Appendix 1. Ecosystem and Socioeconomic Profile of the Snow Crab stock in the Eastern Bering Sea Report Card

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*With Contributions from:*

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# Current Year Update

The ecosystem and socioeconomic profile or ESP is a standardized framework for compiling and evaluating relevant stock-specific ecosystem and socioeconomic indicators and communicating linkages and potential drivers of the stock within the stock assessment process (Shotwell et al., In Review). The ESP process creates a traceable pathway from the initial development of indicators to management advice and serves as an on-ramp for developing ecosystem-linked stock assessments. Please refer to the last full ESP and partial ESP documents for further information regarding the ecosystem and socioeconomic linkages for this stock (*list references*).

## Management Considerations

Summary conclusions from ESP for ABC (risk table)

## Modeling Considerations

Summary of indicators with high importance in the Bayesian adaptive sampling routine and discussion of which indicators have had consistent high importance. List of research ecosystem model runs that are currently ongoing and potential for operational use in the future.

# Assessment

## Ecosystem and Socioeconomic Processes

One paragraph description of ecosystem and socioeconomic (if available) conceptual model(s)

## Indicator Suite

One paragraph description of LME level indicators relevant to stock (ESR summary)

### Ecosystem Indicators:

#### 1. Physical Indicators

1. Winter\_Spring\_Arctic\_Oscillation\_Index\_Model: Winter-spring Arctic Oscillation index from the NOAA National Climate Data Center
   * Contact: Erin Fedewa
   * Status and trends: TBD
   * Influential factors: Poor crab recruitment is associated with positive values of the Arctic Oscillation
2. Summer\_Cold\_Pool\_SEBS\_Survey: The areal extent of EBS bottom trawl survey stations with bottom temperatures < 2 degrees C
   * Contact: Erin Fedewa
   * Status and trends: TBD
   * Influential factors: The cold pool provides predator refuge for juvenile snow crab and cold water habitat availability (< 2<U+00B0>C) has been proposed as a critical recruitment bottleneck (Dionne et al., 2003; Parada et al., 2010)
3. Winter\_Sea\_Ice\_Advance\_BS\_Satellite\_National Snow and Ice Data Center Sea Ice: Anomalies of average daily sea-ice extent relative to mean computed over ice-advance season of Jan to Feb
   * Contact: Muyin Wang
   * Status and trends: NA
   * Influential factors: NA

#### 2. Lower Trophic Indicators

1. AMJ\_Chlorophylla\_Biomass\_SEBS\_Satellite: Derived chlorophyll a concentration during spring and summer season (April, May, June) in the northern middle southeastern Bering Sea from the MODIS satellite
   * Contact: Matt Callahan
   * Status and trends: Low this year
   * Influential factors: Larval growth and survival is dependent on high concentrations of diatoms (Paul et al., 1979)
2. Summer\_Benthic\_Invertebrate\_Density\_SEBS\_Survey: Species included in the benthic invertebrate biomass indicator (i.e. brittle stars, sea stars, sea cucumber, bivalves, non-commercial crab species, shrimp and polychaetes) are important prey sources for snow crab. Biomass estimates were determined from the EBS bottom trawl survey catch data for southeastern Bering Sea.
   * Contact: Erin Fedewa
   * Status and trends: TBD
   * Influential factors: Food availability may drive patterns in growth, energetic condition and survival of snow crab

#### 3. Upper Trophic Indicators

1. Summer\_Snow\_Crab\_Juvenile\_Temperature\_Occupancy: Mean bottom temperature weighted by immature female snow crab CPUE at each station of the EBS summer bottom trawl survey
   * Contact: Erin Fedewa
   * Status and trends: TBD
   * Influential factors: Immature snow crab are highly sensitive to bottom temperatures and 2<U+00B0>C is an important maximum temperature threshold (Dionne et al., 2003; Murphy 2020).
2. Summer\_Snow\_Crab\_Juvenile\_Disease\_Prevalence: Prevalence of immature snow crab showing visual evidence of Bitter Crab Syndrome during the summer EBS bottom trawl survey
   * Contact: Erin Fedewa
   * Status and trends: TBD
   * Influential factors: Disease prevalence serves as an indicator of stock health because mortality rates of parasitized crab are believed to be high (Meyers and Burton 2009).
3. Annual\_Snow\_Crab\_Male\_Size\_Maturity\_Model: Mean carapace width of male snow crab at 50% probability of maturation, as determined from maturity curves developed from EBS bottom trawl survey data
   * Contact: Jon Richar
   * Status and trends: TBD
   * Influential factors: Female size at maturity may be indicative of reproductive potential as fecundity increases with increasing female size
4. Summer\_Snow\_Crab\_Male\_Area\_Occupied\_SEBS\_Survey: Calculated as the minimum area containing 95% of the cumulative male snow crab CPUE during the EBS summer bottom trawl survey
   * Contact: Erin Fedewa
   * Status and trends: TBD
   * Influential factors: Shifts in the spatial extent of snow crab are driven by bottom temperatures and cold pool dynamics in the EBS (Fedewa et al., 2020).
5. Summer\_Snow\_Crab\_Male\_Center\_Distribution\_SEBS\_Survey: CPUE-weighted average latitude of the male snow crab stock during the EBS summer bottom trawl survey
   * Contact: Erin Fedewa
   * Status and trends: TBD
   * Influential factors: Shifts in stock centers may indicate temperature-driven shifts northward, or contraction of north-to-south ontogenetic migrations driven by thermal preferences (Orensanz et al., 2004).
6. Summer\_Snow\_Crab\_Consumption\_Pacific\_cod\_Model: The daily summer consumption of snow crab by Pacific cod in the EBS, estimated from Pacific cod diet compositions, EBS trawl survey CPUE, and temperature adjusted length-specific maximum consumption rates
   * Contact: Kerim Aydin
   * Status and trends: TBD
   * Influential factors: Pacific cod predation is a major source of immature snow crab mortality (Livingston, 1989) and in the past, geographic range contraction of snow crab has been attributed to cod predation (Orensanz et al., 2004).
7. Summer\_Snow\_Crab\_Juvenile\_Condition\_SEBS\_Survey: Physiological condition of eastern Bering Sea snow crab just prior to the terminal molt.
   * Contact: Erin Fedewa
   * Status and trends: NA
   * Influential factors: NA

### Socioeconomic Indicators:

#### 1. Fishery Performance Indicators

1. Annual\_Snow\_Crab\_Active\_Vessels\_EBS\_Fishery: Annual number of active vessels in the snow crab fishery to represent the level of fishing effort assigned to the fishery
   * Contact: Brian Garber-Yonts
   * Status and trends: TBD
   * Influential factors: TBD
2. Annual\_Snow\_Crab\_CPUE\_Fishery: Annual catch-per-unit-effort (CPUE), expressed as mean number of crabs per potlift, in the snow crab fishery to represent relative efficiency of fishing effort
   * Contact: Ben Daly
   * Status and trends: TBD
   * Influential factors: TBD
3. Annual\_Snow\_Crab\_Potlift\_Fishery: Annual total potlifts in the snow crab fishery to represent the level of fishing effort expended by the active fleet
   * Contact: Ben Daly
   * Status and trends: TBD
   * Influential factors: TBD
4. Annual\_Snow\_Crab\_Center\_Distribution\_EBS\_Fishery: Center of gravity, expressed in latitude, as an indices of spatial distribution for the snow crab fishery to monitor spatial shifts in fishery behavior
   * Contact: Ben Daly
   * Status and trends: TBD
   * Influential factors: TBD
5. Annual\_Snow\_Crab\_Incidental\_Catch\_EBS\_Fishery: Annual incidental catch of snow crab in other fisheries
   * Contact: Brian Garber-Yonts
   * Status and trends: TBD
   * Influential factors: TBD

#### 2. Economic Indicators

1. Annual\_Snow\_Crab\_TAC\_Utilization\_EBS\_Fishery: Percentage of annual EBS snow crab total allowable catch that was harvested by active vessels
   * Contact: Brian Garber-Yonts
   * Status and trends: NA
   * Influential factors: NA
2. Annual\_Snow\_Crab\_Exvessel\_Value\_EBS\_Fishery: Annual snow crab ex-vessel value of the snow crab fishery landings represents gross economic returns to the harvest sector, as a principal driver of fishery behavior
   * Contact: Brian Garber-Yonts
   * Status and trends: TBD
   * Influential factors: TBD
3. Annual\_Snow\_Crab\_Exvessel\_Price\_EBS\_Fishery: Annual snow crab ex-vessel price per pound represents per-unit economic returns to the harvest sector, as a principal driver of fishery behavior
   * Contact: Brian Garber-Yonts
   * Status and trends: TBD
   * Influential factors: TBD
4. Annual\_Snow\_Crab\_Exvessel\_Revenue\_Share\_EBS\_Fishery: Annual snow crab ex-vessel revenue share, expressed as vessel-average proportion of annual gross landings revenue earned from the EBS snow crab fishery
   * Contact: Brian Garber-Yonts
   * Status and trends: TBD
   * Influential factors: TBD

#### 3. Community Indicators

## Indicator Monitoring Analysis

References for statistical tests for monitoring indicator suite by stage where relevant

### Beginning Stage: Traffic Light Test

One paragraph summary of indicator status and trends over time and last five years trend Report scores by category (if applicable) and overall ecosystem and socioeconomic indicators.

### Intermediate Stage: Importance Test

One paragraph summary of importance results with analysis of highly explanatory variables for stock assessment input of interest (e.g., recruitment estimates)

### Advanced Stage: Research Model Test

Update on ecosystem linked model in development and link to relevant literature or report on model

# Data Gaps and Future Research Priorities

Copy from full ESP

# Tables

Table 1: First stage ecosystem indicator analysis for Snow Crab, including indicator title and the indicator status of the last five years. The indicator status is designated with text, (greater than = "high", less than = "low", or within 1 standard deviation = "neutral" of long-term mean). Fill color of the cell is based on the sign of the anticipated relationship between the indicator and sablefish (blue = good conditions for sablefish, red = poor conditions, white = average conditions). A gray fill and text = "missing" will appear if there were no data for that year.

| **Indicator category** | **Indicator** | **2019 Status** | **2020 Status** | **2021 Status** | **2022 Status** | **2023 Status** |
| --- | --- | --- | --- | --- | --- | --- |
| Physical | Winter Spring Arctic Oscillation Index Model | neutral | **high** | neutral | neutral | neutral |
| Summer Cold Pool SEBS Survey | **low** | NA | **low** | neutral | neutral |
| Winter Sea Ice Advance BS Satellite National Snow and Ice Data Center Sea Ice | **low** | neutral | neutral | neutral | neutral |
| Winter Sea Ice Advance BS Satellite Copernicus Marine and Environment Monitoring Service | **low** | neutral | neutral | neutral | neutral |
| Lower Trophic | AMJ Chlorophylla Biomass SEBS Satellite | neutral | neutral | neutral | neutral | **low** |
| Summer Benthic Invertebrate Density SEBS Survey | neutral | NA | neutral | neutral | NA |
| Upper Trophic | Summer Snow Crab Juvenile Temperature Occupancy | **high** | NA | **high** | neutral | neutral |
| Summer Snow Crab Juvenile Disease Prevalence | neutral | NA | neutral | neutral | neutral |
| Annual Snow Crab Male Size Maturity Model | neutral | NA | **low** | neutral | neutral |
| Summer Snow Crab Male Area Occupied SEBS Survey | **low** | NA | neutral | neutral | neutral |
| Summer Snow Crab Male Center Distribution SEBS Survey | neutral | NA | *high* | *high* | *high* |
| Summer Snow Crab Consumption Pacific cod Model | neutral | NA | neutral | neutral | NA |
| Summer Snow Crab Juvenile Condition SEBS Survey | **low** | NA | neutral | neutral | neutral |

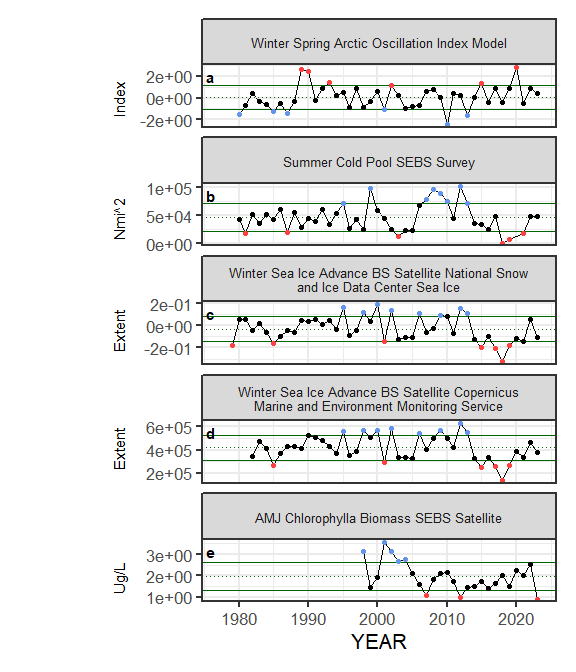
Table 2: First stage socioeconomic indicator analysis for Snow Crab, including indicator title and the indicator status of the last five years. The indicator status is designated with text, (greater than = "high", less than = "low", or within 1 standard deviation = "neutral" of long-term mean). Fill color of the cell is based on the sign of the anticipated relationship between the indicator and sablefish (blue = good conditions for sablefish, red = poor conditions, white = average conditions). A gray fill and text = "missing" will appear if there were no data for that year.

| **Indicator category** | **Indicator** | **2019 Status** | **2020 Status** | **2021 Status** | **2022 Status** | **2023 Status** |
| --- | --- | --- | --- | --- | --- | --- |
| Fishery Performance | Annual Snow Crab Active Vessels EBS Fishery | neutral | neutral | neutral | low | NA |
| Annual Snow Crab CPUE Fishery | neutral | neutral | neutral | neutral | NA |
| Annual Snow Crab Potlift Fishery | neutral | neutral | neutral | neutral | NA |
| Annual Snow Crab Center Distribution EBS Fishery | high | neutral | high | high | NA |
| Annual Snow Crab Incidental Catch EBS Fishery | neutral | neutral | neutral | neutral | neutral |
| Economic | Annual Snow Crab TAC Utilization EBS Fishery | neutral | neutral | neutral | neutral | NA |
| Annual Snow Crab Exvessel Value EBS Fishery | neutral | neutral | neutral | low | NA |
| Annual Snow Crab Exvessel Price EBS Fishery | high | high | high | high | NA |
| Annual Snow Crab Exvessel Revenue Share EBS Fishery | neutral | high | high | neutral | NA |

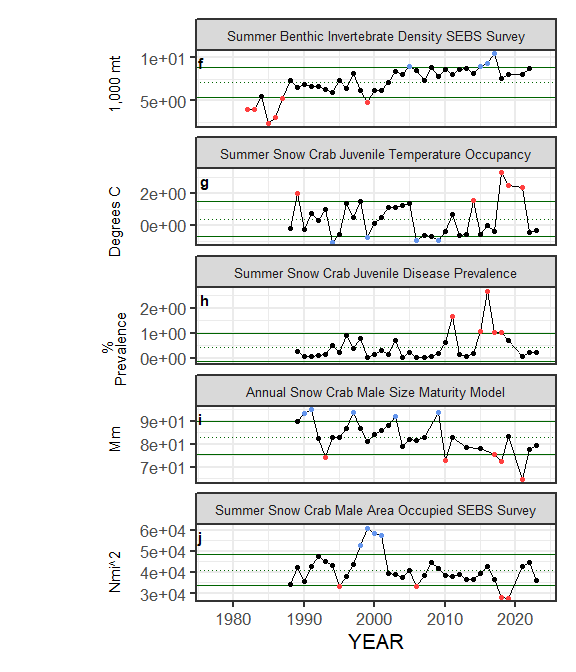
# Figures



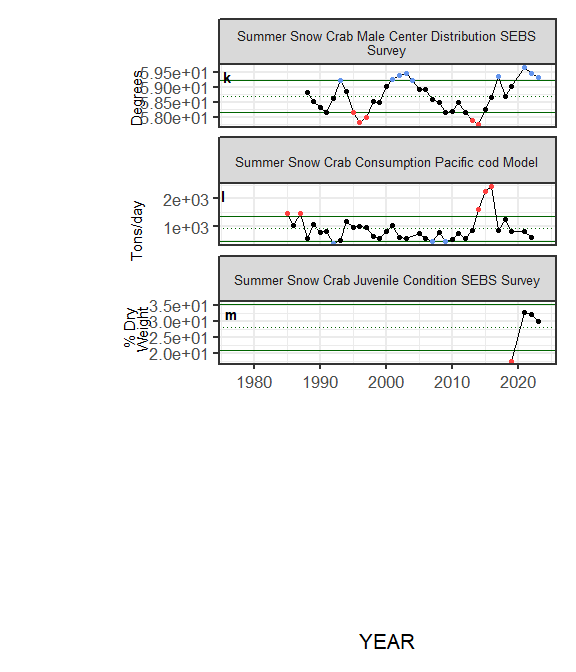
##### Figure 1. Life history conceptual model for Snow Crab summarizing ecological information and key ecosystem processes affecting survival by life history stage. Red text means increases in process negatively affect survival, while blue text means increases in process positively affect survival.



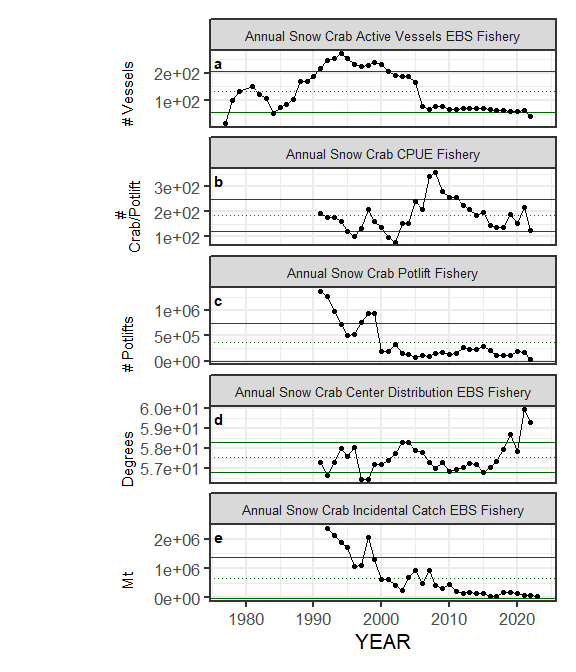
##### Figure ??. Selected ecosystem indicators for Snow Crab with time series ranging from 1977 <U+2013> present. Upper and lower solid green horizontal lines are plus and minus one standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series.



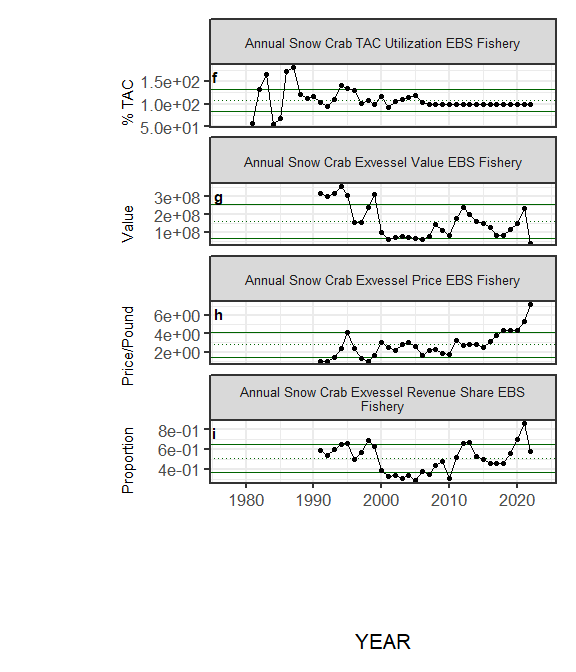
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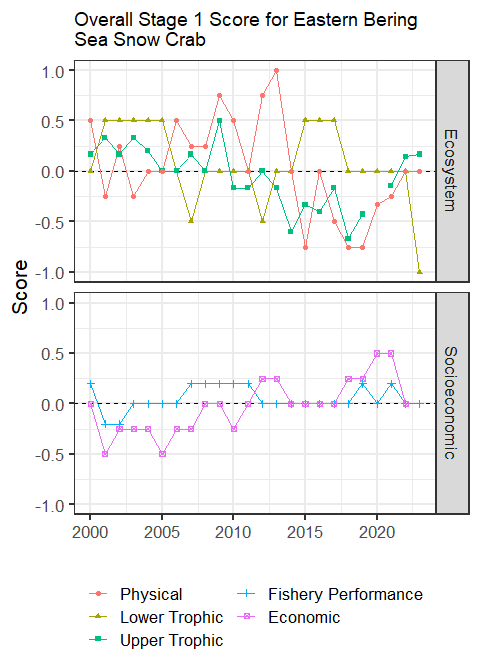
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##### Figure 7. Simple traffic light score for overall ecosystem and socioeconomic categories from 2000 to present.



##### Figure 8. Bayesian adaptive sampling output showing (a) standardized covariates prior to subsetting and (b) the mean relationship and uncertainty (95% confidence intervals) with log Snow Crab recruitment, in each estimated effect (left bottom graph), and marginal inclusion probabilities (right bottom graph) for each predictor variable of the subsetted covariate set