Summary Information for the December 2017 Workshop for bairdi Tanner Crab hosted by the Bering Sea Fisheries Research Foundation (BSFRF)

FOR WORKSHOP PARTICIPANTS AND OTHER INTERESTED STAKEHOLDERS

(Please direct any questions to Scott Goodman, BSFRF)
(206-285-3480, sgoodman@nrccorp.com)

Workshop Dates: December 18-19 (Monday-Tuesday), 2017

Workshop Locations: Centennial Hall, Egan Room, 101 Egan Drive Juneau, Alaska

Steering Committee:

Ben Daly, Bob Foy, Scott Goodman, Nick Sagalkin, Chris Siddon, Buck Stockhausen

Science Advisory Board:

Ben Daly, Bob Foy, Ginny Eckert, Scott Goodman, Gordon Kruse, Steve Martell, Nick Sagalkin, Bernard Sainte-Marie, Chris Siddon, Shareef Sideek, Laura Slater, Dave Somerton, Mark Stichert, Buck Stockhausen, Jie Zheng

Other Participants/Attendees:

Forrest Bowers, Ed Dersham, Tyson Fick, Tyler Jackson, Jake Jacobsen, John Jensen, Scott Kent, Nicole Kimball, Michael Knutson, Heather McCarty, Robert Ruffner, Madison Shipley, Gary Stauffer, Doug Wells, Joel Webb

Workshop Chair:

Scott Goodman

Attached Materials:

Executive Summary and Workshop Recommendations

Summary Notes from Day 1-2 Presentations/Discussion

Workshop Invite and Background Introduction

Workshop Final Agenda & Attached Information on Primary Goals/Stakeholder Questions

Abbreviated Slide Summary – several key slides from presentation decks

Executive Summary (Reached Consensus)

The specific focus and primary question of the BSFRF Bairdi Tanner Crab Workshop was how the treatment of mature female bairdi should be best considered within the ADFG harvest strategy. The presentations, discussions and workshop outcomes led to a revision of this primary question as part of the final recommendations. The primary workshop goals and final recommendations are described below.

The two-day workshop (12/18-19, 2017) was a successful event with 36 attendees participating in a mixed-format presentation and discussion of current Bering Sea bairdi crab harvest management. The BSFRF hosted the workshop and steered the meetings as a cooperative and productive interaction between crab managers and industry stakeholders present. The workshop discussions focused on current approaches and possible revisions toward improvements to the Alaska Department of Fish and Game (ADFG) bairdi harvest strategy. The co-managers – ADFG and National Marine Fisheries Service (NMFS) – were represented at the workshop to provide collaborative input on options considered. The workshop covered what is known vs. not known about Tanner crab and considered several aspects of bairdi biology and how that information forms the basis for management choices – specifically those within the current ADFG bairdi harvest strategy.

The workshop reached general consensus during day two of discussions regarding further consideration of how females and reproductive capacity should be considered in Bering Sea bairdi crab management. Three key summary statements were; 1) uncertainty about the idea of an on-off switch in the harvest strategy based on females, absent other indicators that quantify spawning/mating threats, 2) consideration of an approach that brings the female threshold down in its level of impact within the harvest strategy to function more as a baseline indicator along with other indicators to be identified, and 3) that improved tracking of females from a research perspective could help managers, but that in general, it doesn't appear that arguments for a strict female control rule are as reliable as currently applied.

ADFG managers present provided several important points regarding the most recent efforts to update the bairdi harvest strategy, including three smaller-scale changes (observed vs. size dependent female counting, removal of boundary to include all mature females, and updated reference years for the female threshold), and one higher level application (threshold error-band approach) which were implemented in May 2017 by the Alaska Board of Fish (BOF). These revisions were explained as short-term ("band-aid") fixes, and were part of the consideration in how the workshop recommendations would not focus on small scale issues but adopt an approach to work in collaboration on a holistic review and full revision to the current bairdi harvest strategy. **The workshop came to a consensus that protection of reproductive potential should be included in the revised harvest strategy, with a female rule potentially retained but more focus on male rules, and moving towards more consistent outcomes for industry.**

The workshop participants recognized that bairdi is one stock of many to manage, but that important focus and momentum should be maintained during further collaboration and progress. The BSFRF will continue to assist with bairdi specific work tasks along with normal bairdi management cycle efforts following the workshop as appropriate. The BSFRF would like to acknowledge and thank all participants for their time and efforts to focus on improving bairdi management, especially for travelling for extra work during the holiday season.

Workshop Final Recommendations

1) The restated objective of the full bairdi harvest strategy revision is:

   "Workshop partners recommend an approach to revise the bairdi harvest strategy that improves the economic outlook to the industry and acknowledges the importance of the bairdi reproductive capacity to conserve the stock."

2) Workshop partners agree to a longer term approach that generally follows the schedule requirements of the ADFG and BOF cycle that would bring full bairdi harvest strategy revisions for review in early 2019, final results in late 2019, and for final consideration and implementation by the BOF in 2020.

3) Workshop partners agree on a collaborative approach that will allow input from managers and stakeholders, is multi-tasked relying on a number of work products, and will require some intermediate coordination between ADFG, NMFS, BSFRF, graduate students, and potentially other researchers. Work products will include adhoc analyses of harvest strategy scenarios/options, including coordination with MSE/graduate student work. Progress reports will be provided during continued management efforts and Workshop follow-up to all interested managers and stakeholders.

4) Workshop partners agree to document the information shared, workshop outcomes, summary of findings, road map forward, and to provide updates as appropriate to Bering Sea crab managers and stakeholders.

Chronological Notes (paraphrased transcription from Workshop audio recording)

Day One Presentations (short summary, topics further covered in Day One Discussion below):

Goodman provided workshop introduction and overview – setting context, why the workshop, goals, outcomes, etc.

Stockhausen provided assessment model framework overview – description of what type of model is used for bairdi assessment, what data sources, what assumptions, how it used to inform management and how it provides guidance for setting OFL, ABC and making projections.

Daly and Siddon (with Zheng) provided overview of current ADFG harvest strategy – described history, revisions, current updates and issues, conservation measures built into strategy, some details of the framework, and the outlook for further revisions. Overlay slides (Siddon) showed the data source, management, and seasonal changes over time.

Siddon provided brief overview of where female metrics (mature biomass, etc.) are considered alone or in concert with other metrics.

Sainte-Marie provided overview of Canada's (CA) perspectives on snow crab – he covered spatial differences, species differences between opilio and bairdi, but highlight similarities. His presentation supported different approaches for how females are considered in harvest management. Highlights from his work included the small spatial scale of CA opilio management in contrast to Bering Sea, more robust juvenile length frequency information and growth data.

Foy provided an overview of the most recent information from NMFS bairdi surveys – highlighting updated information on observed recruitment, sex ratios and precision of survey estimated quantities of the historical time series.

Slater provided an overview of female bairdi research – focusing on measures of reproductive health including egg clutch conditions, fertilization, and other variables mostly from crab survey data.

Day One Discussion:

Discussion began with a description of what direct observations of female bairdi health showed. Trends looking at clutch fullness, fertilization rate, and sex ratios were all seen as relatively stable over time. There is no obvious relationship between sperm reserves and sex ratios. This part of discussion was mostly related to Slater's slides. There is interest in looking at a finer spatial scale for reproductive potential trends. Further discussion focused on central question: Do males limit reproductive potential? Females that are both primiparous and multiparous have been found to have enough sperm reserves. Fecundity, measured in number of eggs, has some spatial differences, but nothing significant, and doesn't appear to show any red flags that males are the limiting factor to reproductive potential, but it should be explored on a spatial level. The next discussion question looked at egg production as a measure of reproductive potential. Currently, size-fecundity relationships by clutch size are rigorous and a good overall measurement, but are limited by the time frame of measurement (summer survey only). There is a linkage between shell condition and reproductive capacity (senescence). Discussion suggested that the next steps for better understanding bairdi reproduction would be to look more into reproductive potential for both sexes, specifically quantifying females that haven't had a clutch. Information noted that any field test would not be feasible, because the work relies on microscopes and

egg/sperm collection and is usually performed in a lab setting. Changes in sex ratios were noted to be very important although there are no clear changes apparent in sex ratio from survey data.

Discussion shifts to address how stable measures of reproductive potential are, and whether they can or should play a meaningful role in management. Martell comments that the coefficients of variation for early life history variables (e.g. juvenile mortality) are currently so large that it doesn't allow other measured variables to play a significant role when informing a model. He suggests that the "life history effects" as they are currently understood need further quantification to be useful elements for management. This leads to a discussion on a more informative index, mature female biomass, or egg production index and whether it is worth it to incorporate these biological factors given the uncertainties associated with them, specifically for bairdi. Discussion led back to the approach with two tests in the current harvest strategy: are there enough females and are there enough males to allow for some level of harvest. Both tests include indices of reproductive potential although not more specifically quantified, which allows for inherent buffers.

The discussion moved to Sainte-Marie's review of mature male-female abundance lag and reproductive viability. He noted that snow crab has an S-R relationship with consistent pulses in CA based on their higher level of survey data. Egg production is linked to female biomass and recruitment to the fishery. Tanner crab in the Bering Sea have no clear S-R relationship, and cycles are less understood and more amplified. Additional biomass effects are not apparent, and peaks in male and female biomass are generally synchronized. This means that growth differences between Tanner crab and snow crab are likely different, the survey process is biased as the sex ratios observed don't make sense with a lack of fishing pressure on females. Sainte-Marie is uncertain about the appropriateness of the idea of a cut-off based on female biomass and asks how much the directed fishery affects female abundance. He noted that if mating is occurring and there's a way to quantify it, then is there a good reason for a female biomass threshold? If male biomass is protected to a certain level to ensure mating can occur, then females shouldn't be a solitary deciding factor in the opening of the fishery. He does state that spatial scale is important to consider and if there are big differences between the east and west districts, one assessment may not reflect or be relevant to interactions of males and females across the whole area. Sainte-Marie recommends a neighborhood spatial approach when looking at sex ratios, distributions, and environmental factors such as temperature. Further discussion notes that sperm counts in the Bering Sea are high when compared to the Canadian fishery, and there is little to no effect from fishing on females. As points of caution, in Canada, there is no female threshold, but Sainte-Marie states that reproductive potential could be driven down by excessive fishing on males. On the east coast (CA), the exploitation rates are too small to cause this, but the Bering Sea is much bigger and more spatially varied.

Conservation requires protection of bairdi reproductive capacity, but, as previously stated, there is no clear evidence that fishing has a direct and measurable effect on this. There needs to be a better understanding of how biological data correlates with recruitment and if there is enough concern to be built into the harvest strategy. The male-only model should include a female indicator that can inform harvest, but not be a deciding factor. Martell importantly notes that building a harvest control rule with the current information we have is like building a car without knowing what kind of road is in front of you, and that there needs to be an evaluation of the goals of the harvest strategy, i.e., more consistent harvest, etc. Theoretically, the male-only harvest rule could be more conservative and more consistent than a female threshold, as there is a potential lag between male and female maturity rates. Eckert asks

if there are good reasons to track females from a research perspective and that thus far, it doesn't sound like the arguments for a female control rule are as reliable as currently applied.

The discussion moves on to cover episodic versus constant recruitments, as well as harvest expectations considered in a variety of harvest control rules. The current harvest strategy applies high catch rates when abundance is high but drops sharply dependent on female biomass. This policy yields conservative to no catches until a high abundance year results in very high catch limits. Other alternatives could set limits with small adjustments that result in smaller but consistent catches over time. To determine these scales, risk analyses and trade-offs would need to be evaluated.

Sainte-Marie comments that the clear indicators of mating success vs. failure do not line up with other uncertainties. If there is clear evidence of mating failure, it's already too late for that year, and there needs to be a safeguard of two to three years to be effective. There is a discussion on better indicators, and if a stark change in female sperm reserves and/or barren females would be more informative. Slater states that looking at barren females is a bit of a red herring, and sperm reserves cannot be measured in the field. A changing environment will likely result in changes in crab sizes, habitat, recruitment, and distribution and once again, looking at the species from a spatial and temporal analysis perspective is discussed. Jackson comments that there could be important attention to genetic information to monitor massive reproductive failure leading to genetic declines in populations over time. Overall there is no consensus reached on the female control rule and the discussion is set to be continued the next day.

Day Two Discussion:

The discussion begins with input from the industry participants. After opportunities for all participants to voice their comments and concerns, it becomes clear that the industry representatives in attendance prefer the idea of a stable fishery and market over huge but highly intermittent catches. Tanner crab is the only fishery in the Bering Sea with a strict female threshold, and ultimately the species has been proven to be resilient with large and sudden recoveries after substantial declines. The discussion moved towards mid-term and long-term options and a draft timeline for the process of further revision. Ultimately, the goal is a road map of wholesale changes to the current harvest strategy instead of small "band-aid" fixes.

Sagalkin reemphasizes that if there are to be drastic changes resulting in a stable catch over time there will more than likely be reduced TACs and there would need to be a reconciling of the potential creation of surplus old shell crab. There is a discussion about the willingness of the industry to target these older shell animals and whether there would be a price difference or selective harvest. Sainte-Marie states that Canada underwent a publicity campaign promoting old shell crab as just as worthy as newer shell crab, often containing more meat. To keep the stability in old shell crab harvest, there would need to be enforcement on taking old shell crab and new shell crab at the same rate or old shell crab would dominate the fishery and eventually undergo natural mortality and not contribute to the spawning stock biomass. Industry would prefer there to be no two-tier pricing, where all legal crab regardless of shell condition would be retained (already occurring) and the behavior of boats moving away from grounds dominated by old shell crab would be controlled to prevent the creation of a selected fishery (high grading). The industry expressed support for these considerations, as well as the option of the female threshold being eliminated in favor of lower exploitation rates consistently.

The discussion continues with it being more important to project sex ratios into the future as a potential indicator of a critical threshold for reproductive potential. Sainte-Marie encourages looking at neighborhood scaled measurements either at set distances or in the east and west sub-districts, as these smaller spatial scales could also be a more informative indicator of an S-R relationship. There is a discussion of the survey occurring shortly after or during multiparous mating and if highly aggregated females result in underestimation of abundance, influencing observed sex ratios, as bairdi, will bury themselves in huge clusters often only 100's of meters in dimension. Discussion changes to support Management Strategy Evaluation (MSE) looking over different options for control rules while monitoring sex ratios, number of consecutive and total season closures, overall catch, average catch, as well as other performance metrics. The bias may not be temporally consistent due to selectivity measurements, and this would also need to be taken into account.

Foy restates that a lack of understanding of females makes questions regarding sex ratios hard to answer. There are some years with lots of females that will disappear three or so years later. Stichert emphasizes that it is necessary to understand industry concerns as well as economic feedback. There is a lot of value in the products, and it is critical to make wise use of the resource, potentially even considering a mixed stock fishery. Wells comments on the industry and a need for a change. There needs to be an agreement between management and industry on proper guidelines of the fishery, for example, reducing the discards of undesirable animals and potentially re-evaluating size limits aiming for a no discard fishery. There needs to be a careful consideration of economics vs. sustainability vs. consistency.

There is a quick recap on the control questions: 1) consensus vs. disagreement on reproductive capacity and females in the harvest strategy 2) what is the best estimate of reproductive capacity and 3) if the current approach is correct. Stockhausen states that a better question would be: can the current approach be improved and determined by objectives and how the improvement would be evaluated. This answer depends on the goal of the fishery and the criteria used for evaluation. Sex ratios are a monitored indicator, and the harvest rate could be dampened while an appropriate historical value for critical sex ratio is defined (likely through the MSE process). This could also be done using the neighborhood method to look at small scale differences. Additionally, sperm capacity, which is a lagged indicator, could be used and compared in closed vs. fished areas to define effects. For sex ratios to be utilized in the assessment model there needs to be an understanding that the indicator is highly variable with survey uncertainty and this uncertainty could be minimized with spatial analysis and if small male maturity could be reconciled. The surveys have shown that there are persistent clusters of crabs for multiple years, and this could result in survey bias (either the big clusters are seen, or they're not) driven by patch changes with variable bottom temperatures, temporally.

Stockhausen proceeds with his presentation on how the assessment models can inform the harvest strategy, ending with future direction for the model. These include, but are not limited to, fitting male ogives with chela height data directly in the model for a more accurate metric of male maturity, testing alternative selectivity functions, incorporating BSFRF survey data to improve trawl selectivity scaling information when compared to NMFS survey data, and improve recruitment estimates by incorporating smaller sized crab allowing for better resolved population modes at small sizes, transitioning to a GMACs model framework, and finally considering how bycatch estimates influence the OFL and TAC recommendations.

Daly reconvenes discussion with ways to quantify a buffer with females if the on/off switch were to be removed or minimized. The suggestion is a more continuous female TAC multiplier to avoid sharp declines and fishery closures, while still including a "too low" sweet spot where other fishery components would be explored before a hard and fast closure is put into place. One potential example of this would be a scalar applied to male biomass, where more confidence would allow for a smaller buffer. This sliding approach would scale the TAC as opposed to driving the TAC as the current harvest strategy does. More research and data analysis would be necessary to inform the upper and lower bounds of this scale. There is a discussion on this method, as it is still a female threshold, but more relaxed, and ultimately considered a small level ("band-aid") fix. There are further comments on snow crab and BBRKC harvest strategies, specifically that when female population is low, sperm availability is not believed to be low, and therefore there is little impact on the effective spawning stock biomass by harvest of males. There is a question on how surplus harvestable males are defined, and there is no clear answer currently.

The workshop science advisory board comes to a consensus that protection of reproductive potential should be included in the harvest strategy, with discussion points including more focus on male harvest control rules, and moving towards more consistent outcomes for industry. However, there are still debates about whether this necessitates a female threshold. The best estimate of reproductive potential is still mature female biomass, but this is possibly a better indicator of stock health and not an on/off switch for the fishery. Martell states that clear objectives need to be defined to effectively come up with harvest control rules and allow for a modeler to do their job. If the objective is stability in the fishery, there needs to be an analysis of variability and trade-offs, as small variability could result in a low constant catch with few closure years, and higher variability, medium levels of catch with more closure years. Industry objectives will drive the long-term approach, and stability and conservation are not mutually exclusive. Consistent communication between science, management, and industry is critical for effective harvest control rules to be put in place. There is interest in the industry in catching more old shell crab, and using them is part of this strategy of consistency. Shell condition should be incorporated into the stock assessment model.

There is interest in determining short term goals versus long-term goals and appropriate timelines. In the long run, the science advisory panel would like to see the development of MSE from Madison Shipley in the Punt Lab at the University of Washington, the incorporation of sex ratios into the assessment model, and clear industry and management objectives for the fishery. In the short term, there will be an analysis of current sex ratios and sperm loads, potentially spatially, to create useful bio reference points to be used in the long-term approaches. There is emphasis that tweaks to the existing framework take time and resources, and that the short-term revisions could be on timelines of 1-2 years and long-term, 2+ years. There is interest in adding the monitoring of sperm or collecting of females for better indicators during the summer surveys. There are no red flags at this point for fertilization rates, but looking at the variability in sperm storing by females and how it differs with sex ratio will give a baseline for the proper ratio that could be used in a future harvest control rule. The four main indicators that could be initially looked at are female biomass on a special scale, sperm capacity and variability (annually collected, a one-year lag of information), sex ratios by neighborhood, and recruitment timing and offset from historical data.

The afternoon discussion clarifies recommendations, timelines, and actions. Harvest strategy revisions will be considered in May of 2019 for the 2020 cycle that goes to the State of Alaska Board of Fish (BOF).

The MSE will still be in the works, but there should be preliminary results available by April of 2019, with full results available by September of 2019 assuming Madison Shipley's Master's degree is on track. Shipley will be sure to communicate her progress and will have an ADF&G personnel on her committee along with Buck Stockhausen. This timeline allows for the review to happen in the cycle for ADF&G. There is some discussion on the 50% reduction rate rule in the harvest strategy and the sliding control rule for the error band. These and other small-scale fixes can be addressed in the MSE so the effects on the fishery can be projected and better understood. It is assumed that no short-term band-aid fixes will be made to the harvest strategy until a better understanding of biology and projections are understood. Size and shell condition will be plotted from the survey to look at the potential indicator of selection. Foy will look at neighborhood evaluation of sex ratios, and further explore shell condition in the industry, as well as look at the confidence interval calculation methods to ensure accuracy and consistency. There are only a small number of industry representative present, and the industry will need to provide concrete and specific objectives for the fishery that management can work with. There is acknowledgment of projections incorporating climate change from Stichert and Martell if feasible. In the short term, ADF&G is willing to be flexible and work with NMFS and the industry to provide transparency in their methods and decision making concerning harvest strategy development. The MSE will allow for a full evaluation of the questions concerning female bairdi and pave the way for an overhaul of the current harvest strategy to incorporate the most updated science.

BSFRF
Bering Sea Fisheries Research Foundation

BERING SEA FISHERIES RESEARCH FOUNDATION
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FORGING COOPERATIVE RESEARCH PARTNERSHIPS IN THE BERING SEA

October 30, 2017

Hello all,

On behalf of the Bering Sea Fisheries Research Foundation and cooperative research partners you are invited to attend a cooperative research workshop focused on Bering Sea Tanner crab biology. The topic has been the focus of prior research and management issues over this past year. We have the opportunity to further explore how to improve and update our understanding of important Tanner crab science used to sustainably manage the stock in the Bering Sea. Attached is further information including an introduction to the workshop, logistics, and attendees/invitees. I have spoken with several of you already, as the holidays are approaching quickly, I will be firming up final details to distribute to you all as soon as possible. Please direct any questions you may have to me and thank you for your willingness to participate.

Sincerely,

BSFRF Executive Director,
Scott Goodman

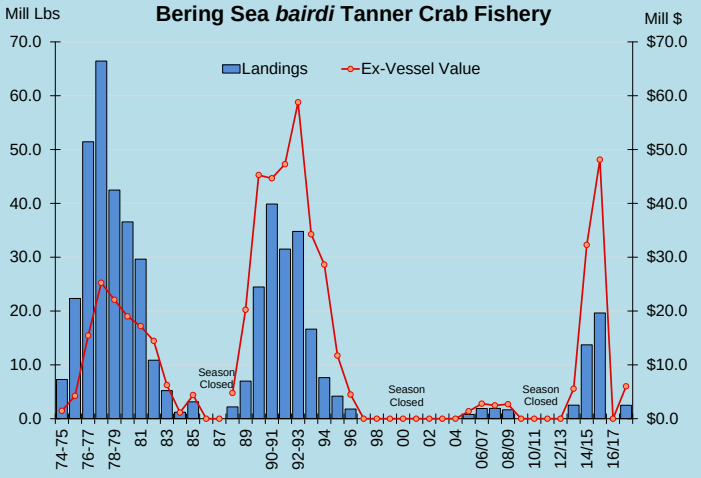
Introduction/Overview of Bairdi Workshop

The 2017 Fall Bairdi Workshop is a collaborative effort focused on improving the understanding of bairdi Tanner crab biology in the Bering Sea to identify areas where management of the stock may be further improved. The specific focus is the state of bairdi crab biology and scientific information within the context of the State of Alaska Harvest Strategy. The ADF&G Harvest Strategy in use for Bering Sea Tanner crab has been revised a number of times and until May of this year had been in place mostly unchanged since 2011. Substantial review has been completed over the last year, mostly by ADF&G staff, to update several components of the Harvest Strategy. The updated components of the strategy led to further flexibility in the 2017/18 consideration of stock status, control rule thresholds, and to a current open season this year in contrast to the closure in the prior year. This workshop looks to build on recent updates with the expectation of identifying further refinements to the Harvest Strategy. A central issue for consideration is the biological rationale for a mature female threshold which determines if the fishery may open.

Bering Sea commercial crab stocks exhibit population fluctuations, yet mechanisms driving this variability are poorly understood. NMFS and ADF&G hold different responsibilities toward the common goal of sustainable exploitation, but ADF&G ultimately manages the seasons and quota. BSFRF has an established presence as a collaborative research partner, which has improved research productivity and overall transparency. Stakeholders in the Bering Sea Tanner crab fishery look forward to providing continued support for improving crab management. The workshop format is intended to increase transparency for the review of historical, updated, or new biological information with co-managers and stakeholders. The workshop will be chaired by Scott Goodman of the Bering Sea Fisheries Research Foundation, and a number of invited researchers will be presenting background or specific information for review and discussion. A core workshop panel of researchers with longer history and depth of understanding with Bering Sea bairdi biology and the fishery will be providing insight and comments. A group of invited stakeholders and other managers will be attending to listen and may provide additional points of discussion. A steering committee is currently finalizing details of workshop questions, necessary presentations, agenda, and potential recommendations for future work.

Brief History of Fishery and Management

The Bering Sea bairdi Tanner crab resource supports a substantial commercial fishery with a widely fluctuating history over the last 40 years. Total catch exceeded 60 million lbs in the late 1970s, sharply declined into the 1980s, followed in the early 1990s by catches recovering to nearly 40 million lbs and the highest historical effort (~300 vessels). From 1995 until 2014, estimates of abundance and biomass remained low and commercial seasons were greatly reduced. During this 20 year period, catches did not exceed 5 million lbs and 12 seasons were closed. Importantly, the stock went through a formal overfishing designation and detailed rebuilding plan during this period. Further, the fishery was rationalized in 2005 which greatly reduced effort and the pace of fishing. More recently, bairdi abundance and biomass have increased and the 2014/15 season catch was nearly 14 million lbs, followed by the 2015/16 season of nearly 20 million lbs. The 25-year high season was followed by a season closure, and the current season is open with a total allowable catch of 2.5 million lbs.



Commercial crab stocks in the Bering Sea are co-managed under a Fishery Management Plan (FMP) and agreement between the National Marine Fisheries Service (NMFS) and Alaska Department of Fish and Game (ADF&G). Both co-managers (NMFS/ADF&G) and other peers participate in annual stock assessment activities as part of the Crab Plan Team (CPT) and North Pacific Fishery Management Council (NPFMC) process. Status of stock is determined, Federal oversight provides specification of two maximum thresholds – the Overfishing Level (OFL) and Allowable Biological Catch (ABC), and then seasons and allocation are determined by ADF&G from regulations defined in State Harvest Strategies per species. In general, the shared oversight follows an annual cycle of surveys, model review, status specification and season setting. The addition of new information or process changes occur periodically which include; new survey or other experimental data, changes in Tier status, model development, revision of Harvest Strategy, or other.

WORKSHOP DETAILS

Goals:

- Consider further refinement to the current ADFG HS for Bering Sea bairdi Tanner crab
- Consider most appropriate measure of reproductive capacity for Bering Sea bairdi Tanner crab
- Determine research work plan toward broader MSE for Bering Sea bairdi Tanner crab

WHEN: DECEMBER [start times, travel dates TBD]

1-2 day workshop dates are DEC 18-19 (MON-TUE)

WHERE: Juneau (current lodging, venue, catered food options underway)

ATTENDEES/INVITEES:

Science Panel

Ben Daly (ADFG)	Sheri Dressel (ADFG) **NA**	Ginny Eckert (UAF)
Bob Foy (NMFS)	Scott Goodman (BSFRF)	Gordon Kruse (UAF)
Steve Martell (Seastate)	Nick Sagalkin (ADFG)	Bernard Saint-Marie (DFA CA)
Shareef Sideek (ADFG)	Chris Siddon (ADFG)	Laura Slater (ADFG)
Dave Somerton (ret NMFS)	Mark Stichert (ADFG)	Buck Stockhausen (NMFS)
Jie Zheng (ADFG)		

Industry/Other

Forrest Bowers (ADFG)	Ed Dersham	Tyson Fick, ABSC
Frank Kelty, BSFRF Board	Scott Kent, NSEDC	Nicole Kimball, PSPA
Jake Jacobsen, ICE Rep.	John Jensen, BOF	Israel Payton, BOF
Edward Poulsen, BSFRF Board	Robert Ruffner, BOF	Gary Stauffer, BSFRF Advisor
Doug Wells, BSFRF Board		

BSFRF
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FORGING COOPERATIVE RESEARCH PARTNERSHIPS IN THE BERING SEA

BSFRF Collaborative Tanner Crab Workshop Agenda - - Centennial Hall, Egan Room, 101 Egan Drive, Juneau

Contact for Chair – Scott Goodman, sgoodman@nrccorp.com, mobile 425-232-5986

MONDAY DECEMBER 18, DAY 1				
From	Until	Who	Item/Topic	Description
9:00 am	10:00 am	All	Coffee/Pastries	Arrival of guests/setup
10:15 am	10:30 am	All	Introductions	All guests intro/sign in
10:30 am	10:45 am	S. Goodman	Workshop Intro	Bairdi intro/context, agenda, why this workshop, ground rules, goals, outcomes
10:45 am	11:15 am	B. Stockhausen	Assess. Model	Overview of model framework
11:15 am	11:30 am		BREAK	
11:30 am	12:30 pm	B. Daly, J. Zheng, C. Siddon	Harvest Strategy	Overview of history, revisions and current. Address females, small-scale revisions, longer-term changes/reviews
12:30 pm	1:30 pm		LUNCH	Provide by Breeze-In at Workshop Hall
1:30 pm	1:45 pm	C. Siddon	Female Crab Perspectives	Overview info for treatment of females in male-only fisheries -
1:45 pm	2:45 pm	B. St-Marie	CA DFO Perspective	Treatment of females in male-only fisheries from the Canadian perspective
2:45 pm	3:45 pm	B. Foy	NMFS survey information	Update on trends from bairdi females in survey data, includes reprod. status, size @ maturity, etc.
3:45 pm	4:00 pm		BREAK	
4:00 pm	4:45 pm	L. Slater	Bairdi Female Life History	Focus on females, recent research updates
4:45 pm	5:00 pm	Questions – Chair/Panel/Others	Important Q's from attendees	Moderated to be part of discussion points/workshop directed outcomes
5:00 pm	5:15 pm		BREAK	
5:15 pm	6:15 pm (~6:30)	Discussion - ALL	Central Workshop Q's	DECISION PT. FOR FEMALES Steered discussion females, HS status, steps ahead, research, etc.
6:15 pm	7:30 pm	Appetizers/Drinks	END DAY 1	Provided at end of Day 1 (Breeze-In/Other)
7:30 pm	------			Steering Committee Dinner
TUESDAY DECEMBER 19, DAY 2				
From	Until	Who	Item/Topic	Description
7:30 am	8:30 am	All	Breakfast	Provide by Breeze-In at Workshop Hall
8:45 am	9:45 am	Discussion - ALL	Central Workshop Q's	Recap from MON, Steered discussion on females, HS status, steps ahead, research, etc.
9:45 am	10:45 am	B. Stockhausen	Assess. Model	Current information & potential for new information/utility
10:45 am	11:00 am		BREAK	
11:00 am	12:30 pm	B. Daly, J. Zheng, Discussion w/ All	HS elements review, MSE – plans for larger scale eval.	Consideration of primary Q's and harvest strategy, framework, elements, etc., Discussion of options/plans for MSE and other utilities to assist with mgt.
12:30 pm	1:30 pm		LUNCH	Provide by Breeze-In at Workshop Hall
1:30 pm	3:30 pm	Steering Committee & All (Format TBD)	Workshop Summary	Develop summary including HS issues, outcomes, research plans

Workshop Ends 3:30-4:00 pm Tuesday

Primary Workshop Goals

1) Provide a detailed background of existing management structure.
   - (Including surveys, model, OFL/ABC/TAC, Tier status, etc, and how these have changed over time)

2) Document what is known about mature female bairdi and why they are a central, limiting factor in management.
   - (concept, females alone or together, data sources, biological knowns, reproductive status, fecundity, etc.)

3) Provide some direction to other tractable improvements to inform management decisions.
   - (HS revision, model/assessment outcomes, other research, MSE, etc.)

Stakeholder/Other questions:

Is an arbitrary female threshold based on some long-term average of female abundance even appropriate in the males only directed fishery? Seems like we should abandon a threshold for mature females in favor of an effective spawning biomass threshold that should consider indices of reproductive potential such as operational sex ratio, sperm storage from previous mating events, and observed fecundity.

Why aren't we using modeled abundance with regards to harvest strategy implementation? I keep hearing that the reason is the department is uncomfortable with the current model because it consistently overestimates 5-inch or greater males. However, conversely, does it not consistently underestimate numbers of females? Why can't modeled male abundance be used but also buffered to account for some of this uncertainty?

Noting these are already built into workshop questions: Is it appropriate/best harvest strategy to use a female threshold in this fishery? How responsive is the strategy to changes in the harvestable surplus of males?

Since females are so small, how can we have confidence in the estimated female abundance from trawl sample data?

How are old shell crab accounted for in TAC setting and what we can do as industry to get access to the foregone harvest?

Aren't there enough safety protections in the harvest strategy already so that if the survey is within the error band for minimum female threshold the fishery could proceed as if the entire error band was above the threshold? For example this year the point estimate from the survey was over the minimum threshold but the harvest is set lower than it would have been under the prior harvest strategy.
Assuming our current understanding that selectivity for bairdi is similar to oplilo is correct, what are the effective harvest rates on total mature males using selectivity under the current harvest strategy?
How can/should the state take survey trawl selectivity into account when they are only considering NMFS survey information as inputs into bairdi harvest strategy?

Does the Pribilofs area closure to crab pot fishing account for any unconsidered protection for mature females? (protecting reproductive potential).

What is the scale of impact on mature female bairdi from bycatch in crab target fisheries and other non-target fisheries? (Does bycatch impact push estimate of mature female biomass (from the model) below the threshold? In SQ conditions there are no negative consequences to bycatch controls on bairdi in non-target crab fisheries if female biomass goes below or is near threshold [error-band]).

SELECTED BAIRDI WORKSHOP SLIDES

Stockhausen (PPT1, 23 slides)

Slides included in packet: 2, 4 (Siddon), 5, 8, 15 (Foy), 17 (Foy), 23

Daly (PPT2, 37 slides)

Slides included in packet: 2, 4, 17, 21, 22, 36, 37

Sainte-Marie (PPT1, 16 slides)

Slides included in packet: 2, 3, 4, 5, 8, 9, 14, 15

Slater (PPT1, 44 slides)

Slides included in packet: 6, 8, 9, 18, 26, 33

Stockhausen (PPT2, 12 slides)

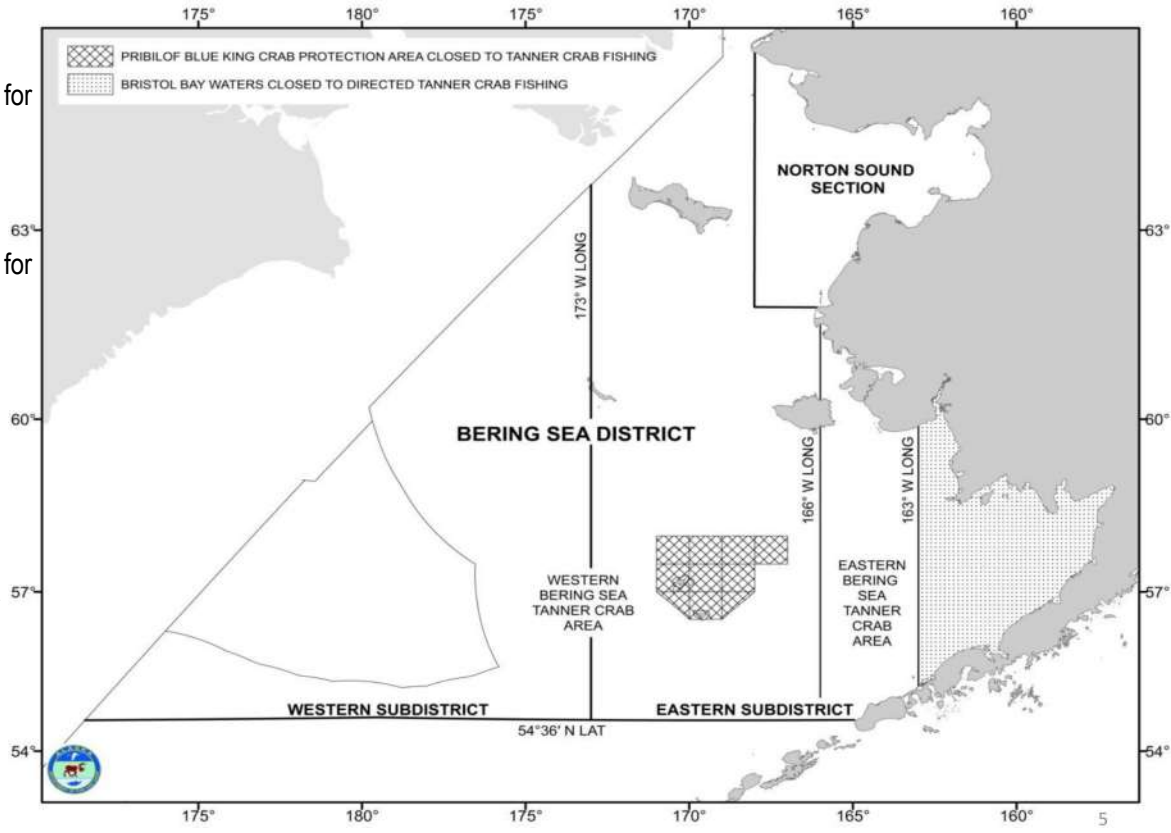
Slides included in packet: 2, 9, 10, 11, 12

Daly (PPT2, 9 slides)

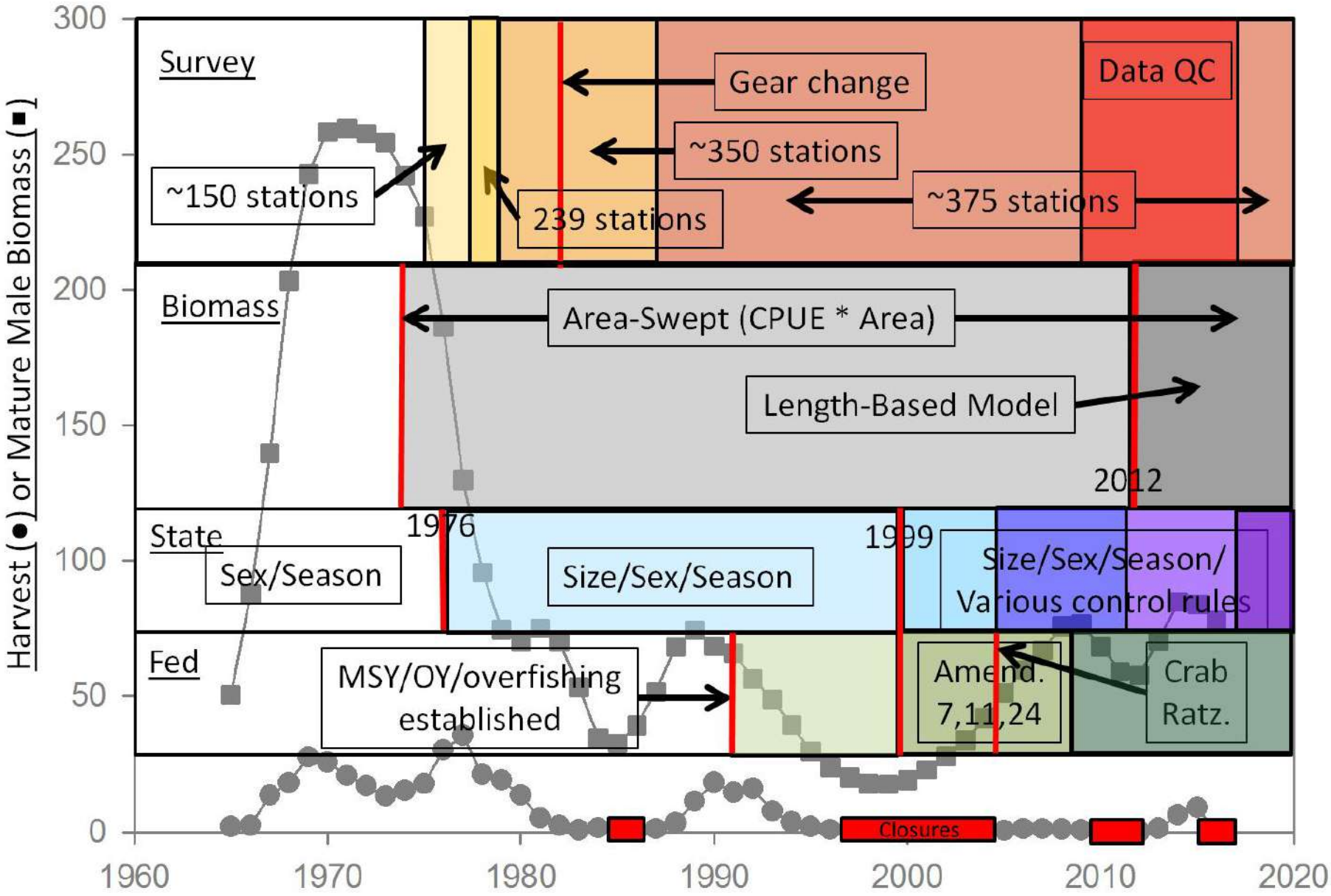
Slides included in packet: 1, 2, 3, 4, 5

Tanner Crab Fisheries In the Bering Sea

- Only male *C. bairdi* may be harvested
  - west of 166°W lon.
    - in a directed Tanner crab fishery
    - up to 5% incidental catch on a vessel registered for the snow crab (C. *opilio*) fishery
  - east of 166°W lon.
    - in a directed Tanner crab fishery
    - up to 5% incidental catch on a vessel registered for the red king crab fishery
- Season is Oct. 15-Mar. 31
- Legal size is
  - 4.4” CW west of 166°W
  - 4.8” CW east of 166°W
- *C. bairdi* is considered to be *Chionoecetes* crab with
  - both eyes completely red
  - labrum notched at 2 points with V-shaped cuts forming “M”
  - i.e., no hybrid characteristics



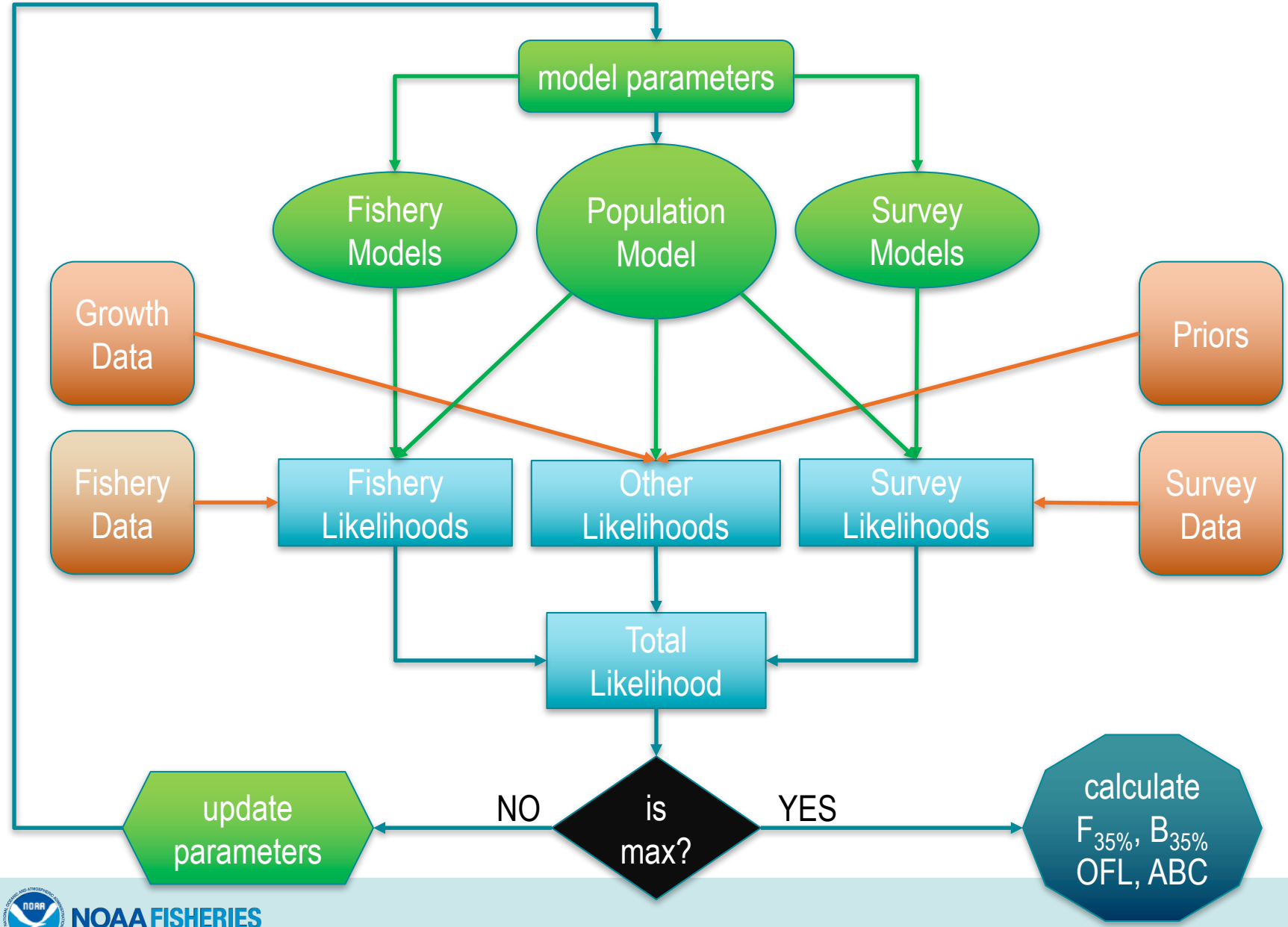
Introduction / Timeline



Some Vocabulary

- **FMP: Fishery Management Plan;**
- **MSY**: **Maximum sustainable yield**; the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. MSY is estimated from the best information available.
- $\mathbf{F_{MSY}}$: fishing mortality rate that results in the MSY being taken, in the long term.
- $\mathbf{B_{MSY}}$: stock (mature male) biomass that results from fishing at constant F_{MSY}.
- **OFL**: **Overfishing limit**; the annual overfishing limit.
- $\mathbf{F_{OFL}/F_{MSY}}$ **control rule**: a harvest strategy to determine the fishing mortality rate that results in the OFL being captured. This strategy is expected to result in a long-term average catch approximating MSY.
- **ABC**: **Acceptable biological catch**; annual catch level of a stock that **accounts for the scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty**. It is set to prevent, with a greater than 50 percent probability, the OFL from being exceeded. The ABC < OFL.
- **ACL**: **Annual catch limit**; the level of annual catch of a stock that serves as the basis for invoking accountability measures. For EBS crab stocks, the ACL= ABC.
- **TAC**: **Total allowable catch**; the annual catch target for the directed fishery for a stock, set to prevent exceeding the ACL for that stock (TAC < ACL).

An Assessment Model Framework

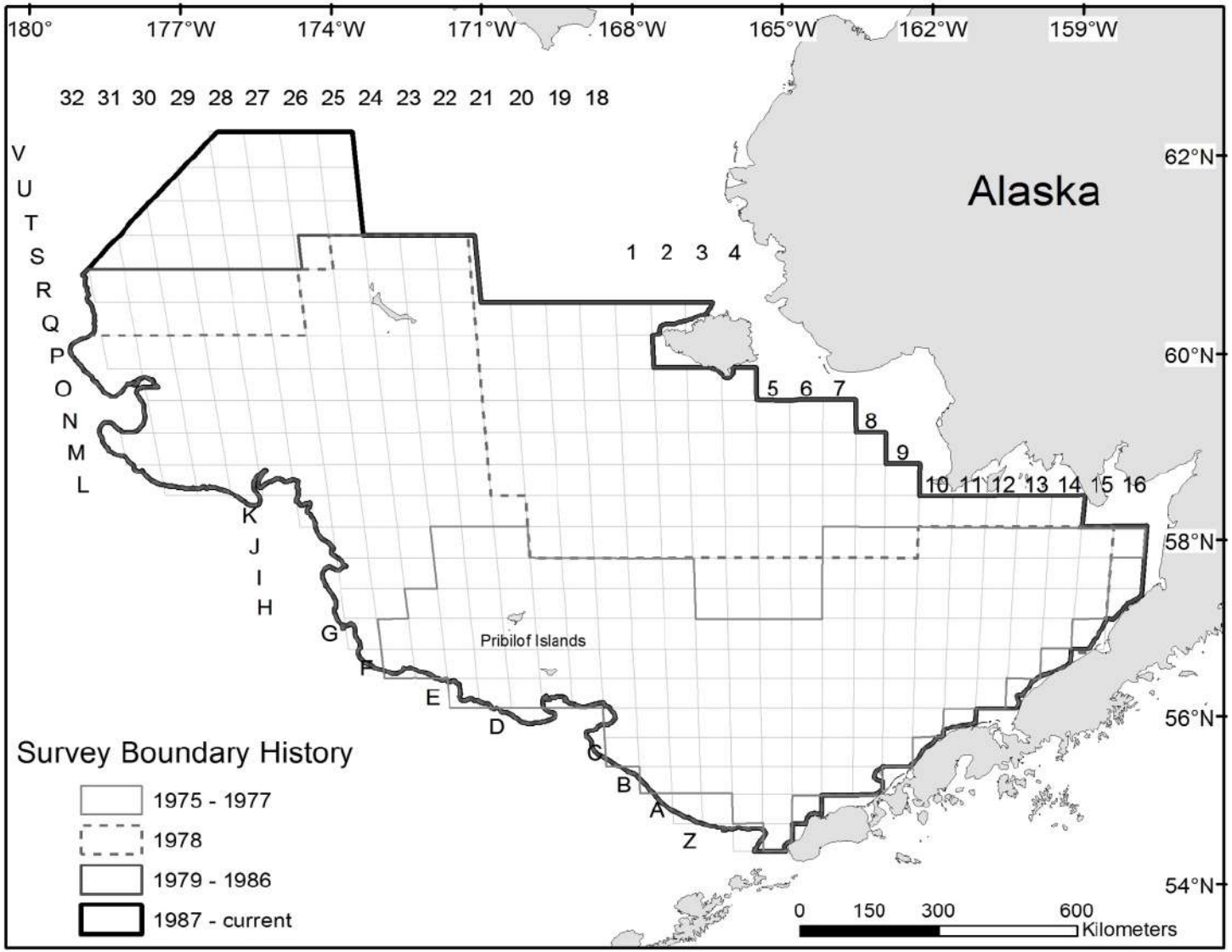


NMFS EBS Trawl Survey

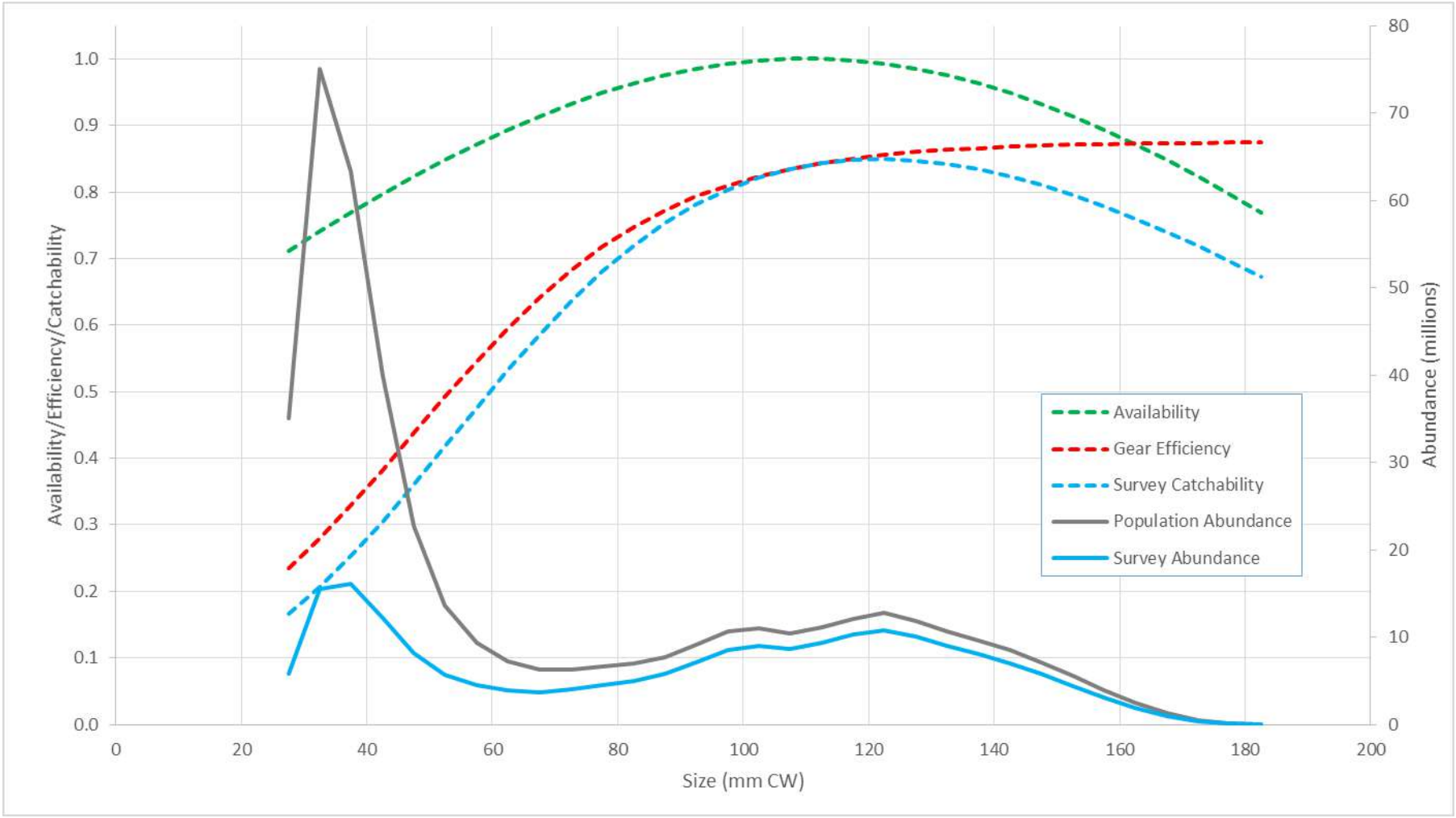
- "Standardized" crab dataset 1975+
  - single gear type since 1982
  - survey area fixed since 1988

- Data collection
  - sort/subsample
  - species
  - sex
  - carapace width/length
  - shell condition
  - female maturity and clutch assessment
    - color
    - condition
    - size
  - individual weight (subset)
  - male chela height (subset)

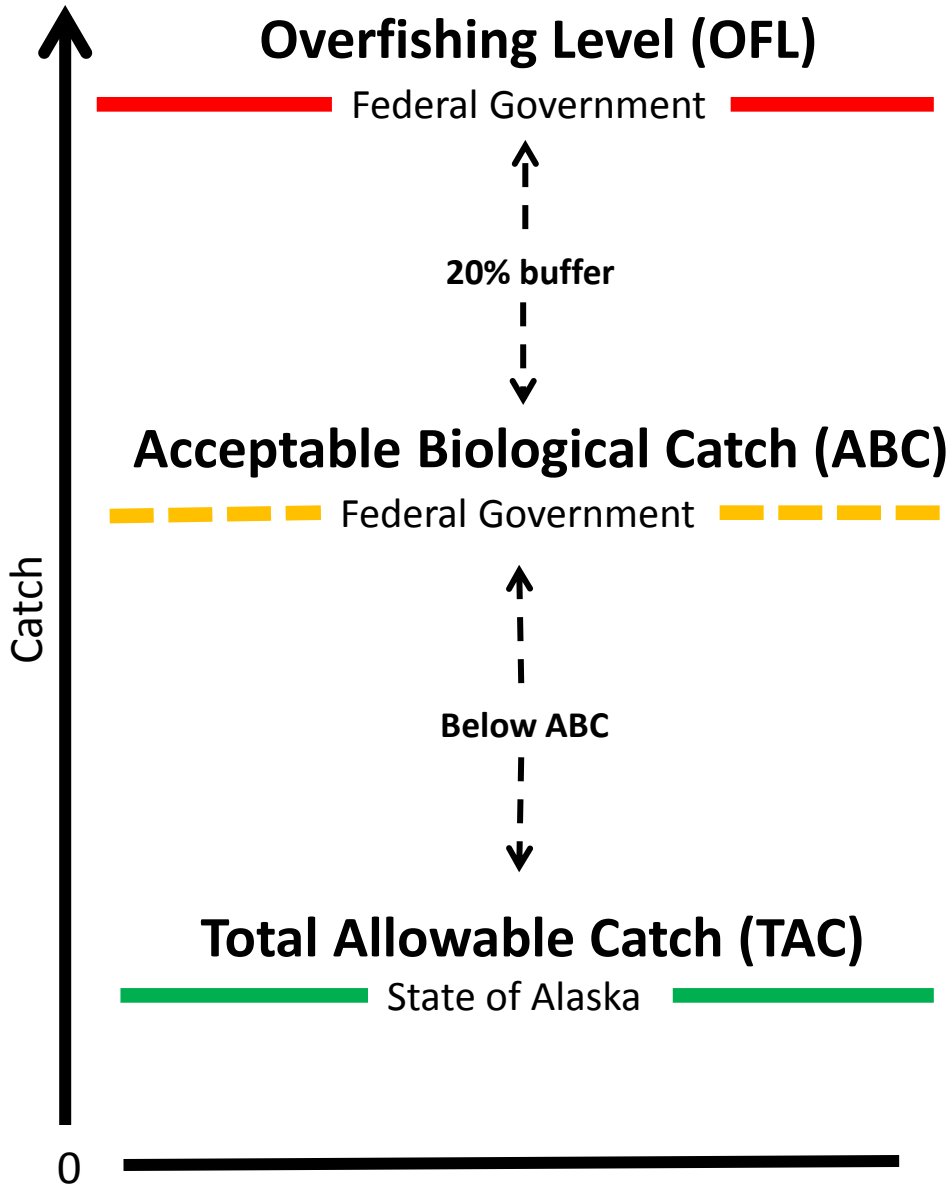
Survey Boundary History



Survey Scaling Issues: Availability, Gear Efficiency, and Survey Catchability



N_{Pop} = 439 million N_{Survey} = 209 million



OFL: Level of fishing mortality that jeopardizes the capacity of a stock to produce the maximum sustained yield on a continuing basis.

ABC: Level of annual catch that accounts for scientific uncertainty and is set to prevent the OFL from being exceeded.

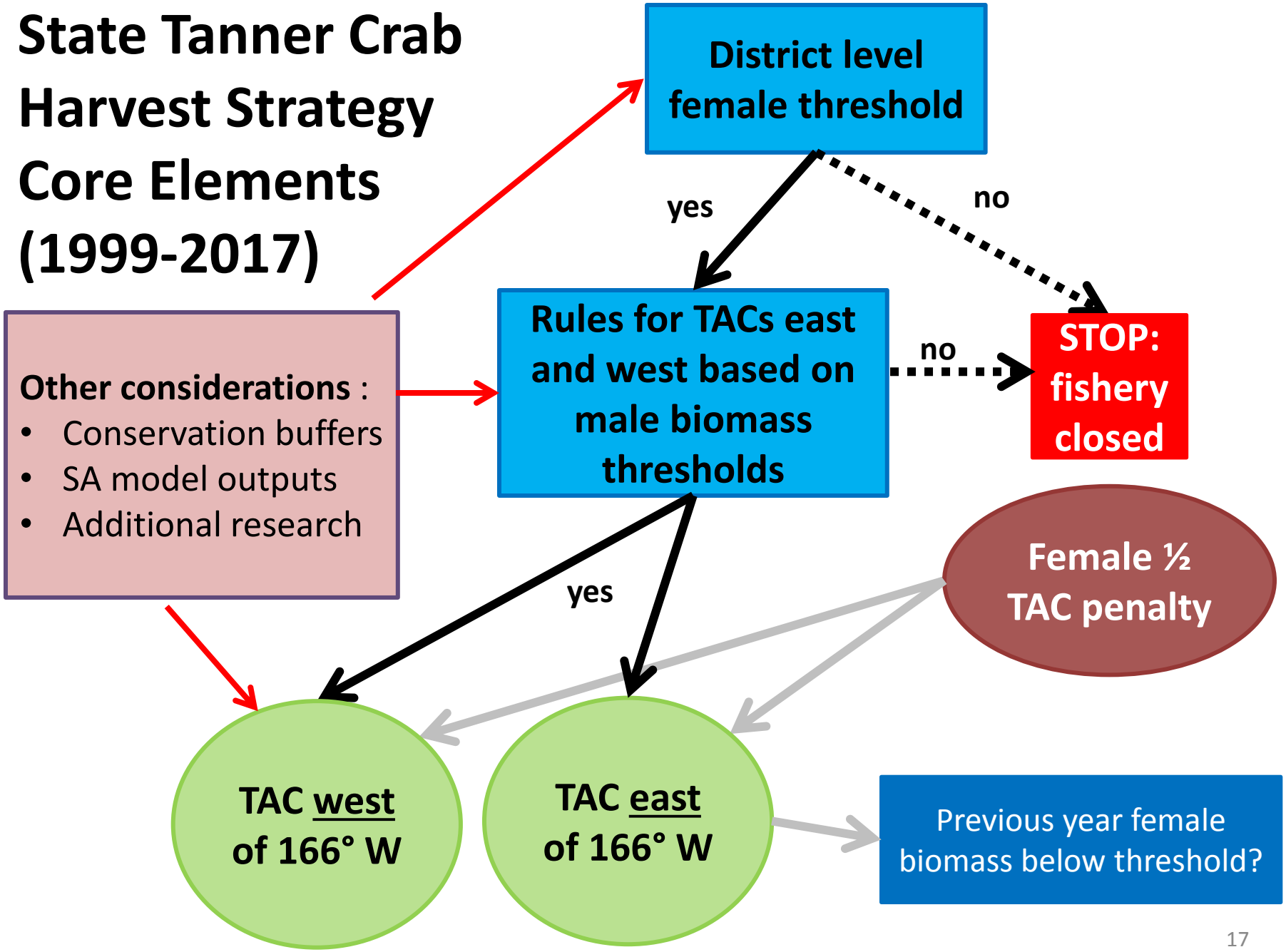
In practice ABC limits mortality of **ALL** male and female crabs regardless of size, from all sources of fishery mortality (i.e. retained catch, bycatch in directed and nondirected crab fisheries, and groundfish fisheries).

TAC: Annual catch target for the directed fishery, set to prevent exceeding the ABC for that stock. **Limits legal sized males**, but must consider all sources of mortality to ensure the ABC is not exceeded. Considers model uncertainty, biological information (e.g., shell condition, spatial dist.), fishery performance, bycatch, etc.

3-S: Size/Sex/Season

- Legal size, males only, no fishing during molting and mating season (~spring, early summer)
- Legal size
  - 1976: legal size was implemented
    - Before 1976, processors regulated sizes based on market considerations.
  - Before 2010: based on Kodiak Tanner crab growth and reproductive data: 5.5”(140mm) for all areas except 5.3” for PWS Tanner crab, which has smaller size at maturity.
  - After 2010, exploitable legal males changed due to considerations of temporal and spatial variation in size at maturity.
    - **east** of 166^{o} W: preferred 5.5” [legal 4.8”]
    - **west** of 166^{o} W: preferred 5.0” [legal 4.4”]
  - In 2015, exploitable legal size for eastern Bering sea Tanner crab, east of 166^{o} W was reduced from 5.5” to 5.0” to align the harvest strategy with the industry-preferred minimum size.
- **3-S based on economic considerations of market value and meat yield, fishing opportunity, protection of females for reproduction, and the intent to allow at least one mating season for mature males prior to harvest**.

State Tanner Crab Harvest Strategy Core Elements (1999-2017)



New Regs: Error Band and TAC computation

- **Below threshold**: fishery closed
- **Within error band**: Allows fishery **IF**,

  B/B_{AVG} for mature males is above 100%

  Then, **TAC = $(B/B_{AVG} - 1) \times (0.9) \times C_{MSY}$, OR,**

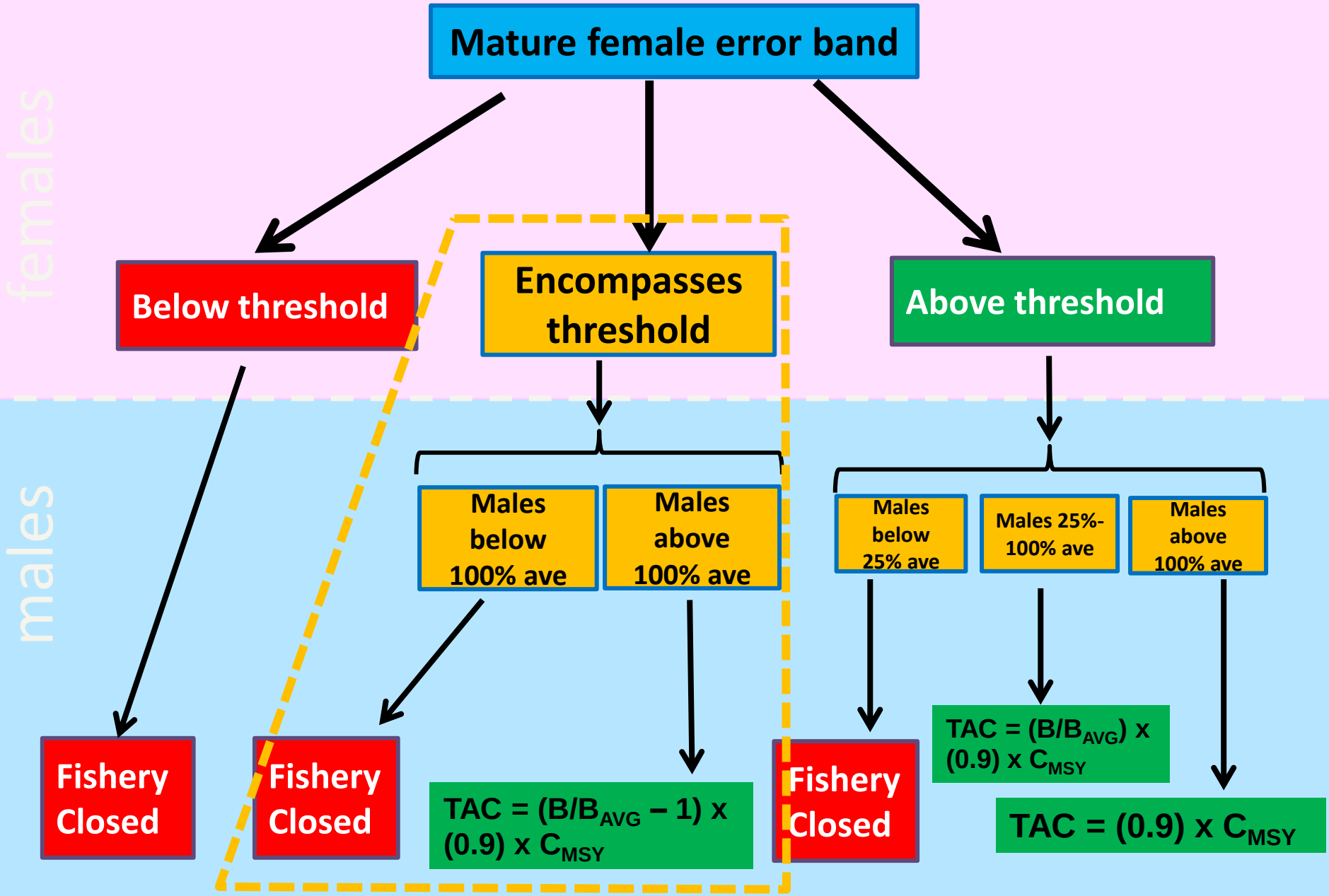
  TAC = $(0.9) \times C_{MSY}$, whichever is less

- **Above threshold**: status quo TAC calculations

  If B/B_{AVG} is below 25%, TAC = 0

  If B/B_{MSY} is between 25% and 100%, TAC = $B/B_{AVG} \times 0.9 \times C_{MSY}$

  If B/B_{MSY} is above 100%, TAC = $0.9 \times C_{MSY}$


females
males
Mature female error band
Below threshold
Encompasses threshold
Above threshold
Males below 100% ave
Males above 100% ave
Males below 25% ave
Males 25%-100% ave
Males above 100% ave
Fishery Closed
Fishery Closed
TAC = (B/B$_{AVG}$ – 1) x (0.9) x C$_{MSY}$
Fishery Closed
TAC = (B/B$_{AVG}$) x (0.9) x C$_{MSY}$
TAC = (0.9) x C$_{MSY}$

Scale of potential future revisions

Small fix

Mid-level fix

Large/ fundamental fix

BandAids to existing framework

Minor update examples:

- Threshold calculations: years, area, maturity def., etc
- Preferred sizes
- ½ TAC reduction rule modification

Moderate updates:

- Female "error band" or "sliding scale" control rules
- Model outputs
- Account for newshell-oldshell selectivity?

Complete rebuild:

- **Protect sustainability/reproductive potential?**: ESB, TMB, egg production index, sex ratio, etc
- **Exploitation rates** on mature/legal males
- **Spatial management:** How many management areas?
- **Additional conservation buffers:** shell condition selectivity, area closures
- **Hybrids?:** Should they be considered? How?
- **Model outputs:** How best utilize?
- **MSE or other analyses**

Road Map: where to go form here

- Workshop
  - Reach general consensus about “best science”: females, harvest strategy, assessment model, etc.
- Shorter-term: more “BandAids”?
  - Small to mid-level fixes to existing framework
  - **Options for females:** 1) status quo, 2) remove, 3) “sliding scale”, 4) something else
- Longer-term: complete rebuild
  - Protect sustainability (reproductive potential)
  - Management areas
  - Exploitation rates + caps
  - MSE, model outputs, full vetting, etc., etc.
  - Do this in conjunction with snow crab harvest strategy rebuild?

Canadian male-only (= crab) fisheries

West Coast

- Dungeness crab (*Metacarcinus magister*)
- Grooved tanner crab (*Chionoecetes tanneri*)

East Coast

- Snow crab (*Chionoecetes opilio*)
- Rock crab (*Cancer irroratus*)
- Toad crabs (*Hyas araneus*, *H. coarctatus*)

Females in Canadian crab fisheries

Canadian crab assessments, the case arising, consider only male biomass and condition for recommending input (effort) and/or output (quota) controls

> "Dungeness Crab stocks are managed by a minimum size limit and male only harvest which conserves the reproductive potential of crab stocks. As a result, population assessments are not required prior to fishing as with many other species and quotas are not set."
> http://www.dfo-mpo.gc.ca/species-especes/profiles-profils/dungeness-crab-crabe-dormeur-eng.html

Underpinned by the belief that small males are sufficiently abundant and performing, or that large males survive in sufficient numbers and condition, to ensure adequate mating of all mature females

However, the mating system of many crabs is not understood well enough to evaluate whether or not male abundance and competency can meet female needs

Females in Canadian crab fisheries

Ignoring possible undesirable genetic effects of fishing large males, the assumption that reproductive potential is fully protected because there is a minimum size limit and females are not harvested is verified if fishing does not reduce:

- abundance of mature females, due e.g. to incidental mortality from the directed fishery (or any other fishery) or mortality from lack of mates
- reproductive success of females, due e.g. to mate or sperm limitation

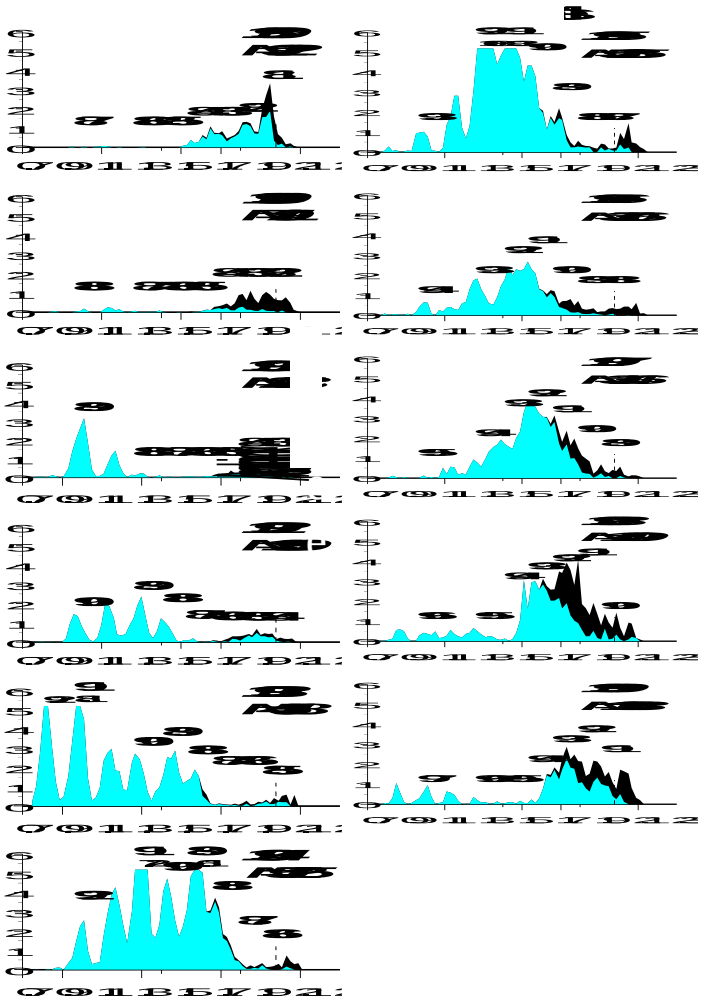
Therefore, mature females may be considered as a secondary stock health or productivity indicator, in which case they are monitored to some degree for:

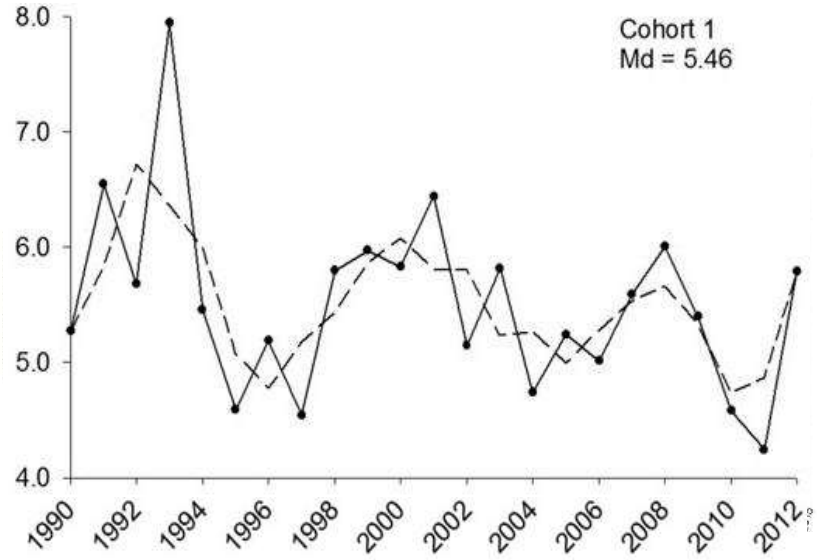
- abundance and size/age structure
- mating success (e.g. mating scars, sperm plugs, sperm reserve)
- realized fecundity (e.g. % mature females that are berried, per capita fecundity)

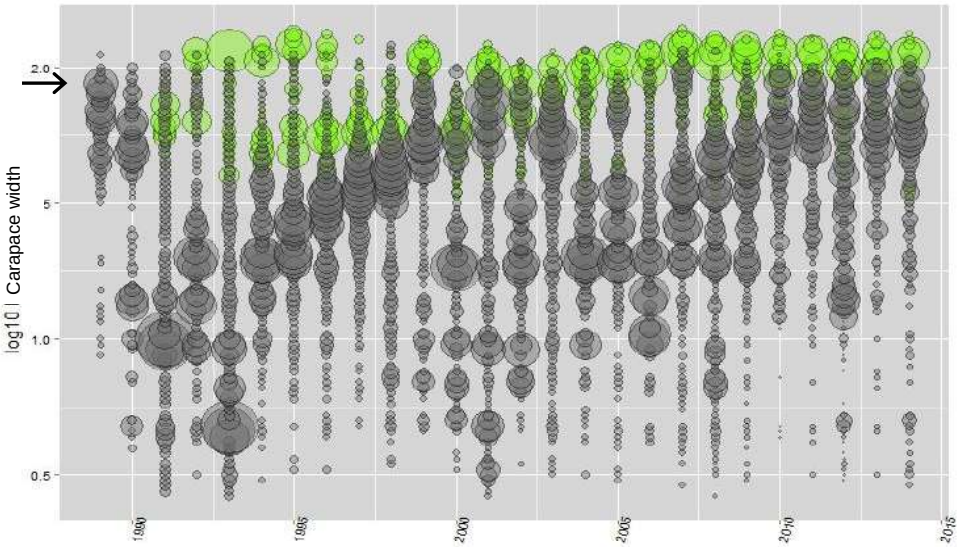
Why *Chionoecetes* (*opilio*) females should be considered

- No direct fishing mortality on females and little evidence of indirect mortality due to fishery
- Males differ in reproductive competency with size and relative age (time elapsed since terminal molt, i.e. shell condition)
- Recruitment is cyclic (or sporadic) so population operational sex ratio and mate characteristics vary considerably over the years
- Female reproductive success is related to operational sex ratio and, in particular, to the relative abundance of large, older-shell males
- Size of adult females and males is sensitive to temperature and possibly density, so it can change over the years and vary in space whereas minimum legal size is usually fixed

Snow crab recruitment

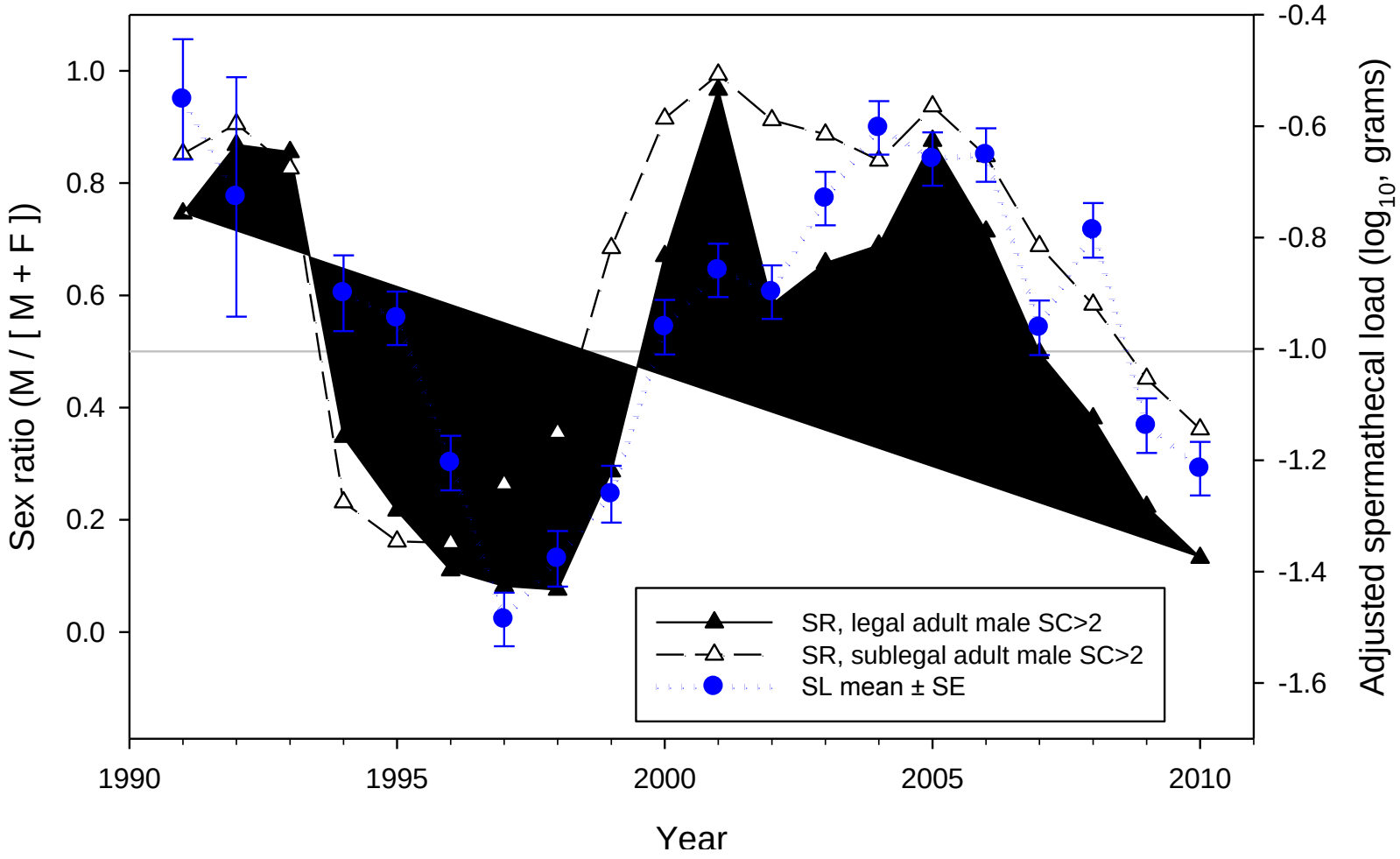




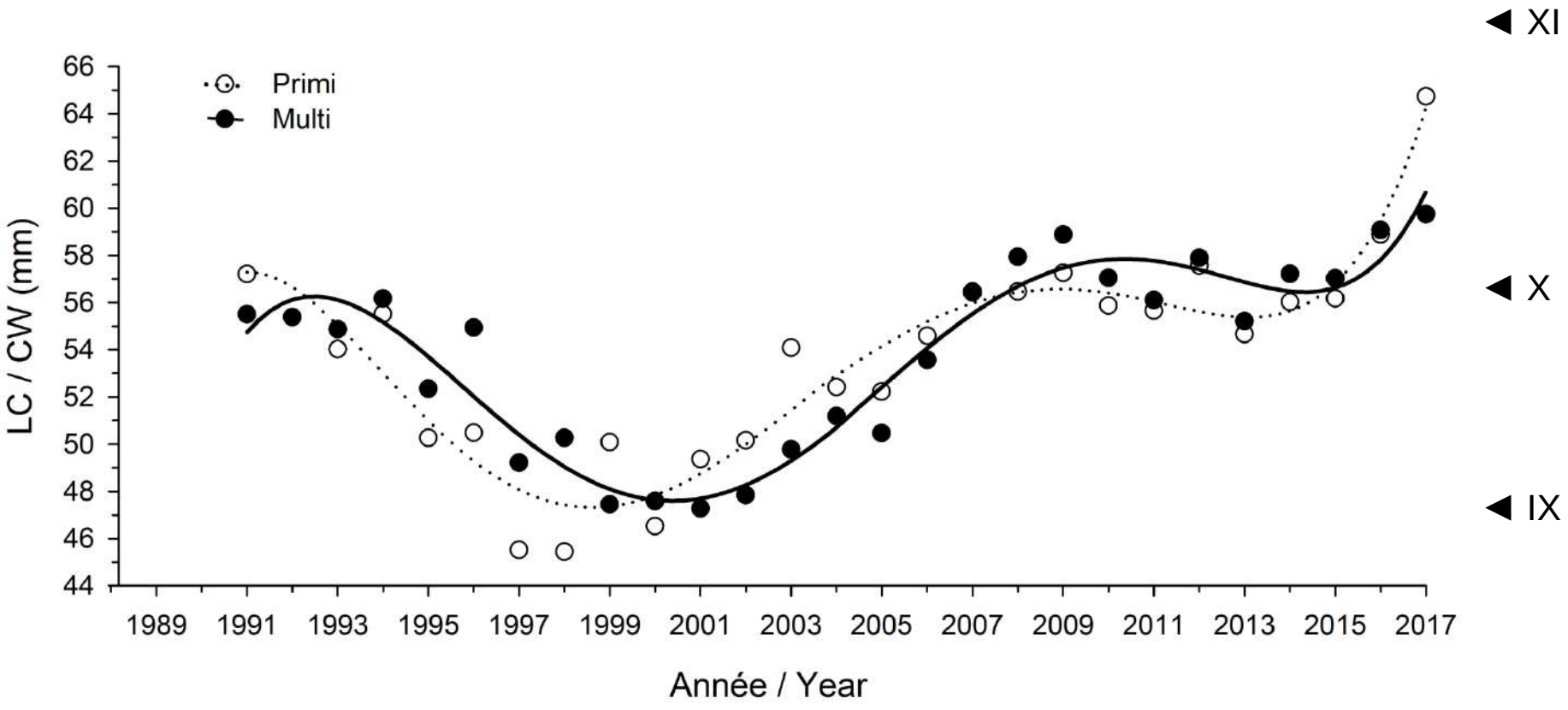


Fisheries and Oceans Canada
Pêches et Océans Canada

Snow crab operational sex ratio and primipara sperm reserve



Temporal variability of snow crab female adult size



Increase in fecundity over instar IX:

≈90% at instar X; ≈270% at instar XI

Summary and Outlook

- No clear evidence yet that snow crab mature female numbers are being modified by the directed fishery
- Snow crab female mating-reproductive success is dependent on large male relative abundance
- Size structure of females and males change dynamically and a fixed minimum legal size may be inappropriate for protecting full reproductive potential

BUT:

- How much reproduction is needed – is the goal of conserving full reproductive potential reasonable/necessary?
- The answer may depend on the role of females in snow crab population cyclicity and on the severity of challenges to population integrity (warming)

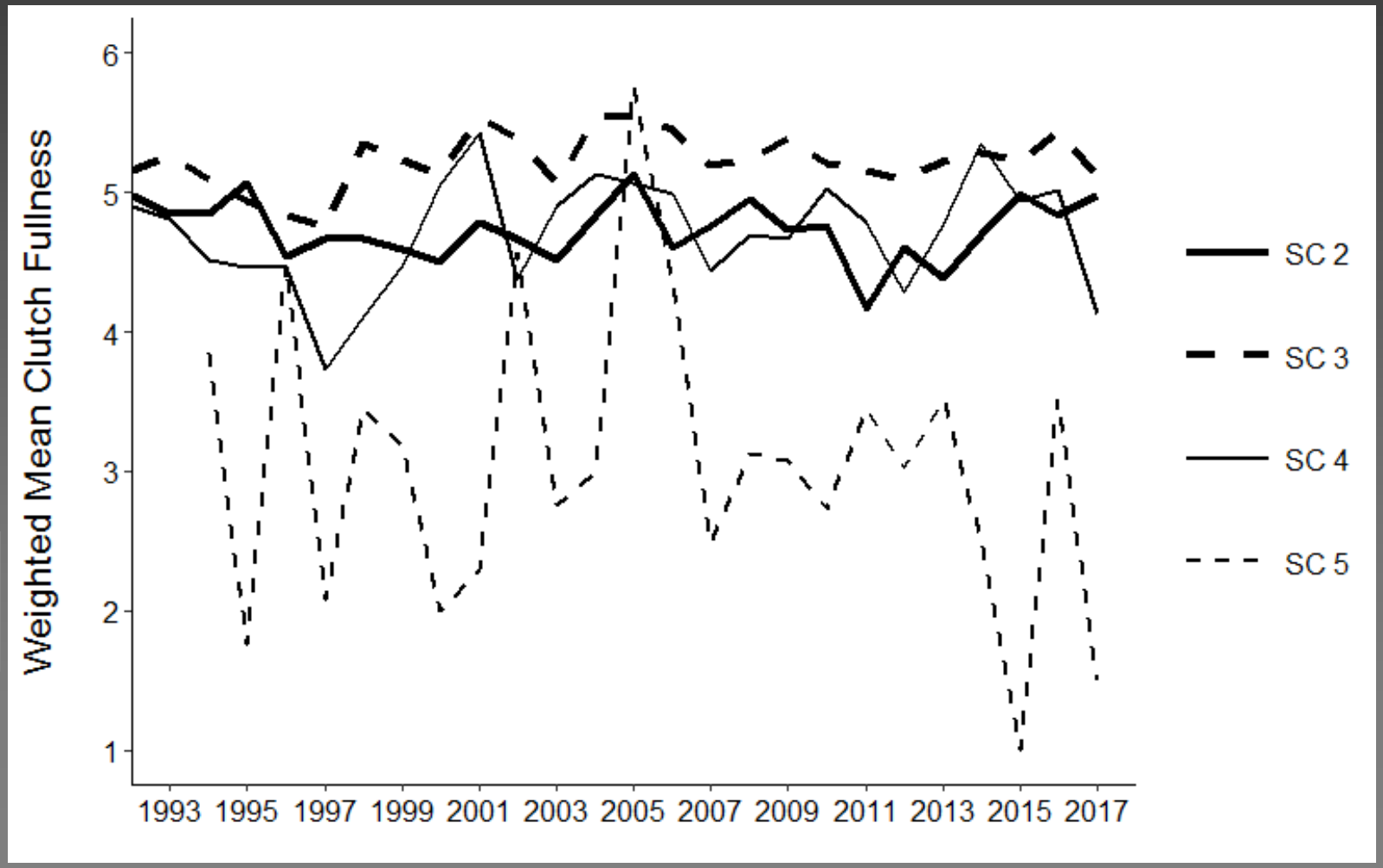
Tanner Crab Workshop Questions

Female Bairdi & Metrics of Reproductive Potential

a) **Is fertilization success problematic?**
b) What are the optimal sex ratios?
c) Are males limiting reproductive potential?
d) Is an egg production index a better measure of reproductive potential?
e) Is a combined mature male/female index (ESB) appropriate?
f) Is there a linkage between observed shell condition and reproductive capacity?

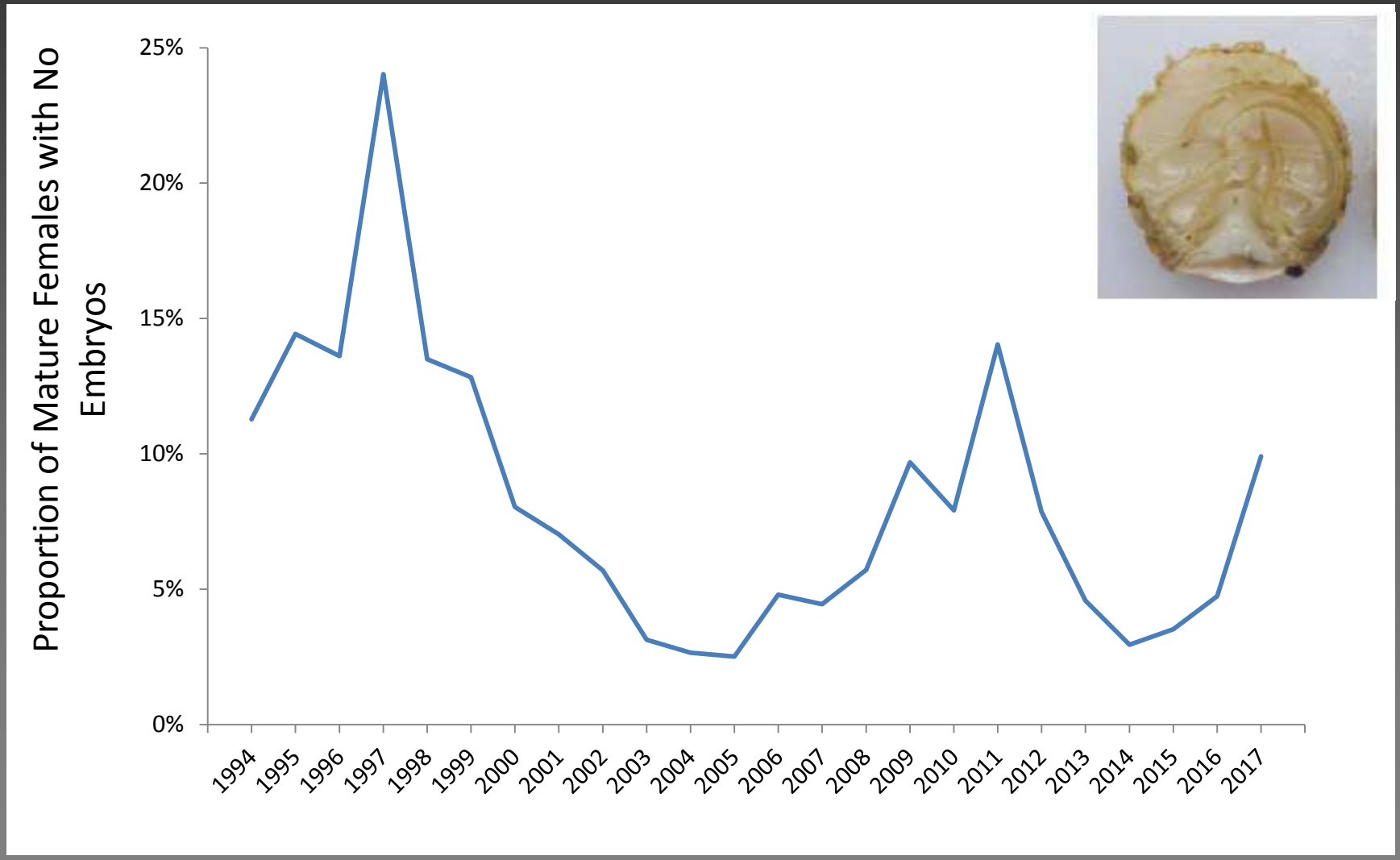
Results

- Trends in clutch fullness over time



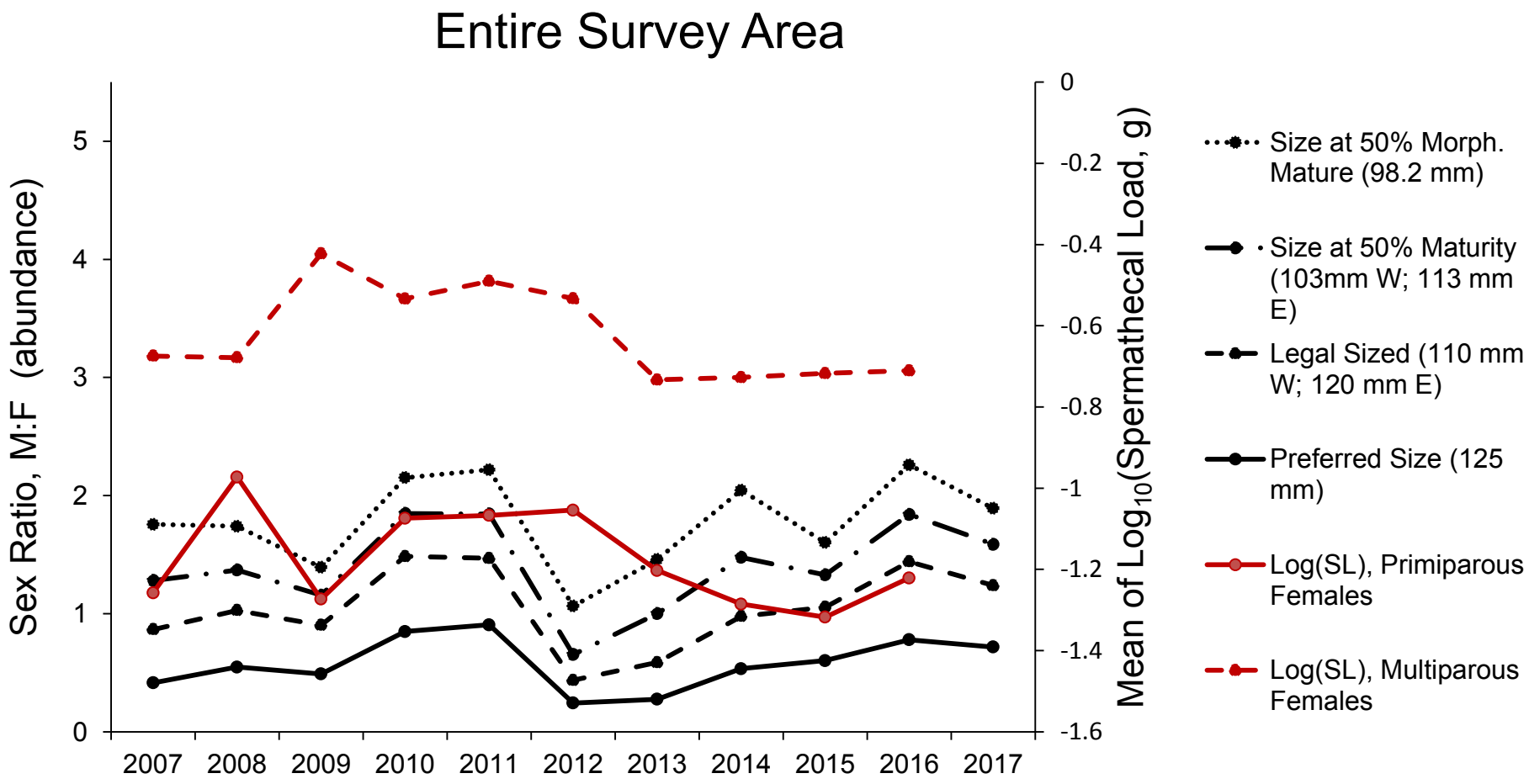
Results

- Barren females over time



Results

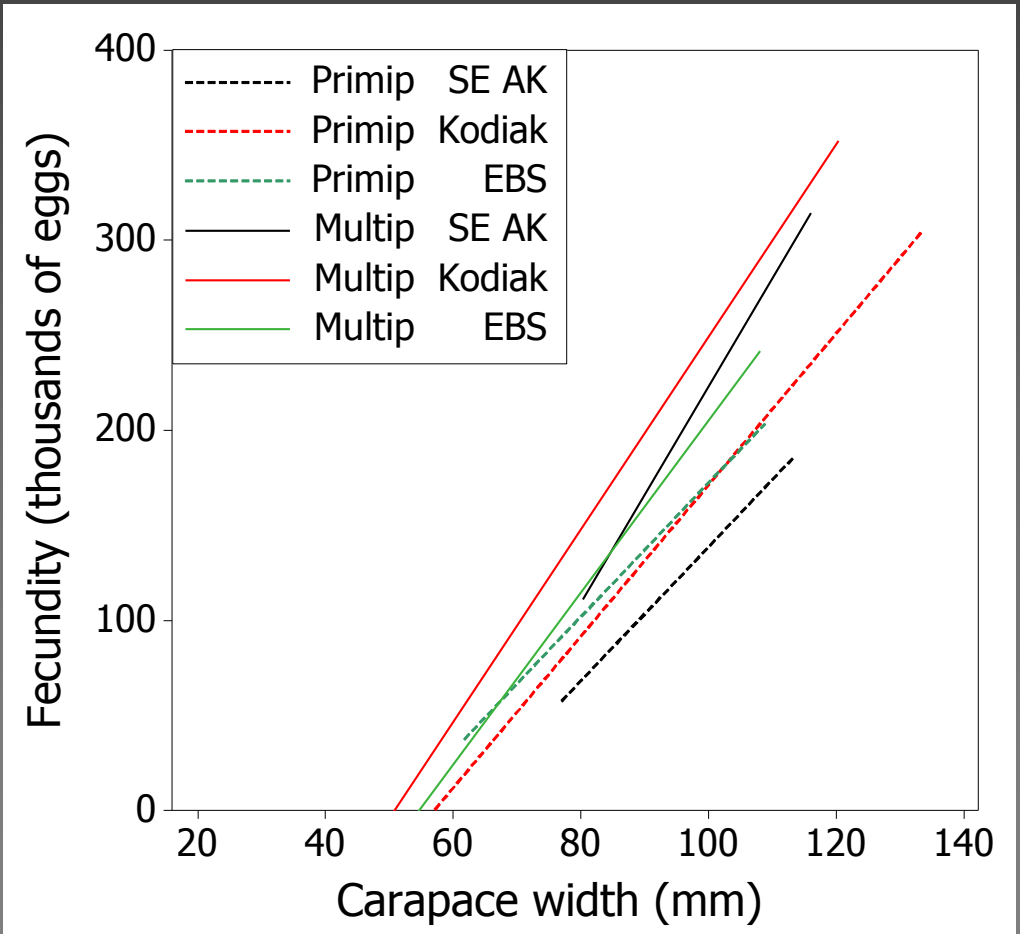
Trends in Sex Ratios and SL



Results

Statewide Comparisons: Fecundity

Appears similar to other Tanner crab populations in Alaska

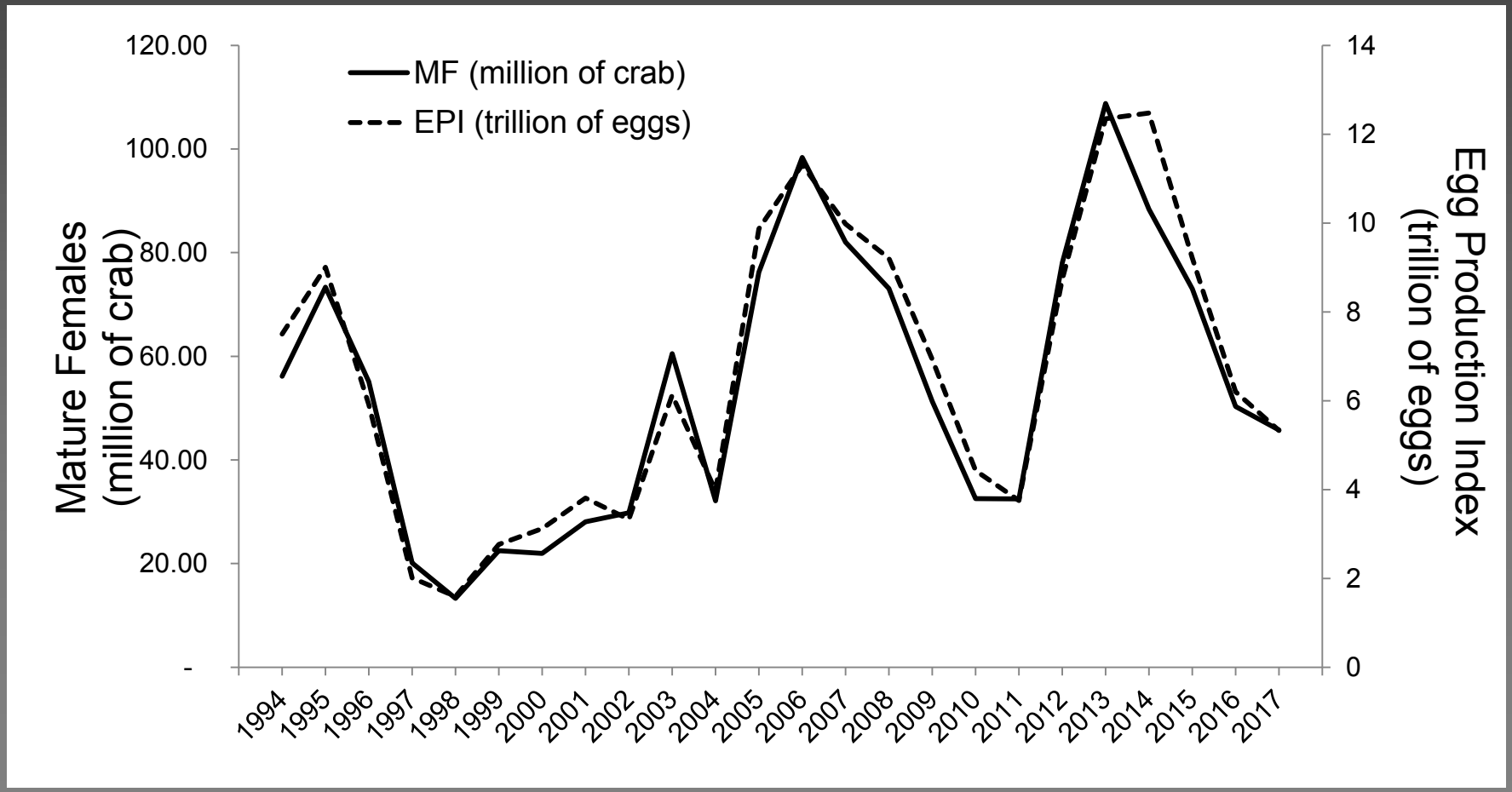


IACM presentation in 2014 including Joel Webb and Carrie Worton's data

Results

Egg Production Index

comparison with mature female abundance
Pearson correlation coefficient = 0.95, p-value = <<0.001



How does/can the assessment inform the harvest strategy?

How does…?

- Estimated natural mortality rates
- F_{MSY}/F_{OFL}
- Estimated fishery selectivity and retention curves

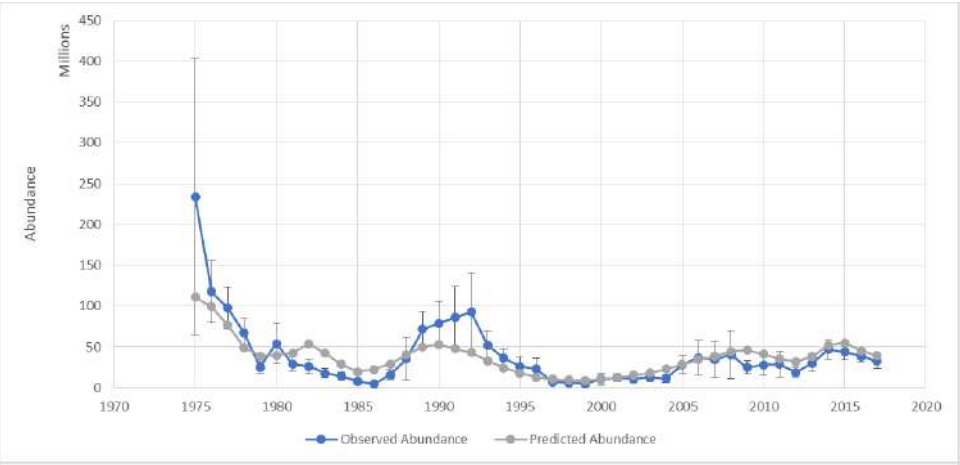
How can…??

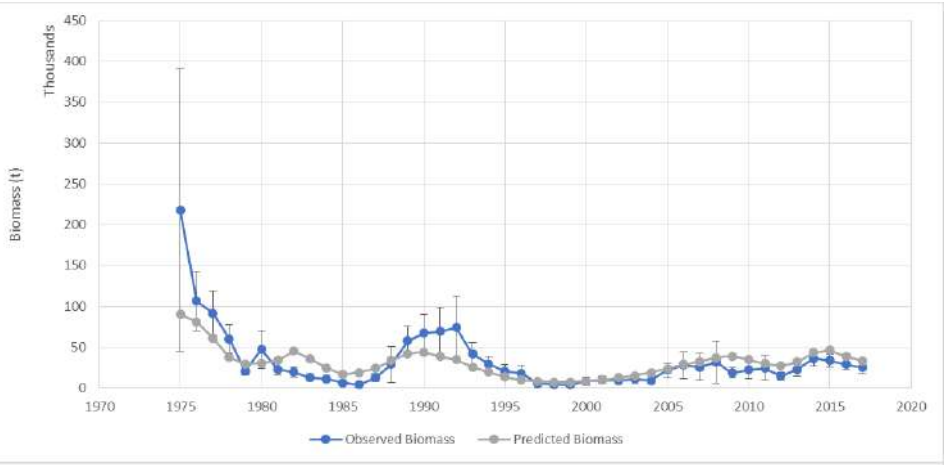
- Model-estimated survey biomass time series
- Estimated current population abundance/biomass by maturity state and 5 mm size bins
- Estimated growth rates
- Estimated probabilities of maturity

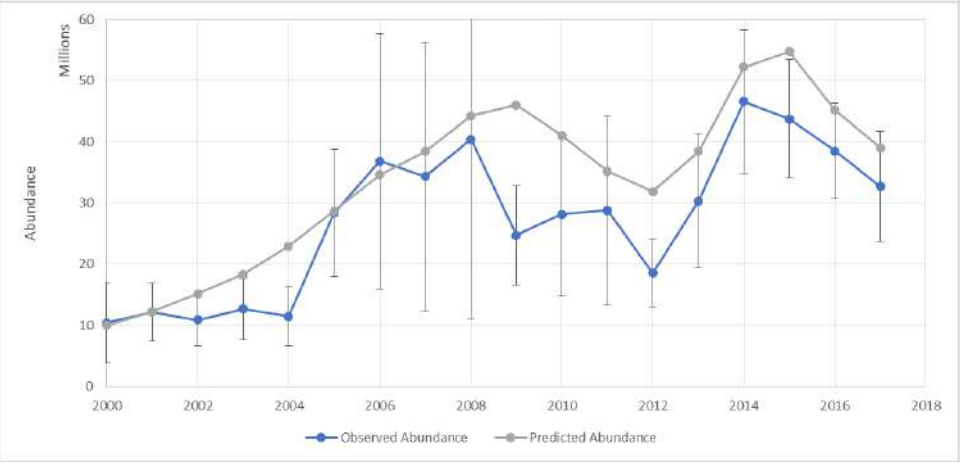
Considerations

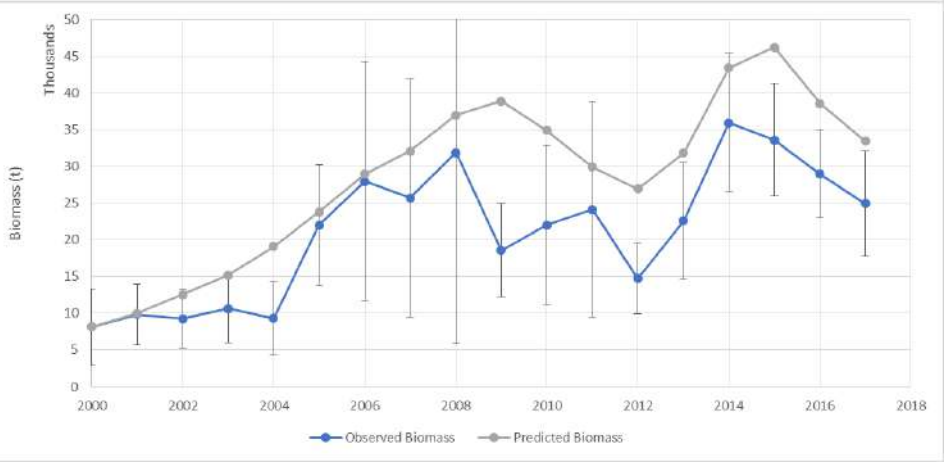
- Model overestimates numbers of large male crab
- Current model estimates are entire-stock estimates
- Harvest strategy needs area-specific estimates
  - use NMFS trawl survey splits to apportion model estimates to areas?
- Future direction: Incorporate area-specific directed fishery information into model

Survey Legal Abundance and Biomass









Management Reference Points

Not overfished
No overfishing

Basis for the OFL

Year	Tier[A]	B_{MSY}[A]	Current MMB[A]	B/B_{MSY}[A]	F_{OFL}[A] (yr^{-1})	Years to define B_{MSY}[A]	Natural Mortality[A,B] (yr^{-1})
2013/14	3a	33.54	59.35	1.77	0.73	1982-2013	0.23
2014/15	3a	29.82	63.80	2.14	0.61	1982-2014	0.23
2015/16	3a	26.79	53.70	2.00	0.58	1982-2015	0.23
2016/17	3a	25.65	45.34	1.77	0.79	1982-2016	0.23
2017/18	3a	29.17	43.31	1.49	0.75	1982-2017	0.23

Management Performance

Year	MSST	Biomass (MMB)	TAC (East + West)	Retained Catch	Total Catch Mortality	OFL	ABC
2013/14	16.98	72.70[A]	1.41	1.26	2.78	25.35	17.82
2014/15	13.40	71.57[A]	6.85	6.16	9.16	31.48	25.18
2015/16	12.82	73.93[A]	8.92	8.91	11.38	27.19	21.75
2016/17	14.58[C]	80.57[A]	0	0	1.14	25.61	20.49
2017/18		43.31[B]				25.42[C]	20.33[C]

Why does the OFL seem so high?

- The OFL is for TOTAL CATCH, and includes handling mortality applied to discarded crab
- No reliable stock-recruit relationship exists for Tanner crab
  - Can't evaluate true productivity of stock (i.e., can't calculate F_{MSY}, B_{MSY}, MSY)
- Assessment uses proxies ($F_{35\%}$, $B_{35\%}$) based on spawner-per-recruit considerations
- Assessment estimates current MMB ≈ unfished MMB
  - $\Rightarrow$ can take big chunk (~65%) of current MMB before reaching $B_{35\%}$
- Assuming $F_{MSY} = F_{35\%}$ may overestimate true productivity of stock
  - $F_{MSY} = F_{35\%} \Rightarrow$ maximum *sustainable* yield occurs when B is 35% of unfished biomass
  - "35%" is based on a meta-analysis of primarily groundfish stocks
  - lower productivity $\Rightarrow$ higher SPR rate (e.g., 50%) corresponds to $F_{MSY} \Rightarrow F_{MSY} < F_{35\%}$ and "true" OFL < calculated OFL
- Uncertainty in other factors
  - estimated growth transition probabilities (model overestimates mean growth increments)
  - estimated probabilities of terminal molt (somewhat circular reasoning here)
  - estimated fishery selectivity and retention curves
  - mean recruitment calculation (e.g., time period)

Future directions for the assessment model

- Fit male maturity ogives based on chela height data directly in model
- Test alternative selectivity functions
- Incorporate BSFRF survey data
  - side-by-side data to improve main scaling information
    - NMFS selectivity/catchability
  - improve recruitment estimation
    - provide better-resolved population modes at small sizes
- Transition to Gmacs assessment model framework

How can we improve the harvest strategy?

- Overly complicated
  - Re-build harvest strategy from the ground up, no more Band-Aids
- Remove thresholds: sharp drops in TAC depending on value of point estimate relative to long-term averages
  - Incorporate “sliding scale” concepts to achieve more continuous TAC multipliers
- Uncertainty about female harvest control rule in a male only fishery
  - Need better understanding of reproductive biology
- Re-think spatial management
  - What is the stock structure?
  - How many management areas are appropriate?
- Consideration of uncertainty in population estimates
  - Incorporate assessment model estimates

Scale of potential future revisions

Small fix

Mid-level fix

Large/ fundamental fix

BandAids to existing framework

Minor update examples:

- Threshold calculations: years, area, maturity def., etc
- Preferred sizes
- ½ TAC reduction rule modification

Moderate updates:

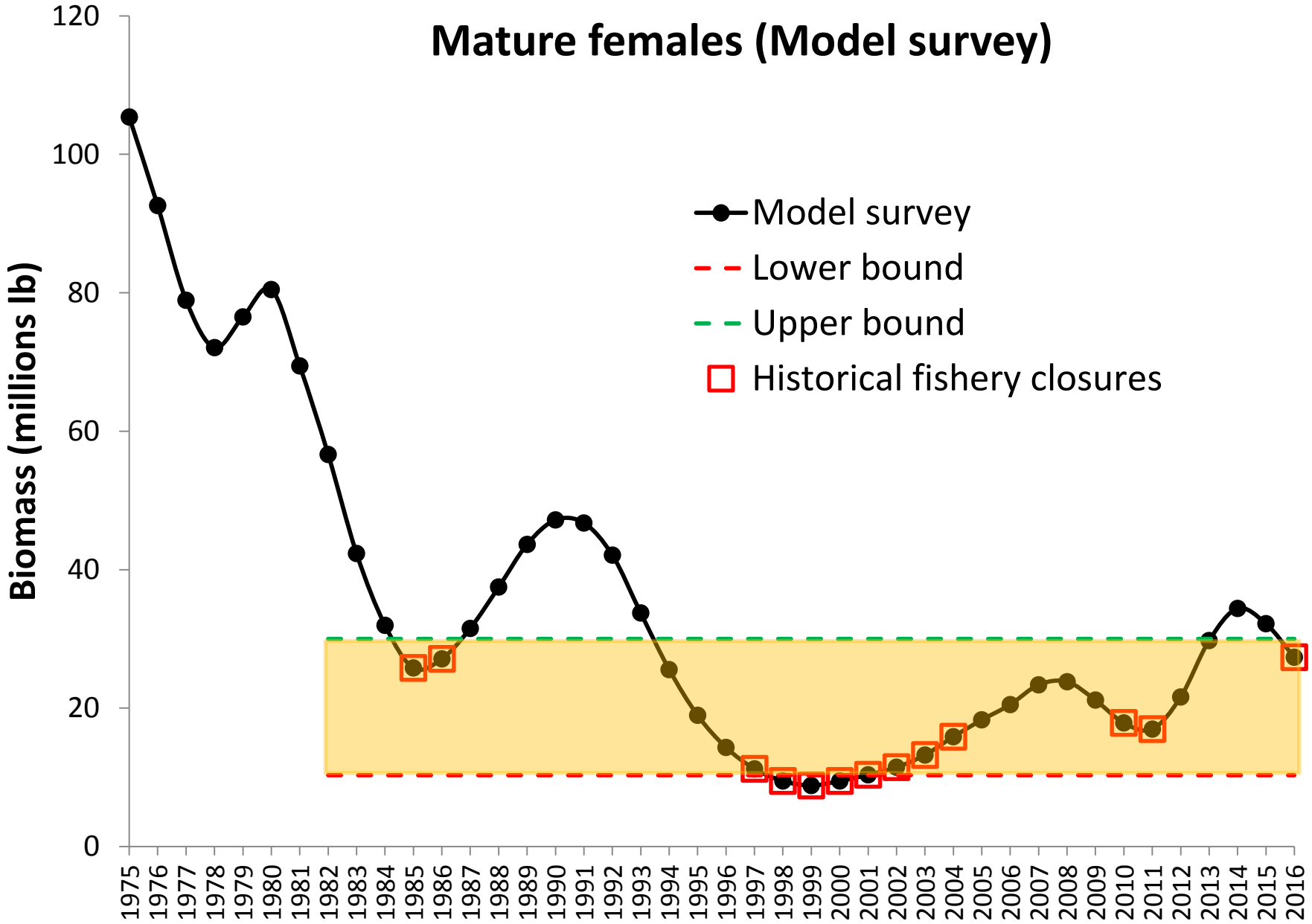
- Female "error band" or "sliding scale" control rules
- Model outputs
- Account for newshell-oldshell selectivity?

Complete rebuild:

- **Protect sustainability/reproductive potential?**: ESB, TMB, egg production index, sex ratio, etc
- **Exploitation rates** on mature/legal males
- **Spatial management:** How many management areas?
- **Additional conservation buffers:** shell condition selectivity, area closures
- **Hybrids?:** Should they be considered? How?
- **Model outputs:** How best utilize?
- **MSE or other analyses**

Road Map: where to go form here

- Workshop
  - Reach general consensus about “best science”: females, harvest strategy, assessment model, etc.
- Shorter-term: more “BandAids”?
  - Small to mid-level fixes to existing framework
  - **Options for females:** 1) status quo, 2) remove, 3) “sliding scale”, 4) something else
- Longer-term: complete rebuild
  - Protect sustainability (reproductive potential)
  - Management areas
  - Exploitation rates + caps
  - MSE, model outputs, full vetting, etc., etc.
  - Do this in conjunction with snow crab harvest strategy rebuild?


Mature females (Model survey)
Biomass (millions lb)
120
100
80
60
40
20
0
Model survey
Lower bound
Upper bound
Historical fishery closures
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
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2016

Sliding scale