Gulf of Alaska Arrowtooth Flounder Data Update

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Contributors: Ned Laman, Beth Matta, Margaret Siple, Jane Sullivan

September 2025, Presentation to the Groundfish Plan Team

Background

- Arrowtooth Flounder (*Atheresthes stomias*, ATF)
- Area: Gulf of Alaska (GOA)
- Tier/Cycle: 3a on four year cycle from prioritization
- Platform: Rceattle (Climate-Enhanced, Age-based model with Temperature-specific Trophic Linkages and Energetics)
- Provided model bridging and alternatives in September 2024
- Approved by Plan Team (pg. 4) and SSC (pg.34) in October 2024

Plan Team or SSC Recommendations

- Collection of recommendations since 2019 from PT and SSC
- Recommend investigation of the following elements:
  - Recent lower recruitment trends and relationship to environmental conditions in the GOA, including the development of an ESP
  - Lack of fit in female survey age and fishery length compositions, including interactions between female natural mortality and selectivity
  - Incorporation of predation mortality estimates from the GOA CEATTLE model
  - Update growth and age-length conversion matrices

Goals

Begin to address the PT/SSC recommendations by:

1. Updating the current ADMB model to TMB to potentially improve parameter estimation
2. Accounting for both the impacts of cannibalism and fishery removals in the population dynamics assessment model used for GOA ATF

We did these last year and they were approved!

New Goals

Address more of the PT/SSC recommendations by:

1. Updating as much of the data as we can in the model
2. Create an ESP and begin to explore recent lower recruitment trends

Data Table

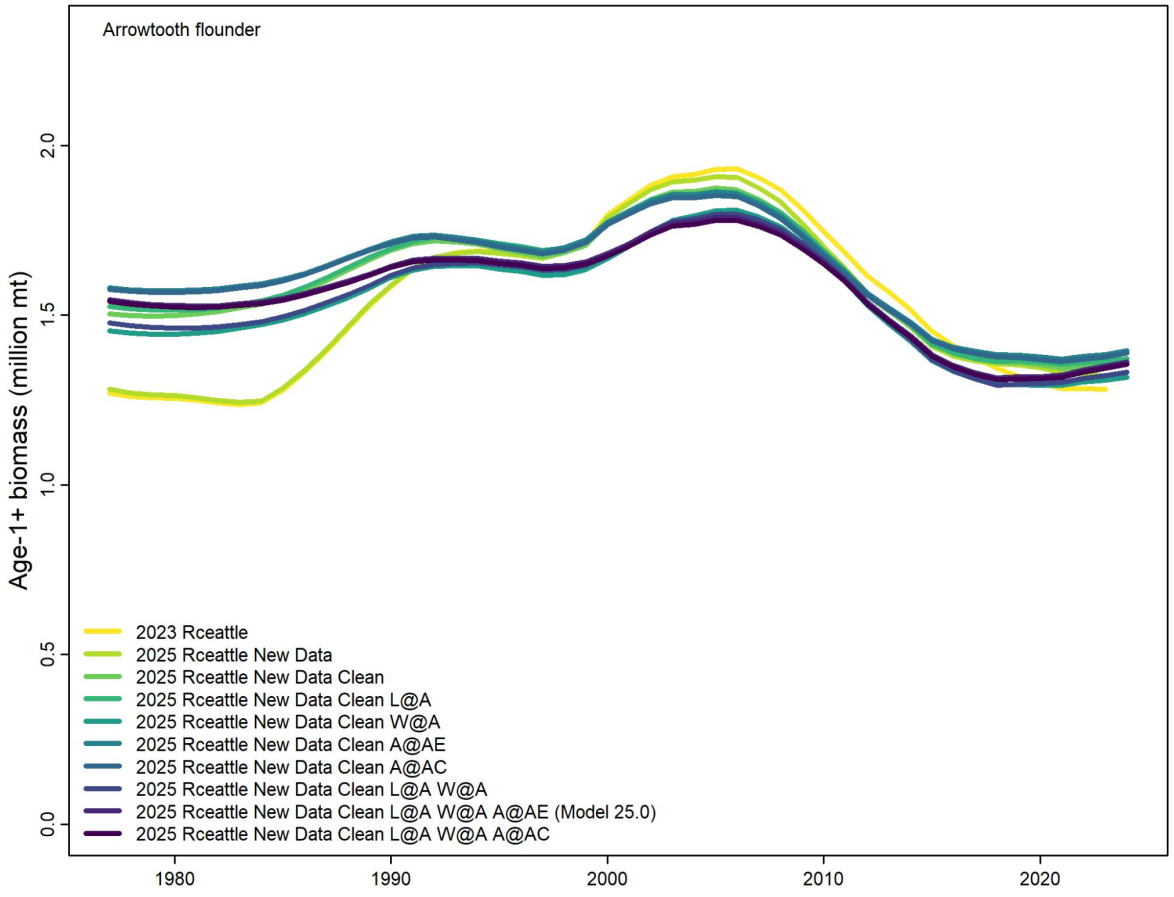
Source	Data	Years
AFSC GOA bottom trawl survey	Survey biomass and standard error	1993,1996,1999,2001,2003,2005,2007,2009 2011,2013,2015,2017,2019,2021,**2023**,**2025**
	Age Composition	1993,1996,1999,2001,2003,2005,2007,2009 2011,2013,2015,2017,2019,**2021**,**2023**
U.S. fisheries	Catch Biomass	1977-2021, **2022-2025**
	Length composition	1991-2020, **2021-2024**

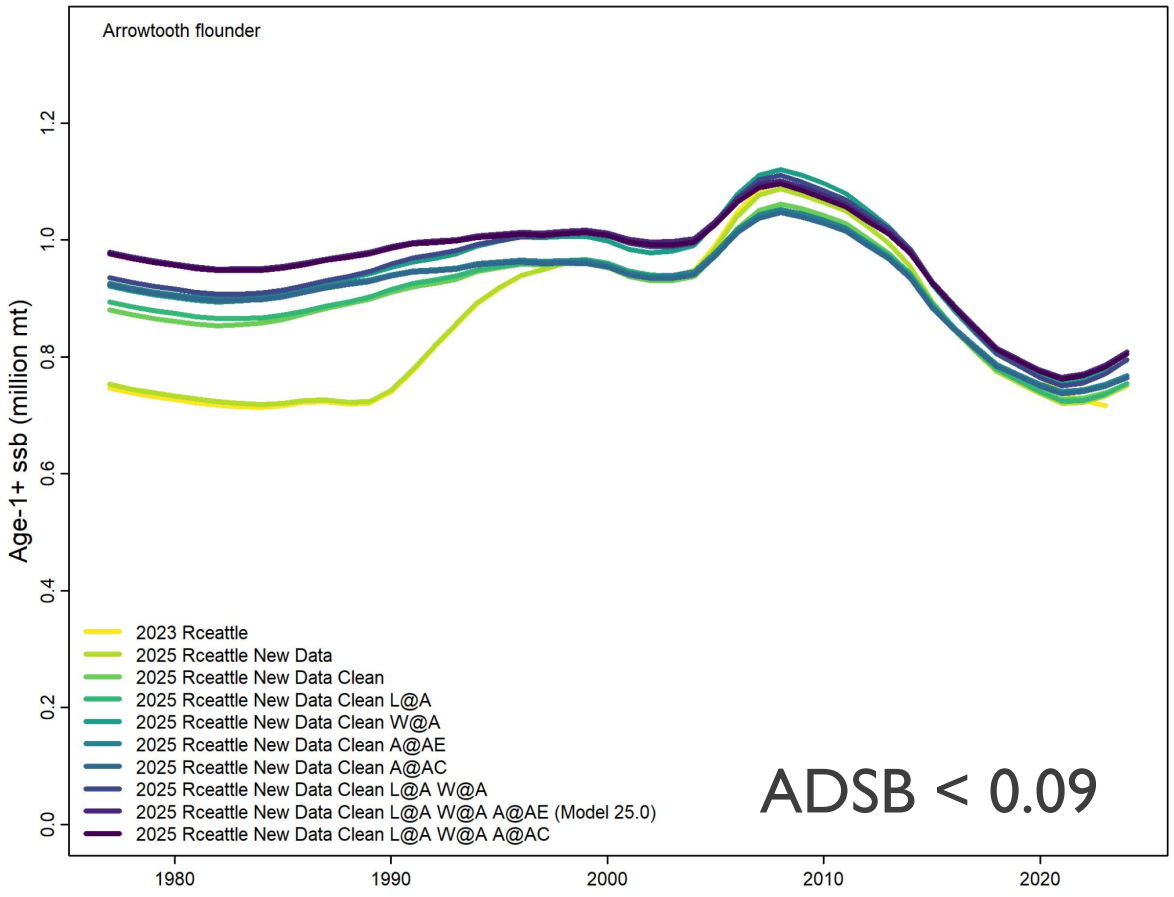
*Note catch is current up to 8/23/2025

Data Improvements

- Input Data
  - New catch, fishery length compositions, survey biomass, age compositions
  - Removed trawl survey and age compositions from non-standardized surveys and years with low confidence in arrowtooth identification (pre-1992)
  - Removed fishery length compositions prior to Observer Program (pre-1991) and years with lower sample sizes (<300 samples)
- Transition matrices
  - Changed fishery length composition bins to match the observed length distribution, also updated the length@age transition matrices and growth curves
  - Updated weight@age and age error with GOA data and provided a sensitivity to the age error matrix calculation (empirical versus modeled)

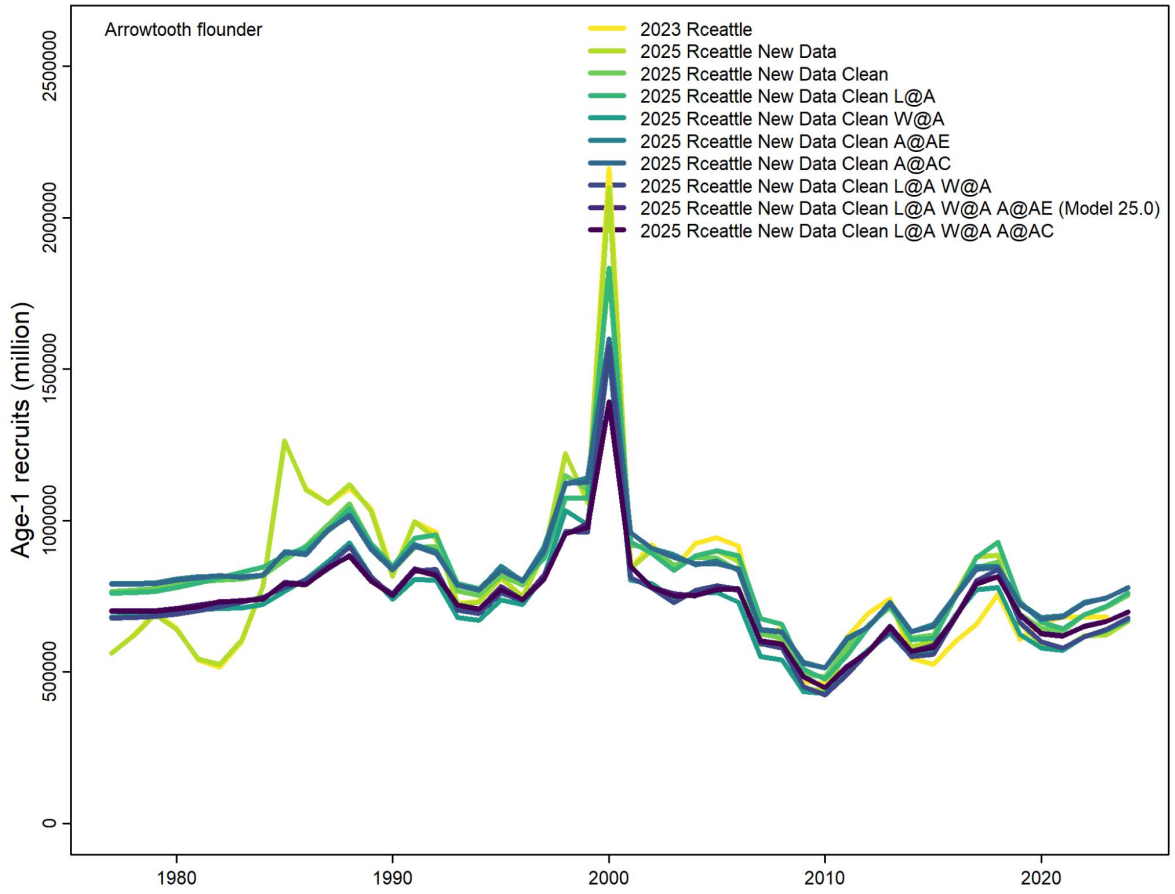
Comparison of Data Improvements





Recruitment

- Comparison with 2023 model
  - Similar trends over time
  - Lower estimates in largest recruitment year
- Age-1 recruitment been declining since 2000.
- Above average recruitment for 2017 year class.
- Supported in new age data



Models for November

1. Model 25.0: single-species TMB based Rceattle model with data improvements that fixes sex-specific M (females = 0.2 and males = 0.35) and treats annual recruitment as random effects
2. Model 25.1: Model 25.0 but estimates sex-specific M instead of fixing M

Models for Research

1. Cannibalism-enhanced single species model: multi-species TMB based Rceattle model that estimates sex-, age-, and time-varying M due to cannibalism from arrowtooth (M2), sex-specific residual mortality (M1), and treats annual recruitment as random effects

Discussion

1) Are the list of models ok to bring forward for November?
2) Are there any elements that we are missing that the Plan Team would like us to include?

Gulf of Alaska Arrowtooth Flounder Ecosystem and Socioeconomic Profile (ESP) Draft Full Report

Kalei Shotwell, Jennifer Bigman, Russel Dame



ESP Team and Contributors: Matt Callahan, Wei Cheng, Bridget Ferriss, Esther Goldstein, David Kimmel, Abby Jahn, Jean Lee, Zack Oyafuso, Lauren Rogers, Sean Rohan, Margaret Siple, Joletta Silva, Kally Spalinger

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Overview

- Appendix 7A in SAFE Report
  - Recommended in 2016 since part of GOA Integrated Ecosystem Research Program
  - ESP mini conducted in 2024, full 2025
- Justification
  - High biomass and important ecosystem role as GOA predator
  - Classified as data-rich stock
  - GOA Plan Team recommended exploring recruitment and environmental trends

Appendix 7A. Ecosystem and Socioeconomic Profile of the arrowtooth flounder stock in the Gulf of Alaska

S. Kalei Shotwell, Jenny Bigman, and Russel Dame (Editors)
September 2025

With Contributions from:

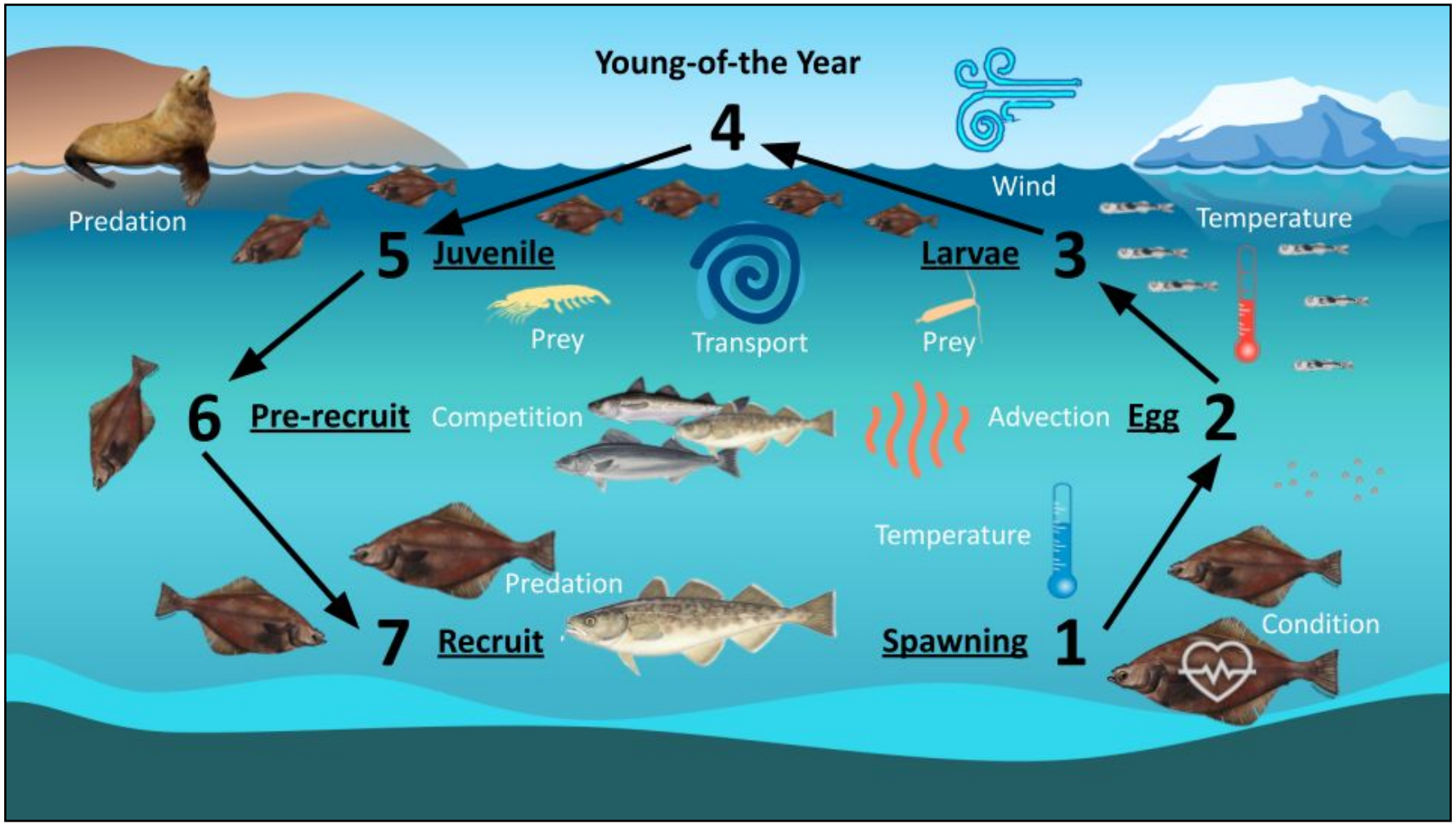
ESP Team: Grant D. Adams, Jennifer Bigman, Russel Dame, Bridget Ferriss, Esther Goldstein

ESP Data: Matt Callahan, Wei Cheng, David Kimmel, Abby Jahn, Jean Lee, Zack Oyafuso, Lauren Rogers, Sean Rohan, Margaret Siple, Joletta Silva, Kally Spalinger

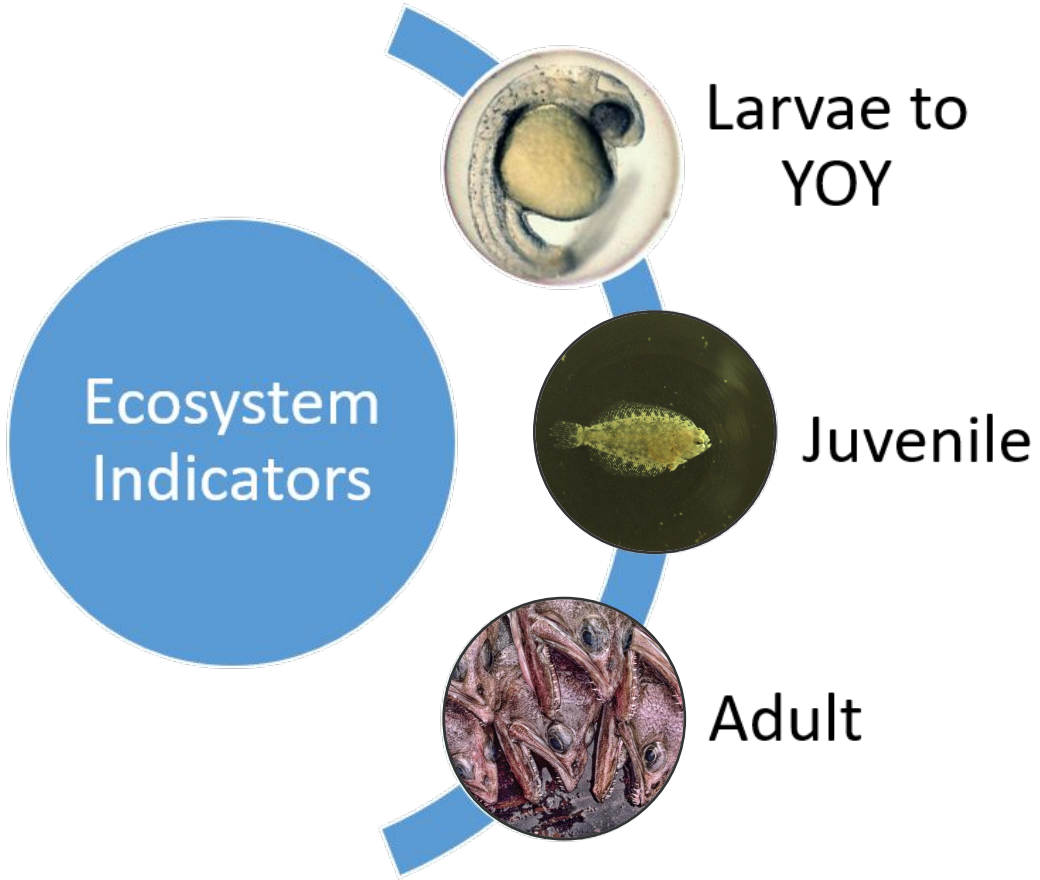
This report may be cited as: Shotwell, S.K., J. Bigman, and R. Dame. 2025. Appendix 7A. Ecosystem and Socioeconomic Profile of the arrowtooth flounder stock in the Gulf of Alaska. *In*: Shotwell, S.K., G.D. Adams, D.H. Hanselman. 2025. Assessment of the arrowtooth flounder stock in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/library/safe-reports/.

Appendix 7A

Ecosystem Processes - Conceptual Model



Ecosystem Indicators



1. Spring sea surface temperature (satellite), -
2. Spring eddy kinetic energy (satellite), +
3. Spring arrowtooth larvae (EcoFOCI), +
4. Spring larval prey (EcoFOCI), -
5. Summer YOY prey (EcoFOCI), +
6. Summer/Fall YOY Prey (MACE), +
7. Age-1 predation mortality (2, CEATTLE), -
8. Age-1 arrowtooth (ADF&G nearshore), +
9. Adult arrowtooth CPUE (ADF&G nearshore), +
10. Biomass eaten arrowtooth (CEATTLE), -
11. Bottom temperature (trawl survey), -
12. Area occupied (VAST), <>
13. Center of biomass east/north (2, VAST), <>
14. Adult arrowtooth condition (trawl survey), +
15. Arrowtooth ration (CEATTLE), -

Indicator Development

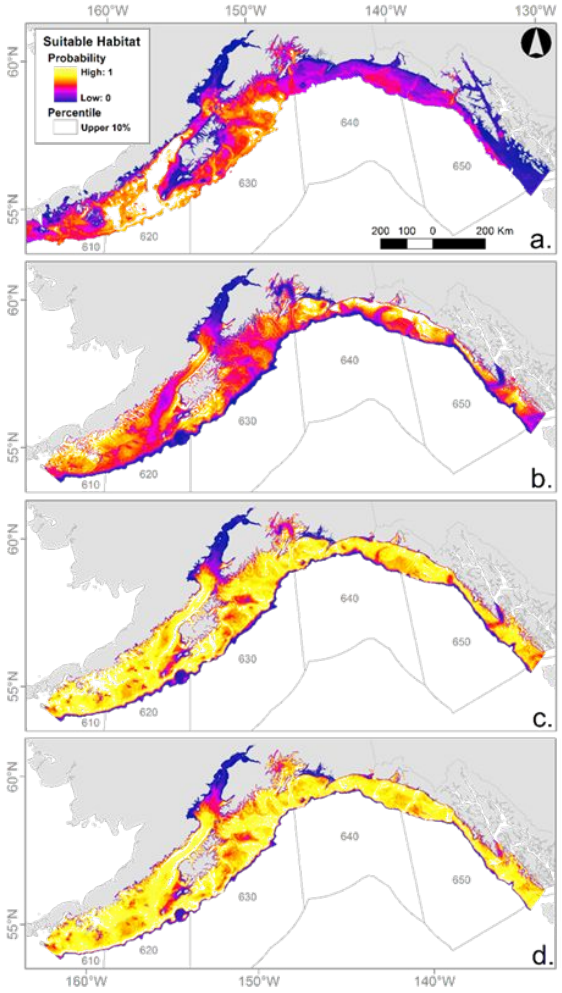
Shotwell et al., 2022

Larval

Early Juvenile

Late Juvenile

Adult

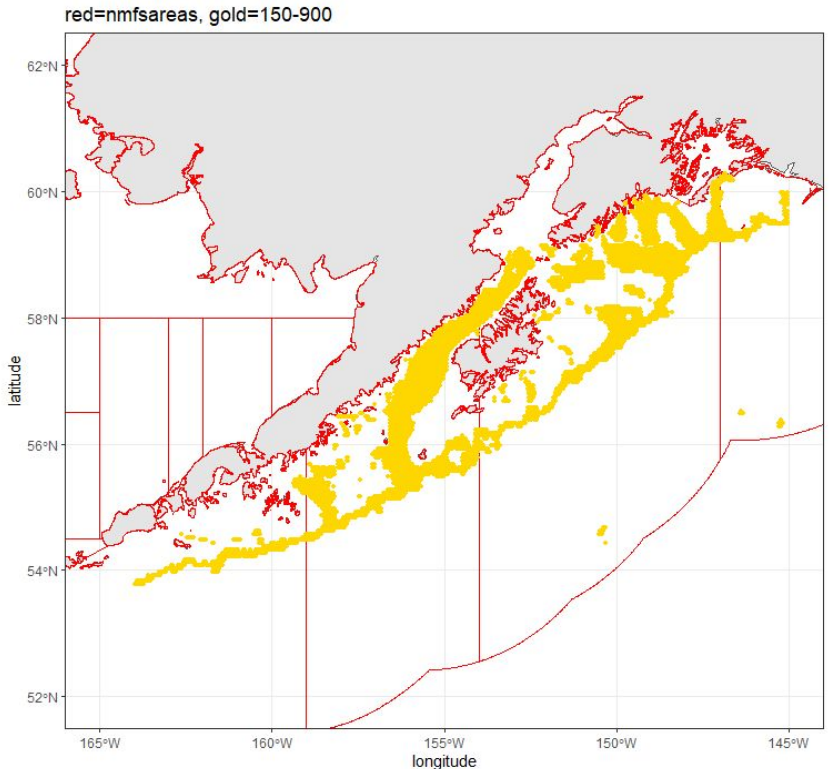


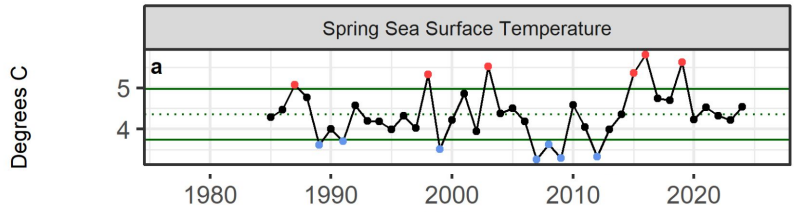
ATF Larval filters

Depth: 150-900m

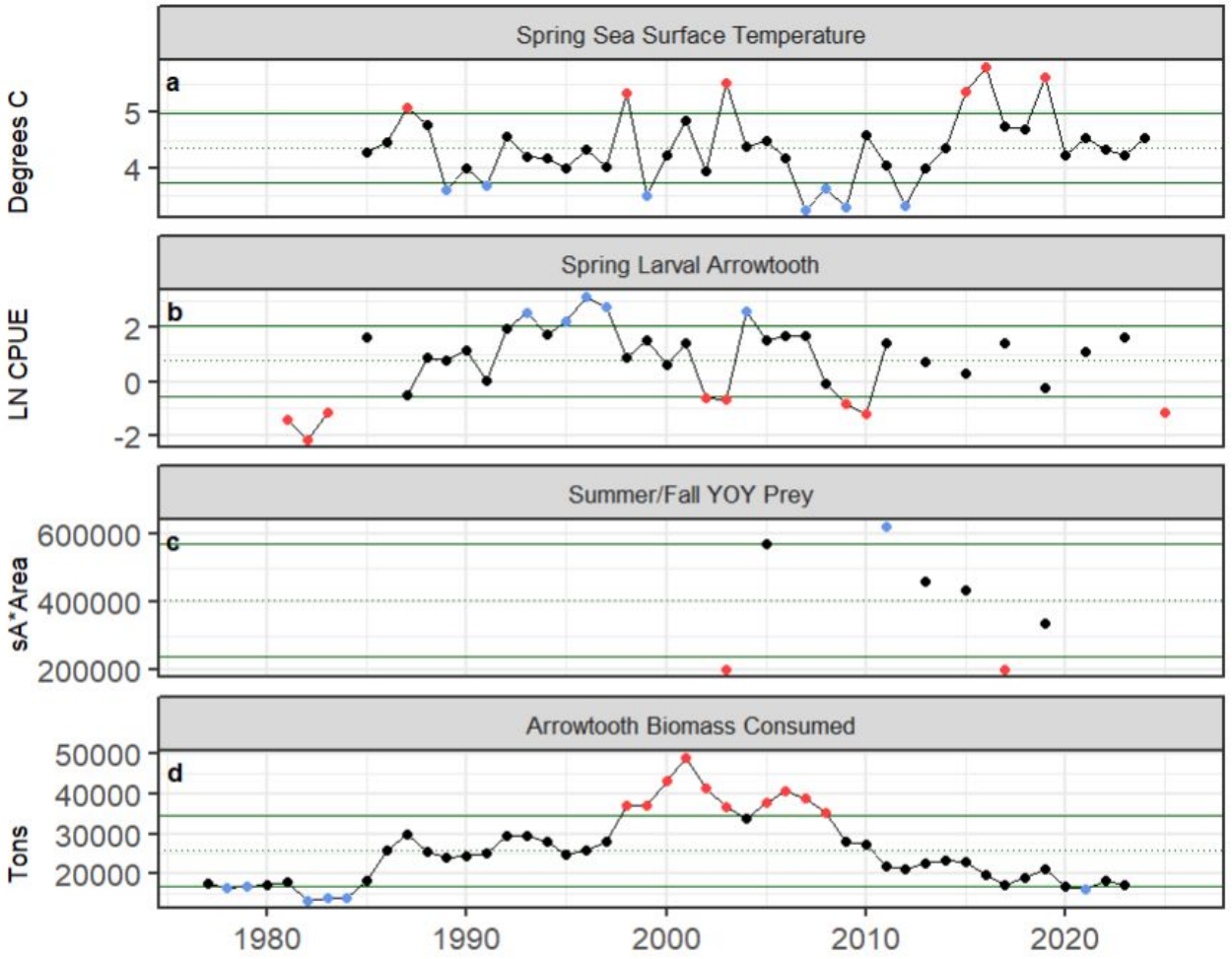
Area: 620,630

Season: Feb-April





Ecosystem Indicators Interpretation



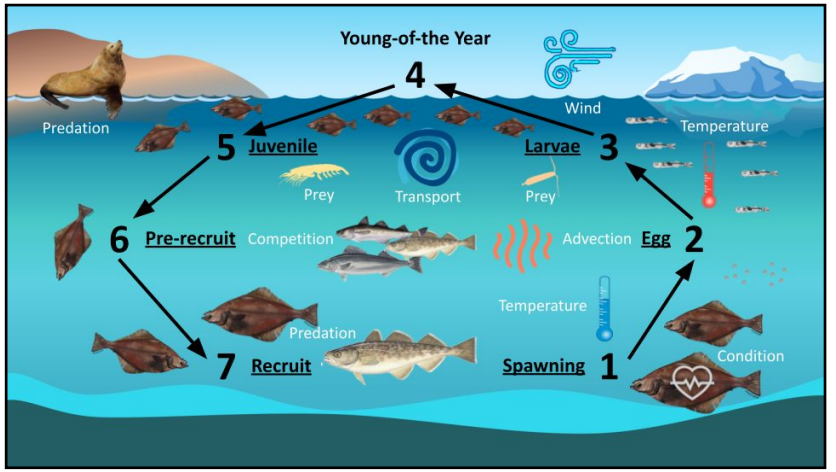
- Spring surface temperatures in the core arrowtooth distribution remain near average implying potentially less lipid-rich zooplankton and may impact feeding conditions.
- Near lowest abundance in time series implies poor foraging, low reserves for overwintering, potentially poor 2025 year class.
- Euphausiids steadily dropping over time series suggesting poor foraging conditions (need to update).
- Estimate of arrowtooth flounder consumed by predators in CEATTLE multispecies model. As predators decline, so does the predation pressure on arrowtooth.

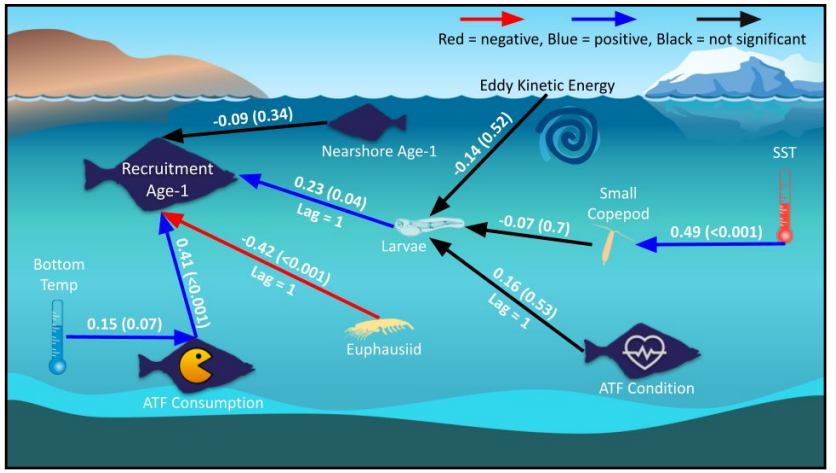
Ecosystem Status Table

Indicator category	Indicator	2020 Status	2021 Status	2022 Status	2023 Status	2024 Status	2025 Status
Larval_YOY	Spring Sea Surface Temperature	neutral	neutral	neutral	neutral	neutral	NA
	Spring Eddy Kinetic Energy	*high*	*high*	neutral	neutral	*high*	neutral
	Spring Larval Arrowtooth	NA	neutral	NA	neutral	NA	**low**
	Spring Larval Prey	NA	neutral	NA	neutral	NA	NA
	Summer YOY Prey	NA	NA	NA	neutral	NA	NA
	Summer/Fall YOY Prey	NA	NA	NA	NA	NA	NA
Juvenile	Female Predation Mortality Age1	*low*	*low*	neutral	*low*	NA	NA
	Male Predation Mortality Age1	*low*	*low*	neutral	*low*	NA	NA
	Small Arrowtooth ADFG	neutral	neutral	neutral	neutral	NA	NA
Adult	CPUE Arrowtooth ADFG	neutral	neutral	neutral	neutral	NA	NA
	Arrowtooth Biomass Consumed	neutral	*low*	neutral	neutral	NA	NA
	Summer Bottom Temperature	NA	neutral	NA	neutral	NA	NA
	Arrowtooth Area Occupied	NA	**high**	NA	neutral	NA	neutral
	Arrowtooth Center of Biomass East	NA	**low**	NA	neutral	NA	neutral
	Arrowtooth Center of Biomass North	NA	**low**	NA	neutral	NA	neutral
	Adult Arrowtooth Condition	NA	neutral	NA	neutral	NA	NA
	Arrowtooth Ration	*low*	*low*	neutral	neutral	NA	NA

Causal Workflow in ESPs

1. Start with ESP synthesis, conceptual model, and indicator suite (example top right)
2. Create causal diagram or Directed Acyclic Graph (DAG) (example bottom right)
   - Use synthesis and any established relationships from ESP to develop mechanism table
   - Make DAG based off relationships defined in mechanism table (use Daggity or similar)
3. Use Dynamic Structural Equation Model (DSEM, Thorson et al., 2024) for estimation
   - Test multiple models (full, simple, AR1, IID), evaluate relationships, model selection
4. Review results with ESP Teams and iterate

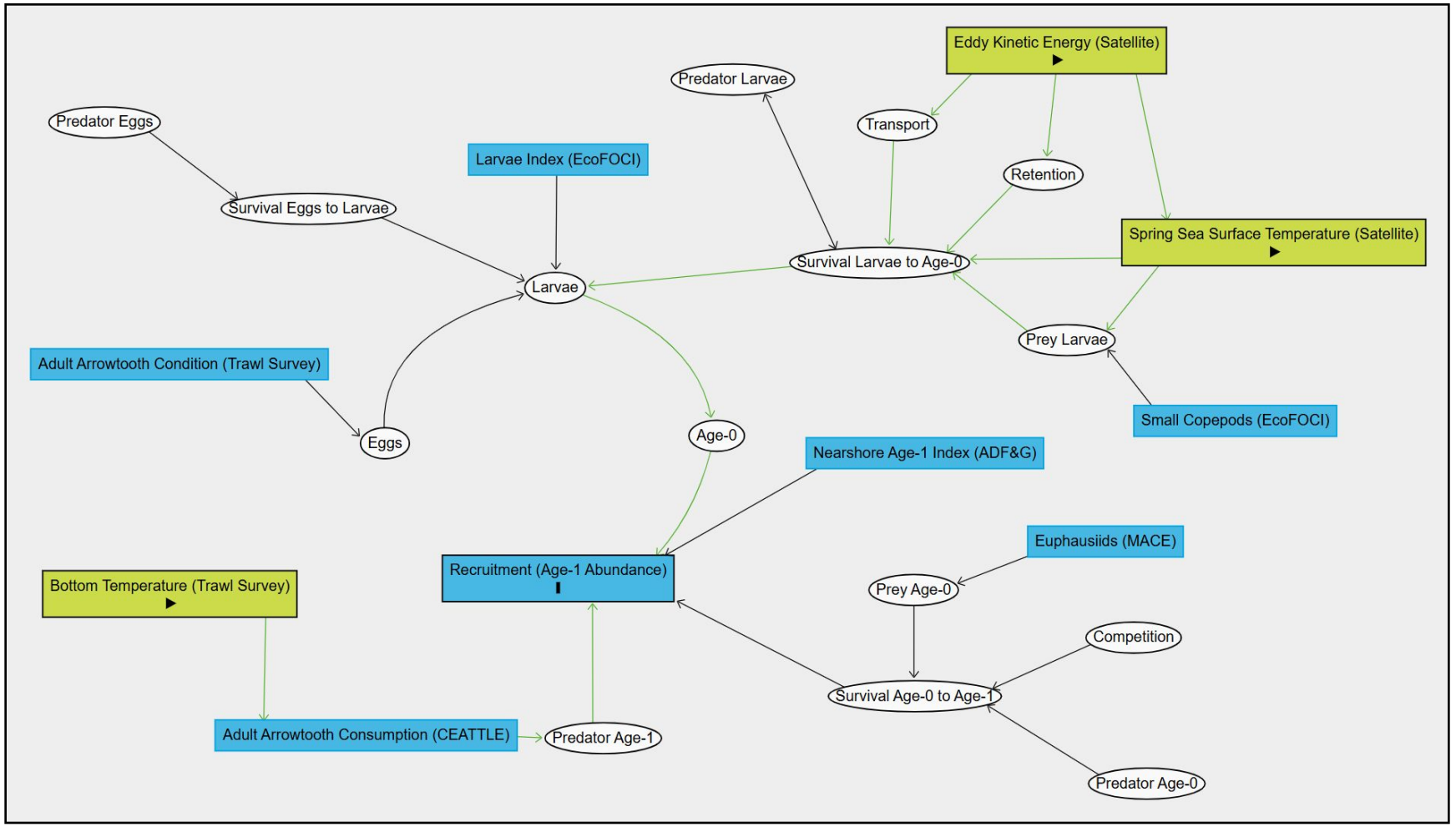




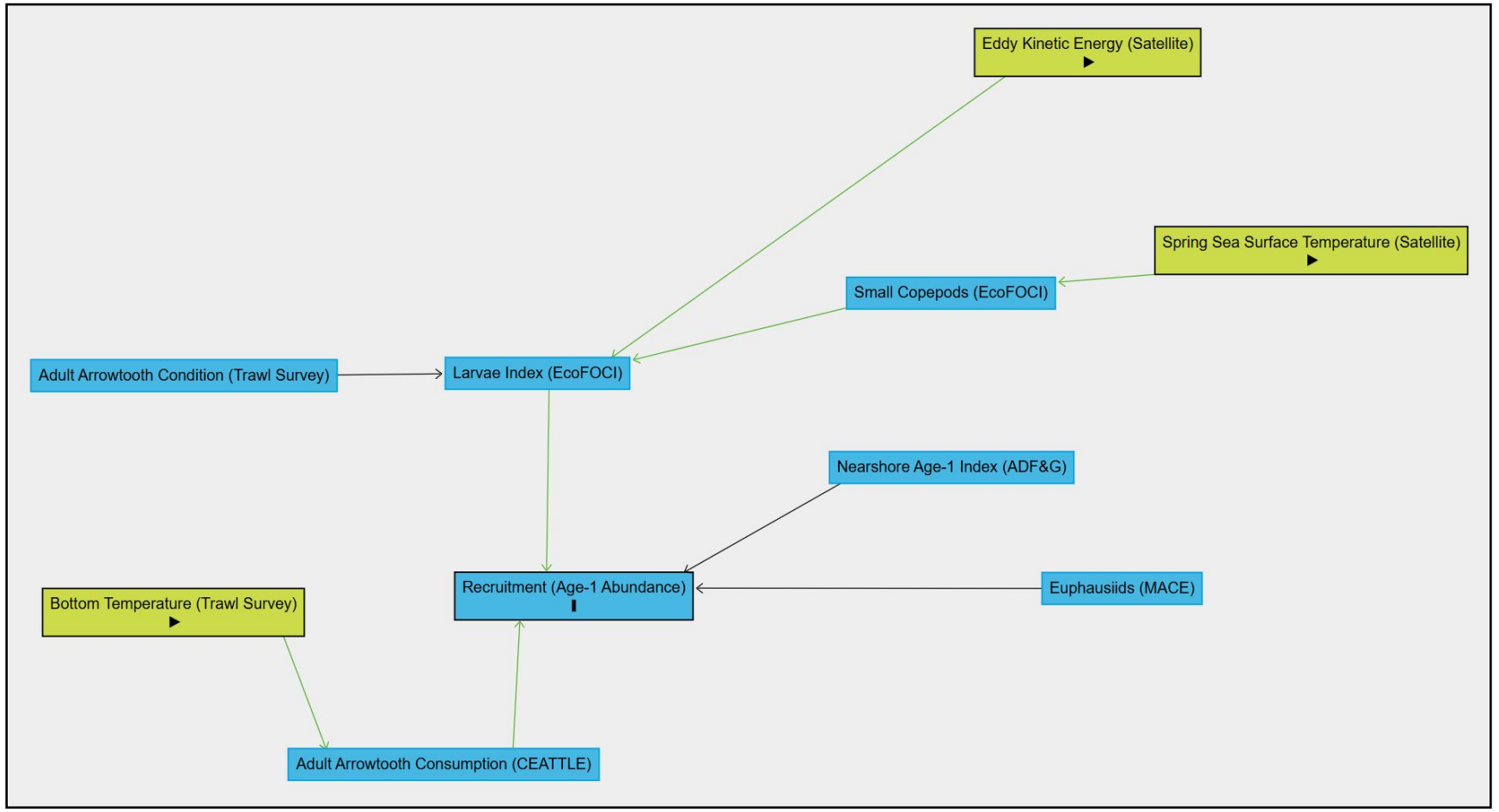
Ecosystem Mechanism Table

Link	Description	Relationship / Lag
Temperature to predation	Higher temperatures increase metabolism that will increase consumption (Holsman and Aydin, 2015).	Positive / 0
Euphausiids to age-1 recruitment	Euphausiids are a common prey of age-1 arrowtooth (Paul et al., 1999, Doyle et al., 2018).	Positive / 1
Temperature to small calanoid copepods	Marine heatwave influences the size (warm = more small copepods) and abundance of the copepod community (low large copepods in spring; Kimmel et al., 2023).	Positive / 0
Small calanoid copepods to larval abundance	Trophic modeling studies suggest biomass of arrowtooth flounder may be strongly influenced by changes in bottom-up production in plankton; fish < 200 mm eat zooplankton (Aydin et al., 2007; Doyle et al., 2018).	Negative / 0
Eddy kinetic energy (eke) to larval abundance	More eddy kinetic energy (EKE) in western GOA determines years of high recruitment (Goldstein et al., 2020)	Positive / 0
Adult condition to larval abundance	More energy reserves (Rohan et al., 2023) can be allocated to spawning and eggs/larvae would have more lipid reserves providing resilience from increased temperatures	Positive / 1
Larval abundance to age-1 recruitment	Recruitment and biomass may be related to density dependent effects at juvenile stage (Shotwell et al., 2022).	Positive / 1
Nearshore age-1 to age-1 recruitment	The abundance of age-1 fish in ADFG nearshore survey (Spalinger et al., 2023) relates to the abundance of age-1 recruits	Positive / 0
Predation to recruitment	Pacific cod and pacific halibut represent the highest proportion of predation on > 30 mm individual arrowtooth flounder; Cannibalism on the individuals 30-299 mm (Doyle et al., 2018, Adams et al., 2022).	Negative / 0

Full Directed Acyclic Graph (DAG)

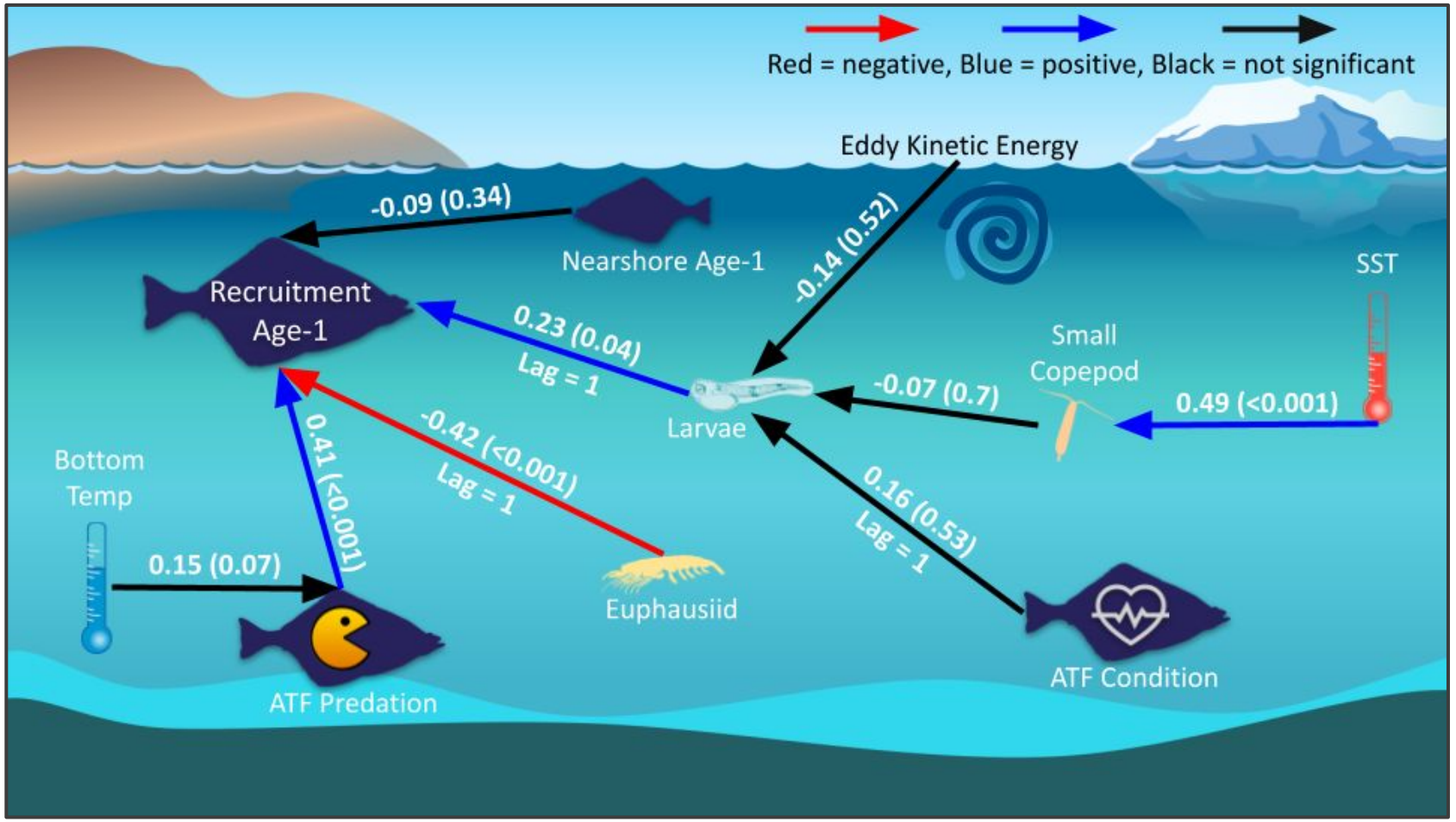


Simplified Directed Acyclic Graph (DAG)



Simplified DAG with Estimated Effects

Model	AIC
causal	733.0
IID	781.2
AR1	737.5



Causal Results Table

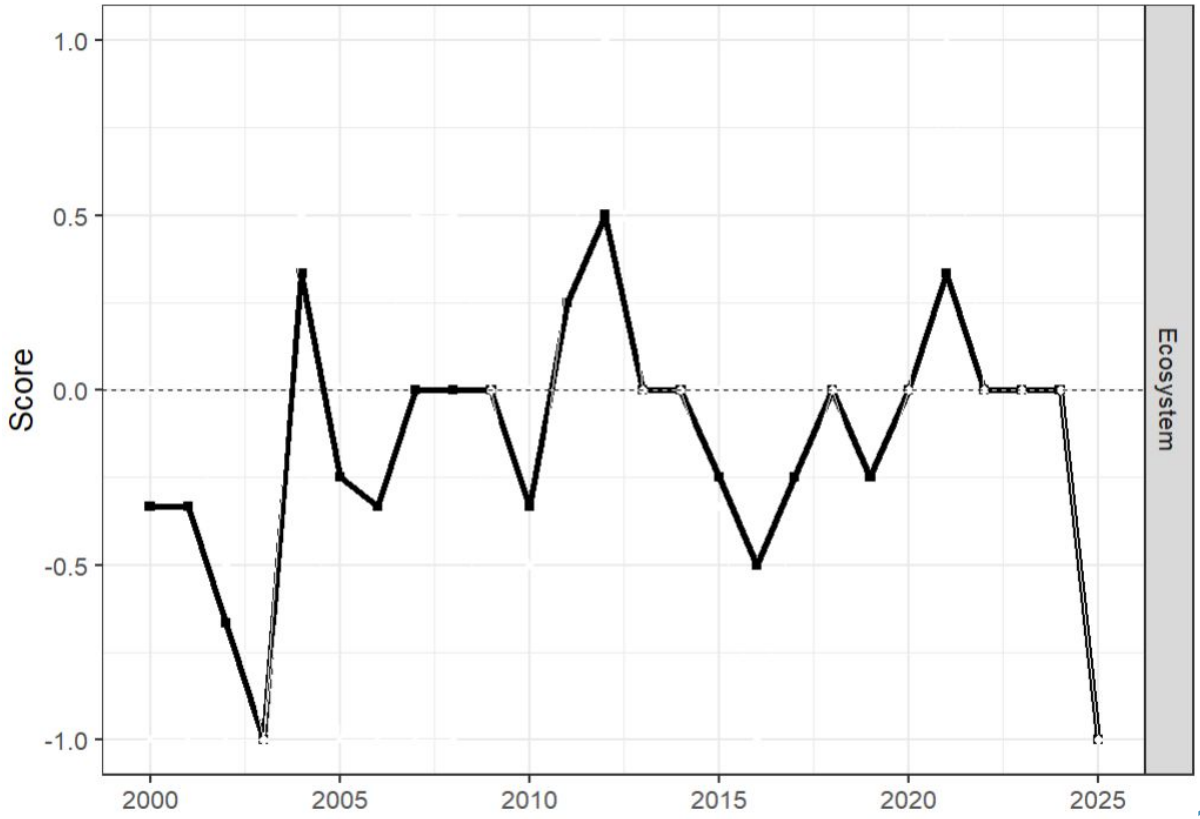
Link	Data from ESP (Indicator Title)	Estimate (P-value)	Relationship Change	Improvement Suggestions
Temperature to predation	Summer Bottom Temperature	0.15 (0.07)	None	Match bottom temp to period of predation on age-1 arrowtooth MOM6
Euphausiids to age-1 recruitment	Summer/Fall YOY Prey	-0.42 (<0.001)	Positive to Negative	Longer time series during YOY pelagic existence, e.g., EcoFOCI fall euphausiids time series
Temperature to small calanoid copepods	Spring Sea Surface Temperature	0.49 (<0.001)	None	More refined spatial match to pelagic arrowtooth larvae
Small calanoid copepods to larval abundance	Spring Larval Prey	-0.07 (0.7)	None	Determine actual prey size for arrowtooth larvae in late spring from diet samples, could switch to large copepod time series
Eddy kinetic energy (eke) to larval abundance	Spring Eddy Kinetic Energy	-0.14 (0.52)	Positive to Negative	Determine if entrainment leads to higher prey or being swept out of system, refine seasonal match
Adult condition to larval abundance	Adult Arrowtooth Condition	0.16 (0.53)	None	Refine to just mature adults rather than all arrowtooth
Larval abundance to age-1 recruitment	Spring Larval Arrowtooth	0.23 (0.04)	None	Determine if a YOY summer/fall index also exists for additional data linkages
Nearshore age-1 to age-1 recruitment	Small Arrowtooth ADF&G	-0.09 (0.34)	Positive to Negative	Refine size range based on new size age matrix in model, remove Aleutian samples
Predation to recruitment	Arrowtooth Biomass Consumed	0.41 (<0.001)	Negative to Positive	Switch to more prominent predator of arrowtooth age-1 (e.g., Pacific cod adult biomass)

Ecosystem Status Table - Reorganized

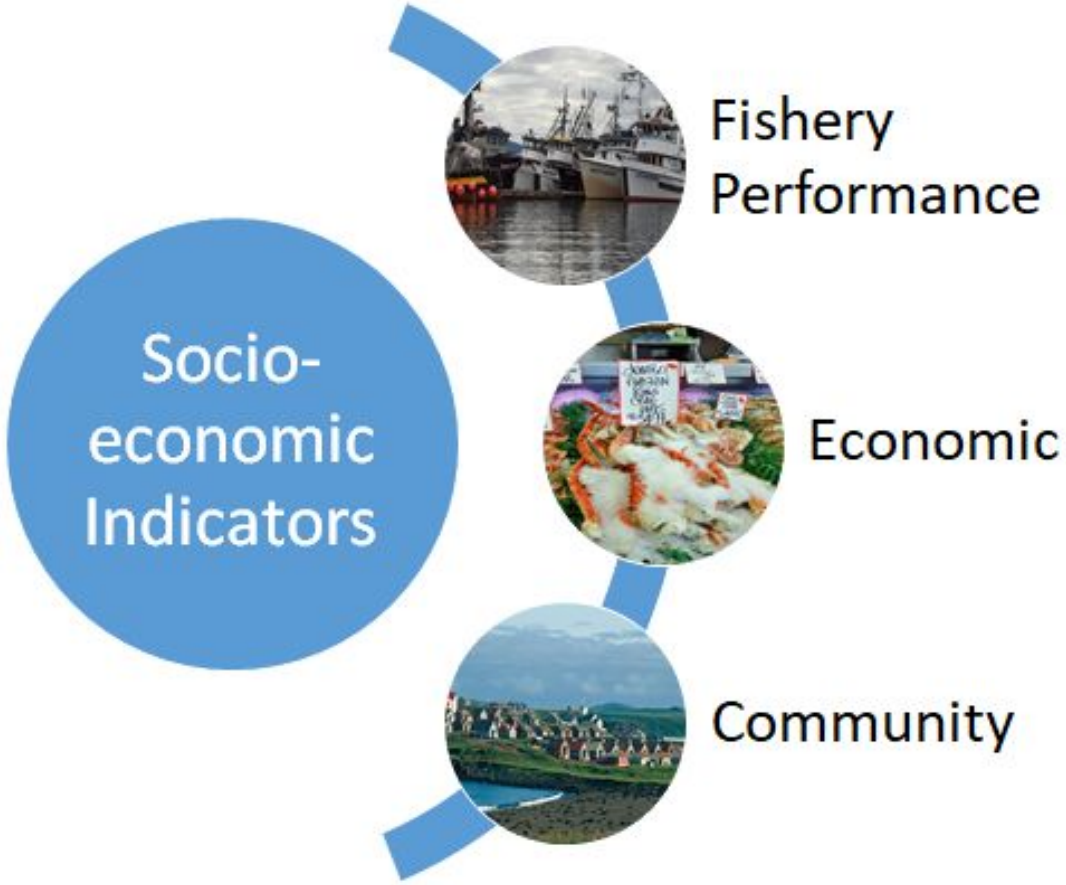
Indicator category	Indicator	2021 Status	2022 Status	2023 Status	2024 Status	2025 Status
Predictive	Spring Sea Surface Temperature	neutral	neutral	neutral	neutral	NA
	Spring Larval Arrowtooth	neutral	NA	neutral	NA	**low**
	Summer/Fall YOY Prey	NA	NA	NA	NA	NA
	Arrowtooth Biomass Consumed	**low**	neutral	neutral	NA	NA
Contextual	Spring Eddy Kinetic Energy	*high*	neutral	neutral	*high*	neutral
	Spring Larval Prey	neutral	NA	neutral	NA	NA
	Summer YOY Prey	NA	NA	neutral	NA	NA
	Female Predation Mortality Age1	*low*	neutral	*low*	NA	NA
	Male Predation Mortality Age1	*low*	neutral	*low*	NA	NA
	Small Arrowtooth ADFG	neutral	neutral	neutral	NA	NA
	CPUE Arrowtooth ADFG	neutral	neutral	neutral	NA	NA
	Summer Bottom Temperature	neutral	NA	neutral	NA	NA
	Adult Arrowtooth Condition	neutral	NA	neutral	NA	NA
	Arrowtooth Ration	*low*	neutral	neutral	NA	NA
Monitoring	Arrowtooth Area Occupied	**high**	NA	neutral	NA	neutral
	Arrowtooth Center of Biomass East	**low**	NA	neutral	NA	neutral
	Arrowtooth Center of Biomass North	**low**	NA	neutral	NA	neutral

Simple Indicator Score

- Predictive
  - 4 of 17 indicators significant in the simplified DSEM model
  - 3 were from larval/YOY category, 1 from adult
  - Remained average from 2024
- Contextual
  - 10 of 17 indicators considered contextual

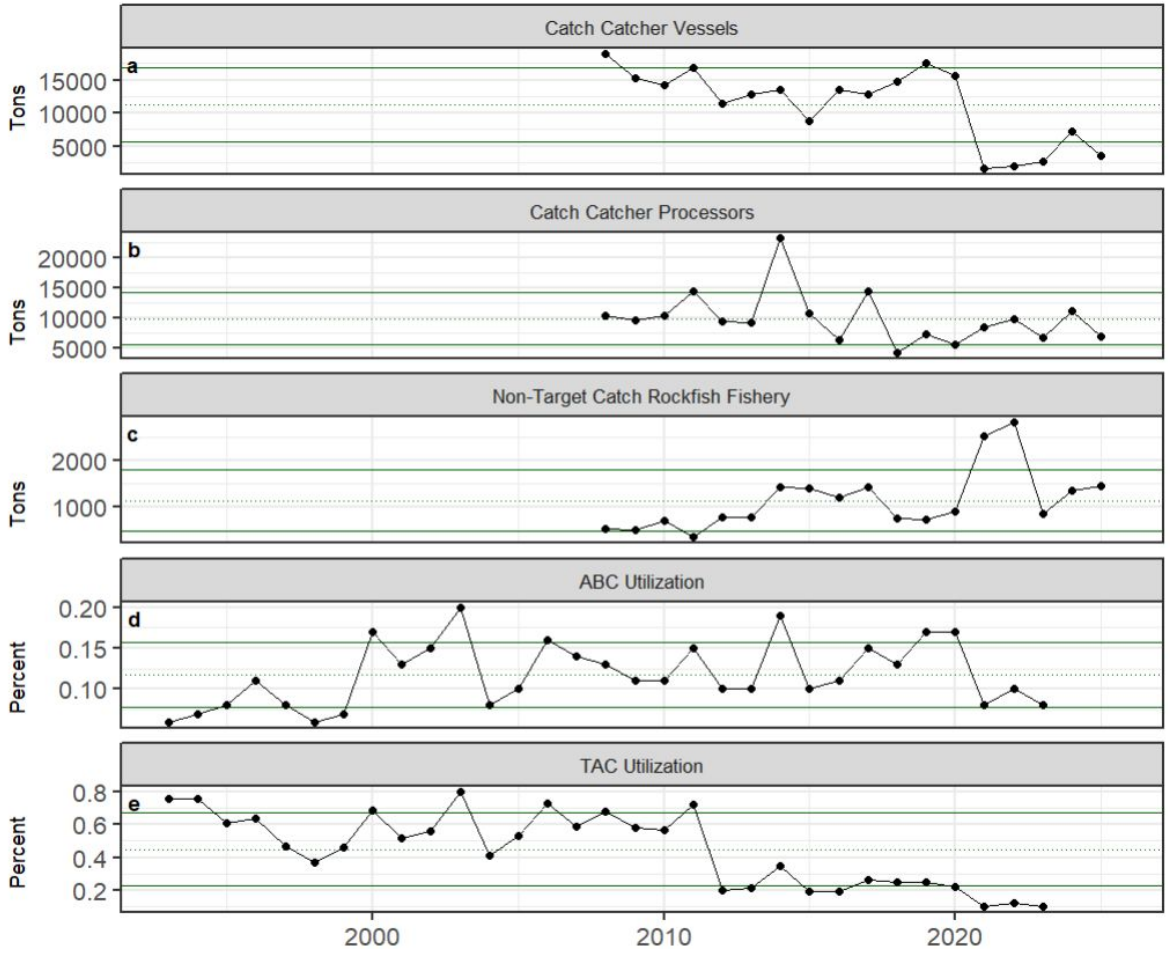


Socioeconomic Indicators



1. Catch from catcher vessels
2. Catch from catcher processors
3. Non-target catch in rockfish fishery
4. ABC Utilization
5. TAC Utilization
6. Ex-vessel value
7. Ex-vessel price per pound
8. Revenue per unit effort

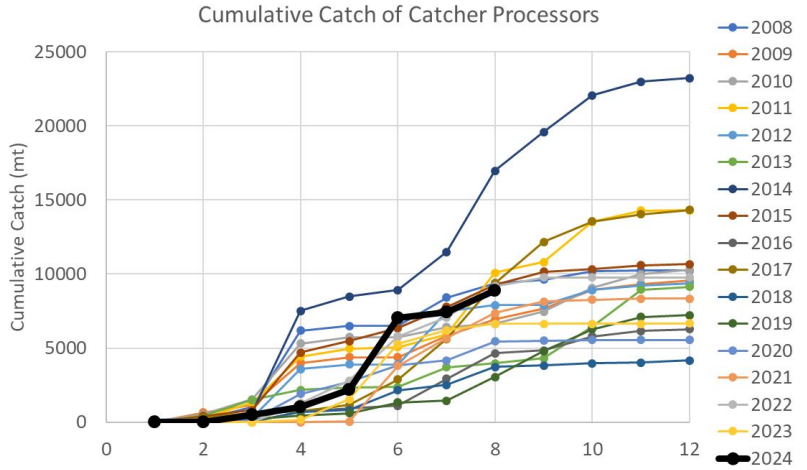
Fishery-Informed Indicators

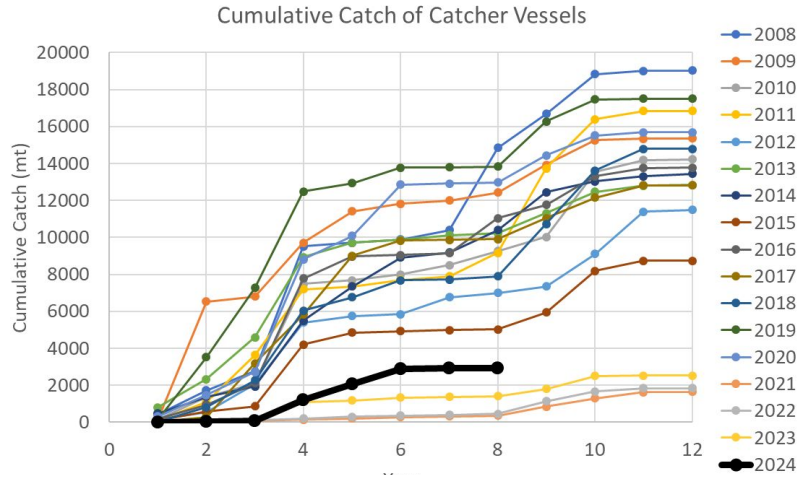


- Catcher vessel shifted in 2020 to lowest arrowtooth catch of the time series and remains low implying change in fleet behavior
- Catcher processor catch more variable, slightly increasing since low in 2018, implying a redistribution of arrowtooth
- Rapid changes of a non-target catch may imply a shifting distribution into non-preferred habitat and could increase competition/predation.
- ABC utilization variable but generally below 20%, increasing until 2020, and then low
- TAC utilization shifted from high period in 2012 and has remained low, TACs were much smaller (more than half) prior to 2012

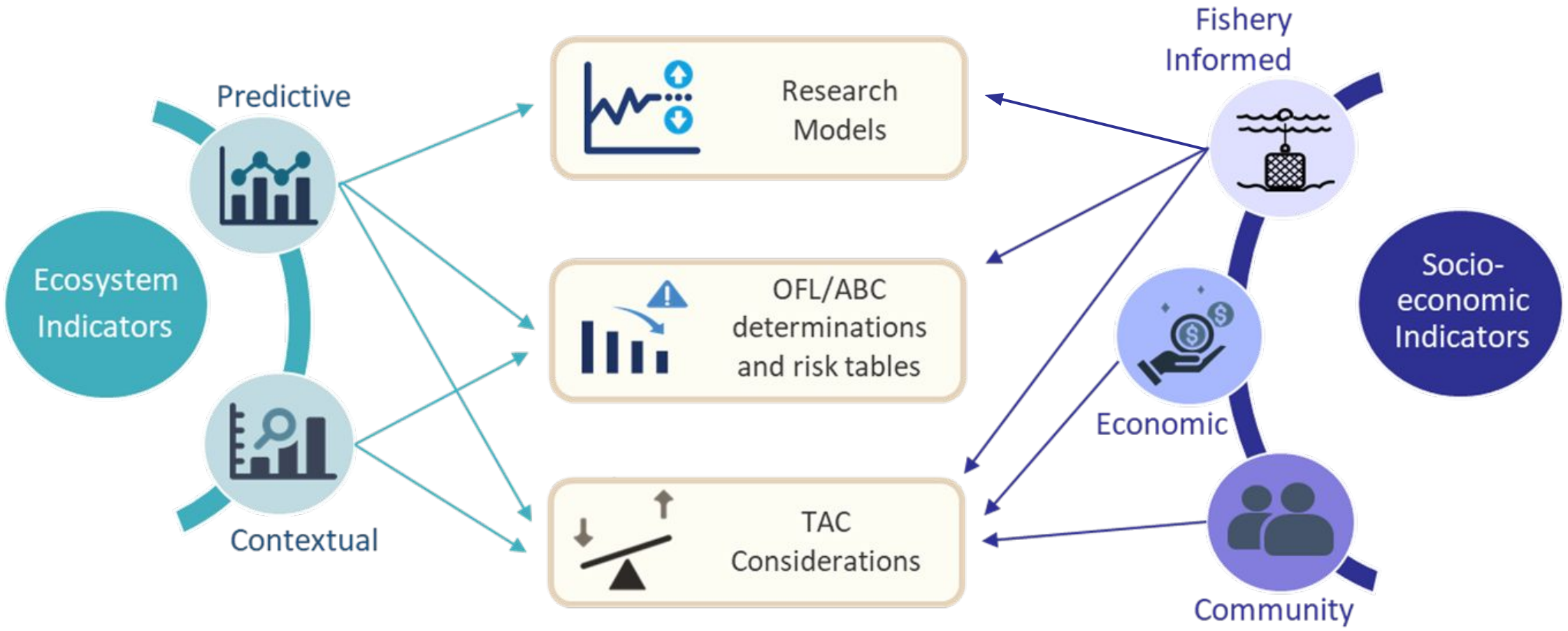
Socioeconomic Status Table

Indicator category	Indicator	2020 Status	2021 Status	2022 Status	2023 Status	2024 Status	2025 Status
Fishery Informed	Catch Catcher Vessels	neutral	low	low	low	neutral	low
	Catch Catcher Processors	neutral	neutral	neutral	neutral	neutral	neutral
	Non-Target Catch Rockfish Fishery	neutral	high	high	neutral	neutral	neutral
	ABC Utilization	high	neutral	neutral	neutral	NA	NA
	TAC Utilization	low	low	low	low	NA	NA





Indicator Pathways to Decisions



Plans for November

- Explore DSEM models then integrate to Rceattle
  - Meeting with ESP Team next week, review DAG, identify models to test
  - Once determined models then add to DSEM branch of Rceattle
  - Use recommended operational model as starting point
- Re-organize indicators based on results and provide summary
  - Use predictive, contextual, monitoring categories
  - Coordinate with ESR to create risk table template of highlights
  - Combine with results of multispecies research model
  - Identify options for how to use these results for advice (e.g., projections)

Discussion

1) Do the plans for November seem reasonable?
2) Is there any feedback on current indicator suite (interpretation, caveats, missing indicators, etc.)?
3) Any thoughts on the causal/DSEM workflow and options for using the results for informing our decisions?
    - Use in projections for off-cycle years, use in the risk tables, use as gut check on operational model…

Thank You!

Contact:

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