Appendix A. Ecosystem and Socioeconomic Profile of the Snow Crab Stock in the Eastern Bering Sea - Report Card

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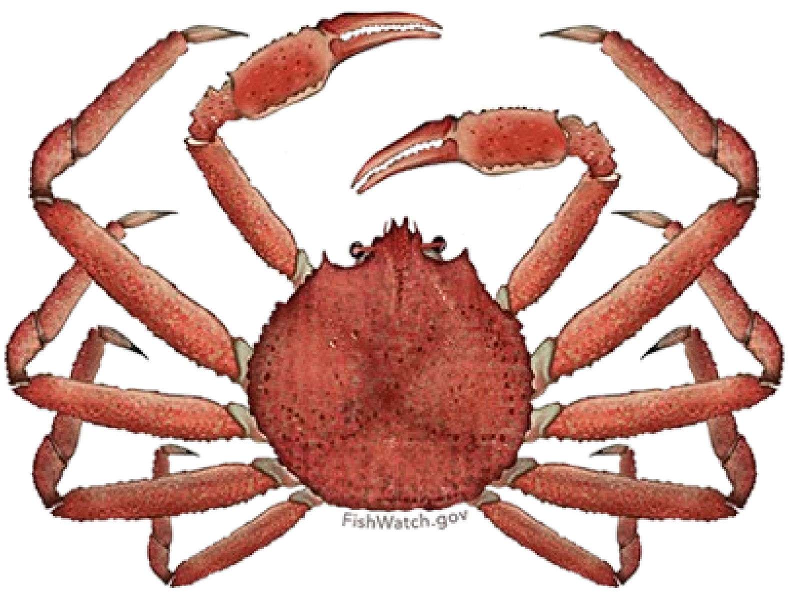

With Contributions from:

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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., *Accepted*). 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 document (Fedewa et al., 2022) which is available within the eastern Bering Sea (EBS) snow crab stock assessment and fishery evaluation or SAFE report for further information regarding the ecosystem and socioeconomic linkages for this stock.

Management Considerations

The following are the summary considerations from current updates to the ecosystem and socioeconomic indicators evaluated for snow crab:

- In 2023, summer bottom temperatures and the spatial extent of the cold pool remained near-average in the eastern Bering Sea following a 2018-2019 marine heat wave. The Arctic Oscillation was slightly positive this past winter.
- Juvenile snow crab occupied -0.3°C bottom waters on average, suggesting optimal cold-water habitat availability for predator refuge.
- Anomalously low levels of chlorophyll-a in 2023 indicate a less pronounced spring bloom and poor feeding conditions for larval snow crab.
- Following a dramatic increase in the prevalence of bitter crab syndrome and Pacific cod predation in 2016 coinciding with a large snow crab recruitment event, disease prevalence remains near-average. Pacific cod consumption on snow crab has also remained near-average in 2021 and 2022.
- The center of mature male abundance remains more northerly than average, indicative of a large-scale distribution shift from historic mid-shelf habitats.
- Juvenile snow crab were in very poor body condition prior to the 2021 population collapse, although 2021-2023 condition estimates have returned to near-average.
- The Bering Sea snow crab fishery was closed to targeted fishing for the first time in history, representing severe economic hardships for industry alongside BBRKC fishery closures.
- Incidental catch of snow crab in EBS groundfish fisheries has remained near-average for the past 5-year period.

Modeling Considerations

The following are the summary results from the intermediate and advanced stage monitoring analyses for snow crab:

- The highest ranked predictor variables in the intermediate stage monitoring analysis were 1) juvenile snow crab temperature of occupancy and 2) Pacific cod consumption, although effect sizes were relatively small and marginal inclusion probabilities were < 0.5 for all predictors.
- The advanced stage monitoring analysis provides updates on developing research ecosystem linked models that are not yet included as a model alternative in the main stock assessment. We have not received updates on new research ecosystem linked models for snow crab at this time.

Assessment

Ecosystem and Socioeconomic Processes

We summarize important processes that may be helpful for identifying productivity bottlenecks and dominant pressures on the stock in conceptual models detailing 1) ecosystem processes by snow crab life history stage (Figure 1). Please refer to the last full ESP document (Fedewa et al., 2022) for more details.

Indicator Suite

The following list of indicators for snow crab is organized by categories: three for ecosystem indicators (physical, lower trophic, and upper trophic) and three for socioeconomic indicators (fishery performance, economic, and community). A title, short description and contact name for the indicator contributor are provided. We also include the anticipated sign of the proposed relationship between the indicator and the stock population dynamics where relevant. Please refer to the last full ESP document for detailed information regarding the ecosystem and socioeconomic indicator descriptions and proposed mechanistic linkages for this stock (Fedewa et al., 2022). Time series of the ecosystem and socioeconomic indicators are provided in Figure 2a and Figure 2b, respectively. Modifications to ecosystem indicators in 2023 include: 1) Chlorophyll-*a* concentrations derived from MODIS have now been replaced with a European Space Agency (ESA) GlobColour blended satellite product because the satellites that hold the MODIS instruments will soon be retired due to changes in their orbits, 2) due to the 2023 snow crab fishery closure, the industry-led Skipper Survey included in the last full ESP was not conducted, 3) winter sea ice extent data from the ERA5 reanalysis have been replaced with data from the NOAA National Snow and Ice Data Center, and 4) Pacific cod consumption estimates now include unidentified *Chionocetes* as well as identified *C. opilio* from stomach contents. These modifications will preclude direct comparison to indicator timeseries in previous ESP documents. In addition to indicator modifications, a new indicator, juvenile snow crab condition, has been added to the suite of upper trophic indicators.

Ecosystem Indicators:

Physical Indicators (Figure 2a.a-c)

a.) Winter-spring **Arctic Oscillation** index from the NOAA National Climate Data Center (contact: E. Fedewa). Proposed sign of the relationship is negative and the time series is lagged five years for intermediate stage indicator analysis

b.) The **areal extent of the summer cold pool** as EBS bottom trawl survey stations with bottom temperatures < 2°C (contact: E. Fedewa). Proposed sign of the relationship is positive and the time series is lagged four years for intermediate stage indicator analysis.

c.) January-February average **winter sea ice extent** in the Bering Sea (contact: E. Fedewa). Proposed sign of the relationship is positive and the time series is lagged three years for intermediate stage indicator analysis.

Lower Trophic Indicators (Figure 2a.d-e)

d.) April – June average **chlorophyll-*a* concentration** on the north-middle shelf of the eastern Bering Sea, calculated with the ESA GlobColour blended satellite product (4km resolution, 8 day composite data) from MODIS satellites (contact: M. Callahan and J. Nielsen). Proposed sign of the relationship is positive and the time series is lagged five years for intermediate stage indicator analysis.

e.) Summer **benthic invertebrate density**, determined from EBS bottom trawl survey stations included in the 50th percentile of mean snow crab CPUE. Invertebrates include brittle stars, sea stars, sea cucumber, bivalves, non-commercial crab species, shrimp and polychaetes. (contact: E. Fedewa). Proposed sign of the relationship is positive and the time series is lagged one year for intermediate stage indicator analysis

Upper Trophic Indicators (Figure 2a.f-k)

a.) Mean juvenile snow crab **temperature of occupancy**; bottom temperature weighted by immature snow crab CPUE at each station of the EBS summer bottom trawl survey (contact: E. Fedewa). Proposed sign of the relationship is negative and the time series is lagged one year for intermediate stage indicator analysis.

b.) Prevalence of immature snow crab showing visual symptoms of **Bitter Crab Disease** during the summer EBS bottom trawl survey (contact: E. Fedewa). Proposed sign of the relationship is negative and the time series is lagged three years for intermediate stage indicator analysis.

c.) 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: J. Richar). Proposed sign of the relationship is positive.

d.) **Mature male snow crab area occupied**, calculated as the minimum area containing 95% of the cumulative mature male snow crab (>95mm) CPUE during the EBS summer bottom trawl survey (contact: E. Fedewa). Proposed sign of the relationship is positive.

e.) CPUE-weighted **average latitude** of the mature male snow crab stock (>95mm) during the EBS summer bottom trawl survey (contact: E. Fedewa). Proposed sign of the relationship is positive.

f.) 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: K. Aydin). Proposed sign of the relationship is negative and the time series is lagged three years for intermediate stage indicator analysis.

g.) Summer **snow crab juvenile condition**, as determined from water content in the hepatopancreas (% dry weight) sampled from snow crab on the EBS bottom trawl survey (contact: L. Copeman). Proposed sign of the relationship is positive and the time series is lagged one year for intermediate stage indicator analysis.

Socioeconomic Indicators: (all monetary values are inflation-adjusted to $2023 value)

Fishery Performance Indicators (Figure 2b. a-e)

a.) Annual **number of active vessels** in the snow crab fishery, representing the level of fishing effort assigned to the fishery (contact: J. Lee)

b.) Annual **catch-per-unit-effort** (CPUE), expressed as mean number of crabs per potlift, in the snow crab fishery, representing relative efficiency of fishing effort (contact: B. Daly)

c.) Annual **total potlifts** in the snow crab fishery, representing the level of fishing effort expended by the active fleet (contact: B. Daly)

d.) **Center of gravity**, expressed in latitude, as an index of spatial distribution for the snow crab fishery to monitor spatial shifts in fishery behavior (contact: B. Daly)

e.) Annual **incidental catch** of snow crab in EBS groundfish fisheries (contact: J. Lee)

Economic Indicators (Figure 2b. f-i)

f.) Percentage of the annual EBS snow crab **total allowable catch** (TAC) (GHL prior to 2005) that was harvested by active vessels, including deadloss discarded at landing (contact: B. Daly)

g.) Annual snow crab **ex-vessel value** of the snow crab fishery landings, representing gross economic returns to the harvest sector, as a principal driver of fishery behavior (contact: J. Lee)

h.) Annual snow crab **ex-vessel price per pound**, representing per-unit gross economic returns to the harvest sector, as a principal driver of fishery behavior (contact: J. Lee)

i.) 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: J. Lee)

Indicator Monitoring Analysis

There are up to three stages (beginning, intermediate, and advanced) of statistical analyses for monitoring the indicator suite listed in the previous section. The beginning stage is a relatively simple evaluation by traffic light scoring. This evaluates the current year trends relative to the mean of the whole time series, and provides a historical perspective on the utility of the whole indicator suite. The intermediate stage uses importance methods related to a stock assessment variable of interest (e.g., recruitment, biomass, catchability). These regression techniques provide a simple predictive performance for the variable of interest and are run separate from the stock assessment model. They provide the direction, magnitude, uncertainty of the effect, and an estimate of inclusion probability. The advanced stage is used for testing a research ecosystem linked model and output can be compared with the current operational model to understand information on retrospective patterns, prediction performance, and comparisons of other model output.

Beginning Stage: Traffic Light Test

We use a simple scoring calculation for this beginning stage traffic light evaluation. Indicator status is evaluated based on being greater than ("high"), less than ("low"), or within ("neutral") one standard deviation of the long-term mean. A sign based on the anticipated relationship between the ecosystem indicators and the stock (generally shown in Figure 1a and specifically by indicator in the Indicator Suite, Ecosystem Indicators section) is also assigned to the indicator where possible. If a high value of an indicator generates good conditions for the stock and is also greater than one standard deviation above the mean, then that value receives a '+1' score. If a high value generates poor conditions for the stock and is greater than one standard deviation above the mean, then that value receives a '-1' score. All values less than or equal to one standard deviation from the long-term mean are average and receive a '0' score. The scores are summed by the three organizational categories within the ecosystem (physical, lower trophic, and upper trophic) or socioeconomic (fishery performance and economic performance) indicators and divided by the total number of indicators available in that category for a given year. The scores over time allow for comparison of the indicator performance and the history of stock productivity (Figure 3). We also provide five year indicator status tables with a color or text code for the relationship with the stock (Tables 1a,b) and evaluate each year's status in the historical indicator time series graphic (Figures 2a,b) for each ecosystem and socioeconomic indicator. Socioeconomic indicators representing the target fishery are reported by calendar year through 2022, the last year that the fishery was open. Incidental catch is reported for the most recent full calendar year.

We evaluate the status and trends of the ecosystem and socioeconomic indicators to understand the pressures on the snow crab stock regarding recruitment, stock productivity, and stock health. We start with the physical indicators and proceed through the increasing trophic levels for the ecosystem indicators then evaluate the fishery performance and economic indicators as listed above. Here, we concentrate on updates since the last ESP report card. Overall, the physical and lower trophic indicators scored below average for 2023, while the upper trophic indicators were average (Figure 3). Compared to 2022 traffic light scores, recent year results are same for the physical and lower trophic indicators, and an increase for the upper trophic indicators. The fishery performance and economic indicators were not updated for 2023 due to the closure of the fishery.

Following the 2019-2020 highest Arctic Oscillation index in history (Zhang et al., 2021), the winter-spring Arctic Oscillation index returned to near-neutral in 2023. Poor snow crab recruitment has been associated with positive values of the Arctic Oscillation (Szuwalski et al., 2021), suggesting that large-scale weather and climate anomalies in 2019/2020 could have impacted stock productivity. Cold pool spatial extent and sea ice concentration in 2023 were average, indicating a return to near-normal conditions in the Bering Sea following anomalously warm temperatures and record low sea ice concentration in 2018-2019. Highly stenothermic juvenile snow crab appear to benefit from these cold bottom temperatures and increased sea ice extent (Dionne et al., 2003).

Lower trophic level indicators include chlorophyll-*a* biomass and benthic invertebrate biomass, both of which represent potential prey resources for pelagic and benthic snow crab stages. Chlorophyll-a concentrations during the 2023 spring bloom were the lowest in the 26-year eastern Bering Sea time series. Sea ice extent in March indicates that while the bloom timing was near-average (J. Nielsen, personal communication), low chlorophyll-a concentrations and subsequently less diatoms in the water column may drive increased larval mortality due to less favorable feeding conditions (Incze et al., 1987). Benthic invertebrate density estimates are not yet available for 2023, but the time series has been trending upwards for the 5 years and increases in benthic invertebrate density in 2022 were attributed to above-average catches of non-commercial crab species, sea anemones and sea squirts.

Upper trophic level indicators, include snow crab disease, predation, physiological condition and spatial distribution indicators. Bitter crab disease (BCD) prevalence remained below-average in 2023 following a record-high prevalence in 2016 that likely drove high mortality rates in juvenile snow crab. The 2016 peak in infection coincided with a large recruitment event of small (20-30mm) snow crab, which are more susceptible to BCD due to increased molt frequency (Messick and Shields, 2000). Below average disease prevalence following the 2021 snow crab population collapse is consistent with low stock density, although as the snow crab population continues to rebuild, an increased proportion of small snow crab in the system could lend to higher disease prevalence in the near future. Peaks in Pacific cod consumption of snow crab in 2016 also coincided with the large snow crab recruitment event, and this indicator has been trending downward since.

Following a dramatic reduction in male size at 50% probability of maturation in 2021, size at maturity increased by over 15mm in 2023 to remain slightly above the long-term average. While this indicator is indicative of population-level shifts in the average size at maturity, temporal trends may be driven by recruitment variability and cohort effects (Murphy 2021). Temperatures occupied by juvenile snow crab declined dramatically in 2022 from record-high temperatures in 2018-2021, and in summer 2023, juveniles occupied -0.3°C bottom waters on average. Occupied temperatures below 1°C indicate that cold-water habitat critical for evading groundfish predators was widely available for stenothermic juvenile snow crab. While mature male snow crab spatial extent was below-average in 2023, the male center of distribution has remained well above-average since 2021. High densities of large males northwest of St. Matthew Island and along the shelf edge in recent years may suggest temperature-driven distributional shifts (Orensanz et al., 2005).

The inclusion of a new upper trophic level indicator to quantify body condition of juvenile snow crab is both justified and timely due to concerns with high densities of snow crab and hypothesized starvation effects preceding the 2021 snow crab stock collapse (Szuwalski et al., *accepted*). Recent research has linked declines in body condition and lipid storage of early juvenile snow crab to warmer temperatures and reduced food quality in the Bering Sea (Copeman et al., 2021). Furthermore, previous laboratory studies have demonstrated that adequate energetic stores are prerequisites for molting, growth, and survival in snow crab early life history stages (e.g. Lovrich and Ouellet, 1994). A snow crab condition indicator was developed using hepatopancreas percentage dry weight (dry weight/wet weight ratio), and validated with fatty acid analyses (Copeman et al., *in prep*). The rapid incorporation of this indicator following the conclusion of the current year bottom trawl survey provides a metric for body condition of juvenile snow crab just prior to the energetically costly terminal molt, and annual data collections are planned for the foreseeable future. Despite the small sample size (n = 4 years), the new metric indicates that juvenile snow crab were in very poor condition in 2019 and indicator trends suggest poor survival to recruitment just prior to the stock collapse.

Fishery performance indicators are reported through the most recent calendar year (corresponding to the 2022-2023 crab season) and missing data are attributed to the 2023 directed snow crab fishery closure, with the exception of incidental catch in the (currently ongoing) EBS groundfish fisheries, reported through 2023. Due to a first-ever fishery closure, social and economic indicator information is extremely limited for 2023, and the ABSC Skipper Survey results reported in the last full ESP could not be conducted. However, we note that these missing data should emphasize the economic hardships being faced by the snow crab harvesters and processors during these closure periods in lieu of more meaningful community indicators that have not yet been developed. The following discussion notes trends in socioeconomic indicators in recent years leading up to the fishery closure.

The active snow crab fleet during 2022 declined to 42 vessels, the lowest level since 1977 at the beginning of the time series, and approximately 68% of the average number of vessels participating during the previous five years. Relative to the substantially reduced TAC (less than 13% of the previous year and less than 20% of the previous five-year average), less consolidation of fishing activity occurred than would be expected based on economic efficiency, and it is unclear if other factors driving this level of vessel participation will persist if TAC levels remain comparably low. CPUE in the fishery declined from 218 the previous year to 124 legal crab per potlift, and total potlifts declined from 172 thousand in 2021 to 37 thousand, with both indicators approaching the lower bound of one standard deviation below the long term (1991-current) average, respectively. The latitude of the center of gravity of fishing activity during 2022 shifted somewhat south compared to the previous year, but remained approximately two standard deviations greater than the long-term average. Incidental catch in EBS groundfish fisheries during 2021 declined for a fourth consecutive year to 77 thousand kg, approaching the lower bound of the long-term range of variation. TAC utilization reached 99% for the 2021-2022 snow crab fishery, however, fishing extended later than usual, with four vessels making landings later than May 15.

Economic performance indicators included in this ESP are reported through calendar year 2021, the most recent year for which data are available. With a TAC of 18.37 thousand metric tons, the highest since the 2014-2015 crab season, combined with historically high market values for snow crab driven by high consumer demand during the first two years of the covid-19 pandemic, estimated ex-vessel revenue in the snow crab fishery during 2021 exceeded $219 million, approaching the upper bound of one standard deviation above the long-term (1991-2021) average. Average ex-vessel price per pound reached a historical high in 2021, increasing by 25% from 2020, to $4.97 per pound, greater than two standard deviations higher than the historical average since 1991 (adjusted for inflation). As a result of the historically high ex-vessel value of the snow crab fishery during 2021, combined with the closure or reduced TAC levels in most crab and other fisheries targeted by the snow crab fleet, ex-vessel revenue share increased to an unprecedented 85% of total annual ex-vessel landings revenue, summed across all fisheries in which snow crab vessel landed catch during the 2021 calendar year. Although 2022 data is not yet available for economic performance indicators, news reports and other information indicate that market demand for crab and other premium seafood products contracted sharply in 2022, suggesting that economic returns for most or all of the fleet active during the 2021-2022 snow crab season were poor and many vessels likely operated at a loss.

Intermediate Stage: Importance Test

Bayesian adaptive sampling (BAS) was used to quantify the association between hypothesized ecosystem predictors and snow crab recruitment (survey abundance of immature male snow crab, 50 – 65mm), and to assess the strength of support for each hypothesis. In this stage, the full set of indicators is first winnowed to the predictors that have been identified as potential drivers of snow crab recruitment, and highly correlated covariates are removed. We further restrict potential covariates to those that can provide the longest model run and through the most recent estimate of recruitment. This results in a model run from 1993 through the 2021. We then provide the mean relationship between each predictor variable and snow crab recruitment over time (Figure 4a), with error bars describing the uncertainty (95% confidence intervals) in each estimated effect and the marginal inclusion probabilities for each predictor variable (Figure 4b). A higher probability indicates that the variable is a better candidate predictor of snow crab recruitment.

The highest ranked predictor variables based on this analysis were 1) juvenile snow crab temperature of occupancy, and 2) Pacific cod consumption. Inclusion probabilities < 0.5 indicate that the selected suite of indicators explained little variation in snow crab recruitment. Intermediate stage indicator importance tests in future ESP report cards will explore additional statistical techniques to address potential non-stationarity and missing observations.

Advanced Stage: Research Model Test

New research models are currently being explored to assess potential mechanisms for increased mortality (e.g. bitter crab syndrome, cod predation, cannibalism) in 2018-2019 (Szuwalski et al., *accepted*).

Data Gaps and Future Research Priorities

Future research should support the development of indicators that quantify snow crab physiological and biological responses to rapidly changing ecosystem conditions in the Bering Sea. Recent, dramatic population declines emphasize the importance of understanding proximate causes and mechanisms for mortality including predator-prey interactions, disease dynamics, shifts in benthic prey production, and responses to thermal stress. Proposed laboratory studies, for example, should focus on defining thermal limits across snow crab life history stages and quantifying temperature-dependent growth, respiration and consumption rates. Many previous studies are limited to mature snow crab and have been assessed only on the eastern Canadian snow crab stock (e.g. Foyle et al. 1989), potentially limiting the applicability of published results to the eastern Bering Sea snow crab stock.

Early life history data gaps also result in difficulties identifying potential recruitment bottlenecks and mechanistic linkages during larval and early benthic stages. Preliminary data collection on existing NOAA survey platforms has facilitated the enumeration of snow crab larvae (J. Weems, personal communication), and relating larval presence and CPUE data to environmental conditions will be critical for groundtruthing existing IBM modeling efforts and better understanding environmental drivers of larval supply and settlement success.

The limited scope and timeliness of socioeconomic indicators reported in the ESP provide limited information regarding the economic stresses on the harvest and processing sectors of the Bering Sea crab fisheries and associated communities resulting from the recent declines in the two principal Bering Sea crab fisheries. These stresses, if persistent, have the potential to induce substantial structural changes in crab harvest and processing industries, as well as management changes intended to mitigate adverse social and economic effects, ultimately inducing systematic operational changes in the behavior of snow crab fishing vessels. Developing community indicators to highlight these economic hardships during fishery closures is also of critical importance in light of multiple crab fishery closures. Research in spatial aspects of the EBS snow crab fishery with direct relation to the stock assessment may provide the basis for further development of relevant and informative socioeconomic indicators for use in the ESP. As well, improving the timeliness of socioeconomic indicators should be explored, including use of models for nowcast/forecast of time series, and or alternate or proxy measures that track key socioeconomic indicators.

As indicators are improved or updated, they may replace those in the current suite of indicators to allow for refinement of the BAS model and potential evaluation of performance and risk within the operational stock assessment model. Modifications to current indicators or additional indicators proposed for the 2024 snow crab ESP include: 1) developing a snow crab mature female clutch fullness indicator, as a measure of fecundity or reproductive potential, 2) refining the Pacific cod consumption indicator by standardizing consumption rates by the number of snow crab in the EBS/NBS, 3) including spring bloom type (i.e. ice-associated or open-water) and bloom timing indicators (contact J. Nielsen) as proxies for larval snow crab/spring bloom temporal overlap and pelagic energy exchange to the benthos, and 4) developing indicators that quantify overlap between crab and fishing gear during vulnerable life history periods, and metrics of vulnerable to these fishing gear interactions. The annual request for information (RFI) for the snow crab ESP will include these data gaps and research priorities along with a list of additional new indicators that could be developed for the next full ESP assessment.

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Tables

Table 1a. First stage ecosystem indicator analysis for snow crab, including indicator title and the indicator status of the last five available years. The indicator status is designated with text, (greater than = "high", less than = "low", or within 1 standard deviation = "neutral" of time series mean). Fill color of the cell is based on the sign of the anticipated relationship between the indicator and the stock (blue or italicized text = good conditions for the stock, red or bold text = poor conditions, white = average conditions). A gray fill and text = "NA" 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	**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 1b. First stage socioeconomic indicator analysis for snow crab, including indicator title and the indicator status of the last five available years. The indicator status is designated with text, (greater than = "high", less than = "low", or within 1 standard deviation = "neutral" of time series mean). A gray fill and text = "NA" 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

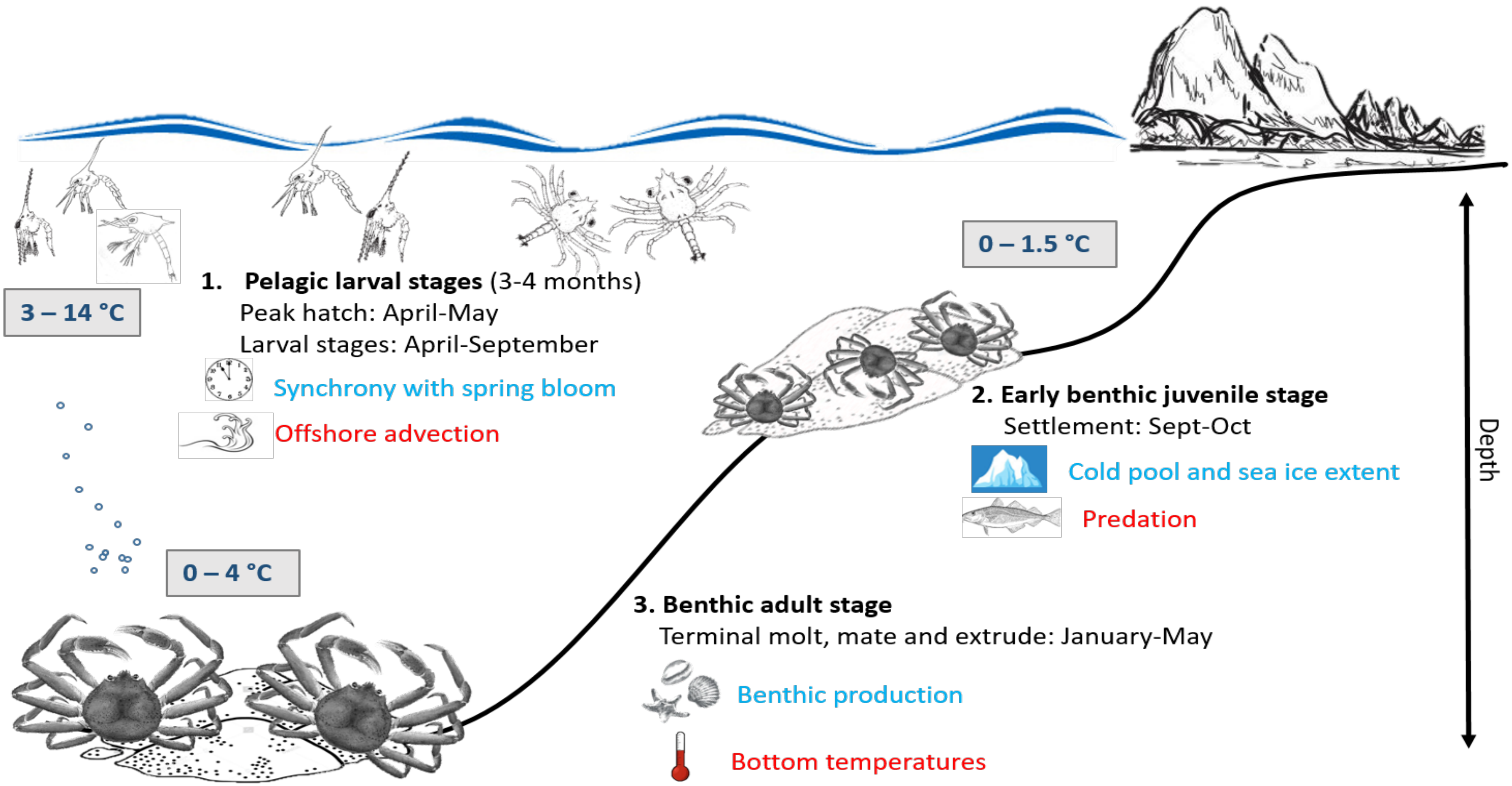

Figure 1: Life history conceptual model for snow crab summarizing ecological information and key ecosystem processes affecting survival by life history stage. Red text means increases in process negatively affect survival, while blue text means increases in process positively affect survival.

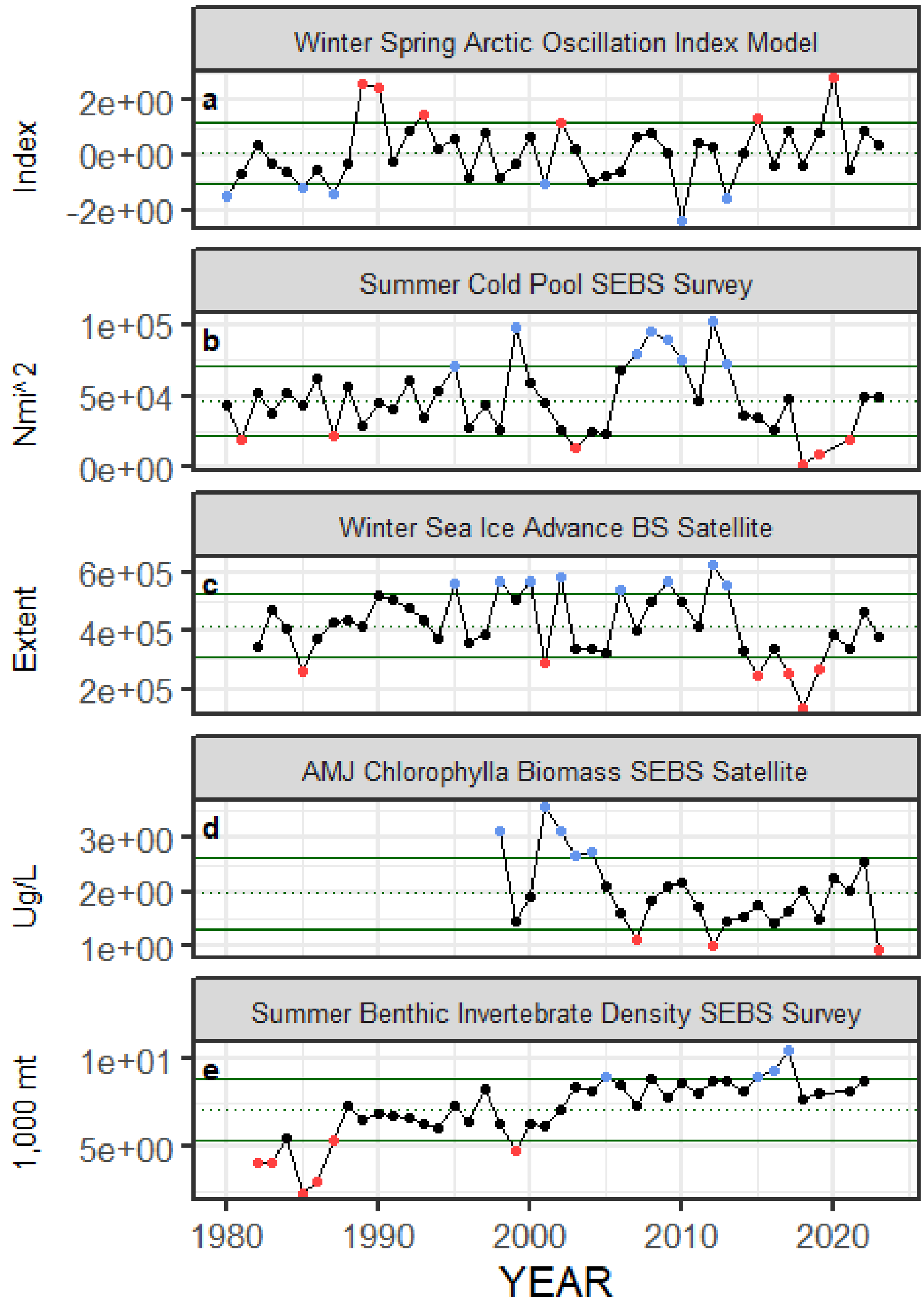

Figure 2a. Selected ecosystem indicators for snow crab with time series ranging from 1980 – present. Upper and lower solid green horizontal lines represent 1 standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series. Dots in the time series are colored if above or below 1 standard deviation of the time series mean and the color represents the proposed relationship for stock, black circle for neutral.

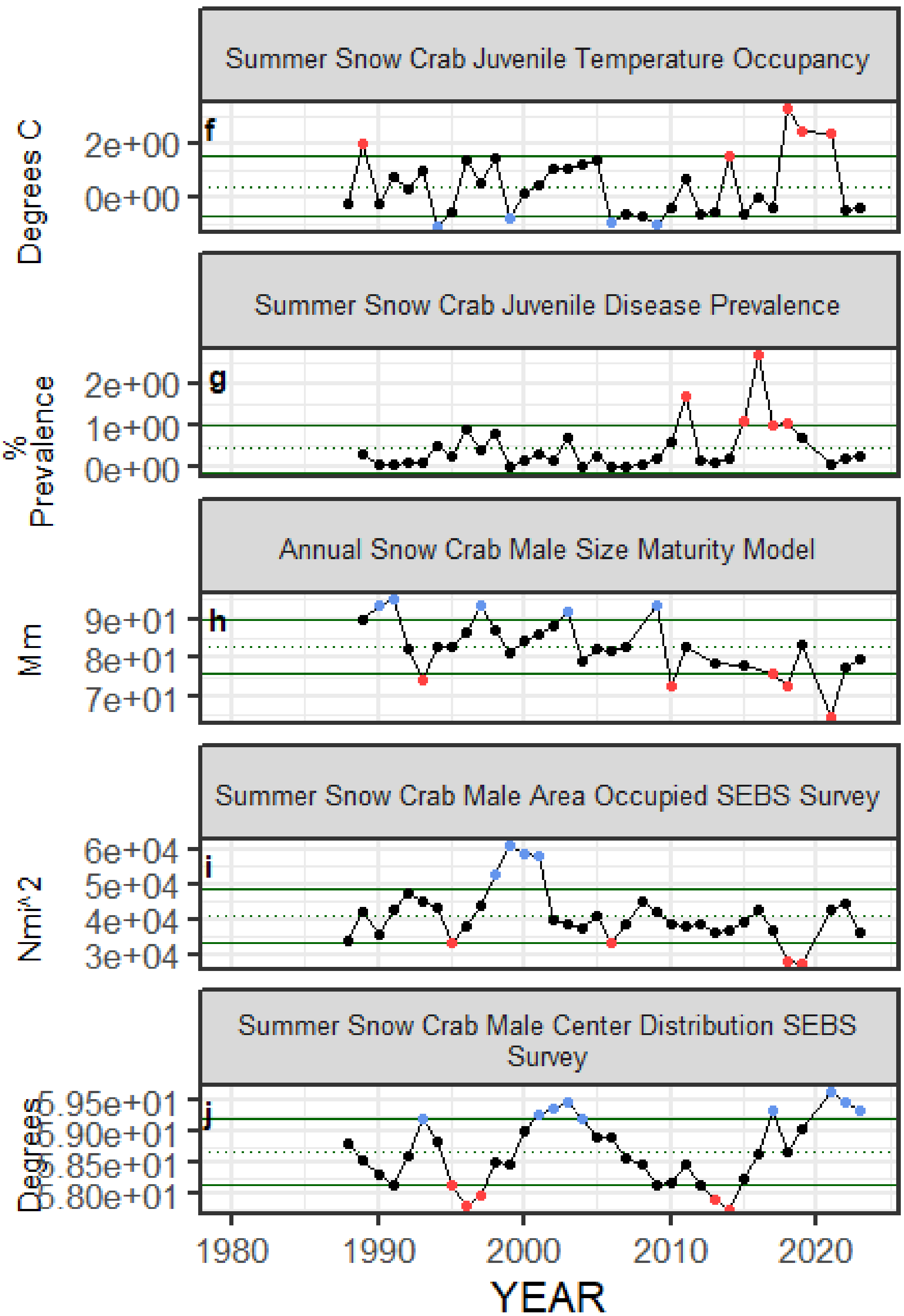

Figure 2a (cont.). Selected ecosystem indicators for snow crab with time series ranging from 1980 – present. Upper and lower solid green horizontal lines represent 1 standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series. Dots in the time series are colored if above or below 1 standard deviation of the time series mean and the color represents the proposed relationship for stock, black circle for neutral.

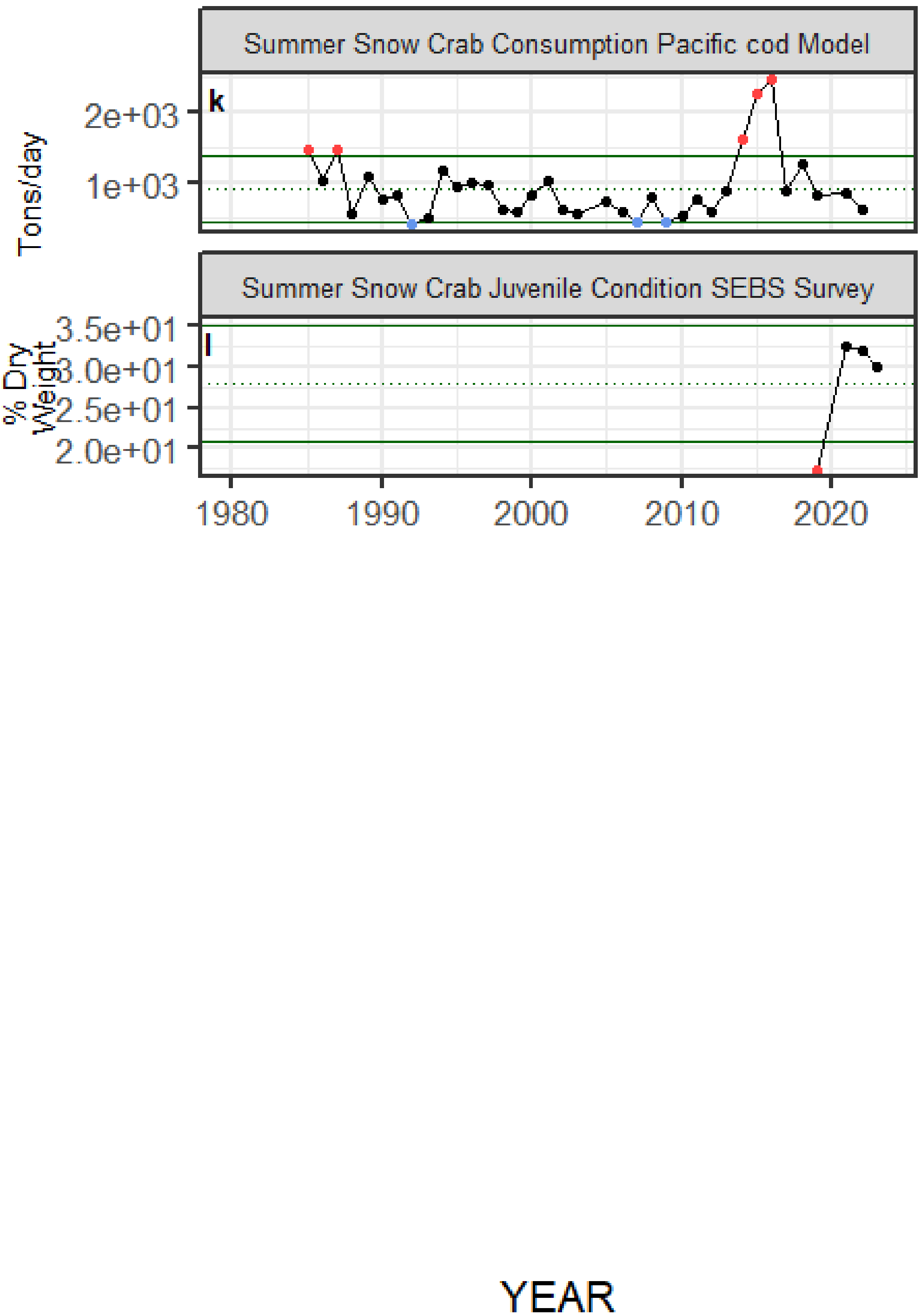

Figure 2a (cont.). Selected ecosystem indicators for snow crab with time series ranging from 1980 – present. Upper and lower solid green horizontal lines represent 1 standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series. Dots in the time series are colored if above or below 1 standard deviation of the time series mean and the color represents the proposed relationship for stock, black circle for neutral.

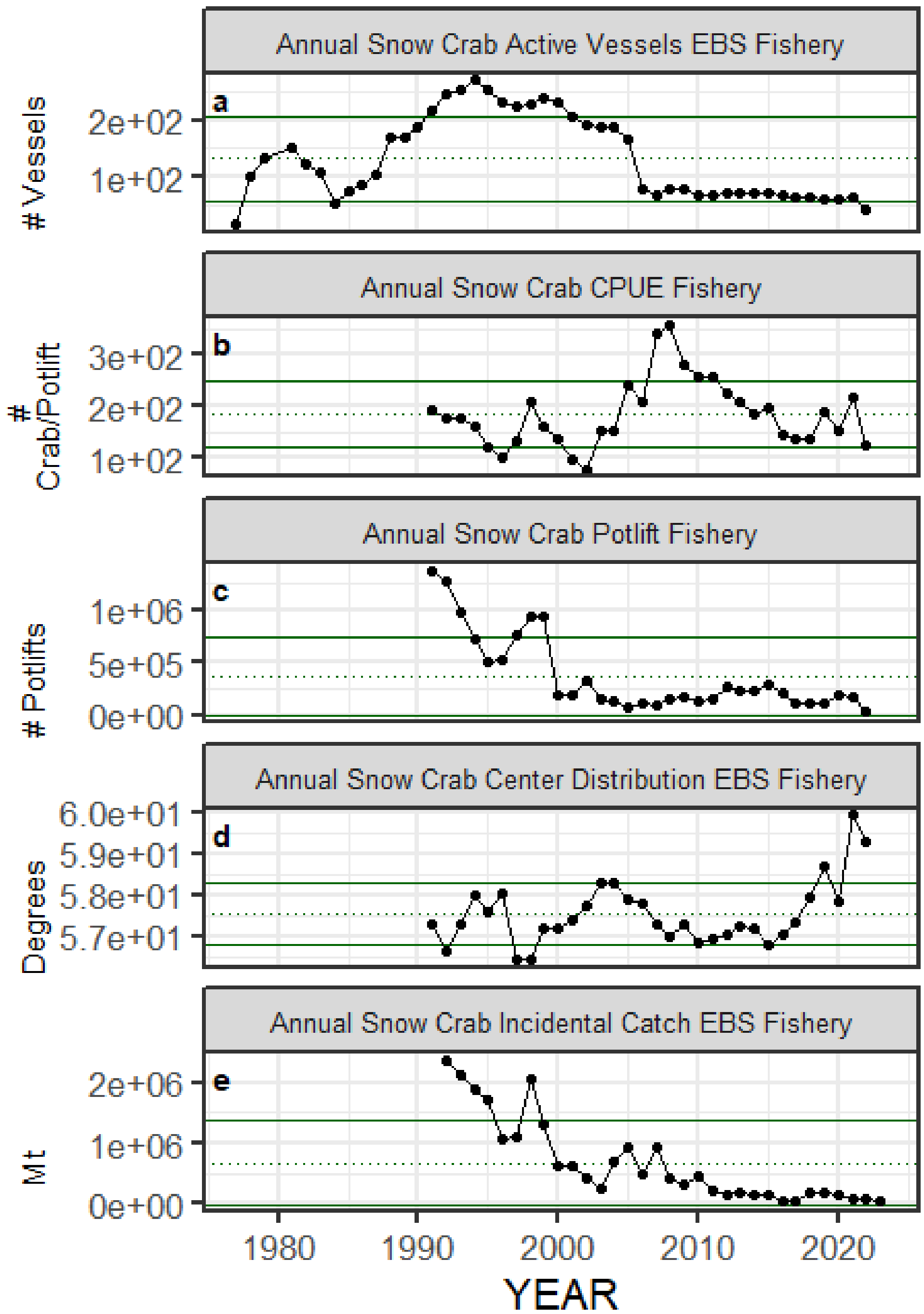

Figure 2b. Selected socioeconomic indicators for snow crab with time series ranging from 1966 – present. Upper and lower solid green horizontal lines represent 1 standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series.

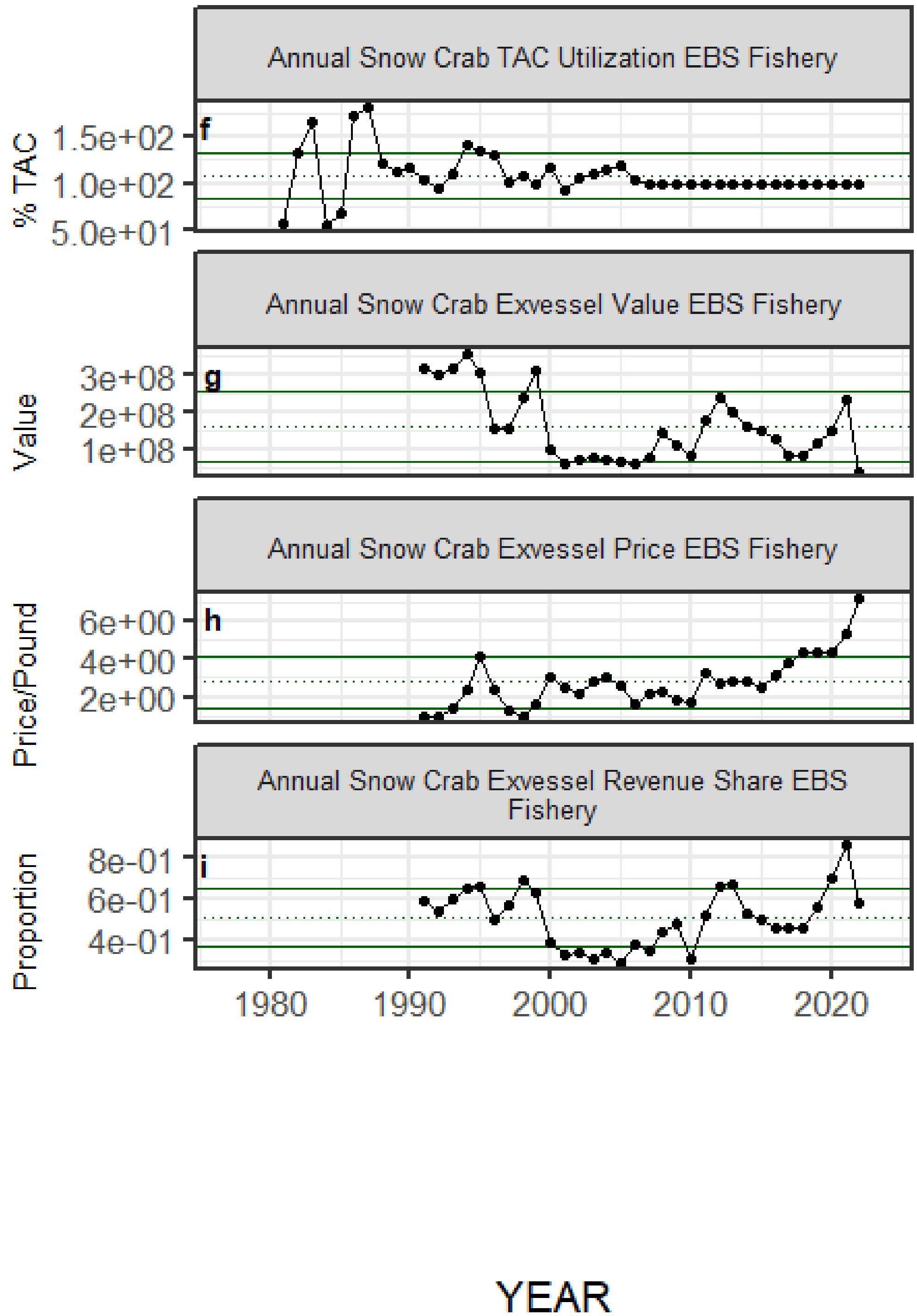

Figure 2b (cont.). Selected socioeconomic indicators for snow crab with time series ranging from 1966 – present. Upper and lower solid green horizontal lines represent 1 standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series.

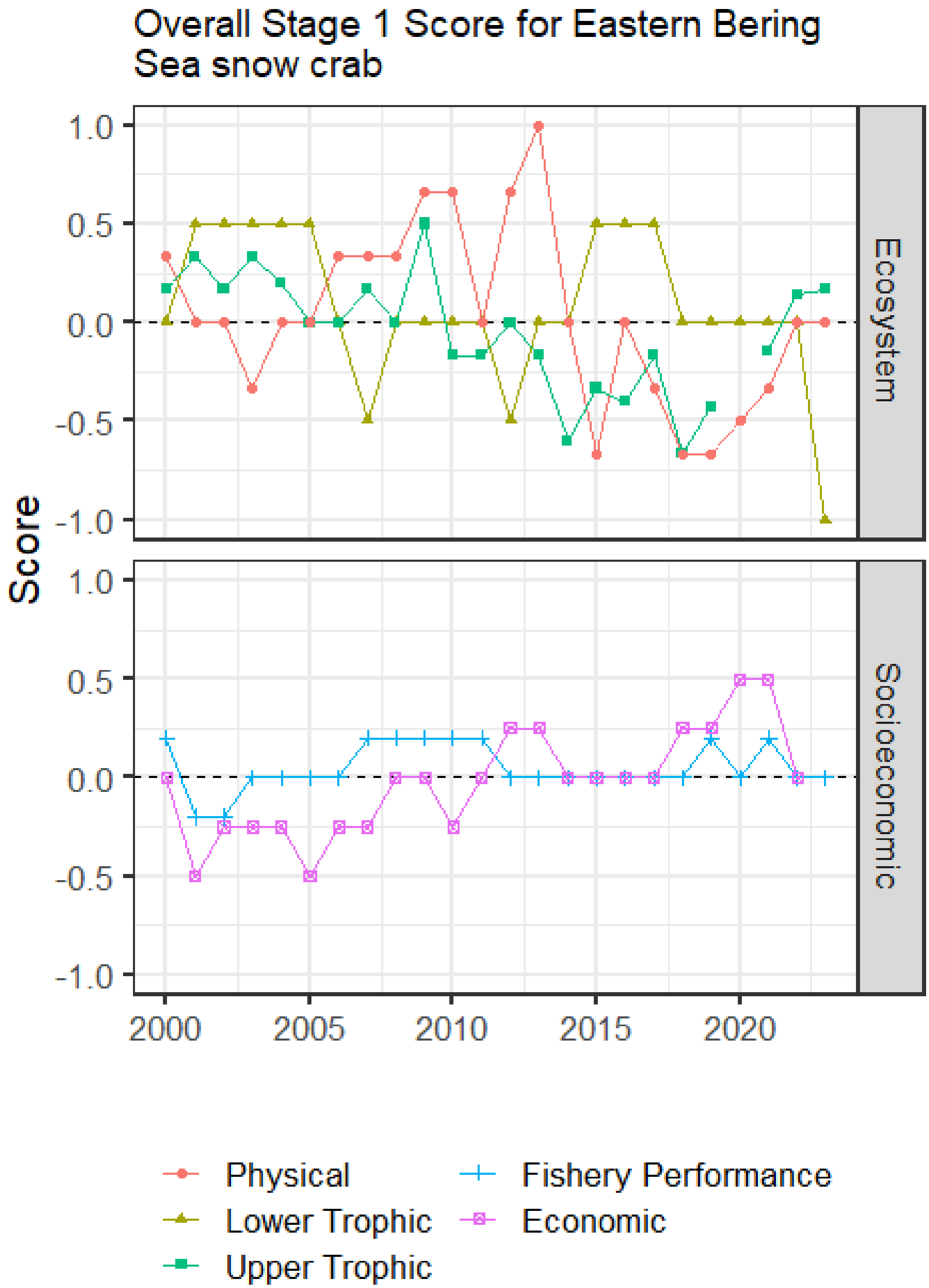

Figure 3: Simple summary traffic light score by category for ecosystem and socioeconomic indicators from 2000 to present.

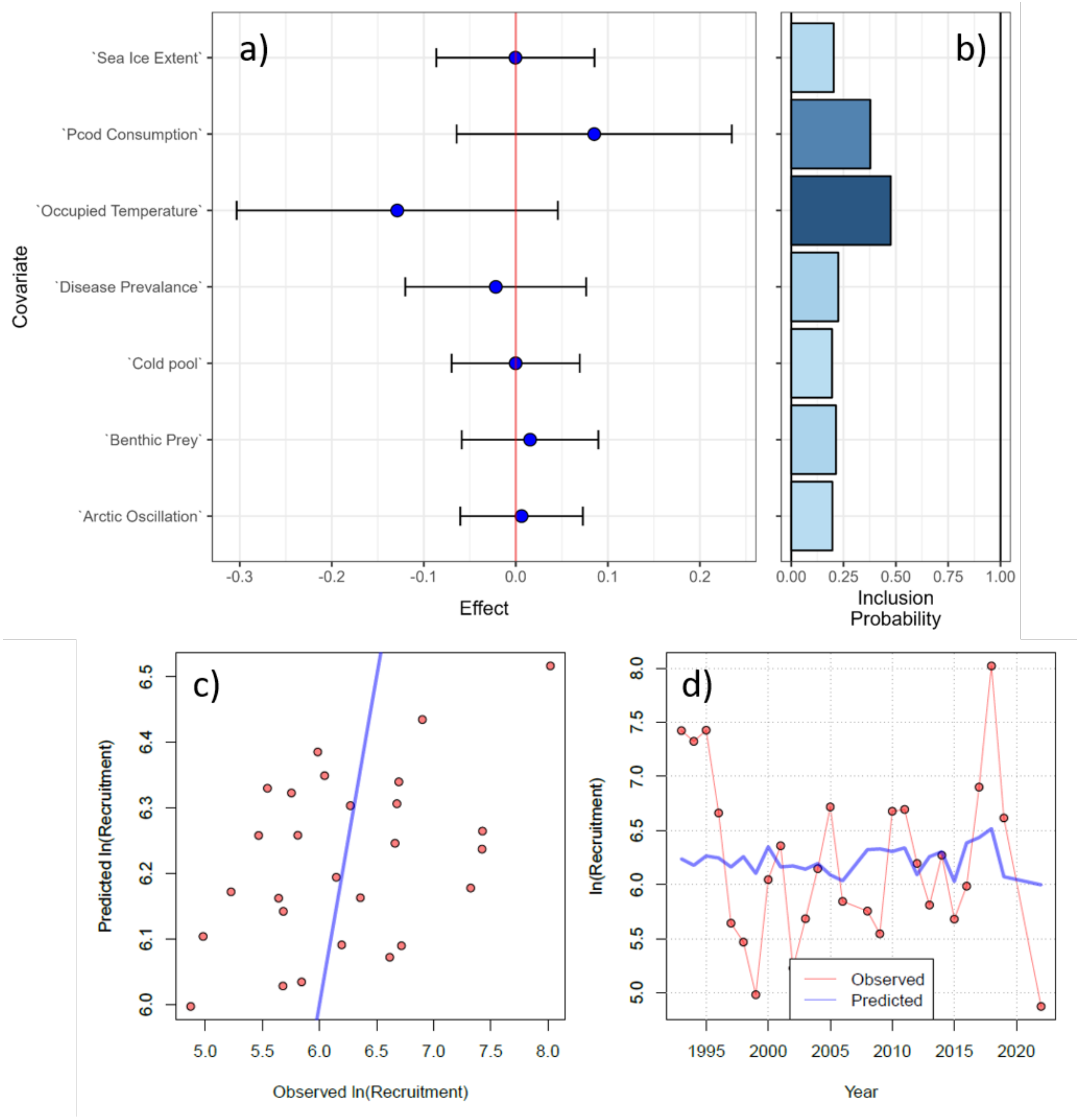

Figure 4. Bayesian adaptive sampling output showing the mean relationship and uncertainty (± 1 SD) with log-transformed EBS male snow crab recruitment (50-65mm male snow crab survey abundance): a) the estimated effect and b) marginal inclusion probabilities for each predictor variable of the subsetted covariate ecosystem indicator dataset. Output also includes model c) predicted fit (1:1 line) and d) average fit across the recruitment time series (1993 – 2021).