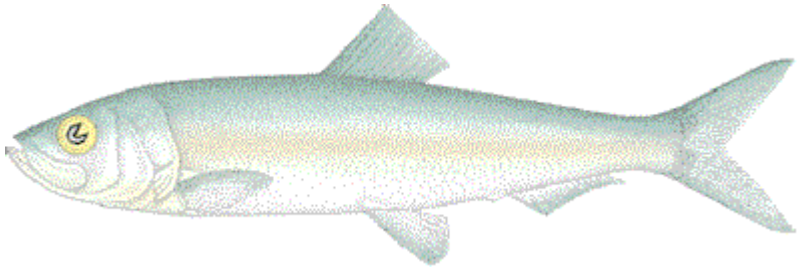
Pacific Herring

Stakeholder Engagement in Stock Assessment & Management Strategy Evaluation Processes



November 2023

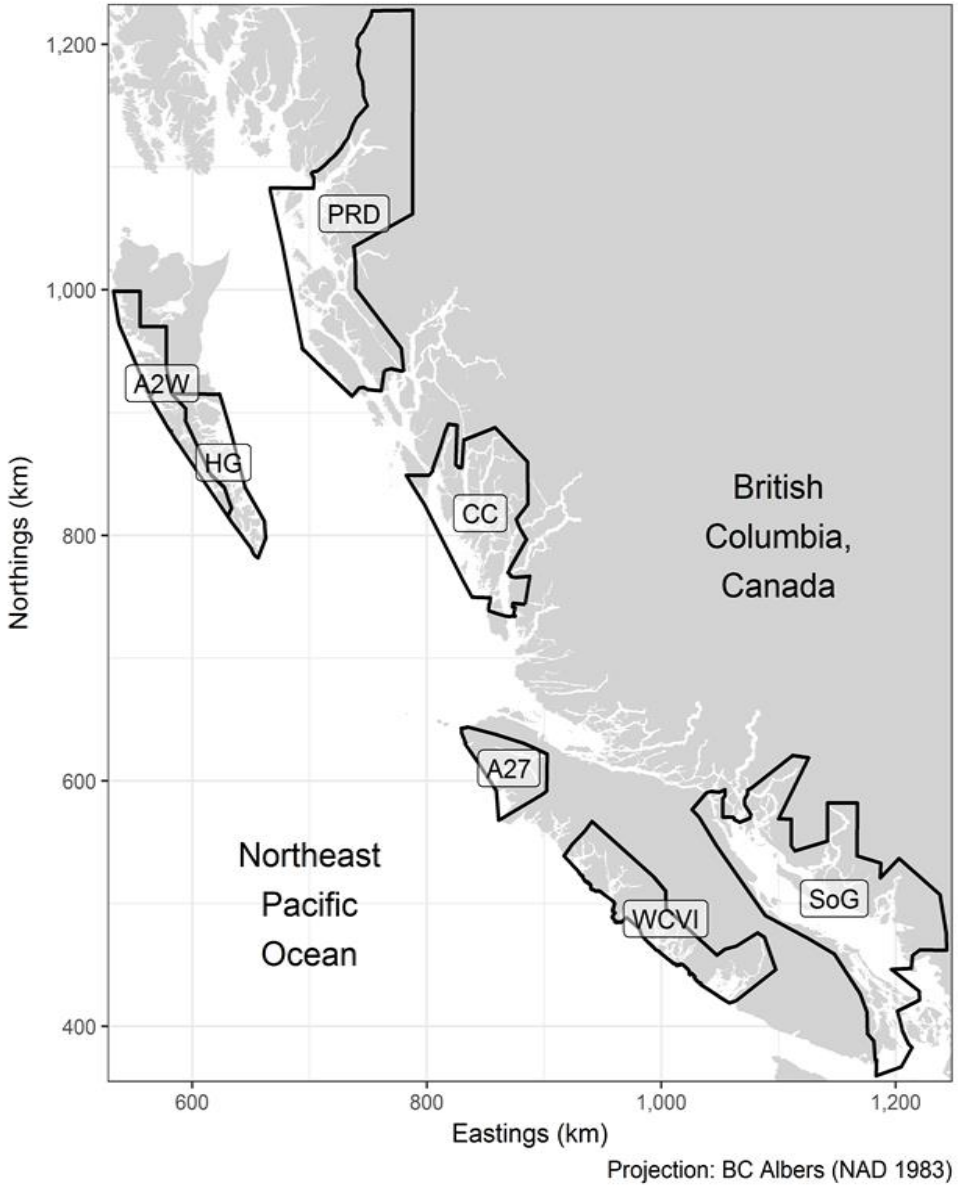
TESA Small Pelagics Workshop
Presenters: Sarah Hawkshaw and Jaclyn Cleary

Outline

- Background
- Stock assessment
  - Survey and data sources
  - Statistical catch at age model
  - Assumptions/uncertainties
- Development of reference points (LRP/USR)
- Management Strategy Evaluation
- Engagement with Indigenous peoples, two project examples
  - West coast of Vancouver Island
  - Haida Gwaii
- Successes and challenges

Background

- Pacific Herring in BC are assessed and managed as 5 major and 2 minor stock assessment regions (SARs)
- Major SARs:
  - Strait of Georgia (SoG), West Coast of Vancouver Island (WCVI), Central Coast (CC), Prince Rupert District (PRD), and Haida Gwaii (HG)
  - Status is determined using a formal statistical catch age analysis with 1-yr forecasts
  - Harvest advice provided using management procedures that have been evaluated through a management strategy evaluation (MSE) process
- Minor SARs:
  - Area 27 (A27) and Area 2 west (A2W)
  - Status is monitored using catch data, biological data, and spawn survey index, when available

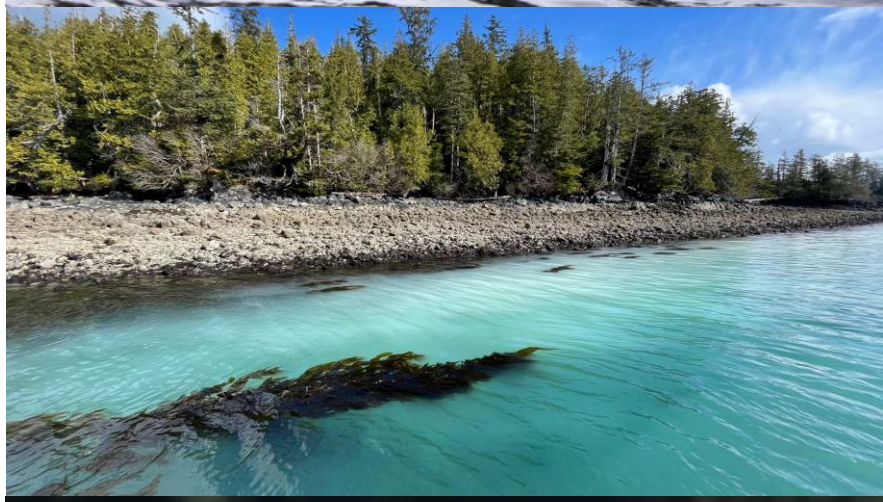


Background

- **Seasonal migratory behavior** in large schooling aggregations.
- **Early age of maturity** (age 2-4) and **high rates of intrinsic population growth** making them more resilient to large mortality events.
- **Annual spawning** (typically spring, varies between area) in key intertidal and shallow subtidal coastal waters on kelp and other seaweeds, eelgrass, bedrock and other bottom substrates.
- Juvenile winter movements and distribution **largely unknown** until they return to spawn.
- Evidence for **migratory and non-migratory** life history strategies.
- **Potential evidence** of finer-scale genetic structure based on spawn timing and geographic separation.
- **Important forage species** for seabirds, other fishes and marine mammals

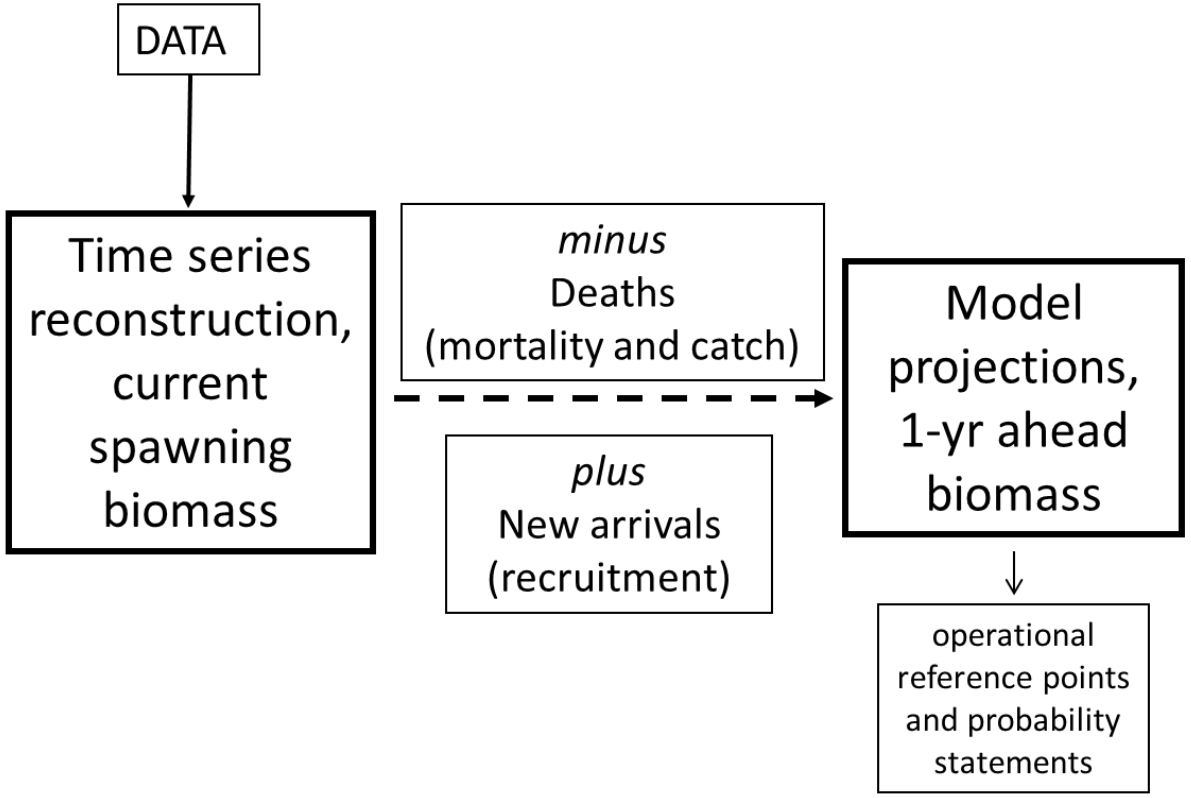
Stock Assessment

- Monitoring, survey and data collection
  - Annual data collection
  - Fisheries catch data
  - Overflights identify areas of spawn
  - Dive and surface surveys to measure spawn deposition
  - Seine test fishing to collect biological samples



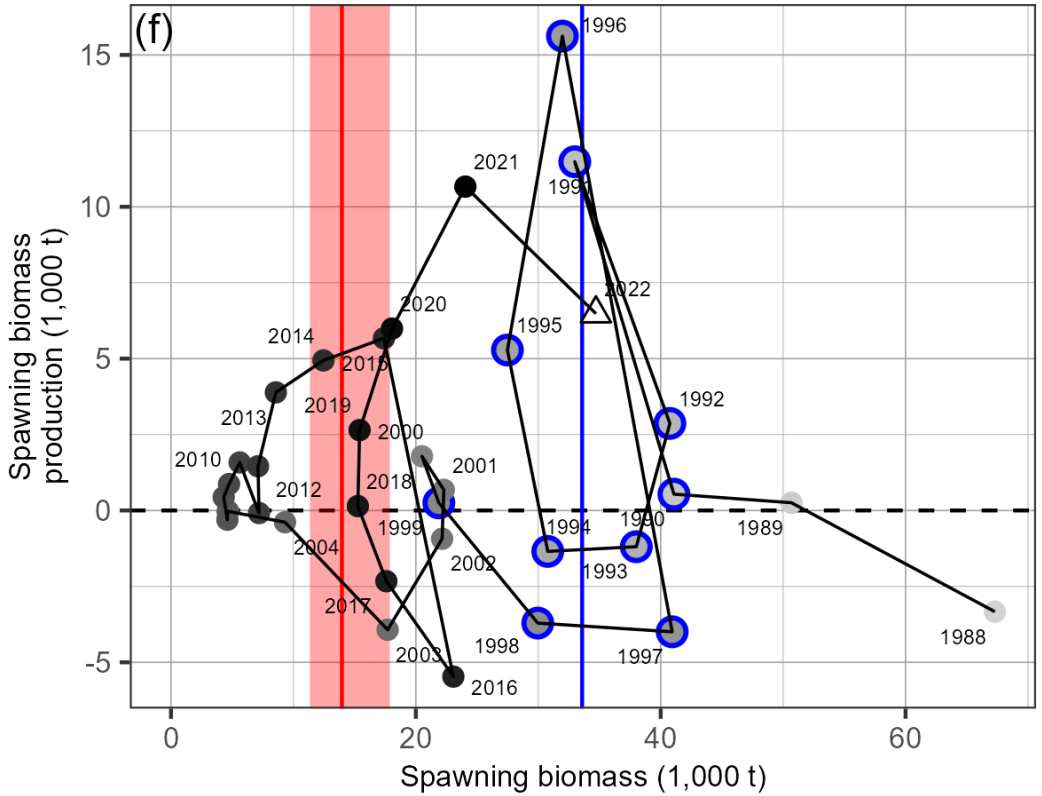
Stock Assessment

- Statistical catch at age model
  - Annual estimates of current spawning biomass, unfished spawning stock biomass, age-2 recruitment (Beverton Holt), time-varying natural mortality, 1-yr ahead biomass projections, depletion and reference points with uncertainty estimates.
  - Input data
    - Spawn survey index: how the relative stock size has changed over time
    - Weight-at-age data: effects of time varying changes can affect the estimate of the theoretical unfished biomass
    - Proportion-at-age data, by gear: informs fishery selectivity and year class strength; age-2 recruitment
    - Fishery catch data, by gear



Reference Points

- **Limit Reference Point (LRP)**
  - Spawning biomass-based LRP of $0.3SB_0$ (unfished spawning biomass) applied for all five major stocks
  - Set using a surplus production analysis in the context of recent persistent periods of low-productivity/low-biomass and high mortality in some areas, attempting to find evidence of a threshold below which the stock becomes impaired
- **Upper Stock Reference (USR)**
  - The average biomass (or index of biomass) over a productive period
  - Set through simulation analysis and engagement in the different stock areas
  - Intended to be operationalized as a target biomass objective (not upper control point)

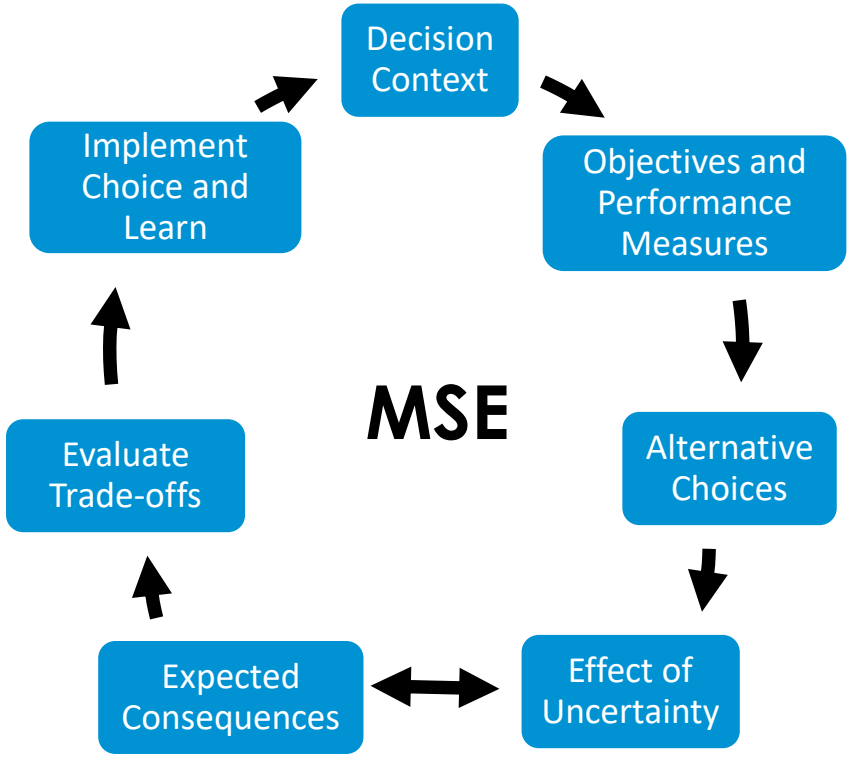


Key uncertainties addressed through research and engagement

- Aggregate stock status may not reflect local and Indigenous experience of stock biomass and stock health
  - Uncertainty re: appropriate spatial scale
  - Scale for biological reference points and management decisions
- Time-varying natural mortality
  - Evidence for density-dependent functional response (some stocks)
  - Changes in predator communities
- Driving the projection model? (ecosystem approaches)
  - Top down: natural mortality
    - Density dependent or independent
  - Recruitment parameterizations (assumed B-H)
    - Typically see large uncertainty in terminal year recruitment, especially largest stock, large rec_devs drives uncertainty in projections

Management Strategy Evaluation

- In 2016 renewal of the Pacific Herring management framework began, including stakeholder engagement in a Management Strategy Evaluation (MSE) process
- The intent of the MSE was to evaluate the performance of candidate management procedures in terms of achieving identified objectives given a range of hypotheses about future stock and fishery dynamics
  - Where operating model scenarios are used to increase our understanding of the impacts of key uncertainties on management choices



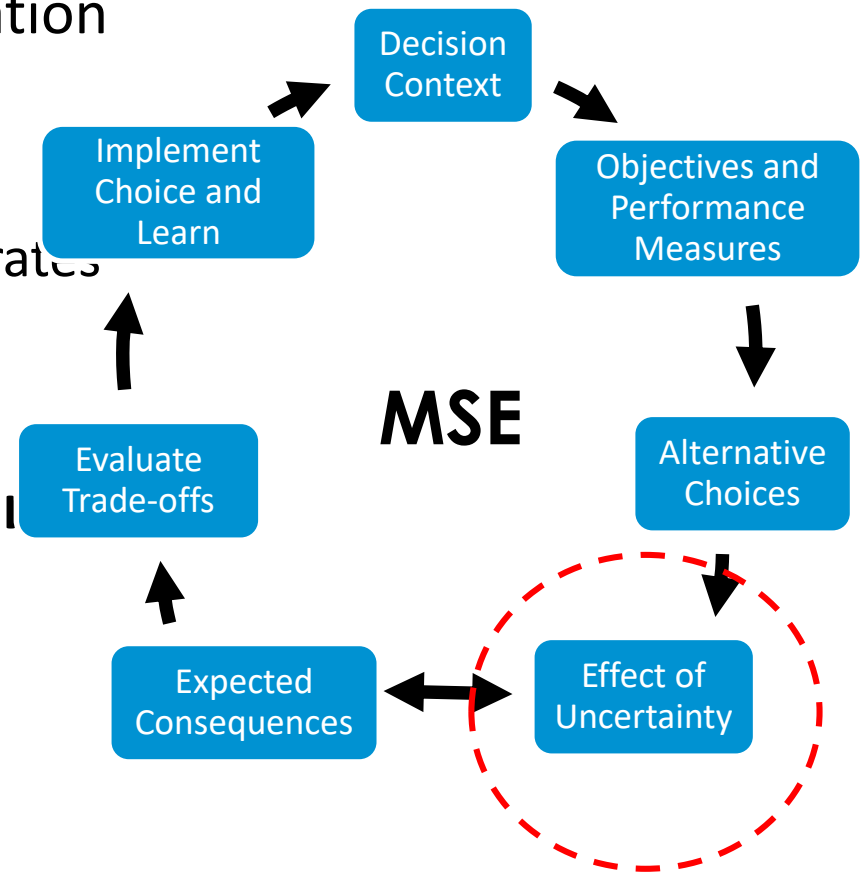
Engagement to address key uncertainties:

1) Nuu-chah-nulth ʔuuʔaałuk ƛusmit (taking care of herring) project

- Project led by the Nuu-chah-nulth Nation (WCVI), collaboration with Landmark Fisheries Research and DFO
- Predation mortality and density-dependent M
  - Historical evaluation of predator biomass and consumption rates
  - Future work: M-scenarios to drive the projection model

2) Haida Gwaii ʼíináang | iinang Pacific Herring Rebuildi Plan: An Ecosystem Approach

- Co-developed with the Haida Nation, Parks Canada and Fisheries and Oceans Canada
- MSE, spatial and temporal dynamics, environmental drivers of productivity



West Coast of Vancouver Island
Nuu-chah-nulth ʔuuʔaałuk ƛusmit (taking care of herring)

Analysis is led by the Nuu-chah-nulth Nations* with Landmark Fisheries Research, DFO is a collaborator

Motivation and scope: Develop management system that reflects Nuu-chah-nulth knowledge and objectives, accounting for:

1) **Predation mortality** on Herring
2) Aggregate and subpopulation management approaches
3) Potential for temporal and spatial management options

*Nuu-chah-nulth Nations is comprised of 14 member nations/ tribes

Modelling predation mortality via bio-energetic requirements of predators

- **Bio-energetics:** determining the annual consumption of herring by each predator, based on predator energy requirements, diet, herring energy content, and spatio-temporal overlap

- Predator consumption of herring (C) based on four factors

$$C = P \cdot \pi \cdot d \cdot \rho$$

Predator Abundance

Per-capita daily prey consumption

Number of days of spatial overlap

Proportion of prey in predator diet

Slide from Landmark Fisheries Research
Doherty, Johnson, Benson, Lane, Cleary, Cox. *In Prep.*

Estimating predator consumption via bio-energetic requirements of predators

- Major predators on Herring **identified by** the Nuu-chah-nulth Nations
    - The list of key predators of herring came both from current observations of predators feeding on herring and eggs during spawning season, and recounts of traditional use of marine species in Nuu-chah-nulth territory and balances they were able to achieved through seasonal harvesting, incl. whaling

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Estimating predator consumption via bio-energetic requirements of predators

- Major predators on Herring **identified by** the Nuu-chah-nulth Nations

  - Pacific Hake (Small [< 50 cm], Large [> 50 cm])
  - Humpback Whales (Winter and Summer feeding groups)
  - Stellar Sea Lions
  - Harbour Seals
  - Grey Whales

Total Natural Mortality = Predation Mortality + Basal Mortality

- Pacific Hake
- Humpback Whales
- Stellar Sea Lions
- Harbour Seals
- Grey Whales

- Disease
- Starvation
- Post-spawn mortality
- Senescence
- Unreported catch
- Other predators
- …

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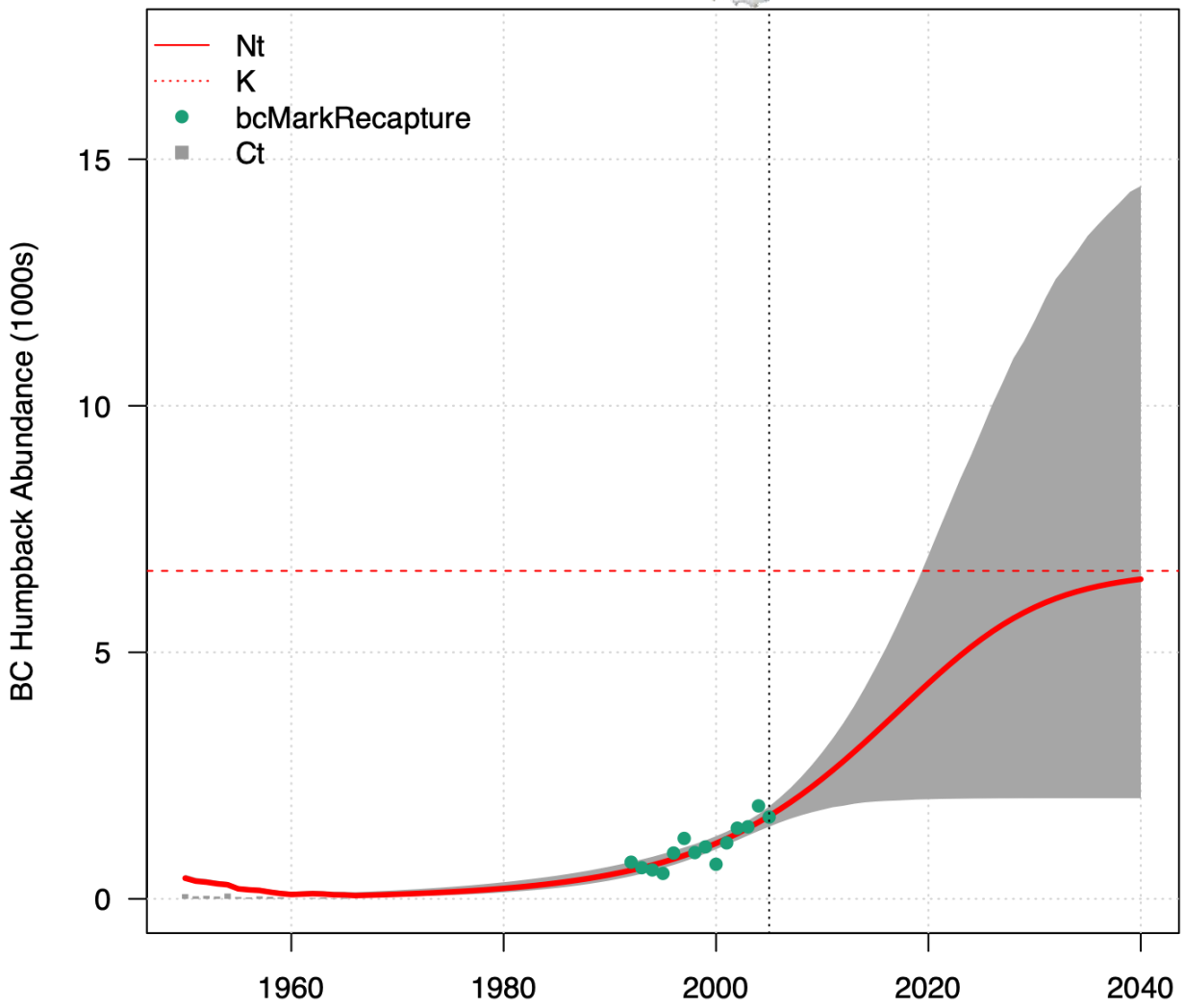
BC Humpback Whales

- Mark-recapture estimates used as absolute abundance (Ford et al. 2009)
- Commercial whaling records (Nichol and Heisse 1992)
- Estimate that 13% of BC Humpback population is feeding in WCVI (Nichol et al. 2010)



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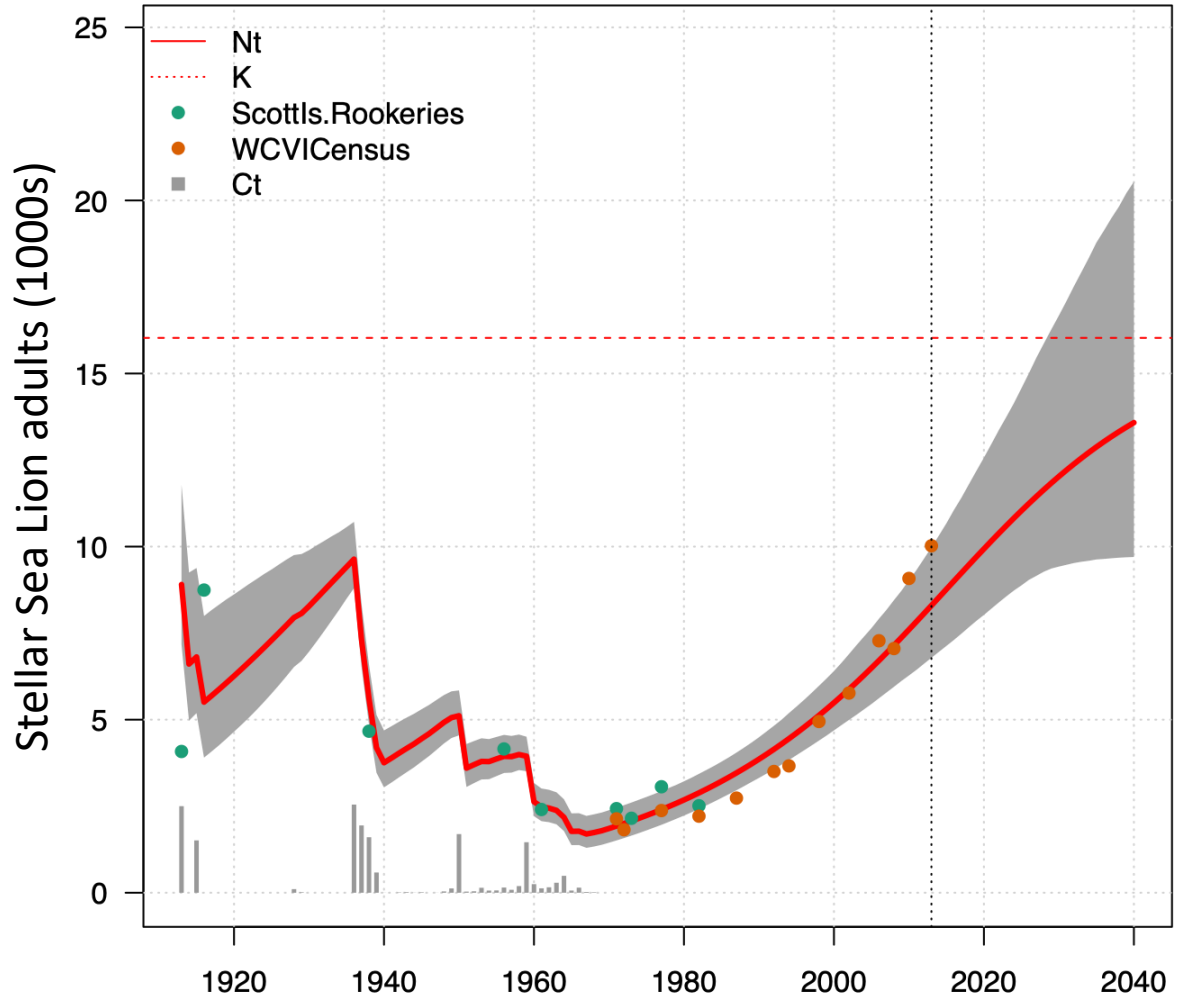
WCVI Steller Sea Lions

- Relative abundance index from rookery counts (1913-1982)
- Absolute abundance from census (1971-2012)
- Assumes population was harvested prior to 1913



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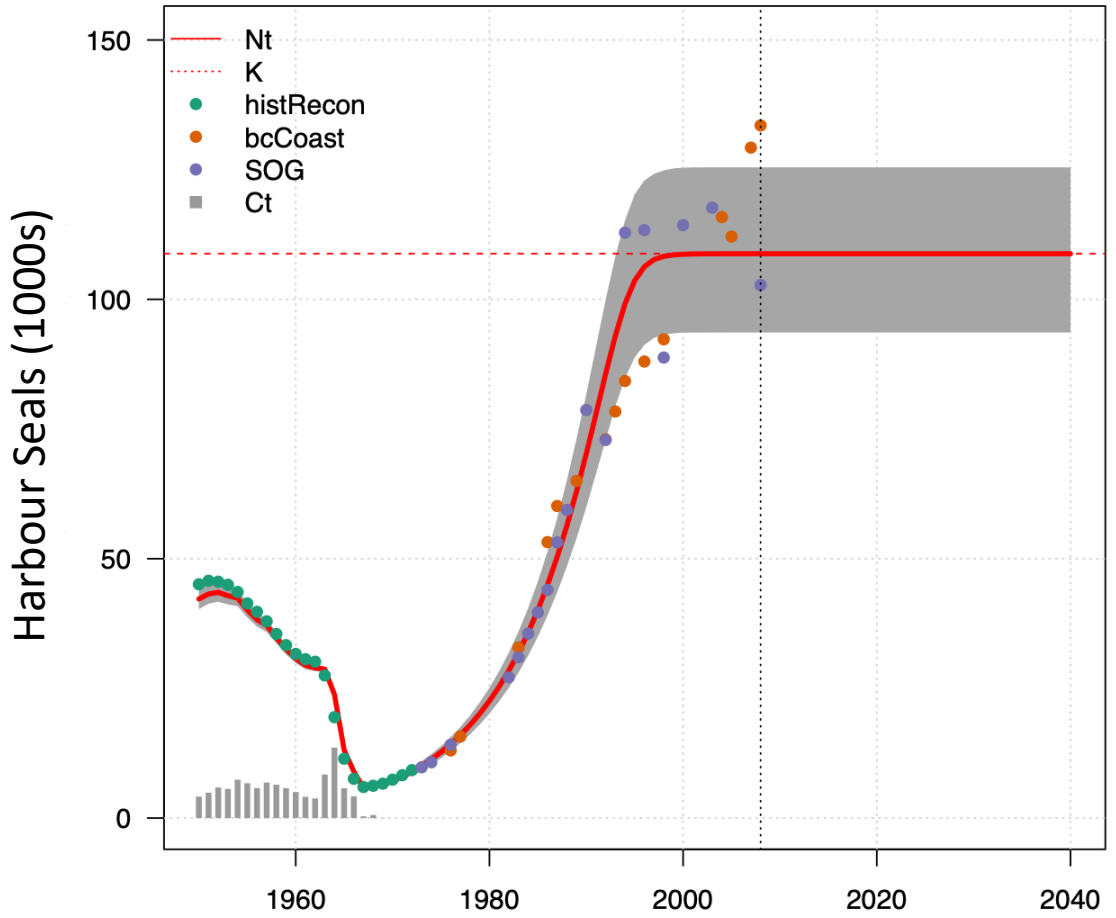
BC Harbour Seals

Abundance data

- non-SOG (Olesiuk 2010)
- SOG
- Historical reconstruction of absolute abundance (1950-1972) (DFO 2010)

- Assume **5.1%** of population is feeding in WCVI SAR (Olesiuk 2010)



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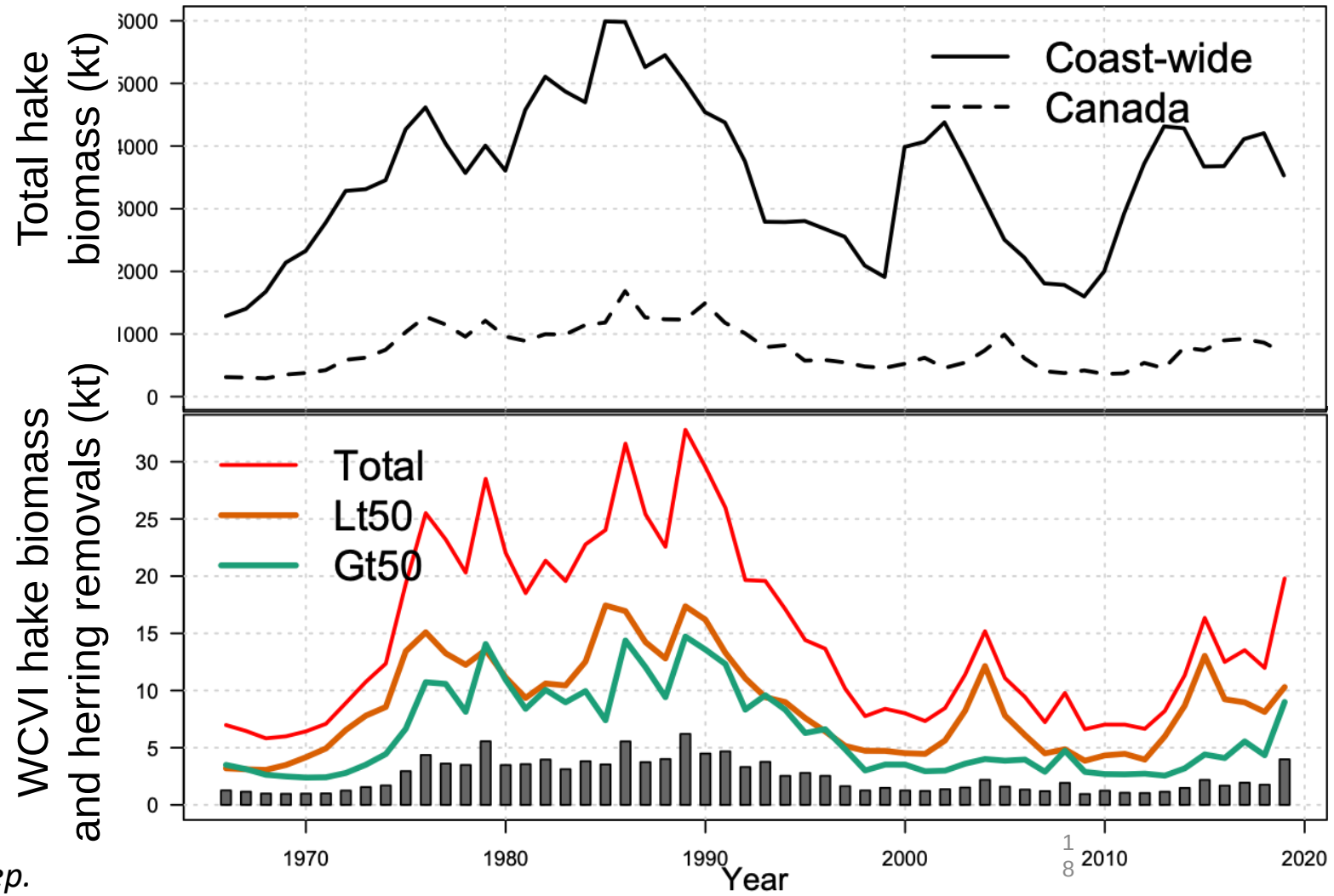
Spatial estimates of WCVI Pacific Hake biomass

Acoustic survey data used to apportion annual coastwide biomass into
WCVI biomass-at-age

Two piscivorous Hake predator length classes



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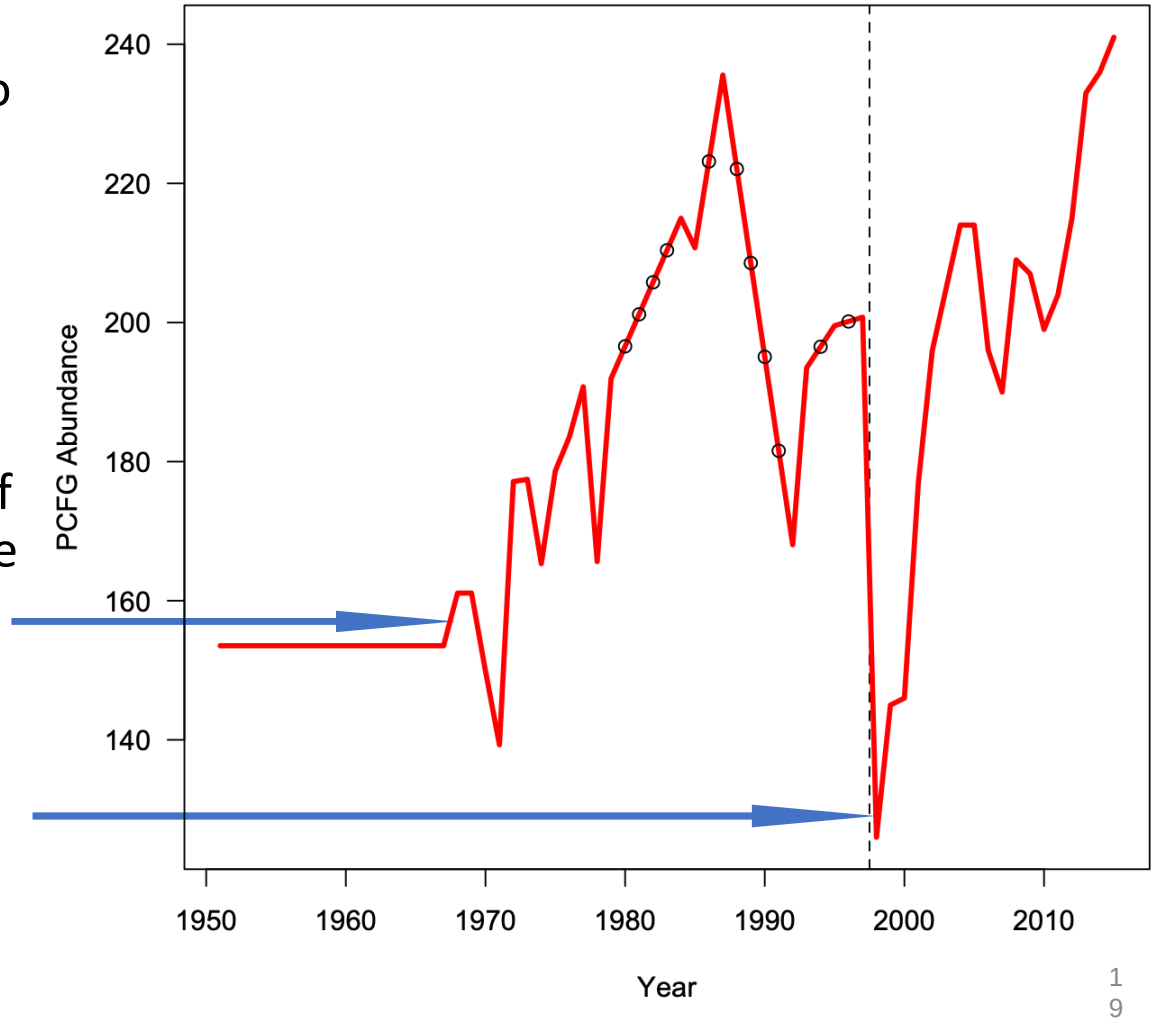
Gray Whales

Pacific Coast Feeding Group appear to be primary sub-population with potential for feeding on eggs in WCVI

1960-1997 estimated as proportion of Eastern North Pacific stock abundance estimates (Durban et al. 2017)

Abundance estimates 1998-2015 (Gavrilchuk et al. 2021)



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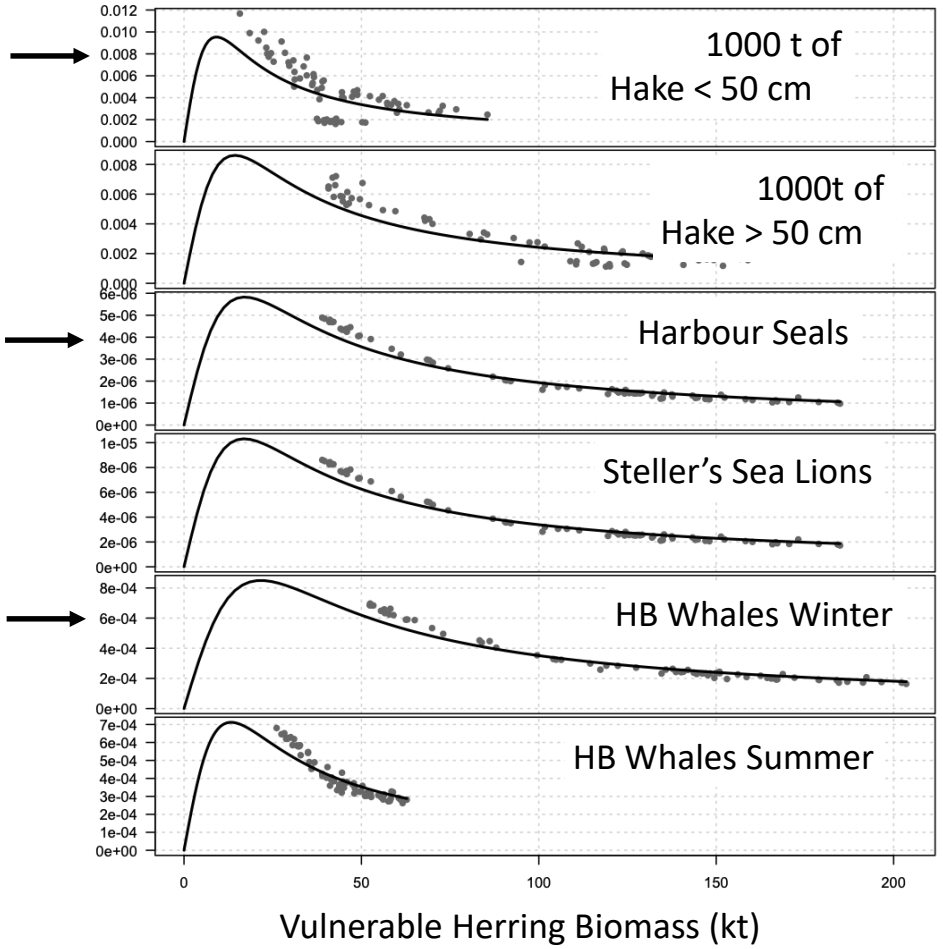
Characterize the relationship between available Herring biomass and predation mortality rates

Every 1000 t of hake consumes roughly 0.8% of available herring

Each seal consumes roughly 0.0004% of available herring

Each whale consumes roughly 0.06% of available herring



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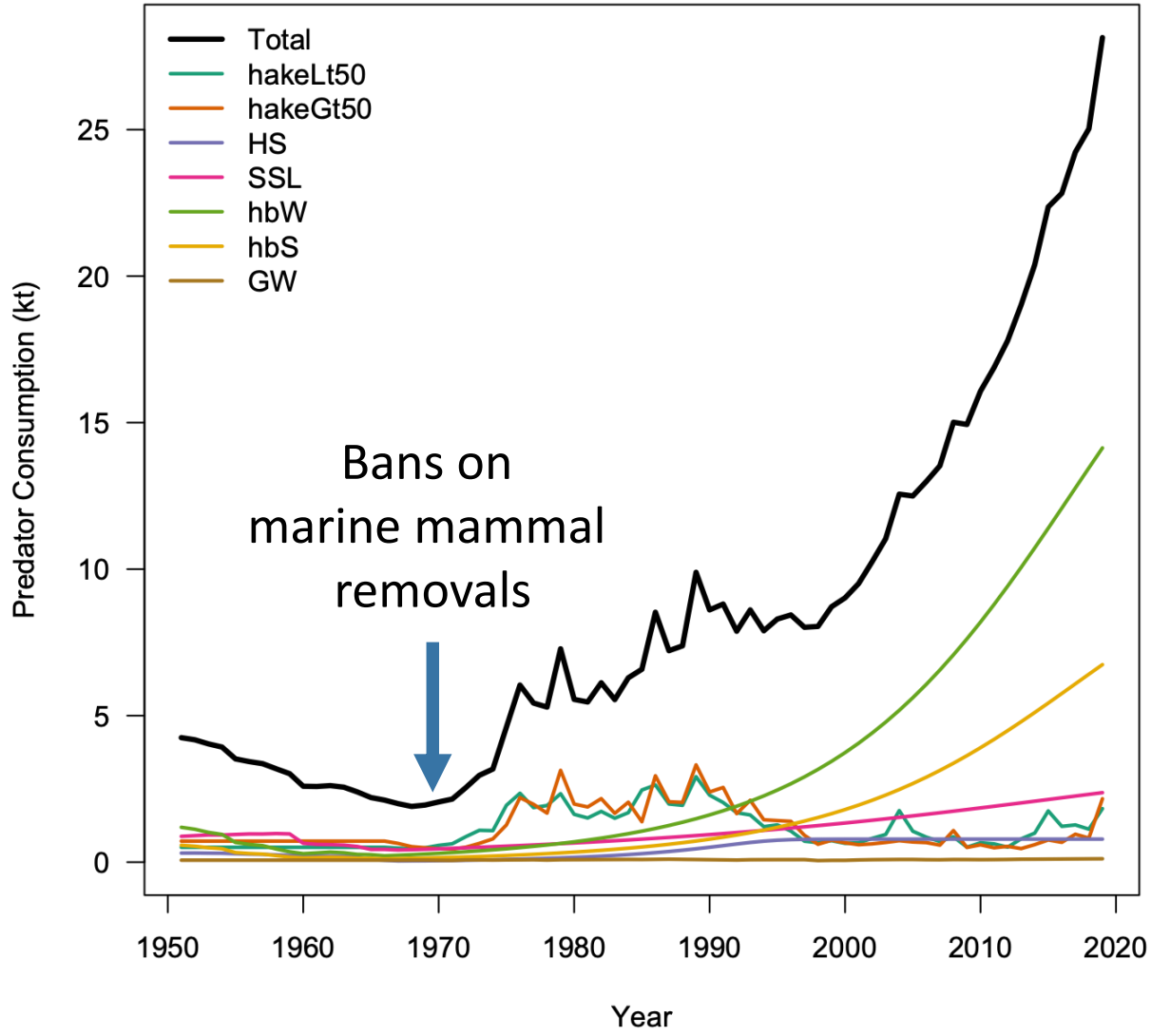
Predators may be consuming **a lot** of herring

Total predator consumption is used as *observed catch* input for fitting herring operating models

Total predation mortality estimated from a combination of consumption and predator abundance



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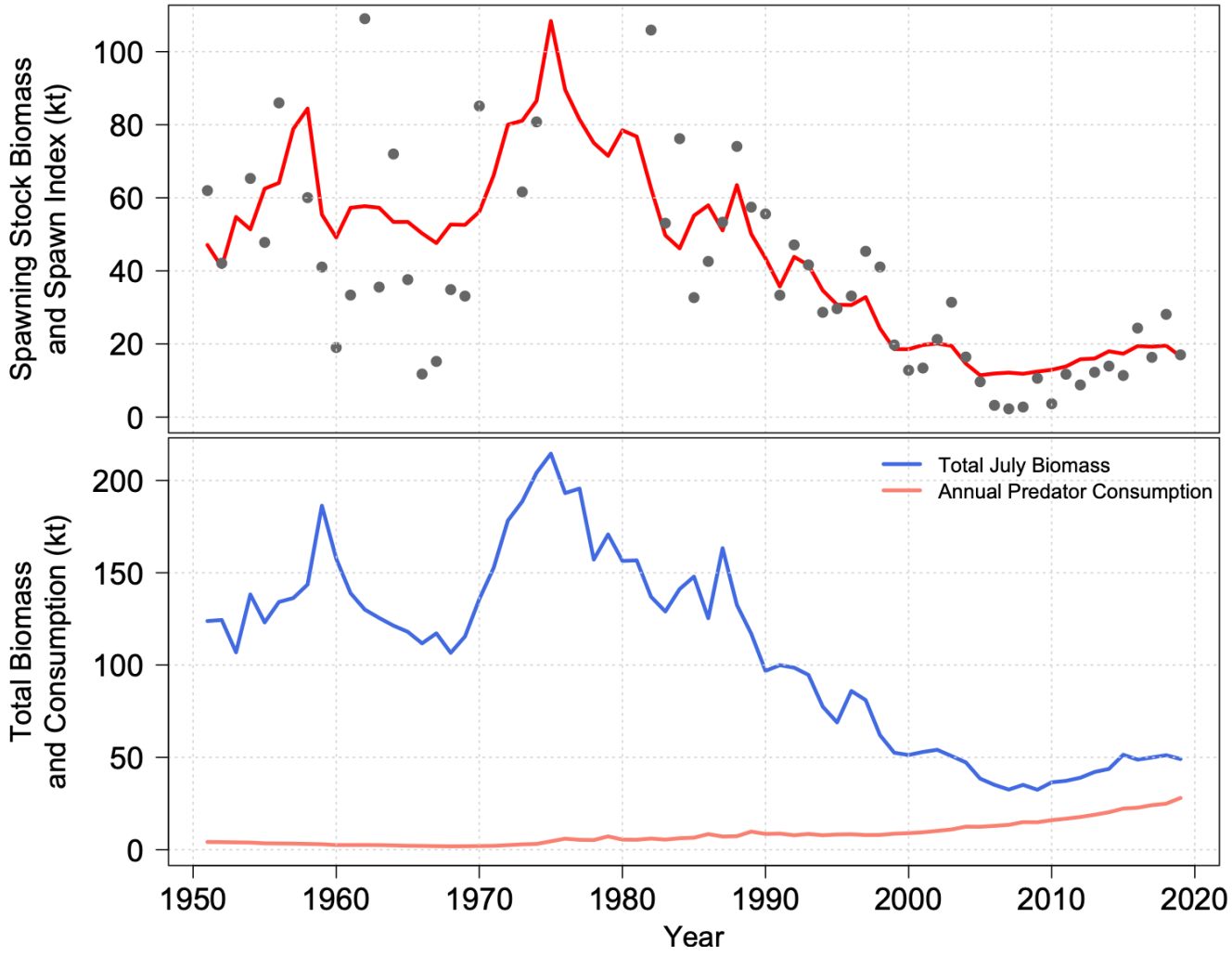
Predator consumption is approaching total biomass



Total biomass= total herring biomass (all ages) from the operating model

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Recap and Implications for BC Herring management in general

- Project motivation: Nuu-chah-nulth repeatedly questioned stock assessments that do not capture observed changes in WCVI ecosystem
- Phase 1 of NTC-BCSRIF project aimed to quantify observed ecosystem changes and their implications for WCVI Herring stock assessment and management
- Results to date suggest that total herring predation by fish and marine mammals has increased dramatically over the past 40 years
- Based on current estimates **predation balances herring production**, limiting scope for future increases in biomass
- Most stock assessment models would never give this level of insight

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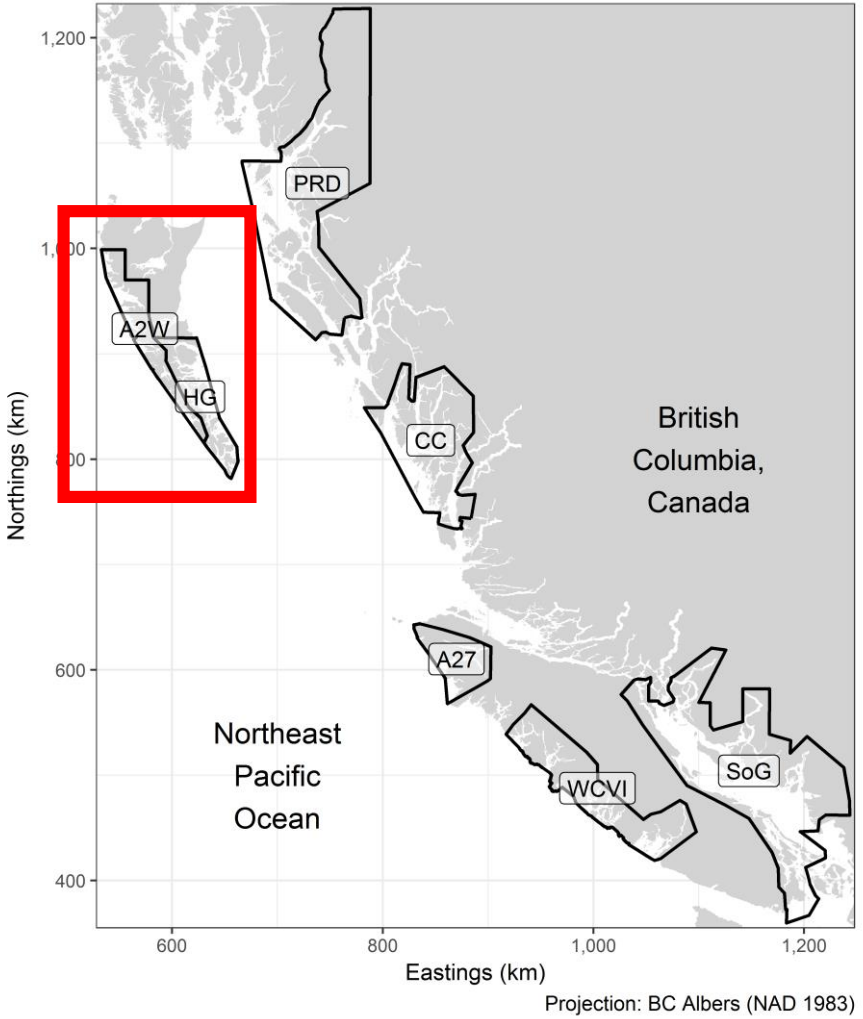
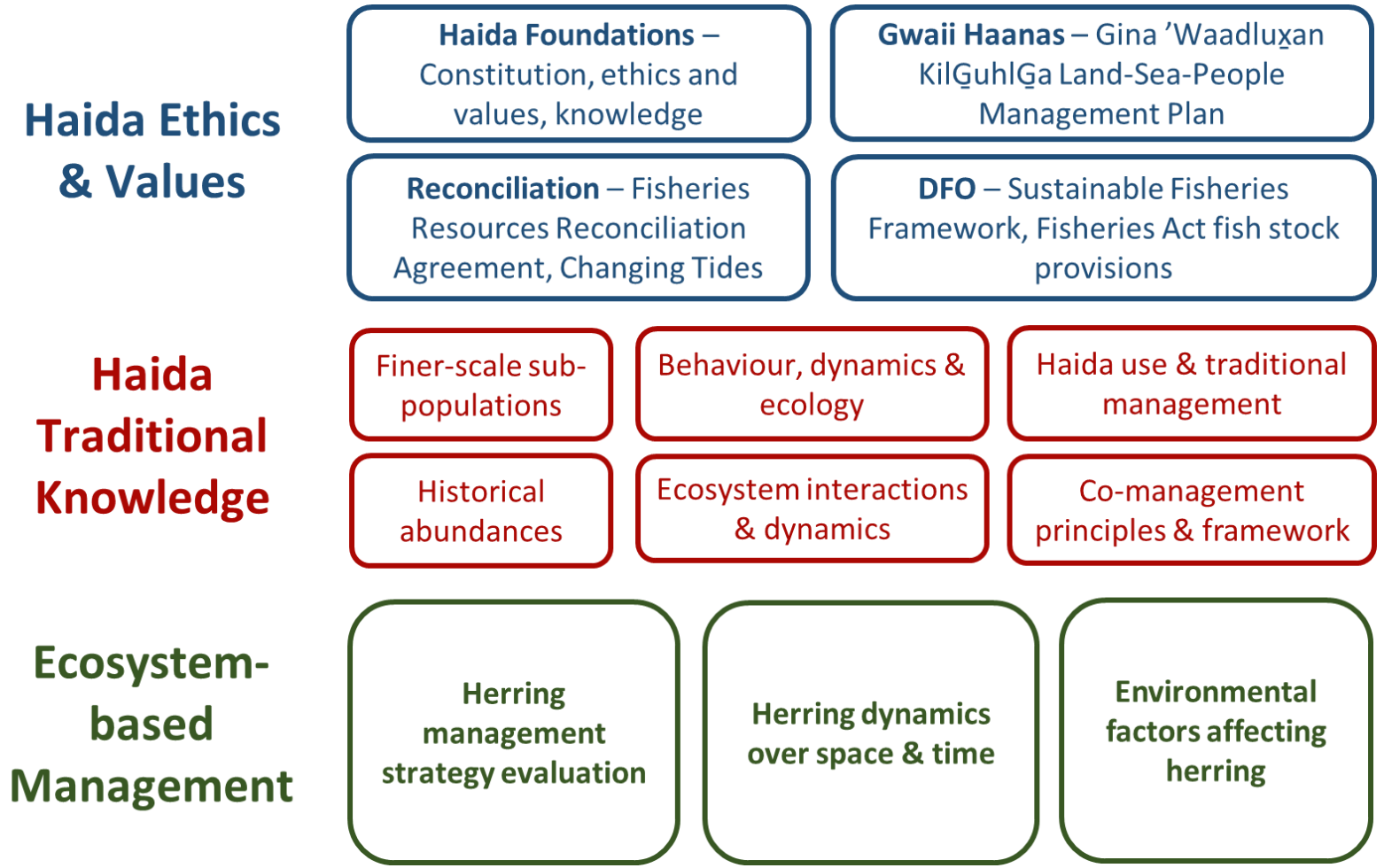
Doherty, Johnson, Benson, Lane, Cleary, Cox. *In Prep.*

Haida Gwaii ʼíináang | iinang Pacific Herring Rebuilding Plan: An Ecosystem Approach

- Co-developed with the Haida Nation, Parks Canada and Fisheries and Oceans Canada
- Multiple commitments in the region to co-develop a rebuilding plan for HG herring
- Plan incorporates both scientific and traditional knowledge

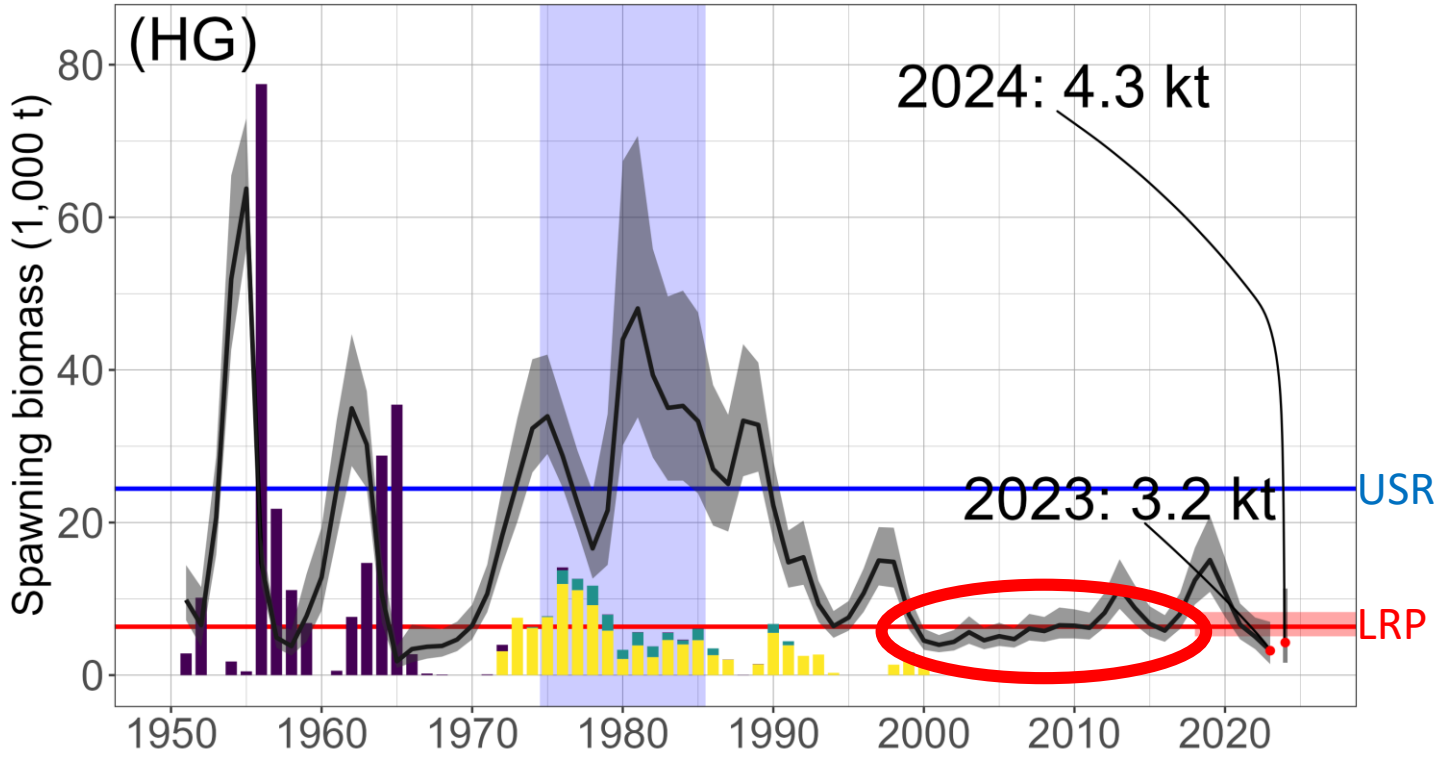


Haida Gwaii ’íináang | iinang Pacific Herring Rebuilding Plan: An Ecosystem Approach



Haida Gwaii ʼíináang | iinang Pacific Herring Rebuilding Plan: An Ecosystem Approach

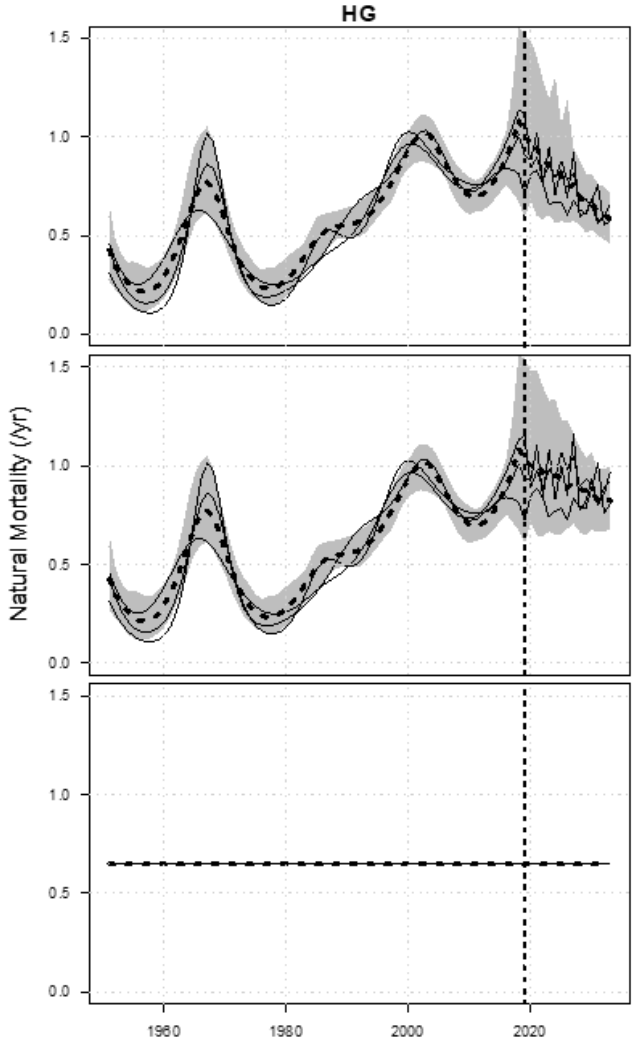
- The Haida Gwaii (HG) herring major stock has been in a low biomass, low growth state since 2000
- No commercial herring fisheries have occurred since 2004



Haida Gwaii ʼíináang | iinang Pacific Herring Rebuilding Plan: An Ecosystem Approach

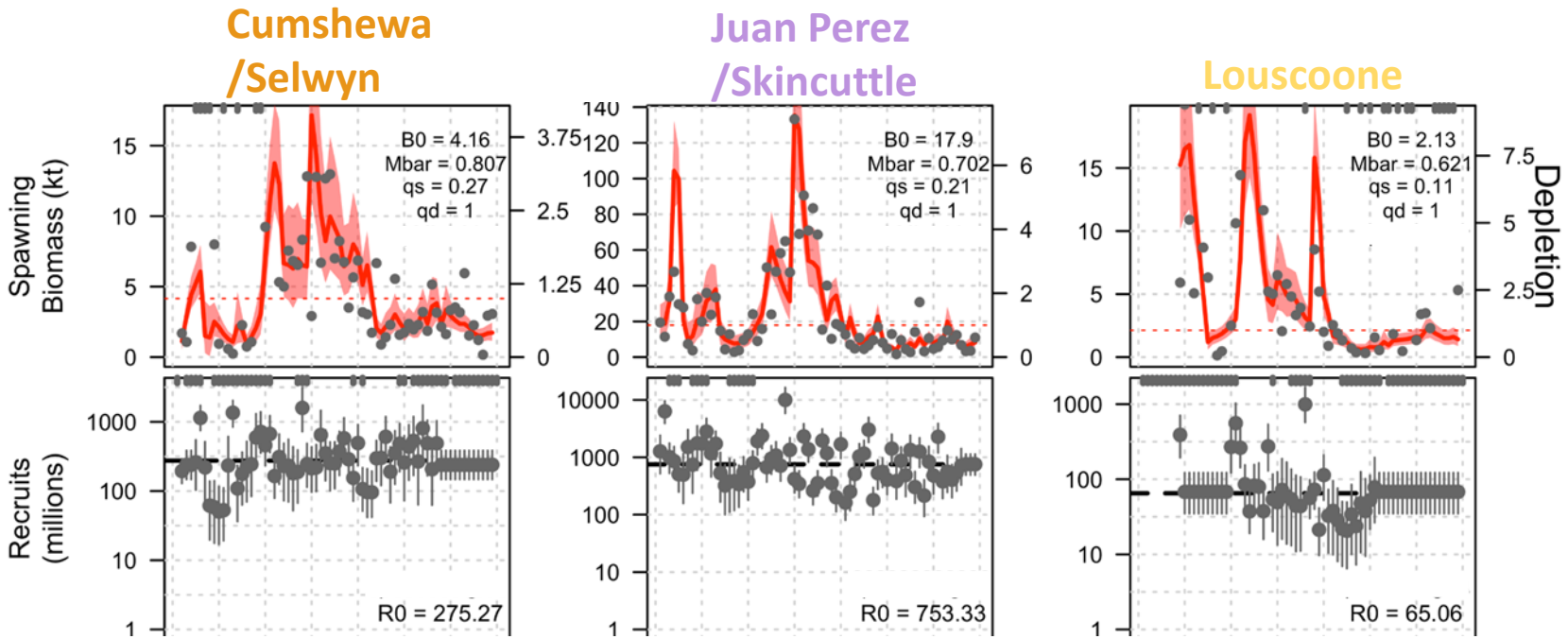
- **Management Strategy Evaluation**
  - Cycle 1 (pre-rebuilding plan):
    - Aggregate spatial structure
    - Coast-wide objectives and operating model assumptions (3 natural mortality scenarios)
    - Results indicated that no management procedure, including No Fishing, was able to meet the conservation objective with high probability

		Conservation	Biomass	Yield		
	Criterion	Obj 1 (LRP)	Objective 2	Objective 3	Objective 4	Catch < 650 t
		> 75%	>50%	< 25%	max	min
Scenario MP	Label	$P(B_t > .3B_0)$	$P(B_t > .6B_0)$	AAV	$\bar{C}_t$	$P(C_t < 650)$
HG_DDM 9	NoFish_NoFSC	0.36	0.1	0	0	1
HG_DDM 8	NoFish_FSC	0.33	0.09	10.6	0.16	1
HG_DDM 7	HS30-60_HR.05	0.32	0.09	31.45	0.25	0.88
HG_DDM 3	minE.5B0_HR.1	0.32	0.08	40.1	0.3	0.87



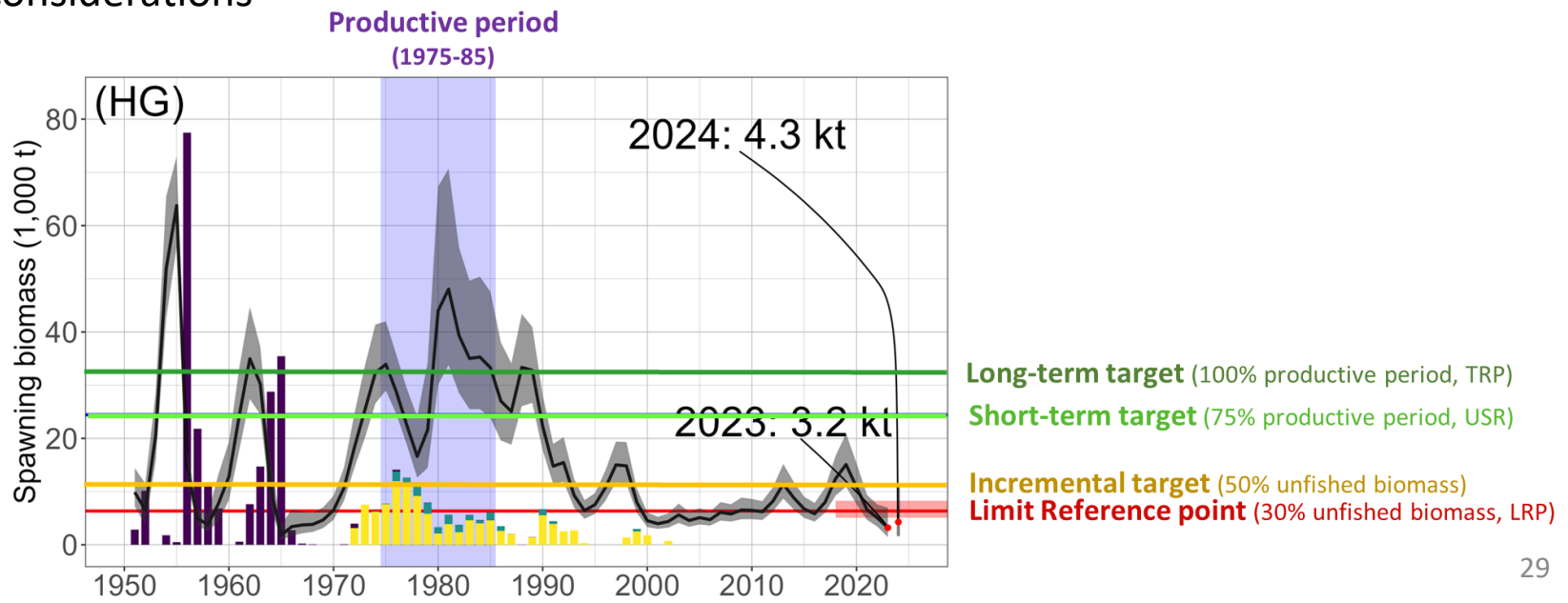
Haida Gwaii ʼíináang | iinang Pacific Herring Rebuilding Plan: An Ecosystem Approach

- **Management Strategy Evaluation**
  - Cycle 2 (rebuilding):
    - Defines spatial sub-stocks for finer-scale management



Haida Gwaii ’íináang | iinang Pacific Herring Rebuilding Plan: An Ecosystem Approach

- **Management Strategy Evaluation**
  - Cycle 2 (rebuilding):
    - Defines spatial sub-stocks for finer-scale management
    - Updated HG objectives, including rebuilding targets and socio-economic considerations



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- **Management Strategy Evaluation**
  - Cycle 2 (rebuilding):
    - Defines spatial sub-stocks for finer-scale management
    - Updated HG objectives, including rebuilding targets and socio-economic considerations
    - Updates to operating model assumptions (72 scenarios), including additional scenarios for natural mortality, productivity, and different fishery impacts

Historical operating model scenarios

Factor	Level	Description
Age-1 M	**a1Mmean**	Age-1 natural mortality rate is set to the time-averaged natural mortality rate for each sub-stock
	a1M1.25	Age-1 natural mortality rate is set to 1.25 in all sub-stocks
	a1M1.64	Age-1 natural mortality rate is set to 1.64 in all sub-stocks
Stock-recruit Steepness	**sr0.5**	Stock-recruit steepness is set to 0.5 for all sub-stocks
	sr0.67	Stock-recruit steepness is set to 0.67 for all sub-stocks
	sr0.8	Stock-recruit steepness is set to 0.8 for all sub-stocks
Time-varying M correlation	**identM**	Time-varying random walk deviations in age-2+ natural mortality $M_{2+,p,t}$ are assumed to be identical (100% correlated) among sub-stocks for the history and projection
	diffM	Time-varying random walk deviations in age-2+ natural mortality $M_{2+,p,t}$ are assumed to be independent (0% correlated) among sub-stocks for the history, and generated in the projections with correlations empirically derived from historical deviations

Projection operating model scenarios

Factor	Level	Description
Return to average M	**rw5**	Natural mortality return to the historical average over the first 5 projection years (2020-2024)
	rw15	Natural mortality return to the historical average over the 15 projection years (2020 – 2034)
Post-ponding mortality	**loPondM**	Average ponding induced mortality set to $\overline{M}_{SOK} = 0.315$, corresponding to a 73% survival rate
	hiPondM	Ponding induced mortality set to $\overline{M}_{SOK} = 1.05$, corresponding to a 35% survival rate

Haida Gwaii ʼíináang | iinang Pacific Herring Rebuilding Plan: An Ecosystem Approach

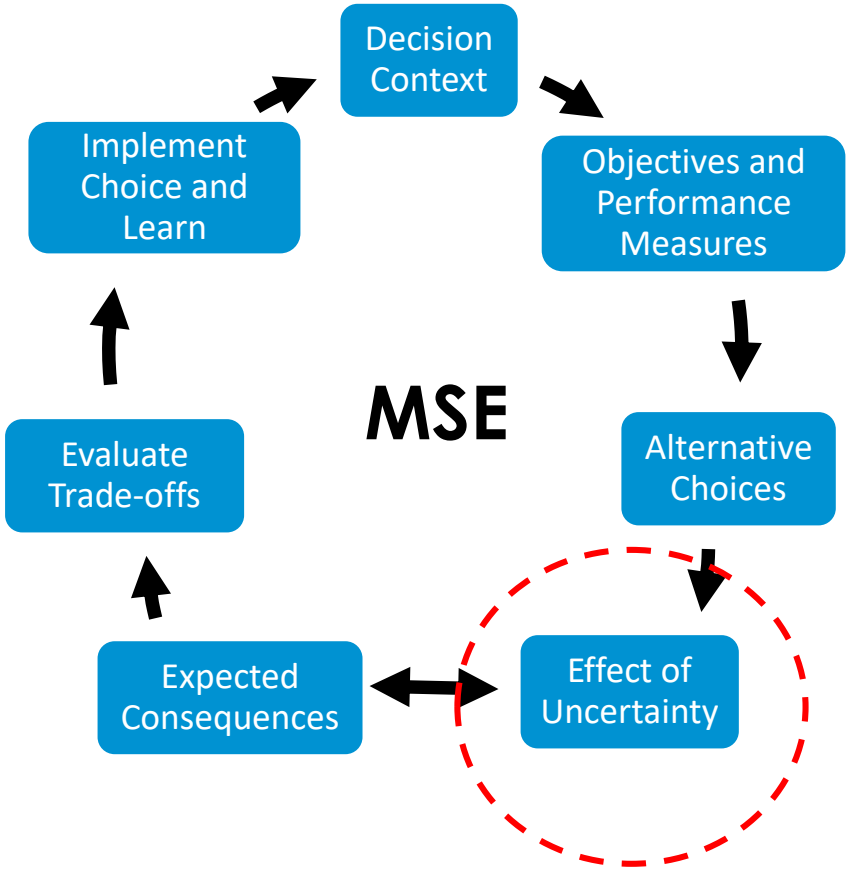
- **Management Strategy Evaluation**
  - Cycle 2 (rebuilding):
    - Defines spatial sub-stocks for finer-scale management
    - Updated HG objectives, including rebuilding targets and socio-economic considerations
    - Updates to operating model assumptions (72 scenarios), including additional scenarios for natural mortality, productivity, and different fishery impacts
    - Little difference in growth and timeline for rebuilding under No Fishing compared to fishing scenarios
    - Low likelihood of rebuilding in the short term (within 15 years, 3 herring generations), largely due to environmental factors outside of our control

Engagement to address key uncertainties:

We talked about two project examples:

1) Nuu-chah-nulth ʔuuʔaałuk ƛusmit (taking care of herring) project

2) Haida Gwaii ’íináang | iinang Pacific Herring Rebuilding Plan: An Ecosystem Approach



<u>Contributing factors to success of these projects</u>

- Understanding the decision context:
  - Who can be involved (who can be a partner)
  - What are the management decisions and mechanism for linking project outcomes into the existing science-mgmt. framework
- Collaborations were scoped to address key uncertainties
- Currently no commercial fisheries in these two areas

Thank you!

References

- DFO. 2020. Evaluation of Management Procedures for Pacific Herring (Clupea pallasii) in Haida Gwaii, Prince Rupert District, and the Central Coast Management Areas of British Columbia. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/003.
- DRAFT Haida Gwaii ’iinaang | iinang Pacific Herring: An ecosystem overview and ecosystem-based rebuilding plan.
- DFO. 2023. Stock status update with application of management procedures for Pacific Herring(Clupea pallasii) in British Columbia: Status in 2023 and forecast for 2024. DFO Can. Sci.Advis. Sec. Sci. Resp. 2023/xxx
- Doherty, Johnson, Benson, Lane, Cleary, Cox. The role of fishing and predation mortality in Pacific herring (Clupea pallasii) population dynamics and implications for biomass reference points. *In Prep.*