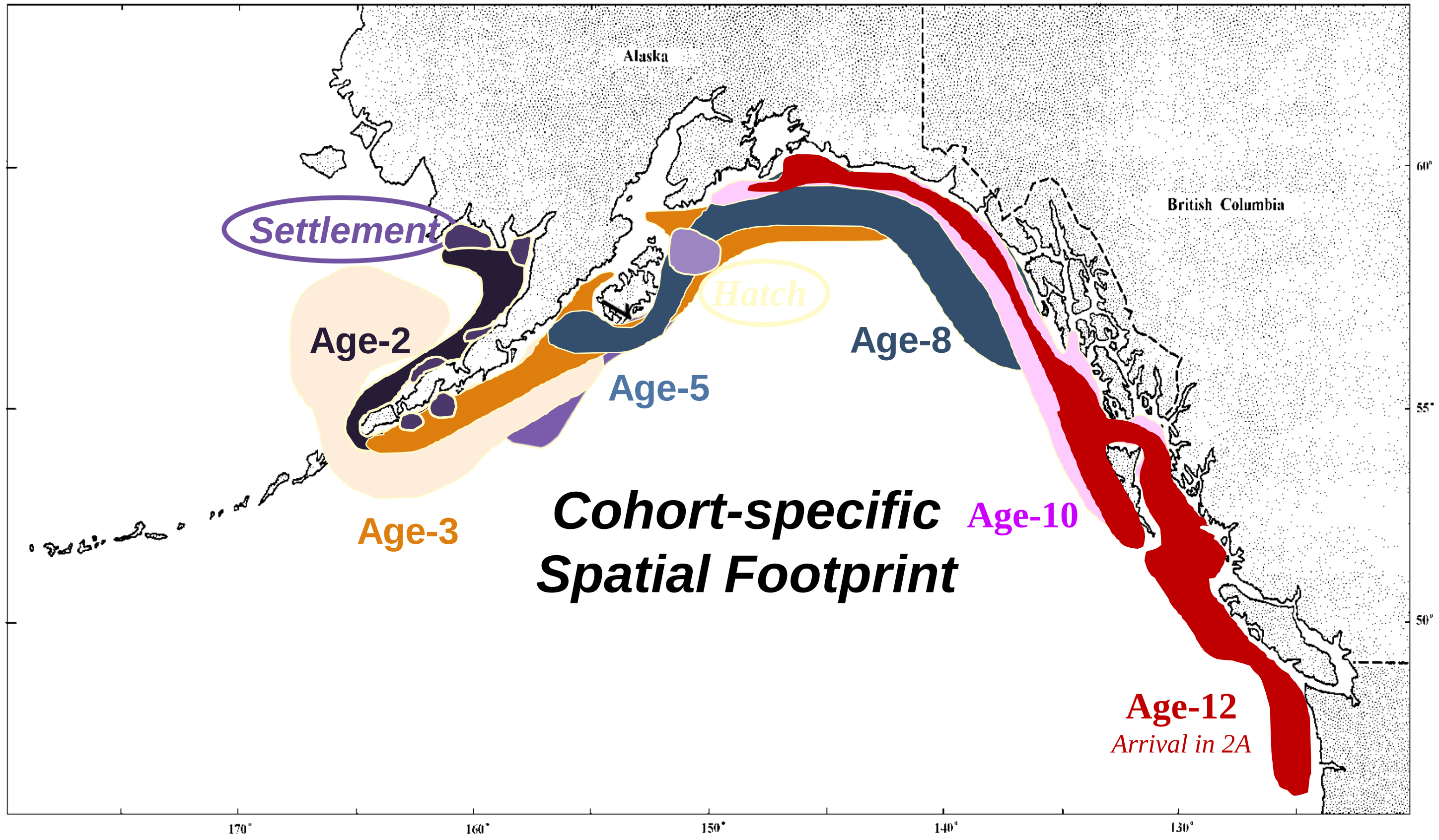
Multi-decadal scale	Annual scale
Far-reaching institutional objectives	*Immediate Constituency concerns*
Identify recruitment sources for all harvest sectors, quantify downstream mortality impacts, and resolve between long-term changes in migration versus spatial recruitment dynamics	**2A Tribes question whether the Southern Salish should be a separate Regulatory Area**
Juvenile otolith microchemistry (Proj. 620)	**Salish Sea PAT-tagging (Proj. 646.13)**

In this Planning Model I'll tend toward the left side: i.e., essentially decadal-scale

An operational question

What information/data would we need to model each step in the process?

- Example: spatial progression of a distinct source population



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A conceptual approach

What information/data would we need to model each step in the process?

- *A conceptual life-history model* allows us to identify elements

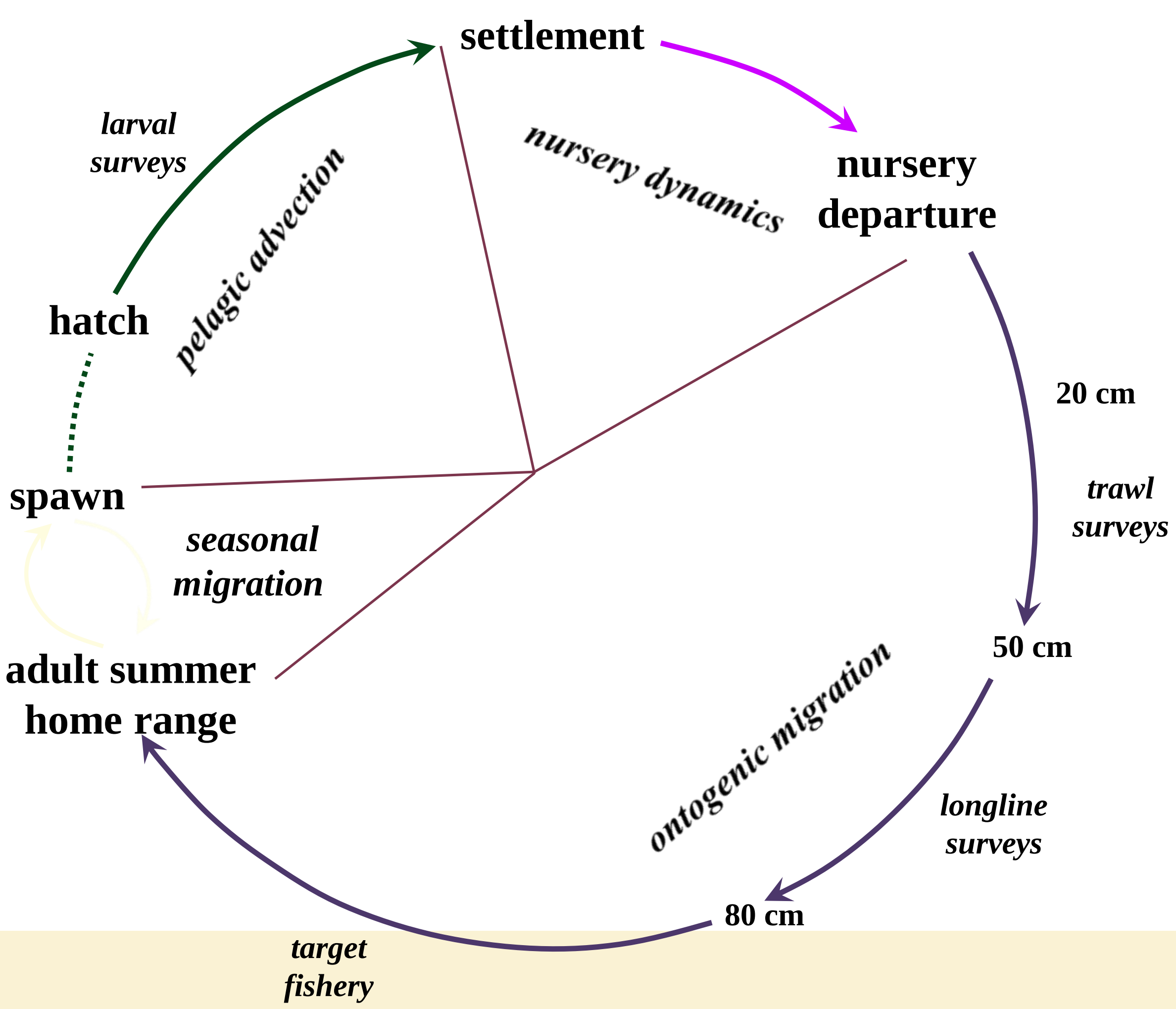
"Elements" will translate directly into individual research projects (= budgetary plans)

A conceptual approach

WARNING: this is about to metamorphose!

A connectivity-based life-history circle

… to follow an individual through time



A connectivity-based life-history circle

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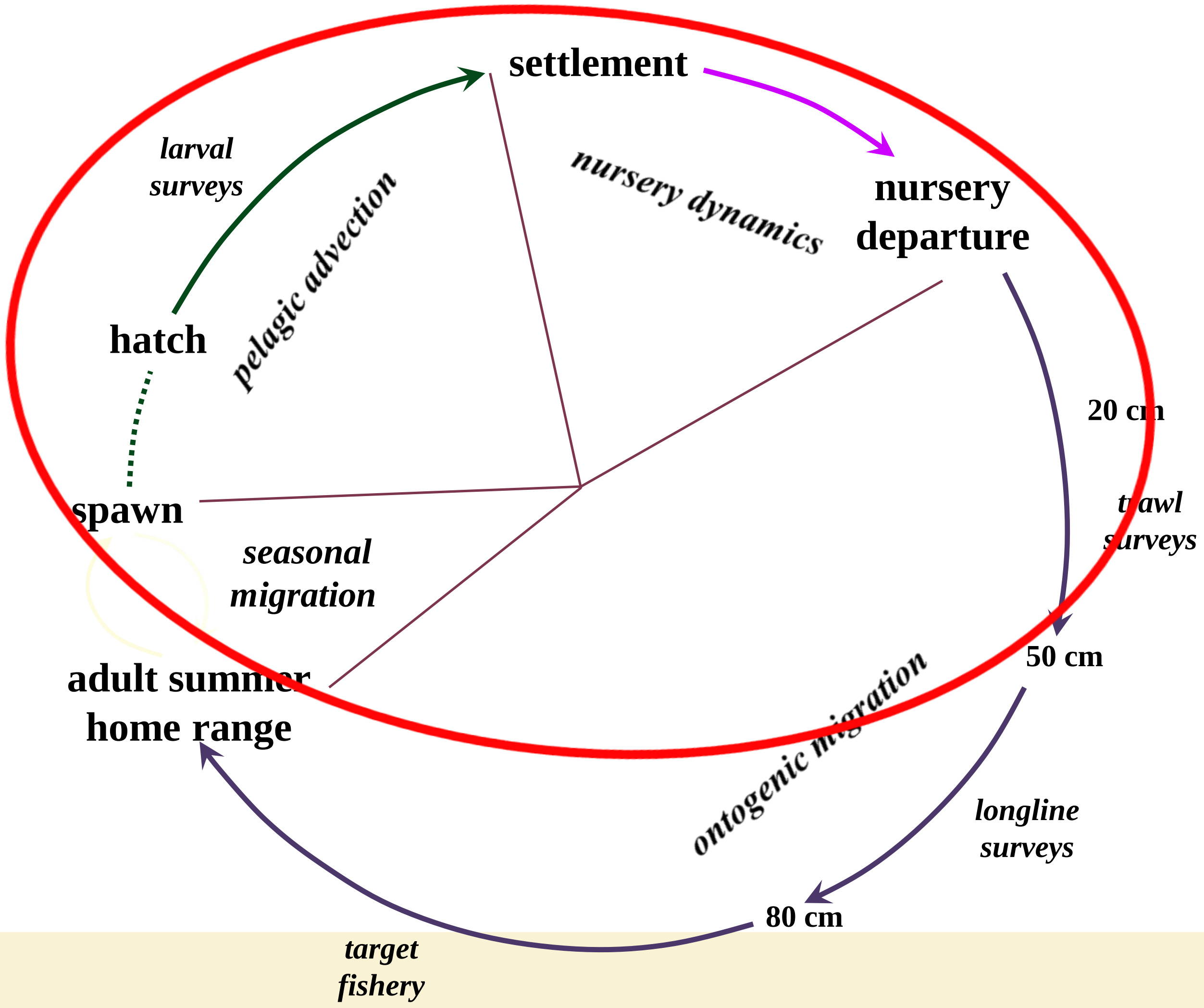
A connectivity-based life-history circle

What data are needed*: from egg release to appearance in surveys?



* to parameterize a spatially-explicit landscape ecology model

From life-history model to research planning

What data are needed*: from egg release to appearance in surveys?

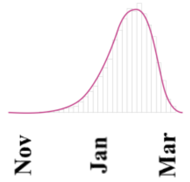
Step 1: Release (spawn) eggs

Locations

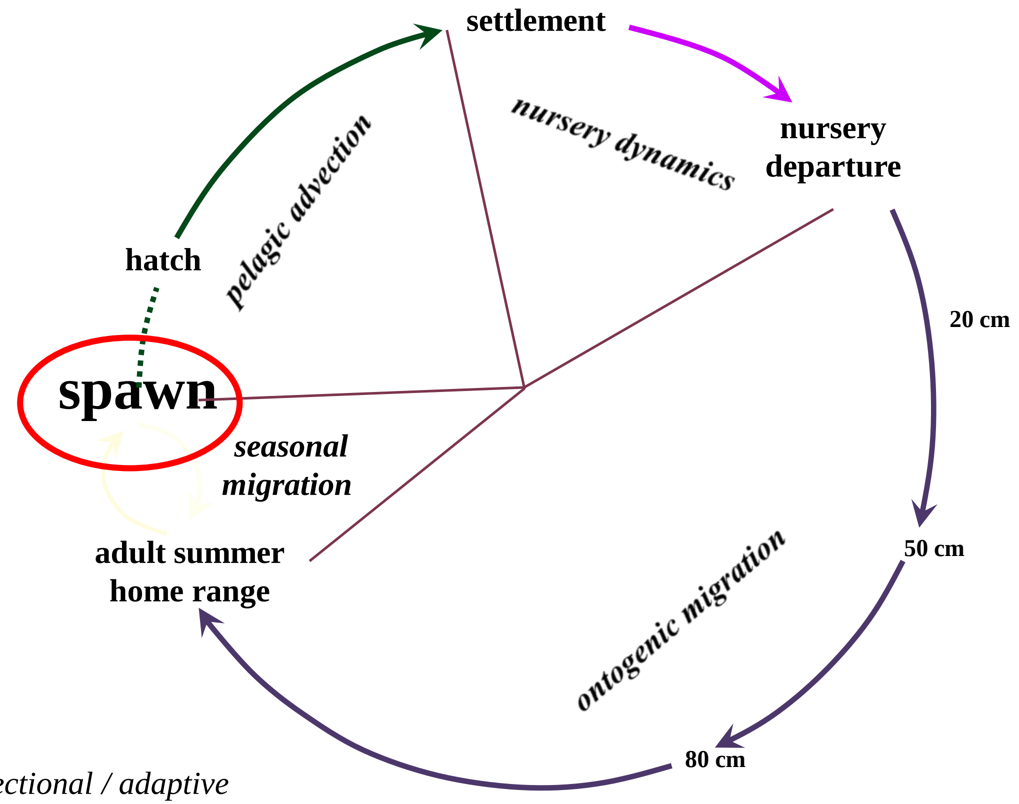
- latitude / longitude
- spatial extent (= initial larval-pool coverage)
- depth strata

Timing

- single-location, group-level distributions



- spatial variance (e.g., latitudinal trend?)
- temporal variance (e.g., climate change?)
  - *site fidelity vs. straying; random straying vs. directional / adaptive*



* to parameterize a spatially-explicit landscape ecology model

From life-history model to research planning

What data are needed*: from egg release to appearance in surveys?

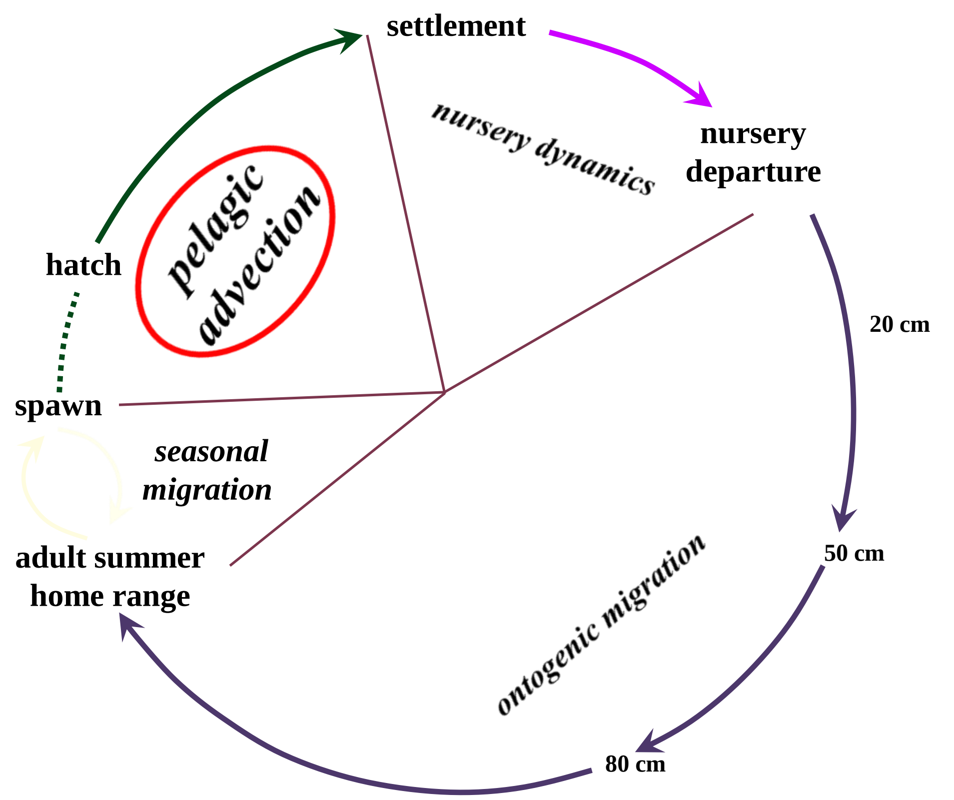
Step 2: Advect larvae

Physical-oceanographic forcing model

- collaborator with appropriate skills

Larval IBM

- developmental model: rates (e.g., degree-day formula); critical feeding periods; temperature / salinity tolerance; mean vertical position by stage
- vertical migration (DVM vs RDVM) & taxis
- swimming speeds / cues (e.g., auditory coastal orientation *sensu* reef fish)



* to parameterize a spatially-explicit landscape ecology model

From life-history model to research planning

What data are needed*: from egg release to appearance in surveys?

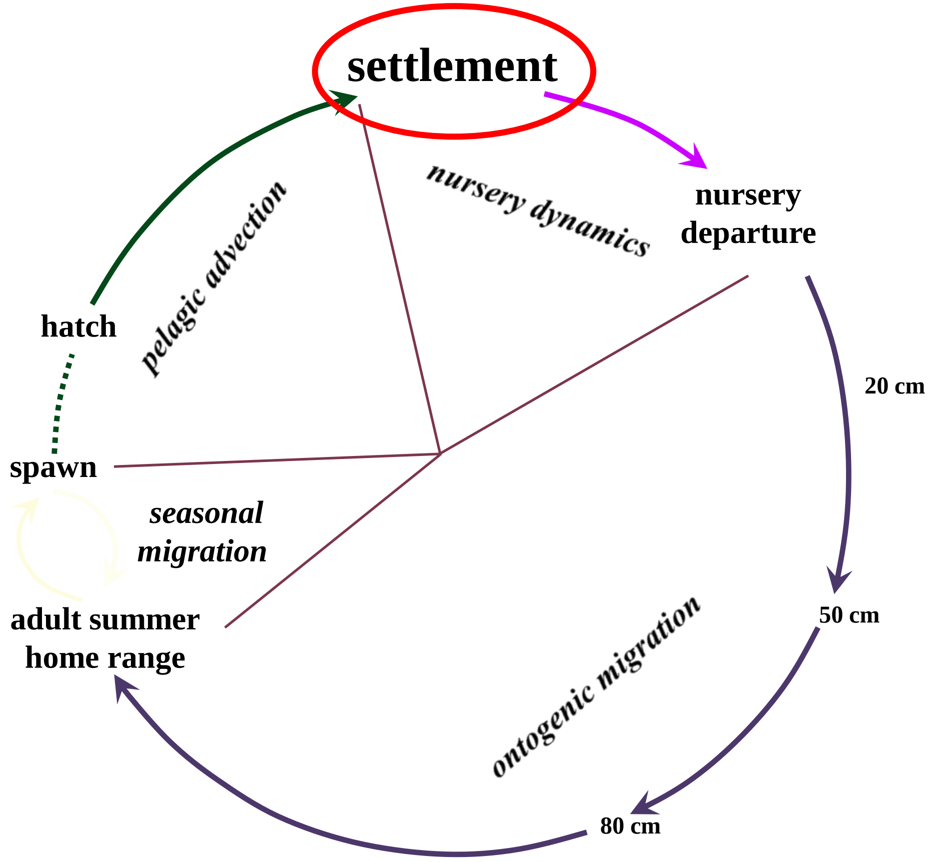
Step 3: Settle larvae

Larval IBM

- settlement preferences (habitat type)
- plastic larval duration (delayed settlement?)

Spatial benthic model

- habitat distribution



* to parameterize a spatially-explicit landscape ecology model

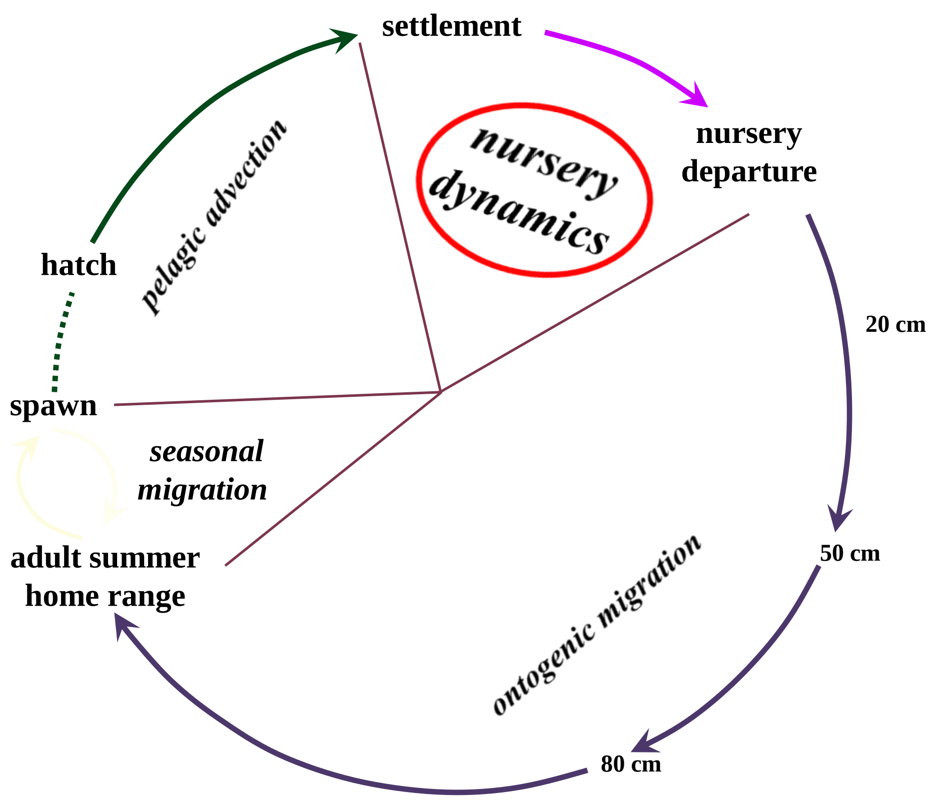
From life-history model to research planning

What data are needed*: from egg release to appearance in surveys?

<u>Step 4: Distribute settlers</u>

Spatial nursery-dynamic model

- early benthic dispersal kernels (magnitudes and forms; random vs. directed; density dependence)
- spatial attrition (mortality)
- emigration cues (developmental, environmental)



*** to parameterize a spatially-explicit landscape ecology model**

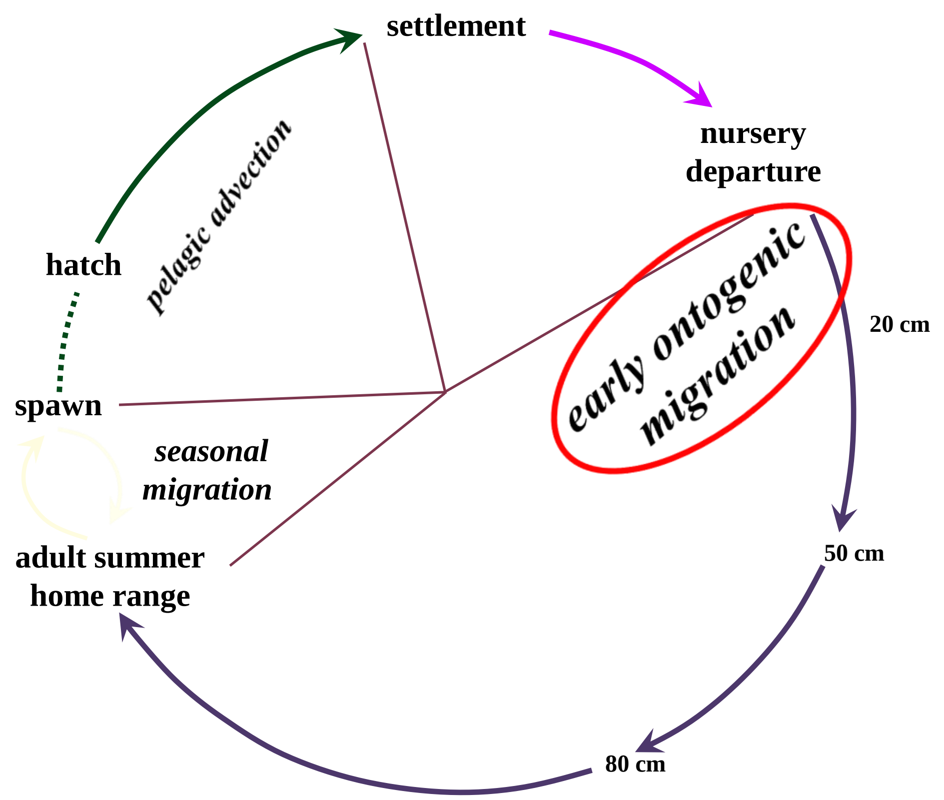
From life-history model to research planning

What data are needed*: from egg release to appearance in surveys?

<u>**Step 5: Grow and migrate emigrants**</u>

Early ontogenic movement

- dispersal kernels ~ages 2-4 (magnitudes and forms; random vs. directed; sex-specific?)



* to parameterize a spatially-explicit landscape ecology model

Translate data needs into discrete projects

For example:

ELEMENT I - Spawning dynamics

A) Summer-to-winter PAT tagging ***(continues Project #s 622, 622.11.84, 622.12, 621.15, 650.21)***

Work Summary*:

Deploy tags in Northern California; GOA Inside Waters; northeastern Bering Sea coastal waters and Navarin Canyon System

Primary Data Product(s):**

Spatial connectivity between feeding (fishing) grounds and functional spawning groups (SSB designations); especially, identification of spawning locations, depths, and coarse-scale spawn-timing

Management Application(s)*:**

- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds

**** Amenable to conversion into formal research proposals***

***** Can be expressed as Metadata summaries describing the variables to be quantified***

****** Noting that this category would ideally be populated by the Quantitative Sciences Branch***

Translate data needs into discrete projects

For example:

ELEMENT I - Spawning dynamics

B) Coastwide long-term archival tagging of spawning stock *(NEW)*

<u>Work Summary</u>:

Deploy fishery-recovery archival tags at strategic locations coastwide on mature stock

<u>Primary Data Product(s):</u>

Refined data on spawn timing; especially individual, latitudinal, and temporal variance in mean spawn timing and duration of the spawning season

<u>Management Application(s):</u>

- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds
- Estimation of seasonally-integrated biomass distribution

Translate data needs into discrete projects

For example:

ELEMENT II – Larval ecology

A) Larval development *(NEW)*

Work Summary:

Conduct larval rearing experiments investigating effects on development of temperature, salinity, and ration

Primary Data Product(s):

Degree-day, salinity, and ration-based developmental schedules/formulae

Management Application(s):

- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds
- Estimation of seasonally-integrated biomass distribution

Translate data needs into discrete projects

For example:

ELEMENT II – Larval ecology

B) Larval behavior: pelagic processes *(NEW)*

Work Summary:

Conduct larval swimming and taxis experiments

Primary Data Product(s):

Quantification of stage-specific swimming speeds and predictions of forcing-dependent vertical distribution

Management Application(s):

- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds
- Estimation of seasonally-integrated biomass distribution

Translate data needs into discrete projects

For example:

ELEMENT II – Larval ecology

C) Larval behavior: settlement processes *(NEW)*

Work Summary:
Continue larval rearing through settlement competence

Primary Data Product(s):
Quantification of physiological settlement window

Management Application(s):
- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds
- Estimation of seasonally-integrated biomass distribution

Translate data needs into discrete projects

For example:

ELEMENT II – Larval ecology

D) Numerical advection modelling ***(continues Duffy-Anderson/Goldstein analyses)***

Work Summary:

Conduct numerical advection analysis for unstudied regions and conditions (e.g., Aleutian Ridge; connectivity between US Bering shelf edge and Russian coast)

Primary Data Product(s):

Estimates of environmentally-governed connectivity distances and relative magnitudes

Management Application(s):

- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds
- Estimation of seasonally-integrated biomass distribution

Translate data needs into discrete projects

For example:

ELEMENT III – Early-benthic (settlement to ~age 2) dynamics

A) Theoretical habitat mapping *(NEW)*

Work Summary:

Examine nautical charts and habitat databases to produce maps of likely settlement distribution

Primary Data Product(s):

Estimates of regionally-explicit settlement (= recruitment source) potential

Management Application(s):

- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds
- Estimation of seasonally-integrated biomass distribution

Translate data needs into discrete projects

For example:

ELEMENT III – Early-benthic (settlement to ~age 2) dynamics

B) Field mapping and sample collection *(NEW)*

Work Summary:

Larval-collector and small-beam trawl surveys at selected settlement areas coastwide

Primary Data Product(s):

Quantification of pelagic larval duration and settlement period (via otolith increment analysis), and relationship between larval supply and relative settlement densities

Management Application(s):

- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds
- Estimation of seasonally-integrated biomass distribution

Translate data needs into discrete projects

For example:

ELEMENT III – Early-benthic (settlement to ~age 2) dynamics

C) Intrinsic dispersal and density-dependent processes *(NEW)*

Work Summary:

Within-year repeat sampling of representative settlement site(s) and translocation studies

Primary Data Product(s):

Estimates of post-settlement attrition (mortality), dispersion, and emigration timing

Management Application(s):

- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds
- Estimation of seasonally-integrated biomass distribution

Translate data needs into discrete projects

For example:

ELEMENT III – Early-benthic (settlement to ~age 2) dynamics

D) Otolith microchemistry as natural tags *(continues Project # 620)*

Work Summary:

Chemical and statistical analysis of otoliths collected under EIII-B

Primary Data Product(s):

Estimation of elemental spatial trending and robustness of elementally-based assignment to spurious errors due to spatial undersampling

Management Application(s):

- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds
- Estimation of seasonally-integrated biomass distribution

Translate data needs into discrete projects

For example:

ELEMENT IV – Early dispersive-phase (~ ages 2-5) processes

A) Early dispersal *(NEW)*

<u>Work Summary</u>:

Focused high-density archival and wire tagging at a single representative nursery source

<u>Primary Data Product(s):</u>

Age- and sex-specific dispersal/dispersion kernels

<u>Management Application(s):</u>

- Definition of Biological Regions
- Establishment of regionally-explicit spawning biomass thresholds
- Estimation of seasonally-integrated biomass distribution

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Translate data needs into discrete projects

Summary: this would define a early life-history Connectivity Research Program composed (11) discrete Projects nested into (4) life-history Elements:

ELEMENT I - Spawning dynamics

Summer-to-winter PAT tagging

Coastwide archival tagging of spawning stock

ELEMENT II – Larval ecology

Larval development

Pelagic-phase behavior

Larval settlement

Numerical advection modelling

ELEMENT III – Early-benthic dynamics

Theoretical habitat mapping

Field mapping and sample collection

Intrinsic dispersal and density-dependent processes

Otolith microchemistry

ELEMENT IV – Early dispersive-phase

Early dispersal

Migration-related topics of potential current interest

1) **Short-term migratory responses to hypoxic conditions**
   - Has bearing on the relationship between survey CPUE and underlying abundance
   - Might be investigated with acoustic tracking, displacement studies, and targeted collection of environmental data
2) **Experimental validation of regional isolation** (e.g., movement across Amchitka Pass)
   - Addressing stock structure, Bioregion, and Local Area Management concerns
   - Well-suited to acoustic gating studies
3) **Sex- and maturity-dependent seasonal redistribution and spawning dynamics** (e.g., migration pathways and spawning-ground-arrival timing)
   - Addresses concerns that winter fisheries could cause long-term demographic shifts
   - Amenable to fishery-recovery and pop-up archival tagging in conjunction with HMM
4) **Effects of climate change on stock on stock redistribution**
   - Addresses concerns regarding changes in total recruitment (long-term yield), regional productivity (quota shifts), and spatial bycatch impacts
   - Invokes studies on larval delivery, settlement patterns, and long-term migration

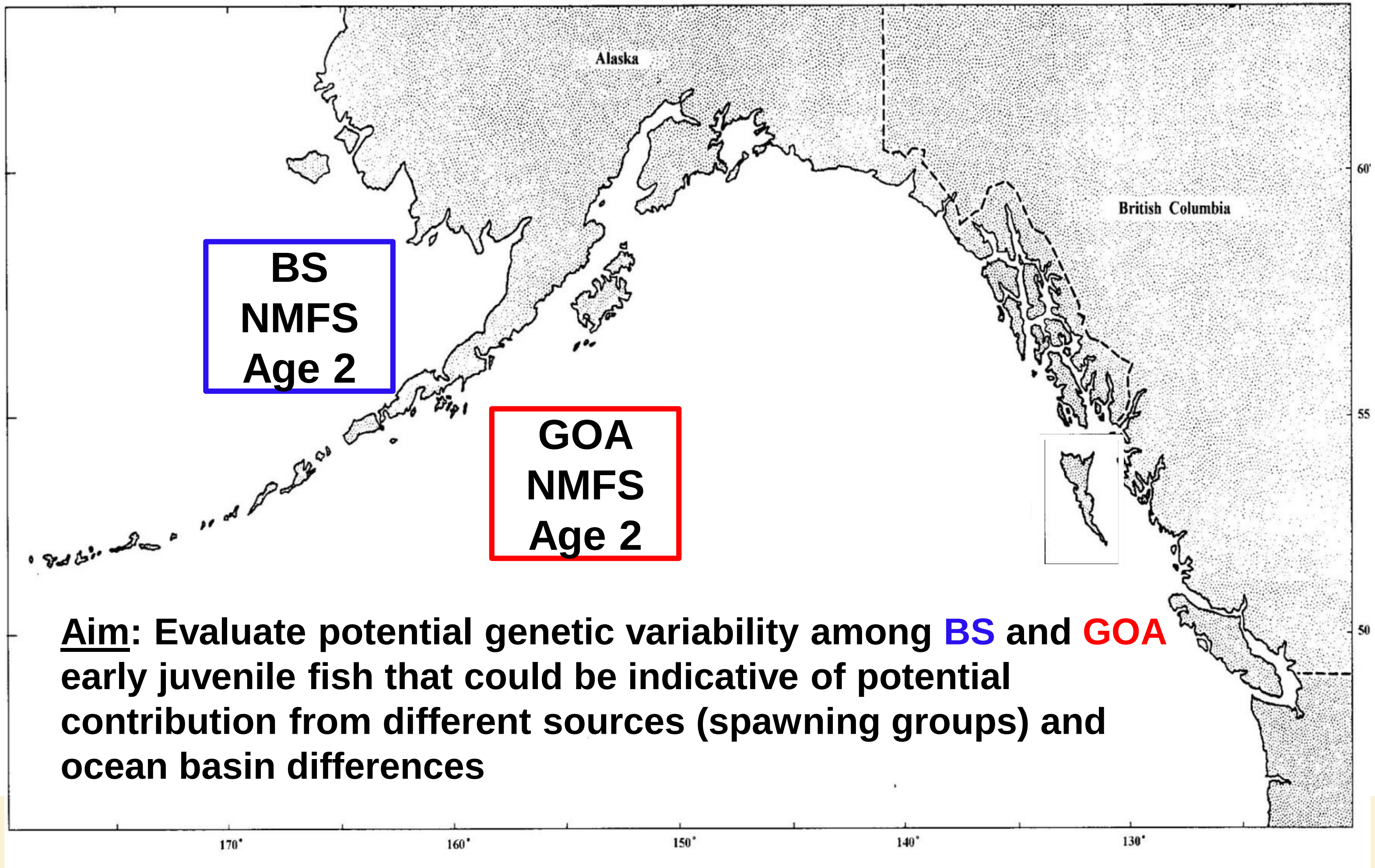
Incorporation of genetics into migration-related research

Initial projects:

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

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 early juvenile fish that could be indicative of potential contribution from different sources (spawning groups) and ocean basin differences

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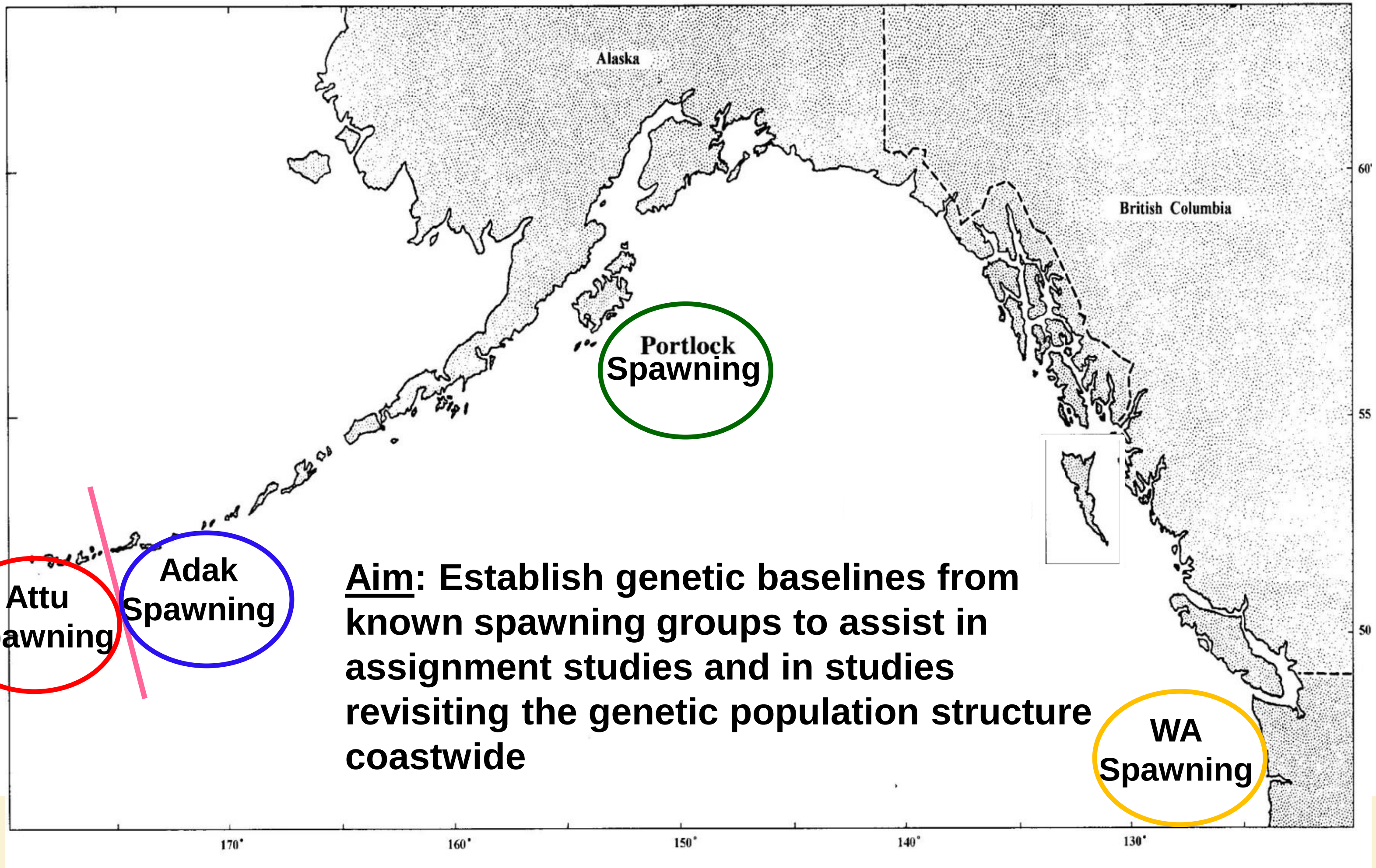
Incorporation of genetics into migration-related research

- **Identification of potential genetic signatures of origin (spawning groups)**



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