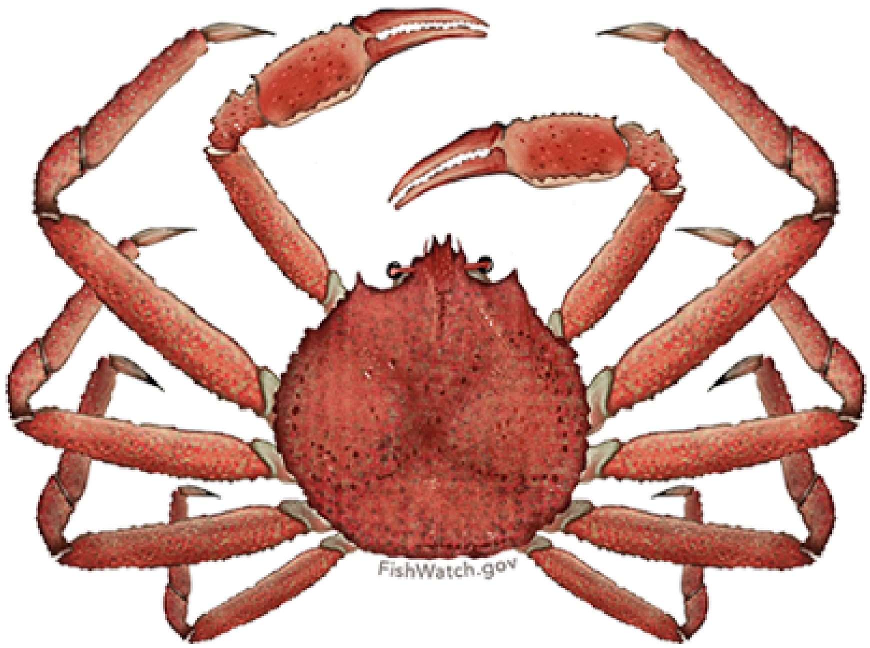
Request for Indicators: Ecosystem and Socioeconomic Profile of the Snow Crab stock in the Eastern Bering Sea

Erin Fedewa, Brian Garber-Yonts and Kalei Shotwell

2021



Stepwise plan and cycle for review of indicator submissions in response to this RFI:

Initial Recommendation	October, 2020
Request Opening	January 7, 2022
Proposed Indicators Due	February 4, 2022
Notification of Selected Indicators	February 25, 2022

Please contact Erin Fedewa (erin.fedewa@noaa.gov) and Kalei Shotwell (kalei.shotwell@noaa.gov) if you would like to respond to this RFI

Process Description and Recommendation

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.

The request for indicators (RFI) document begins the ESP process once an ESP is recommended for a stock. The RFI begins with a summary of the dominant ecosystem and socioeconomic processes influencing the stock and then provides the requested list of potential indicators representing those dominant pressures. Instructions for how to contribute an indicator in response to the stock request are included along with details on the indicator review process, the role and responsibilities of ESP teams and contributors, and use and acknowledgement of the indicator if selected for the ESP.

The North Pacific Fishery Management Council (NPFMC) Scientific and Statistical Committee (SSC) recommended that an ESP be developed for eastern Bering Sea (EBS) snow crab in October 2020 and the NPFMC Crab Plan Team (CPT) requested in May 2021 that draft ESP indicators be presented in September 2021.

CPT Recommendation:

Under the "New Business" heading for the May 2021 Crab Plan Team minutes: "ESP - draft indicators for snow crab, BBRKC indicator update" are requested for the September 2021 meeting.

SSC Recommendation:

"The SSC noted the relatively strong correlations for snow crab and BBRKC with the Arctic Oscillation, and suggests this could be further explored to determine the mechanism. The SSC requests that the CPT or the crab assessment authors examine recruitment estimates across crab stocks to see if they share a common underlying pattern. The SSC recommends that an Ecosystem and Socioeconomic Profile (ESP) be developed for EBS snow crab as time allows that carefully considers what indicators directly affect this stock" (SSC, October 2020, pg. 16)

Stock Request

Here we describe the main ecosystem and socioeconomic indicator needs for the EBS snow crab ESP. This section begins with summary information on ecosystem and socioeconomic processes that identify dominant pressures on the EBS snow crab stock and then provides a potential list of ecosystem and socioeconomic indicators requested for this stock.

Ecosystem Processes

Data evaluated over ontogenetic shifts (e.g., embryo, larvae, juvenile, adult) may be helpful for identifying specific bottlenecks in productivity and relevant indicators for monitoring. As a first attempt, we summarized important ecosystem processes or potential bottlenecks across snow crab life history stages from the literature, process studies and laboratory rearing experiments. Details on why these processes were highlighted, as well as the potential relationship between ecosystem processes and stock productivity are described below.

After molting to maturity, female snow crab mate and extrude new egg clutches each spring, which remain attached to pleopods on the female's abdomen for a full year prior to hatching (Watson, 1970). Fecundity is positively correlated with female size, and primiparous females have a lower fecundity than multiparous females (Sainte-Marie, 1993). The optimal range for embryo development is 0 to 3℃, although laboratory studies indicate that incubation temperatures below 0℃ can trigger diapause or a biennial reproduction cycle (Webb et al., 2007). Peak hatching of snow crab larvae occurs in April (Armstrong et al., 1981) and phyto-detritus may act as a chemical cue for larval release (Starr et al., 1994). Larval duration for each of the two zoeal stages is approximately 30 days (Incze et al., 1982). A longer larval stage associated with cooler temperatures may leave larvae more vulnerable to pelagic predators for a prolonged period. Furthermore, historical larval year-class failures have coincided with low zooplankton abundance over the middle shelf and low water column stability, suggesting that increased larval mortality is related to less favorable feeding conditions (Incze et al., 1987) and mismatches between larval release and the spring bloom (Somerton 1982). Likewise, laboratory studies suggest that relatively high prey densities are required for successful feeding in snow crab zoeae (Paul et al., 1979) Major predators of larval snow crab include yellowfin sole (Armstrong et al., 1980), walleye pollock, jellyfish and juvenile salmon (Kruse et al., 2007).

Snow crab larvae settle between late August to the end of October (Conan et al., 1992). Early benthic instars are cryptic and concentrate in shallow, cold water habitats (Lovrish et al., 1995; Murphy et al., 2010). Previous laboratory studies have shown that adequate energetic stores are prerequisites for molting, growth, and survival in snow crab early life history stages (e.g. Lovrich and Ouellet, 1994), indicating that variability in energetic reserves could represent a potential recruitment bottleneck in snow crab. Both settlement intensity and early benthic survival are likely critical determinants of year-class strength in snow crab (Sainte-Marie et al., 1996), and successful advection to areas of suitable temperature and muddy substrate are thought to be critical criteria for juvenile survival (Dionne et al., 2003). Density-dependence may also play a regulatory role due to high rates of cannibalism (Lovrich and Sainte-Marie 1997) and potential prey resource limitation in juvenile nurseries. Previous studies have shown that Pacific cod, sculpin, skates and halibut are major predators of juvenile snow crab (Livingston et al., 1993; Livingston and deReynier, 1996; Lang et al., 2003) and the cold pool may provide refuge from predators like Pacific cod that avoid waters less than 2℃ (Ciannelli and Bailey, 2005). Juvenile snow crab are especially vulnerable to predation and cannibalism during and immediately following molting.

Spatial patterns in juvenile and adult snow crab distribution are determined largely by ontogenetic migrations linked to size- and sex-specific thermal requirements. Immature snow crab concentrate in colder, shallow waters of the NBS and EBS middle shelves, and have historically avoided thermal habitats >2℃ (Kolts et al., 2015; Murphy, 2020). Likewise, primiparous female snow crab appear to track near-bottom temperature during a northeast to southwest ontogenetic migration to warmer waters near the shelf break (Ernst et al., 2005; Parada et al., 2010). Shifts in centers of distribution of mature female snow crab relative to prevailing currents may affect larval supply to nursery areas (Zheng and Kruse, 2006) and thermal occupancy patterns of snow crab depend on the availability of cold water habitat (Fedewa et al., 2020). While 2℃ may represent a critical temperature threshold for immature snow crab (Murphy, 2020), negative effects on metabolic processes are not apparent in mature snow crab until temperatures exceed 7◦C (Foyle et al., 1989). Temperature also influences molt timing (Dutil et al., 2010), growth rates (Yamamoto et al., 2015), energy stores (Hardy et al., 2000), and body condition (Dutil et al., 2010) of snow crab in the laboratory.

Socioeconomic Processes

As described below, the set of socioeconomic indicators proposed in this ESP are categorized as Fishery Performance and Economic Performance and Community Effects indicators. Fishery Performance indicators are intended to represent processes most directly involved in prosecution of the EBS snow crab fishery, and thus have the potential to differentially affect the condition of the stock depending on how they influence the timing, spatial distribution, selectivity, and other aspects of fishing pressure. Economic Performance and Community Effects indicators are intended to capture key dimensions of the economic and social processes through which outputs, benefits and other effects flowing from commercial exploitation of the fishery are generated and distributed. Notwithstanding these categorical distinctions, the social and economic processes that affect, and are affected by, the condition of the stock are complex and interrelated at different time scales. Moreover, these processes are strongly influenced by the institutional structures of fishery management, which develop over time and include both discrete measures undertaken by in-season management, as well as comprehensive structural changes that induce complex, multidimensional change affecting numerous social and economic processes. Implementation of the Crab Rationalization (CR) Program in 2005 is an example of the latter (a full summary of the management history of the EBS snow crab fishery is beyond the scope of the ESP; see Nichols, et al., 2019).

A key distinction of most observable socioeconomic processes from ecosystem processes associated with the EBS snow crab fishery is that they occur during the fishery, and as such, cannot be captured in indicators that provide advance information for use in informing the current stock assessment. Moreover, data collection and monitoring of many aspects of socioeconomic processes is conducted following the fishing season such that the most recent available data point may be lagged by up to two years behind the current assessment. As such, in the context of the ESP, time series of socioeconomic indicators are largely limited to informing interpretation of historic patterns observed in other data series captured in the assessment, or to providing general context regarding the effects of historic fishery management.

Among other changes, the CR program resulted in rapid consolidation of the EBS snow crab fleet, from a high of 272 vessels in 1994 to 78 during the first year of the CR program, which has subsequently further consolidated to 59 vessels operating in the 2020/21 season. Allocation of tradable crab harvest quota shares, with leasing of annual harvest quota, facilitated fleet consolidation and improved operational and economic efficiency of the fleet, changing the timing of the fishery from short derby seasons to more extended seasons, and inducing extensive and ongoing changes in harvest sector ownership, employment, and income. Crab processing sector provisions of the CR program include allocation of transferable processing quota shares (PQS), leasing of annual processing quota and custom-processing arrangements that enable PQS holders that do not operate a processing plant to purchase IFQ crab landings and direct them to a processing plant for custom processing, and community protection measures, including regional designation on harvest quota, requiring associated catch to be landed to ports within a specified region. While these and other elements of CR program design facilitated similar operational and economic efficiencies in the sector, with more limited consolidation of processing capacity to somewhat fewer locations, and fewer plants in some ports, they have also limited some economic adjustments that would likely have occurred in their absence. Most notably, North regional designation of a large fraction of EBS snow crab IFQ has likely maintained a larger proportion of landings to St. Paul Island than would have occurred otherwise. St. Paul Island has historically and to-date received the largest share of EBS snow crab landings, with Akutan, King Cove, and Unalaska/Dutch Harbor representing the other principal landing ports for EBS landings historically and to-date. See the Council's 10-Year Program Review for the CR Program for detailed description and analysis of program structure and management (Council, 2017).

These and other institutional changes continue to influence the geographic and inter-sectoral distribution of benefits produced by the EBS snow crab fleet, both through direct ownership and labor income in the EBS snow crab harvest and processing sectors, and indirect social and economic effects on fishery-dependent communities throughout Alaska and greater Pacific Northwest region. The full range of fishery, economic, and social processes cannot be captured within the scope of the ESP framework, and more comprehensive set of metrics and indicators intended to inform EBS snow crab fishery management and annual harvest specifications are provided in the annual Crab Economic SAFE.

Proposed Ecosystem Indicators

List of requested indicators and brief indicator description based on dominant drivers for EBS snow crab. Associated contributors and indicator time series (Figures 1a-1b) are included if the indicator has already been or is currently in development.

1.) Physical Indicators
    - **Arctic Oscillation:** Winter-spring Arctic Oscillation index (NOAA National Climate Data Center). Poor snow crab recruitment is associated with positive values of the Arctic Oscillation (Szuwalski et al., 2021).
    - **Cold pool extent:** The areal extent of EBS bottom trawl survey stations with bottom temperatures < 2℃ (contact: E. Fedewa). The cold pool provides predator refuge for juvenile snow crab and cold water habitat availability (< 2 °C) has been proposed as a critical recruitment bottleneck (Dionne et al., 2003; Parada et al., 2010) .
    - **Sea ice extent/retreat:** Monthly sea ice products in the Arctic (National Snow and Ice Data Center). Sea ice extent drives cold pool dynamics in the EBS and snow crab recruitment is positively related to ice cover (Szuwalski et al., 2021).
    - **Ocean acidification index:** pH of bottom waters on the EBS shelf estimated from the Bering10K ROMS model (Pilcher et al., 2019) (contact: D. Pilcher). Prolonged exposure to acidified bottom waters could negatively affect juvenile snow crab growth and survival (ongoing research at Kodiak Fisheries Research Center).
    - **Spring chlorophyll-*a* biomass:** April-June average chlorophyll-a biomass within the north middle shelf of the EBS; calculated with 8-day composite data from MODIS satellites aggregated by BSIERP region (contact: J. Nielsen). Larval growth and survival is dependent on high concentrations of diatoms (Paul et al., 1979).

2.) Lower-trophic Indicators
    - **Intermolt duration index:** Predicted time spent in early benthic instars using laboratory derived temperature-dependent development rates and simulations from a spatially explicit biophysical individual based model (contact: W. Stockhausen): Stage duration is inversely related to temperature so warm years result in more rapid growth rates, shorter intermolt duration and less time spent in vulnerable early life stages (Yamamoto et al., 2015).
    - **Settlement success index:** Measure of "successful" individuals settled in benthic nursery habitat (25-150 m depth) from individual based model simulations (contact: W.

Stockhausen). Successful recruitment is likely linked to retention and settlement on the middle shelf (Hinckley et al., 2010).

- **Snow crab hatch-spring bloom index:** Temporal overlap between spring bloom timing (contact: J. Nielsen) and hatch dates estimated from temperature-dependent embryo development rates. In warm years, the spring bloom occurs in April-June and overlaps with peak snow crab hatching, likely increasing larval survival (Cushing, 1990; Szuwalski and Punt, 2013).
- **Benthic prey biomass:** Combined biomass of benthic invertebrate prey items on the EBS bottom trawl survey (contact: E. Fedewa). Food availability may drive patterns in growth, energetic condition and survival of snow crab.

3.) Upper-trophic Indicators

- **Snow crab recruit physiological condition:** Mean lipid content of juvenile snow crab prior to the terminal molt (contact: E. Fedewa). Survival during the terminal molt may rely on the achievement of a threshold physiological condition (Godbout et al., 2002; Dawe et al., 2012) and significant reductions in the juvenile snow crab condition have been associated with the retraction of the cold pool and warming bottom temperatures (Copeman et al, 2021).
- **Stock area occupied:** Minimum area containing 95% of the cumulative CPUE during the EBS summer bottom trawl survey (contact: E. Fedewa). Shifts in the spatial extent of snow crab are driven by bottom temperatures and cold pool dynamics in the EBS (Fedewa et al., 2020).
- **Immature female snow crab temperature of occupancy:** Mean bottom temperature weighted by immature female snow crab CPUE at each station of the EBS summer bottom trawl survey (contact: E. Fedewa). Immature female snow crab are highly sensitive to bottom temperatures and 2 °C is an important maximum temperature threshold (Dionne et al., 2003; Murphy 2020).
- **Stock center of gravity:** CPUE-weighted average latitude of the stock during the EBS summer bottom trawl survey (contact: E. Fedewa). 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).
- **Population-level estimates of snow crab predation:** 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). 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).
- **Pacific cod-snow crab spatial overlap:** Frequency of positive-catch snow crab stations also containing Pacific cod on the NBS summer bottom trawl survey (contact: Erin Fedewa). Cold pool reductions and subsequent Pacific cod distribution shifts into the NBS may increase Pacific cod predation on juvenile snow crab via climate-driven changes in the strength of spatial overlap between cod and snow crab populations (Hunsicker et al., 2013; Litzow and Ciannelli, 2008).
- **Female snow crab size at maturity:** Mean carapace width of female snow crab at 50% probability of maturation, as determined from maturity curves developed from EBS bottom trawl survey data (contact: J. Richar). Female size at maturity may be indicative of reproductive potential as fecundity increases with increasing female size (Webb et al., 2016).

- **Male snow crab recruit biomass:** Biomass of male snow crab (95-101 mm CW) from the EBS bottom trawl survey that will likely enter the fishery the following year. (contact: J. Richar). Male recruit abundance estimates provide an index of future abundances of legal crab.
- **Juvenile snow crab disease prevalence:** Prevalence of immature snow crab showing visual evidence of Bitter Crab Syndrome during the summer EBS bottom trawl survey (contact: E. Fedewa). Disease prevalence serves as an indicator of stock health because mortality rates of parasitized crab are believed to be high (Meyers and Burton 2009).

Proposed Socioeconomic Indicators

All socioeconomic indicators proposed for the EBS snow crab ESP are derived from in-season management monitoring and reporting systems, including ADFG fish tickets/eLandings and ADFG Crab Observer Program data, and are sourced from the AKFIN database.

1.) Fishery Performance
   - **Area occupied, center of gravity, or other estimated indices of spatial distribution** for the snow crab fishery to monitor spatial shifts in fishery behavior.
   - **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; may be compared to abundance estimates from the survey to see how well they track over time.
   - **Annual total potlifts** in the snow crab fishery to represent the level of fishing effort expended by the active fleet..
   - **Annual number of active vessels** in the snow crab fishery to represent the level of fishing effort assigned to the fishery; responsive to vessel-level costs of entry and operation and TAC level.
   - **Annual incidental catch of snow crab** in other fisheries to determine if there are increases in overlap between the snow crab population and other competitors or predators.

2.) Economic
   - **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; ex-vessel revenue proxies for economic returns in the processing sector, as well as labor earnings in both sectors, but does not capture distributional changes within or between these and other sectors of the 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, and to help explain potential shifts in fishery behavior.
   - **Annual snow crab ex-vessel revenue share** (expressed as vessel-average proportion of annual gross landings revenue earned from the EBS snow crab fishery), representing the relative dependence of active vessels on the EBS fishery, among other catch targets available in the average vessels' portfolio of target species/fisheries.

3.) Community
   - No community performance indicators are proposed for the EBS snow crab ESP.

Instructions for Contributors

This section provides instructions for general metadata and data requirements for contributors who would like to respond to this RFI for the eastern Bering Sea snow crab ESP.

Metadata Fields and Data

Contributions of indicators should include the following metadata fields: name and description of indicator, type of indicator (ecosystem or socioeconomic), primary contact for indicator, intended ESP, frequency of indicator update, start/stop time of indicator, status and trends, influential factors, implications for the eastern Bering Sea snow crab, and relevant references. The description of the indicator should include details on how the indicator is created, the spatial resolution (e.g., cell size for gridded data, area of sampling for a survey), and the operation (e.g., survey name and gear type, satellite sensor and version, stock assessment model output, fishery observer data, community reports). Status and trends should include a comparison of the most recent year value relative to the time-series average and the most recent five year trend relative to the long-term trend of the time series. Influential factors should include information on ecosystem or socioeconomic factors that potentially influence the recent status and trends. Implications for the stock should provide a statement on how the recent indicator status and trends impact the eastern Bering Sea snow crab stock. References should include citations for the indicator (e.g., journal article, ESR contribution, report) where possible.

Potential indicators should meet as many of the following guideline criteria as possible to be included in the ESP for eastern Bering sea snow crab:

- ☐ Meaningful for determining eastern Bering Sea snow crab stock health or productivity
- ☐ Accessible, Consistent, and Timely (or ACT) with commitment to produce for ESP at stated frequency of indicator update and contact information provided
- ☐ Not redundant with data or processes currently accounted for in the stock assessment model
- ☐ Mechanistic link to stock assessment parameter (e.g., recruitment) of eastern Bering Sea snow crab that is vetted by publication, council, or group of experts (e.g., ESP team listed in RFI)
- ☐ Demonstrated error reduction in research ecosystem stock assessment model

Please list all criteria that apply for the submitted indicator and include a short description of evidence that supports each selected criteria.

A time series of the indicator data is also required for successful submission. The file format of the data must be a comma-separated file with three columns that are named in the first header row as YEAR (formatted as a number), INDICATOR_NAME (formatted as a character), and DATA_VALUE (formatted as a number). Once uploaded, the data file will be run through a series of checks to ensure valid connection with the ESP database tables and processing needs.

Indicator Submission

Contributors responding to this RFI should submit potential indicators using the ESP indicator submission tool developed by the Alaska Fisheries Information Network (AKFIN). This is a data management application that facilitates the requested metadata, criteria, and data file uploads for use in creating ESPs. The application provides a communication system between ESP contributors and the ESP teams to review and approve submitted indicators. Contributors interested in responding to this RFI should please email

Erin Fedewa (erin.fedewa@noaa.gov) and Kalei Shotwell (kalei.shotwell@noaa.gov) to set up an account with AKFIN to initiate the indicator submission process.

The RFI for eastern Bering Sea snow crab opens on **January 7, 2022**. Proposed indicators are due on **February 4, 2022**. Indicators will be reviewed by the crab ESP team and indicator evaluations will be provided to all contributors by **February 25, 2022**.

Review and Responsibilities

This section provides a description of the indicator review process by the ESP team, use and credit if the indicator is selected for the ESP, and future responsibilities of the ESP teams and contributors.

Team Review

ESP teams meet virtually in February to review submitted indicators to the RFIs. Indicators will be evaluated based on the following criteria: 1) responsiveness to RFI request and proposed indicators 2) completeness of the requested metadata fields, 3) evidence that the indicator met the listed guideline criteria, and 4) successful upload of indicator data.

Indicator evaluations will be provided to the contributors following the ESP team review and will include the decision on whether the indicator was selected for inclusion in the ESP and a summary of the ESP team review.

Use and Credit

If an indicator is selected for inclusion in an ESP, the submitted data will only be used for the intended ESP. The indicator can also be made available to the public through the ESP webpage, but only if authorized by the contributor. Credit for selected ESP indicators is provided by including the name of the indicator contact in the "With Contributions from:" section of the title page on the annual ESP report (full, partial, and report card). The ESP reports serve as a pathway for providing contextual advice for unaccounted for uncertainty in the main stock assessment and fishery evaluation (SAFE) report and for testing indicators to be included in an ecosystem linked stock assessment model.

Responsibilities

An ESP team typically consists of the facilitator, the lead stock assessment author(s), a status report representative (one from both the ecosystem status report and economic SAFE report teams where possible), and several subject matter experts. Some data rich stocks may require their own team (e.g., Alaska sablefish), while other stocks may be combined under one team to streamline participation and share expert resources (e.g., three Pacific cod stocks). Currently, there is no ESP team for the Bering Sea crab stocks, but we hope to formulate a team following review of this RFI at the September 2021 Crab Plan Team. Once created, the ESP team responsibilities are to 1) create the RFI for a recommended ESP by January, 2) review submitted indicators responding to the RFI by the end of February, 3) create draft ESP reports according to the crab or groundfish schedule (draft schedule link here), and 4) commit to annual updating and review of future indicators for the ESP.

An ESP contributor has successfully responded to the stock RFI and their submitted indicator has been selected by the ESP team to be included in the ESP. The ESP contributor responsibilities are to 1) review sections of the ESP report pertaining to their indicator contribution, 2) respond in a timely manner to questions from the ESP team regarding their indicator contribution, 3) submit current year data (where possible) to the ESP submission tool by September 1 for use in annual ESP report cards, and 4) commit to annual updating and review of their indicator in future ESPs.

Thank you for considering submitting your indicator to this RFI for eastern Bering Sea snow crab. Please send any questions regarding this RFI to Erin Fedewa (erin.fedewa@noaa.gov) and Kalei Shotwell (kalei.shotwell@noaa.gov).

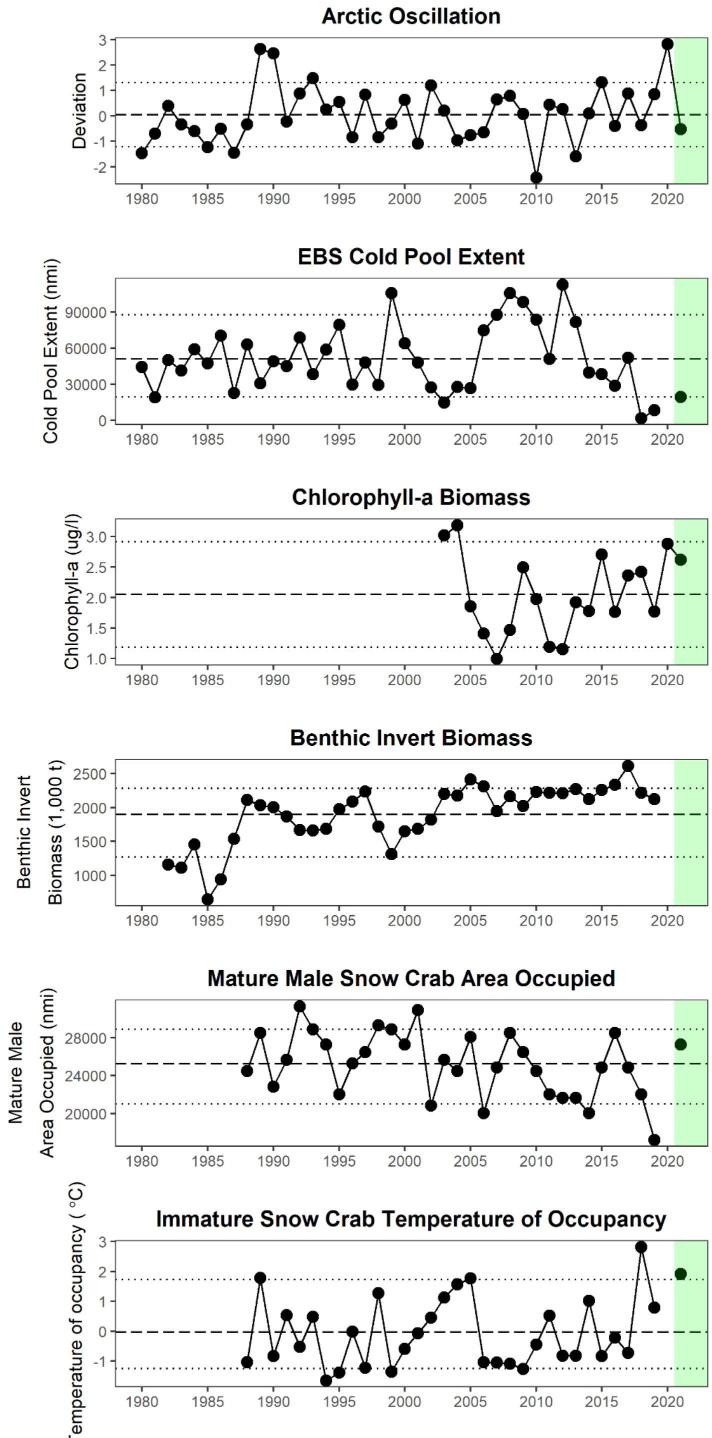


Figure 1a. Proposed snow crab indicators with time series ranging from 1980 – 2021. Upper and lower dotted horizontal lines are 90th and 10th percentiles of time series. Dashed horizontal line is the mean of time series. Light green shaded area represents most recent year data.

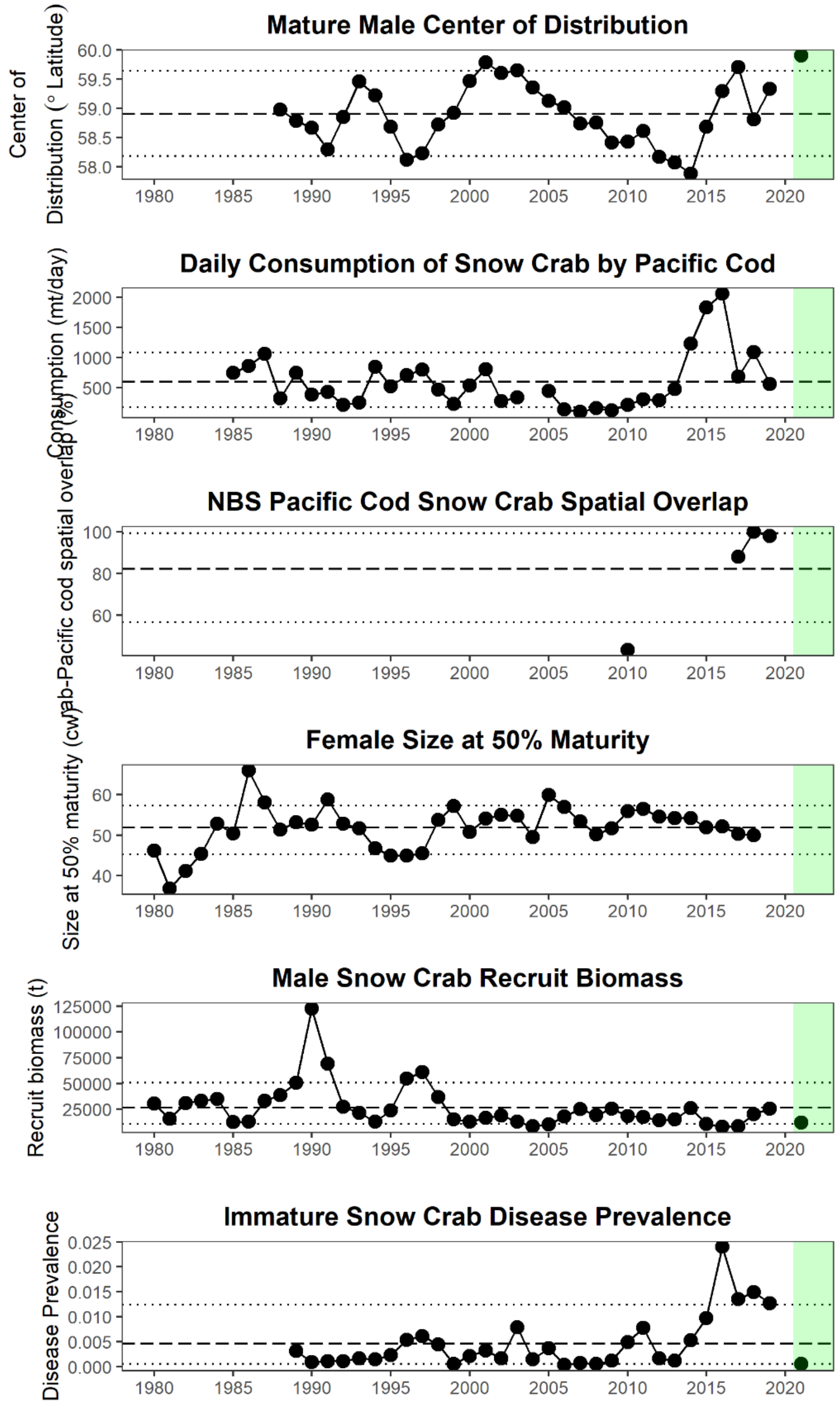


Figure 1b. Additional proposed snow crab indicators with time series ranging from 1980 – 2021.

Literature Cited

Please NOTE: References will be update for the final RFI and will include a DOI or online links to papers where possible

Armstrong et al., 1980

Armstrong et al., 1981

Ciannelli and Bailey, 2005

Conan et al., 1992

Copeman et al, 2021

Cushing, 1990

Dawe et al., 2012

Dionne et al., 2003

Dutil et al., 2010

Ernst et al., 2005

Fedewa et al., 2020

Foyle et al., 1989

Godbout et al., 2002

Hardy et al., 2000

Hinckley et al., 2010

Hunsicker et al., 2013

Incze et al., 1982

Incze et al., 1987

Kolts et al., 2015

Kruse et al., 2007

Lang et al., 2003

Litzow and Ciannelli, 2008

Livingston, 1989

Livingston et al., 1993

Livingston and deReynier, 1996

Lovrich and Ouellet, 1994

Lovrish et al., 1995

Lovrich and Sainte-Marie 1997

Meyers and Burton 2009

Murphy, 2020

Murphy et al., 2010

Orensanz et al., 2004

Parada et al., 2010

Paul et al., 1979

Pilcher et al., 2019

Sainte-Marie, 1993

Sainte-Marie et al., 1996

Shotwell et al., In Review

Somerton 1982

Szuwalski and Punt, 2013

Szuwalski et al., 2021

Starr et al., 1994

Webb et al., 2007

Webb et al., 2016

Yamamoto et al., 2015

Zheng and Kruse, 2006