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Ecosystem & Socioeconomic Profile

Eastern Bering Sea Tanner Crab

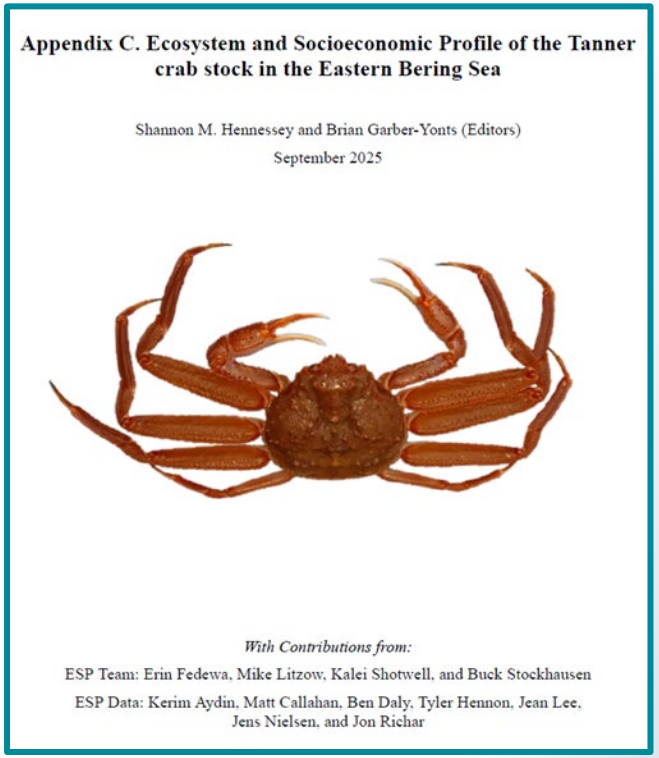
Shannon Hennessey and Brian Garber-Yonts

September 2025

ESP Contributors: Erin Fedewa, Mike Litzow, Kalei Shotwell, Buck Stockhausen, Kerim Aydin, Matt Callahan, Ben Daly, Tyler Hennon, Jean Lee, Jens Nielsen, and Jon Richar

Overview

- Full ESP Document
  - Introduction
    - Justification, data sources
  - Indicator synthesis
  - Indicator assessment
  - Indicator monitoring analysis
    - Importance analyses
    - Traffic light trends
- CPT/SSC responses
- Ecosystem indicator suite
- Indicator importance analysis
- TAC/ABC considerations



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Responses to CPT and SSC

ESPs in General

"The CPT discussed a new approach to categorize ESP indicators into predictive and contextual indicators. ... The SSC provisionally supports this approach, but would like the opportunity to review an example ESP where this approach is applied before fully endorsing it." (SSC, June 2025)

- We intend for the full Tanner ESP to serve as an example of this approach, and look forward to SSC and CPT feedback.

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Responses to CPT and SSC

Tanner ESP

"The CPT asked for information that was used in the initial identification of indicators, including providing relationships of the ecosystem indicators with crab response variables. The CPT suggested that including the response variable(s) in the time series plots for comparison would be useful." (CPT, May 2025)

> The conceptual diagram (Figure C.1) was used for ecosystem indicator development, identifying vulnerabilities based on life history stage from the literature and expert knowledge, and the "Factors influencing trends" and "Implications" bullet points underneath each ecosystem indicator in the Indicator Suite section identify the rationale for the proposed relationship/mechanism. We have added a new figure (Figure C.5) displaying the lagged and standardized ecosystem indicators tested in the final Bayesian Adaptive Sampling Model overlaid with our Tanner crab recruitment response variable.

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Responses to CPT and SSC

"The CPT discussed whether to use survey data or model output estimates for recruitment as a response variable in indicator selection and in the Bayesian Adaptive Sampling (BAS) analysis, especially given the eventual aim to include the indicators in assessments. It could be helpful to review data inputs to other ESPs to consider response variables." (CPT, May 2025)

> While we did not have time to explore this yet, we intend to further test and refine our response variables in future iterations of this process.

"The CPT commented that crab distribution may be influenced by where the fleet is fishing and is not simply a reflection of population movement. In addition, the distribution could be a product of larval release location. Therefore the indicator based on the centroid of adult male distribution is not a simple indicator of population status." (CPT, May 2025)

> We agree that Tanner crab distributions can be influenced by many factors and the centroid of adult male distribution is not an indicator of population status. We have clarified the intent of this indicator in the text, as the centroid of adult male distribution was constructed to provide context on the distribution of the stock itself.

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Responses to CPT and SSC

"The CPT discussed that alternative female reproductive potential metrics might be considered and that it would be helpful to consider what question is being answered in the metric chosen. The current metric of the proportion of females that have a full clutch (measured on the survey as ¾ to full) reflects high reproductive potential. The CPT suggested that a metric that reflects low potential may be more informative of poor environmental conditions and a useful metric when there is future population concern." (CPT, May 2025)

We have created a metric of reproductive failure and are using this new indicator in the place of reproductive potential. While clutch fullness can also indicate the potential status of mate availability, with females using sperm reserves having decreased clutch fullness, and reproductive failure is generally low in EBS Tanner crab, we also identified a change in clutch index protocol in the NMFS survey that impacted our fullness metric prior to 1998. This, in conjunction with the CPT's recommendation, informed our use of reproductive failure to both better capture potentially poor environmental conditions influencing reproductive output and to maximize time series length for indicator importance analyses.

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Responses to CPT and SSC

"The CPT asked for more information on the lags used for each metric in the BAS analysis, as they were not available in the presentation. The author indicated that larval indicators were lagged 4 years, indicators for juveniles were lagged 2 years and some others 1 year. The CPT discussed that these lags need additional consideration (e.g., the lag for the larval indicators was considered to be too short) and explanation in the final ESP." (CPT, May 2025)

> We have reassessed and modified the lags and have provided more rationale for each lag in the Indicator Monitoring Analysis section. We will also provide more detailed information in the presentation to CPT in September.

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Responses to CPT and SSC

"The CPT asked that the results of the BAS analysis include the posterior probability distributions for the model predictions for inclusion on the model fit plot as well as an interpretation of the results in terms of the percent influence each indicator has (e.g., what does a 0.4 for chlorophyll-a concentration mean in terms of changes in recruitment?). Both types of information should be readily available from the results of the BAS analysis. The model fit plot would be enhanced by adding the sampling-based confidence intervals to the data." (CPT, May 2025)

We are currently working to add the sampling-based confidence intervals to the data on the model fit plot and will incorporate this into subsequent iterations of this document, but have been unable to complete this as of yet. We will also work to include interpretation of the results in terms of the percent influence each indicator has.

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Responses to CPT and SSC

"The CPT commented that the time series of indicators used in the BAS analysis are short and that the analysis could be better informed by a longer time series. As the start of the time series is limited by availability of data, the CPT suggested that data for some indicators go back further in time and might be included in an analysis with fewer indicators. The CPT also suggested there might be ROMS output that could be used to extend, in particular, the chlorophyll-a time series further back in time." (CPT, May 2025)

> We have revised our analysis to only include indicators that allow for maximum time series length, removing chlorophyll-a concentration from consideration. Including ROMS output is not tractable at this time as the Bering10K model has been reported to have limited skill in reproducing observed spatial and temporal patterns of primary production (Kearny et al., 2020). We note that the time series length constraint of the BAS analysis continues to be a challenge and we are working on exploring other analysis frameworks, such as Dynamic Structural Equation Modeling (DSEM), that may be better suited to the nature of the data we have available.

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Responses to CPT and SSC

"A draft ESP was also presented and the CPT provided a number of recommendations to the stock assessment author. The SSC concurs with the CPT recommendations and looks forward to the final ESP in October 2025. The SSC also discussed the utility of long-term indicators in the context of changing environmental conditions and recommends adding an indicator on the effects of temperature on size of maturity. While long-term indicators provide historical context, they may not provide adequate context for future conditions. The SSC suggests continued evaluation of indicators and their overall utility." (SSC, June 2025)

This is valuable feedback and is something we will continue to consider and incorporate as we develop indicators and methodologies to evaluate indicator importance. Our current understanding of how temperature affects size at maturity is still incomplete, but analyses are in progress to explore this question. While providing context for future conditions is important, we first have to evaluate stock-indicator relationships and assess predictive capacity before we can use any of these relationships to forecast. Additionally, we need to undergo adequate skill testing on these forecasts for them to be useful. However, we will continue to iterate and evaluate our indicators to work towards this goal.

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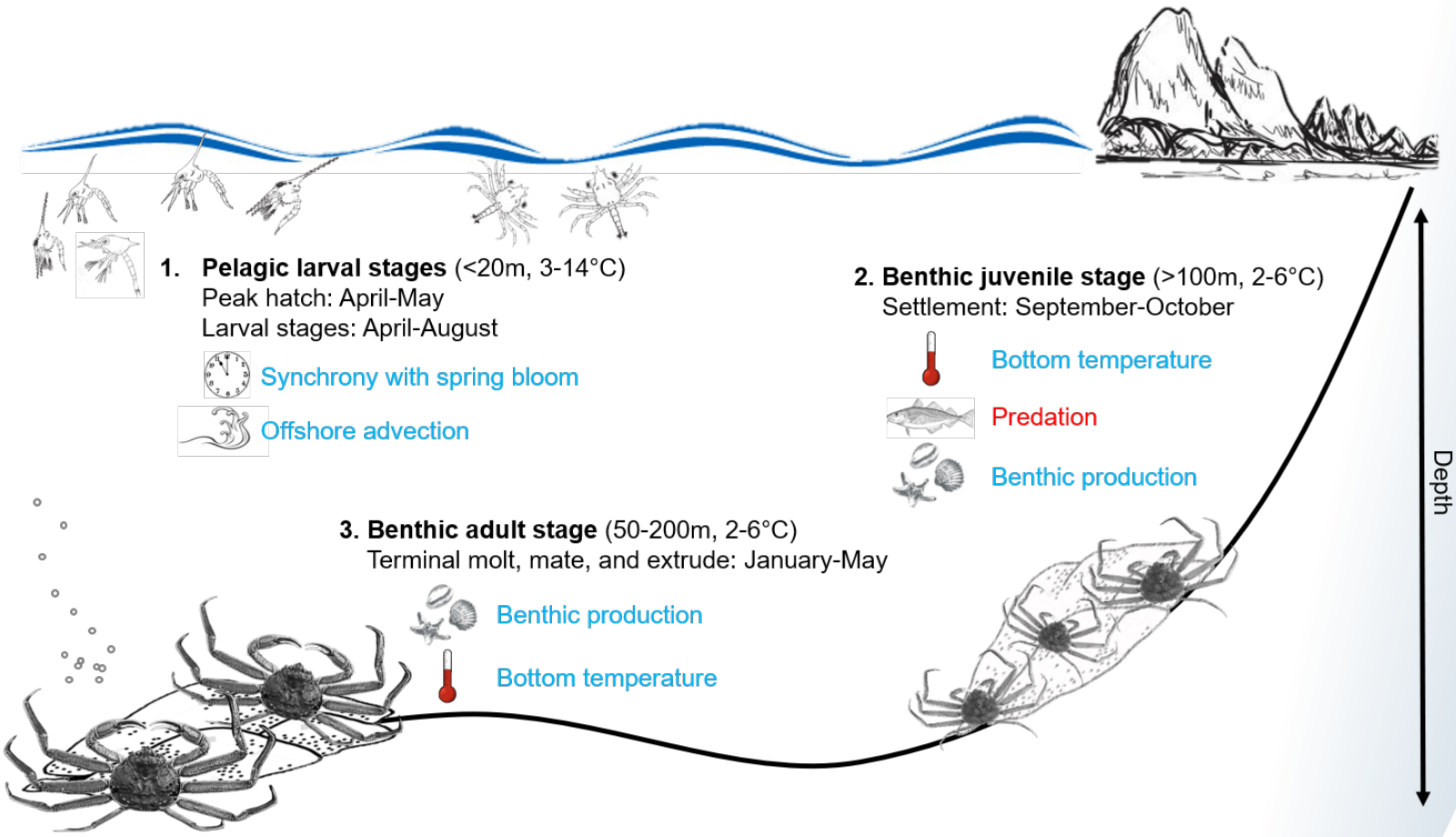
Ecosystem Processes



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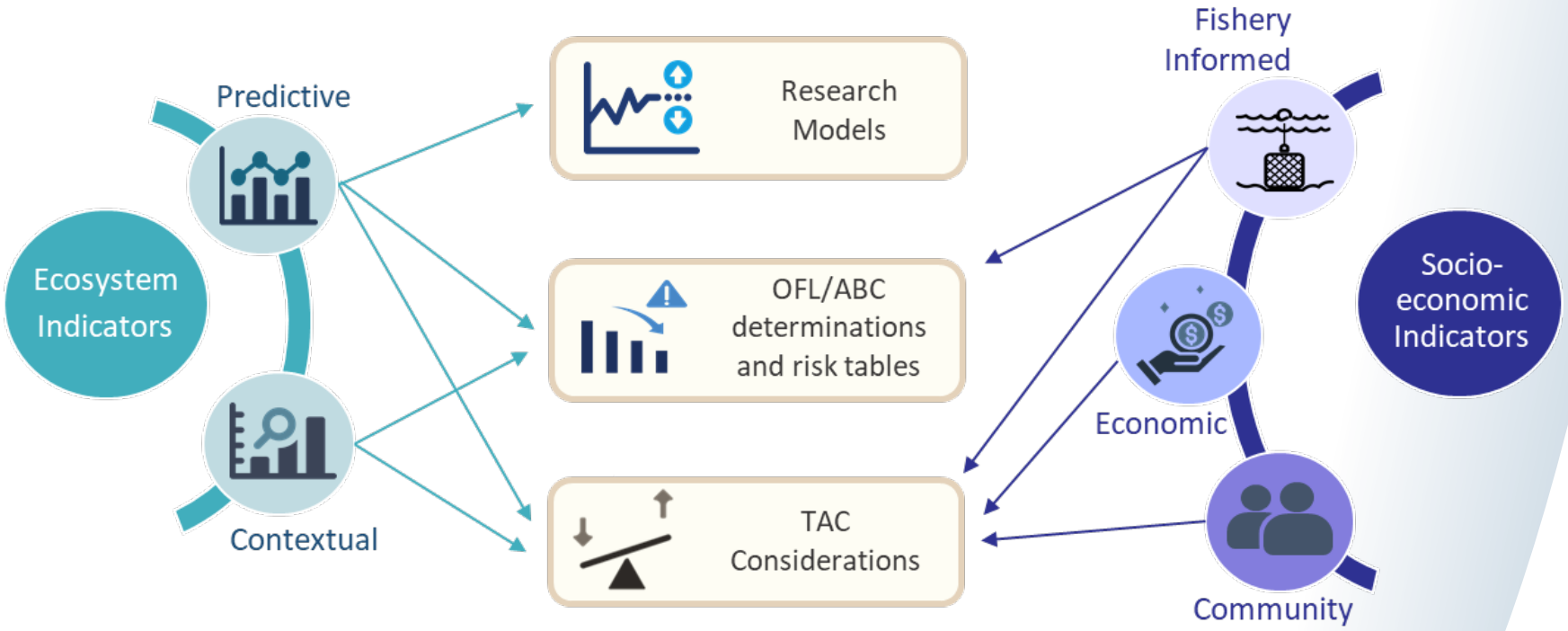
Indicator Decision Pathways



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Ecosystem Indicators

Predictive

- Quantitative, demonstrated relationship with population processes – i.e. recruitment & mortality
  - Evaluated via indicator importance scores, out-of-sample predictive skill, etc.

Contextual

- Potential red flags related to MMB, but not quantitative driver of recruitment
- Anticipatory information or direct measure of status/health of large immature “pre-recruits” or spawning biomass
- Contextual information for management concern or risk table category

All other indicators are categorized as “monitoring”

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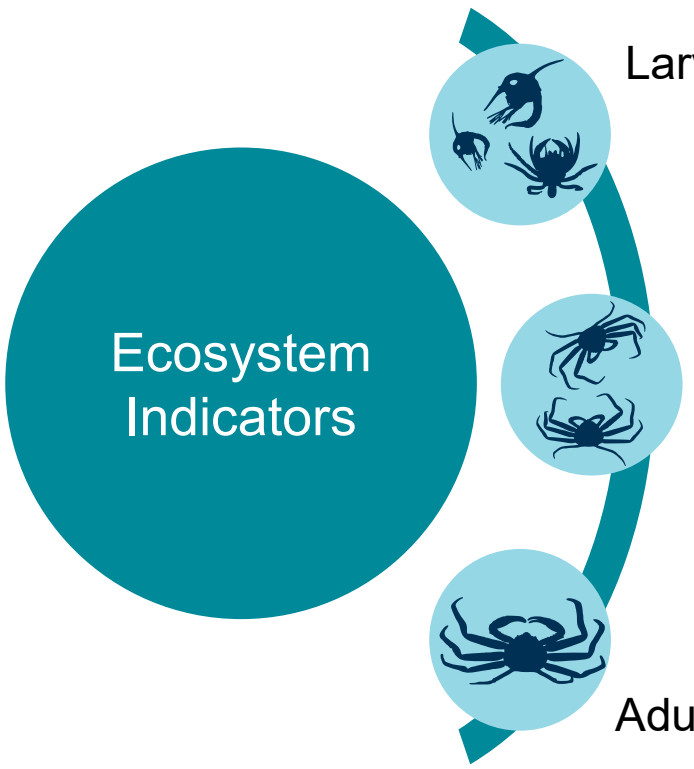
Ecosystem Indicators



Larval

- \+ **Along-Shelf Wind**
- \+ Surface Temperature

Juvenile

- \+ Chlorophyll-*a* Concentration
- \+ Juvenile Temperature of Occupancy
- − Benthic Predator Density
- − Pacific Cod Consumption
- − Juvenile Disease Prevalence
- \+ Benthic Invertebrate Density

Adult

- \+ Male Size at 50% Terminal Molt
- \+ Mature Male Area Occupied
- n/a Mature Male Center of Abundance
- \+ Female Mean Size at Terminal Molt
- − **Female Reproductive Failure**

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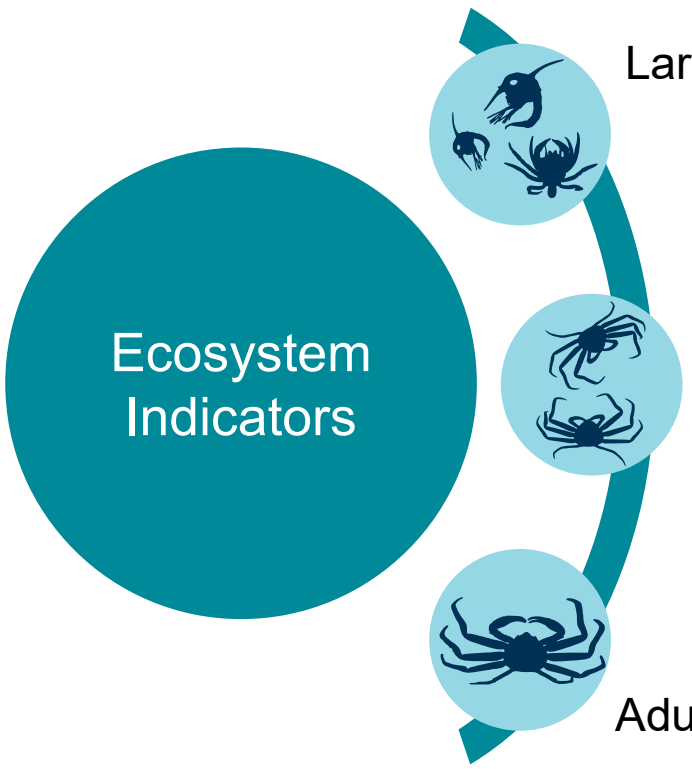
Ecosystem Indicators



Larval
- \+ Along-Shelf Wind
- \+ Surface Temperature

Juvenile
- \+ Chlorophyll-*a* Concentration
- \+ Juvenile Temperature of Occupancy
- − Benthic Predator Density
- − Pacific Cod Consumption
- − Juvenile Disease Prevalence
- \+ Benthic Invertebrate Density

Adult
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- n/a Mature Male Center of Abundance
- \+ Female Mean Size at Terminal Molt
- − Female Reproductive Failure

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Indicator Analysis: BAS Indicator Importance

Indicator	Removal criteria	Lag (years)	Rationale
Surface Temperature		5	Pre-recruit age = 5 years
Along-Shelf Wind		5	Pre-recruit age = 5 years
Chlorophyll-a Concentration	*Time series length*	--	
Juvenile Occupancy Temperature		1	Prior year most informative for survival
Benthic Predator Density		3	Greater impact on small size classes
Pacific Cod Consumption		3	Greater impact on small size classes
Juvenile Disease Prevalence		3	Greater impact on small size classes
Benthic Invertebrate Density		2	More recent conditions inform pre-recruit survival

Larval indicator *Juvenile indicator*

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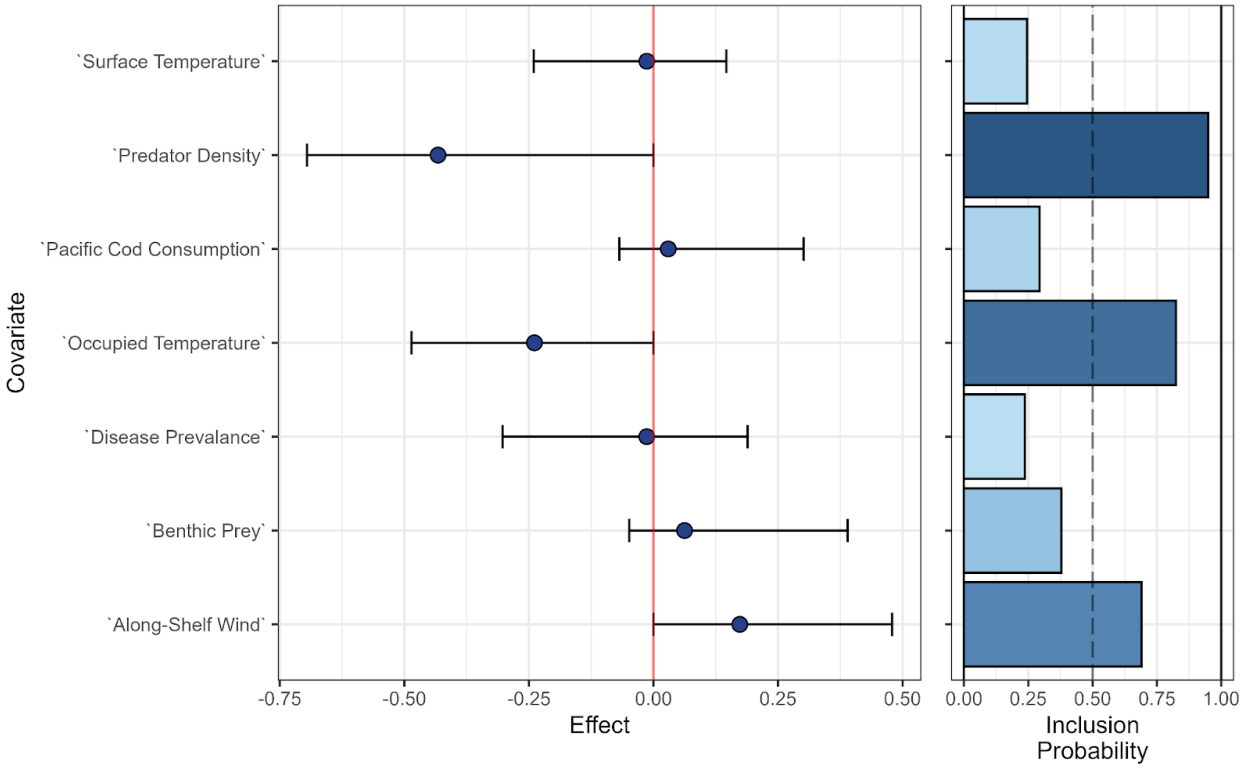
Indicator Analysis: BAS Indicator Importance



Three predictive indicators with strong inclusion probabilities and directional effects on recruitment: benthic predator density, juvenile temperature occupied, and along-shelf wind

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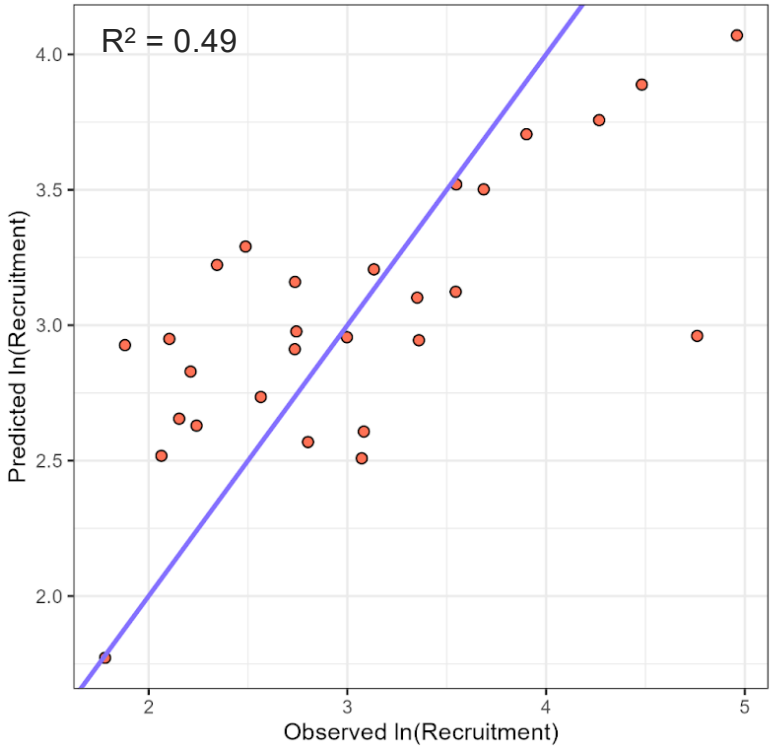
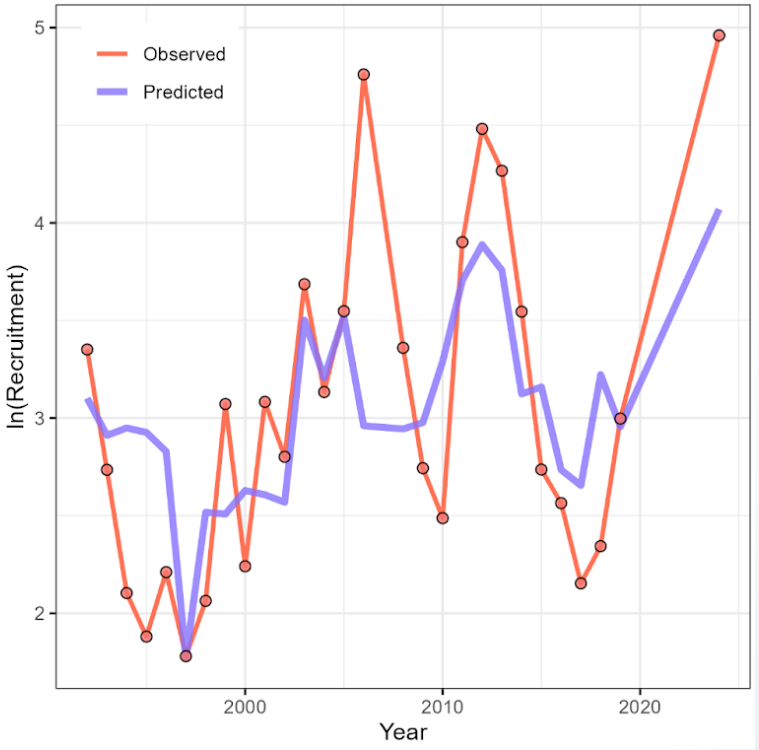
Indicator Analysis: BAS Indicator Importance





The model explained a moderate amount of variation in “pre-recruits” (70-85mm males) from survey estimates

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Ecosystem Indicators

Predictive

- − Benthic Predator Density
- + Juvenile Temperature of Occupancy
- + Along-Shelf Wind

Contextual

- − Juvenile Disease Prevalence
- + Male Size at 50% Terminal Molt
- + Mature Male Area Occupied
- n/a Mature Male Center of Abundance
- + Female Mean Size at Terminal Molt
- − Female Reproductive Failure

Monitoring

- + Surface Temperature
- + Chlorophyll-*a* Concentration
- − Pacific Cod Consumption
- + Benthic Invertebrate Density

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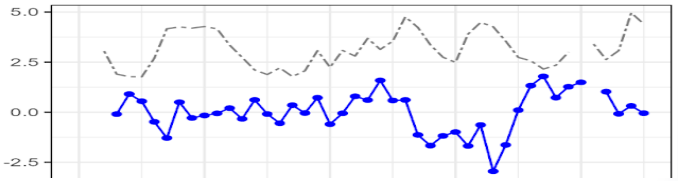
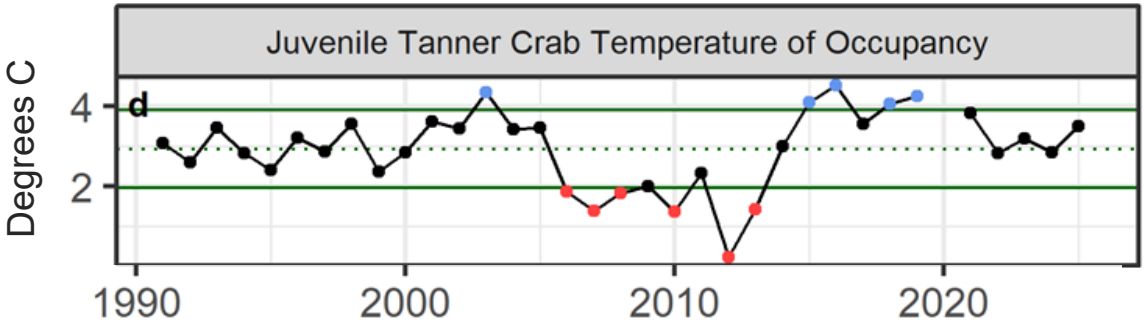
Predictive Indicators





Near-average juvenile Tanner crab temperature occupied of 3.5°C suggests **average growth and survival** in the coming year.

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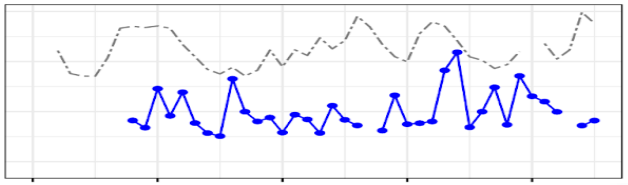
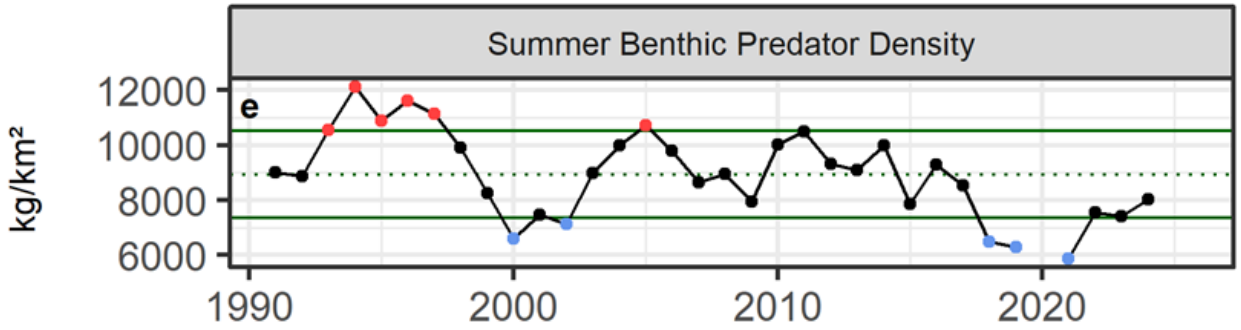
Predictive Indicators





Increasing benthic predator density in core Tanner crab habitats from 2021-2024 suggests **increasing predator-prey interactions** and **reduced survival** of juvenile cohorts relative to the all-time low predator densities.

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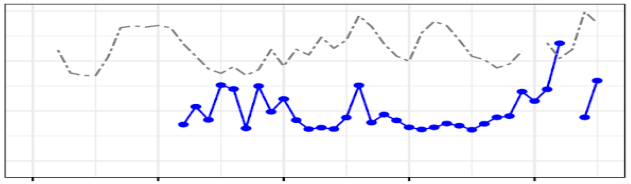
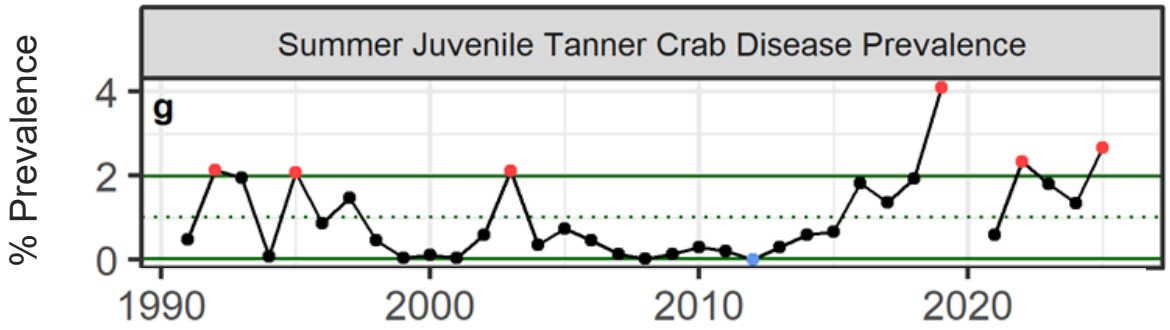
Predictive Indicators





High abundances of small Tanner crab observed in 2025 coincided with high visual prevalence of **bitter crab disease**, which doubled from the previous year to the **2nd highest prevalence** to date (2.7%). This suggests **higher disease mortality** and may be a red flag for larger cohorts as they move through the system.

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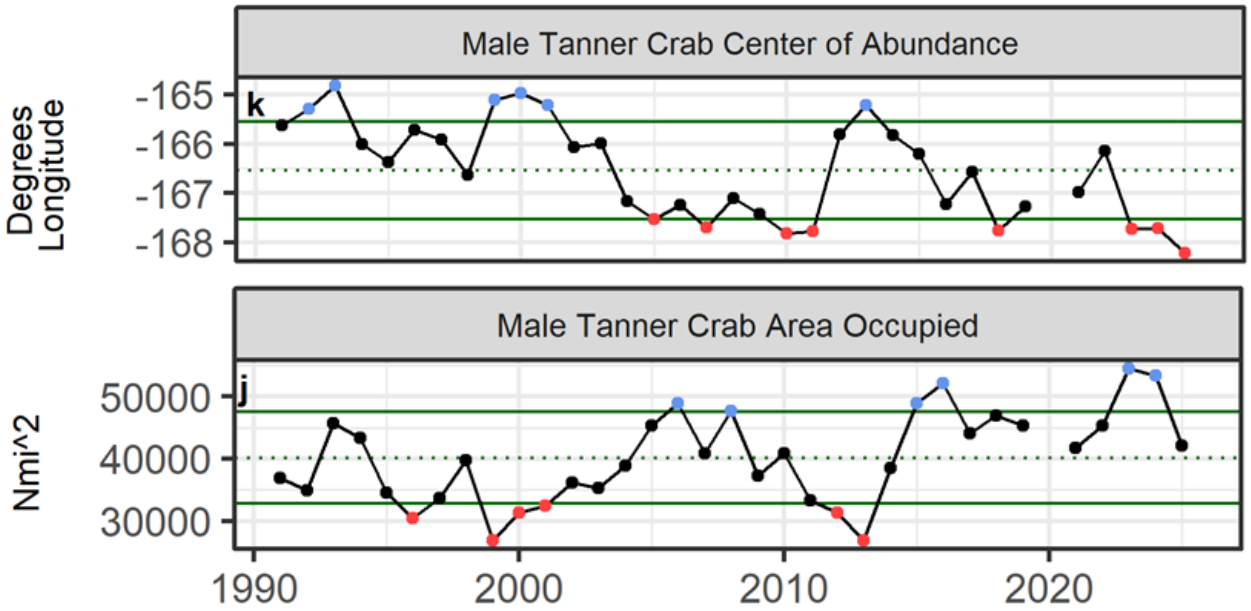
Contextual Indicators



Northwest stock distribution shift and range expansion since 2021 coincided with depressed snow crab abundance. Spatial distribution shift suggests increased utilization of northern outer shelf habitats and the potential for **increased competition** with snow crab, although mature males underwent a **range contraction** in 2025.

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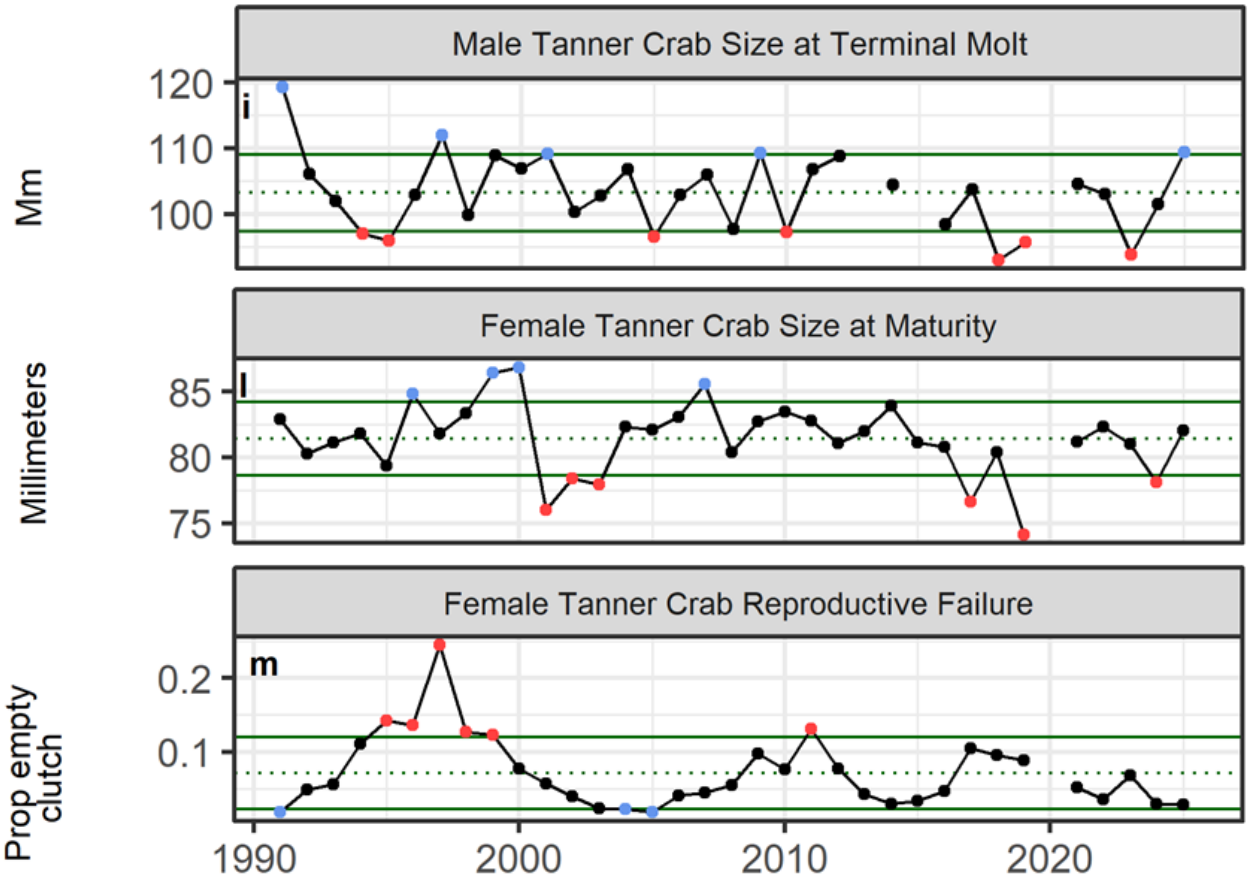
Contextual Indicators



Increased size at maturity for both male and female Tanner crab and **low reproductive failure** (2.9%) suggests **high reproductive potential** of the stock.

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Ecosystem Traffic Light Table

Indicator category	Indicator	2021 Status	2022 Status	2023 Status	2024 Status	2025 Status
Predictive	Juvenile Tanner Crab Temperature of Occupancy	*high*	neutral	neutral	neutral	neutral
	Summer Benthic Predator Density	*low*	neutral	*low*	neutral	NA
	May-June Along-Shelf Wind	neutral	neutral	*high*	neutral	NA
Contextual	Summer Juvenile Tanner Crab Disease Prevalence	neutral	**high**	neutral	neutral	**high**
	Male Tanner Crab Size at Terminal Molt	neutral	neutral	**low**	neutral	*high*
	Male Tanner Crab Area Occupied	neutral	neutral	*high*	*high*	neutral
	Male Tanner Crab Center of Abundance	neutral	neutral	***west***	***west***	***west***
	Female Tanner Crab Size at Maturity	neutral	neutral	neutral	**low**	neutral
	Female Tanner Crab Reproductive Failure	neutral	neutral	neutral	neutral	neutral
Monitoring	Summer Surface Temperature	neutral	neutral	neutral	neutral	neutral
	Chlorophyll-a Concentration	neutral	*high*	*high*	*high*	NA
	Summer Pacific Cod Consumption	neutral	neutral	neutral	neutral	NA
	Summer Benthic Invertebrate Density	*high*	*high*	neutral	*high*	NA

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Next Steps

- Refine / develop ecosystem indicators
  - Juvenile cohort progression
  - Stock spatial patchiness
  - Tanner / snow crab overlap
  - Temperature and size at maturity
- Ecosystem indicator importance
  - Evaluation of lags and time-integrated indicator effects on recruitment
  - Dynamic Structural Equation Models
    - Assess causal relationships

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Questions?

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