

Uncertainty in BSAI crab TAC setting

Benjamin Daly

May 2017 CPT minutes

Regarding Tanner crab harvest strategy.....

ADF&G has computed thresholds using the model outputs in addition to the area swept estimates for analysis. The State is open to considering how to use model outputs in the future; however, this impacts how the model output interacts with the threshold and needs further consideration. The model smooths out the survey data over time to reduce the effects of observation error. The CPT discussed the utility of further aligning the stock assessment model and Federal status determination criteria with the harvest strategy elements.

Regarding today's presentation.....

*The CPT was interested in the State identifying why the model is not used and whether there are ways to improve the stock assessment model so that it can be used in the harvest strategy. **The CPT noted that during the process to establish ACLs, the State had agreed to annually update the CPT on the TAC setting. This includes understanding how uncertainty and crab biology parameters feed into both the harvest strategy and the stock assessment model. The goal is to provide transparency and improve how these two processes work together.***

FMP 6.1 Five-Tier System

.....the Scientific and Statistical Committee annually reviews the Stock Assessment and Fishery Evaluation Report, including the stock assessment documents, recommendations from the Crab Plan Team, and the methods to address scientific uncertainty.

In reviewing the Stock Assessment and Fishery Evaluation Report, the Crab Plan Team and the Scientific and Statistical Committee shall evaluate and make recommendations, as necessary, on:

- the assumptions made for stock assessment models and estimation of OFLs;
- the specifications of the probability distribution of the OFL;
- the methods to appropriately quantify uncertainty in the ABC control rule; and
- **the factors influencing scientific uncertainty that the State has accounted for and will account for on an annual basis in TAC setting.**

FMP 8.2.2. Total Allowable Catch and Guideline Harvest Level

The FMP authorizes the State to set preseason TACs and GHGs under State regulations.....

The State will take into account the following factors, to the extent information is available, in developing harvest strategies or setting TACs and GHGs: (1) whether the ACL for that stock was exceeded in the previous year; (2) stock status relative to the OFL and ACL; (3) estimates of exploitable biomass; (4) estimates of recruitment; (5) estimates of thresholds; (6) market and other economic considerations; **(7) additional uncertainty**; and (8) any additional factors pertaining to the health and status of the stock or the marine ecosystem. Additional uncertainty includes (1) management uncertainty (i.e., uncertainty in the ability of managers to constrain catch so the ACL is not exceeded, and uncertainty in quantifying the true catch amount) and **(2) scientific uncertainty identified and not already accounted for in the ABC (i.e., uncertainty in bycatch mortality, estimates of trends and absolute estimates of size composition, shell condition, molt status, reproductive condition, spatial distribution, bycatch of non-target crab stocks, environmental conditions, fishery performance, fleet behavior, and the quality and amount of data available for these variables).**

FMP 8.2.2. Total Allowable Catch and Guideline harvest Level

The State will establish the annual TAC for each crab stock at a level sufficiently below the ACL so that the sum of the catch² and the State's assessment of additional uncertainty do not exceed the ACL. The State may establish the annual TACs below such a level to account for the other factors identified above. If an ACL is exceeded, the State will implement accountability measures in the fishing season following the overage to account for the overage through a downward adjustment to the TAC for that species by an amount sufficient to remedy the biological consequences of the overage.

² As used here, the term "catch" refers to all sources of fishing mortality included in the ACL for a given stock. Thus, for a stock with a total catch ACL, "catch" includes each of the three catch components identified in section 6.0.1.1 (non-directed fishery discard losses, directed fishery removals, and directed fishery discard losses). For a stock with a retained catch ACL, "catch" includes only the directed fishery removals.

.....Is this being done how the FMP intended?

If not, how can we improve?

Example Areas of Uncertainty

- **BBRKC**: Fishery performance vs abundance estimates
- **Tanner**: model fit, spatial management, closure area
- **snow**: model uncertainty

TAC setting timeline

- NOAA Survey Data: **August 15**
- CPT meeting, assessment model recommendations: **Mid-Sept-ish**
- SSC approves CPT recommendations: **Early-Oct**
- TAC calculations & Internal ADF&G meetings: **Late-September to early-October**
 - **~2 week window**
- TAC announcements: **Early-Oct**
- TAC presentation to public: **~Oct 10**

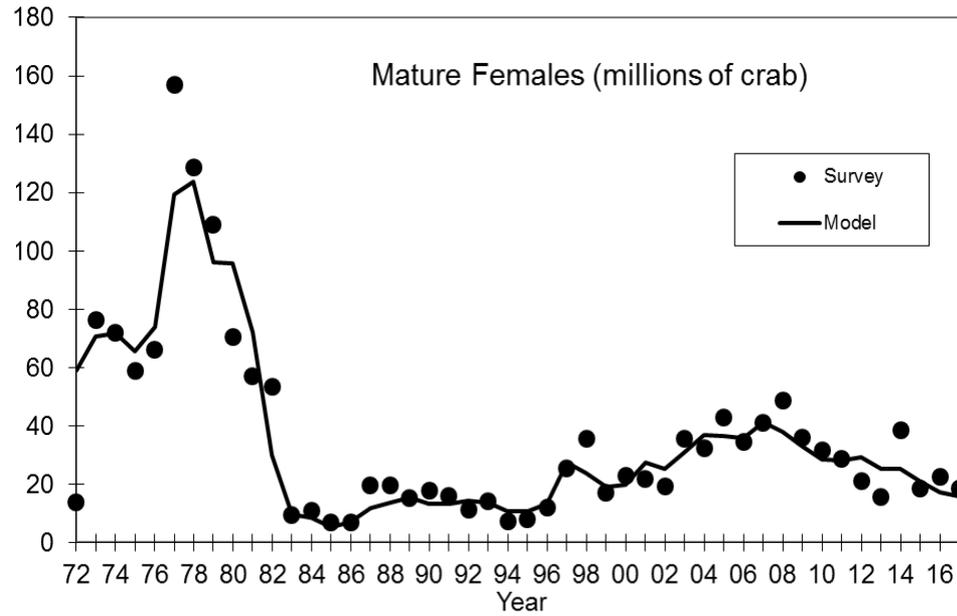
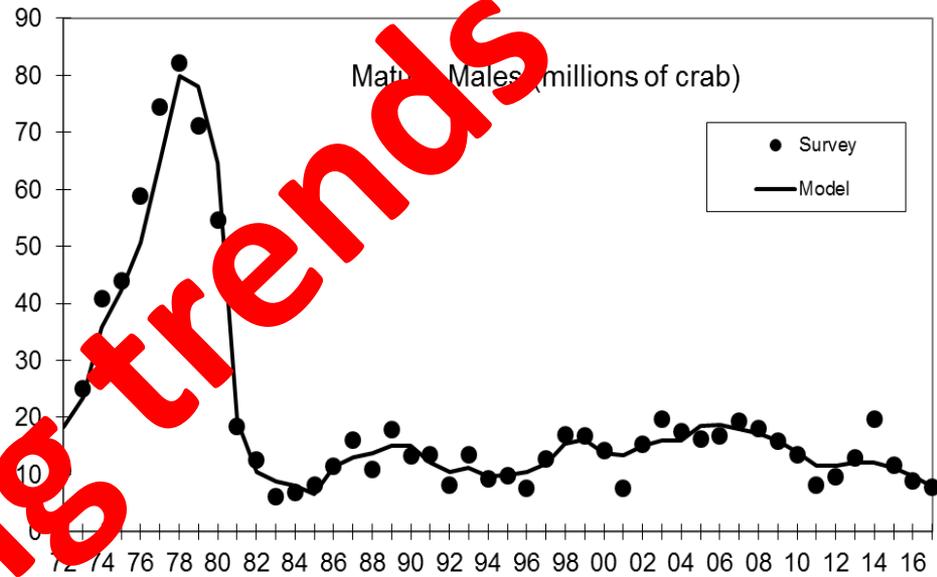
BBRKC

Bristol Bay Red King Crab

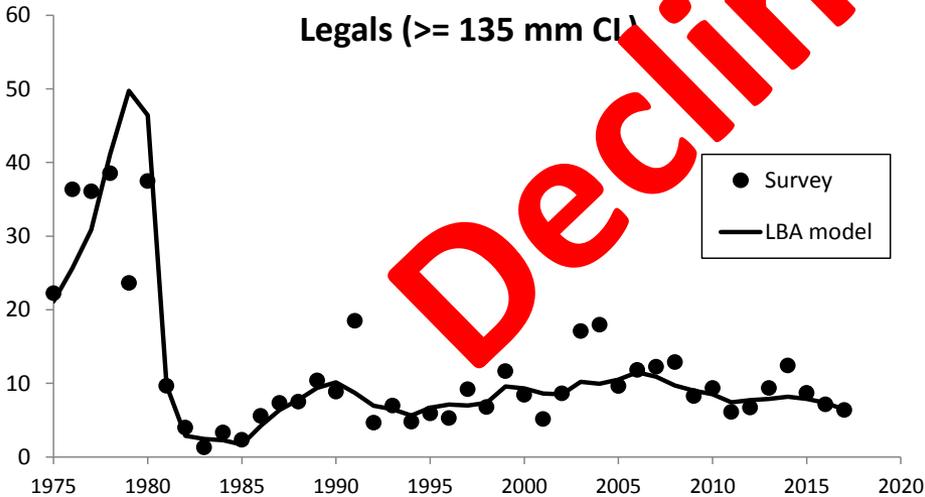
2017 LBA model results

ADF&G length-based analysis (LBA model) fit to area-swept estimates (dots):

- mature male abundance (top right)
 - mature female abundance (bottom right)
 - Legal male abundance (bottom left)
- (J. Zheng, ADF&G).

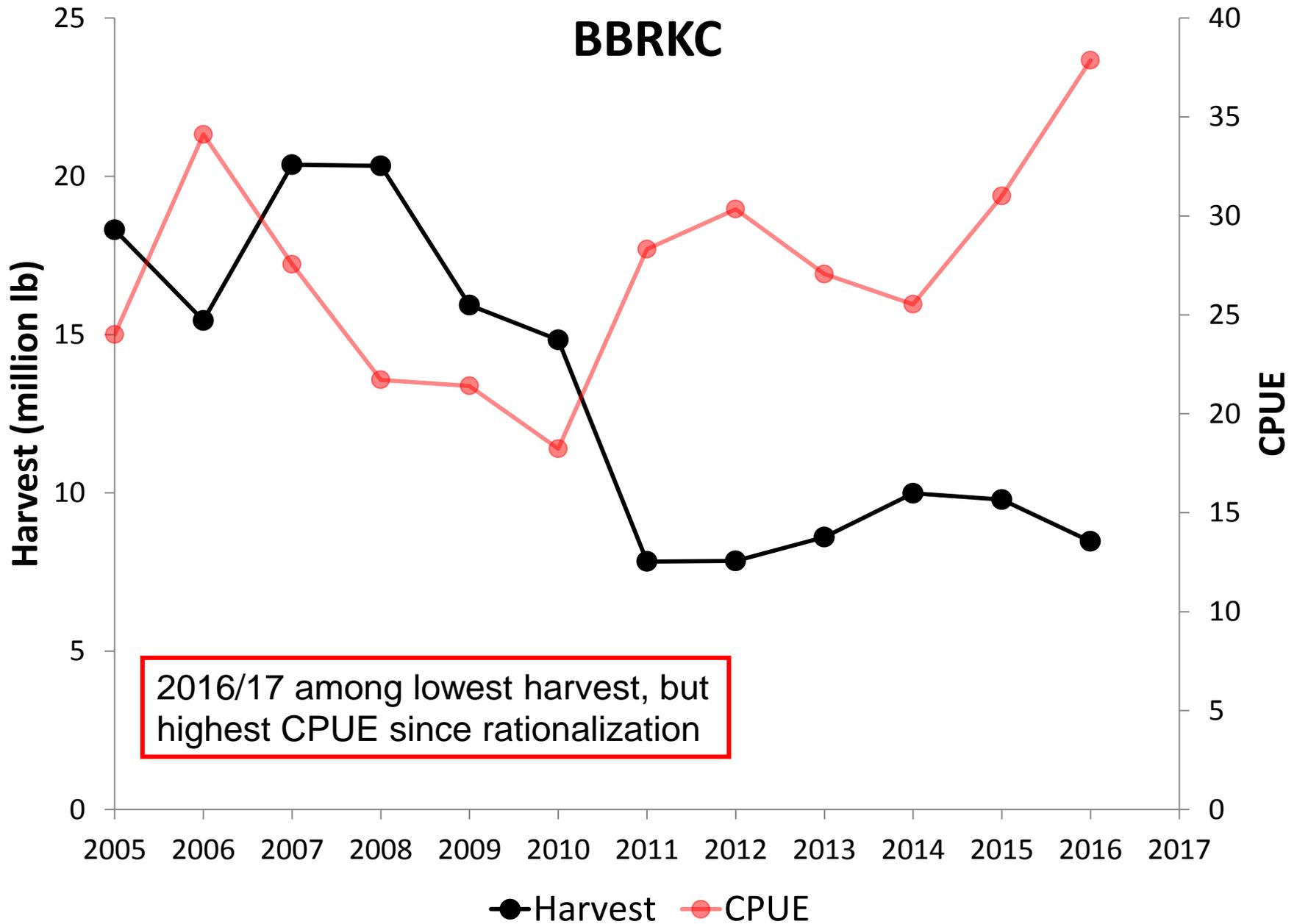


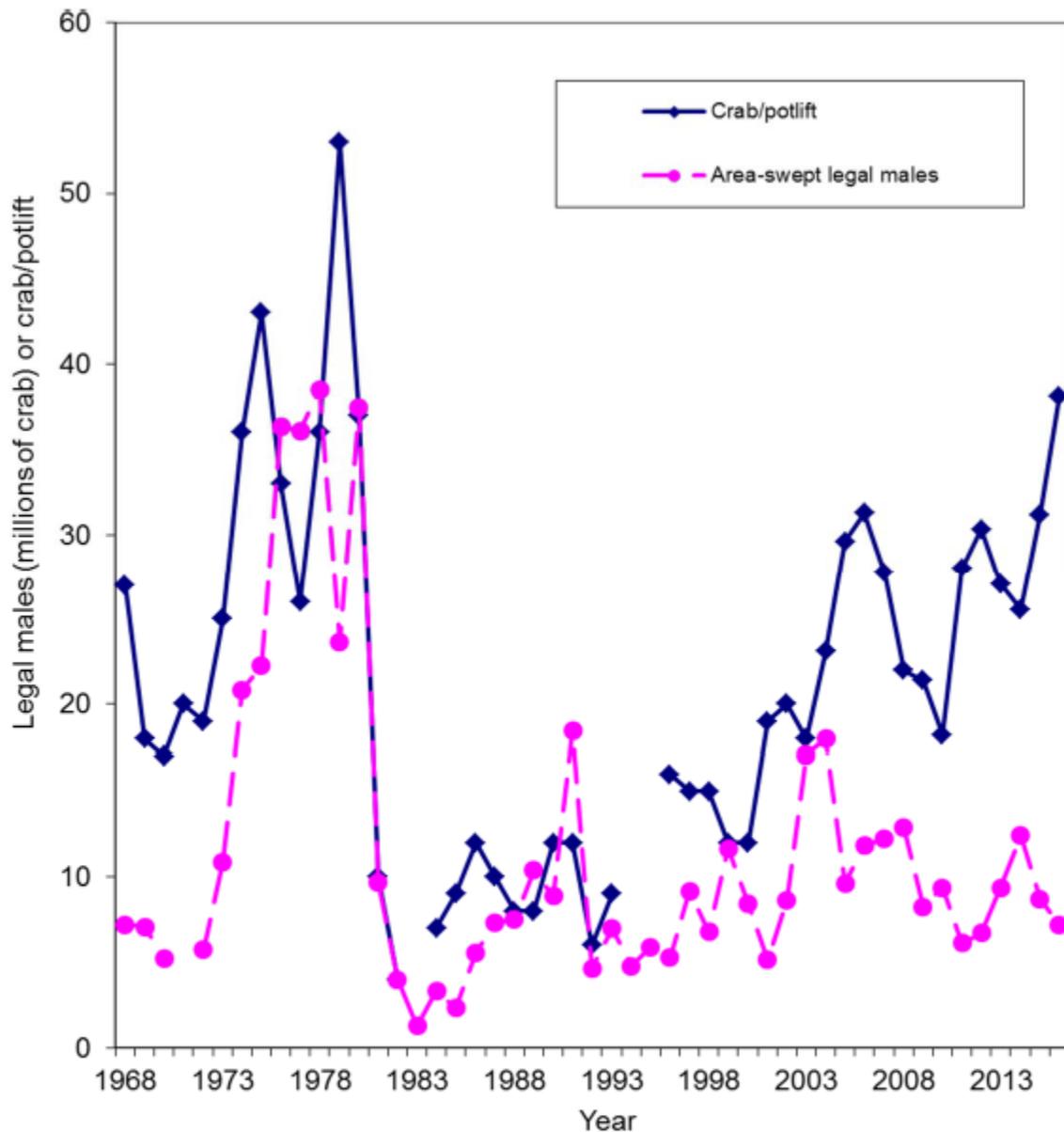
Legals (≥ 135 mm CL)



Declining trends

BBRKC





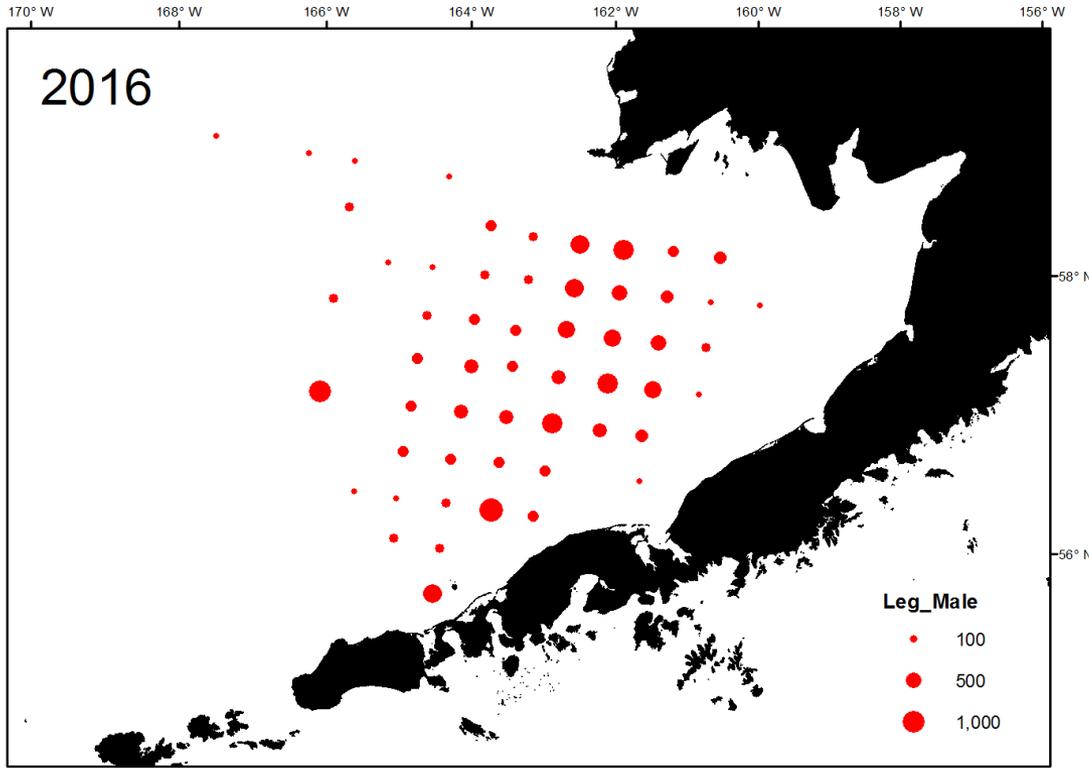
2016/17 CPUE highest since the late '70s, despite recent declines in abundance.

Figure 4. Comparison of survey legal male abundances and catches per unit effort for Bristol Bay red king crab from 1968 to 2016.

Recent Fishery Performance

Disconnect between population abundance and fishery performance.....what gives?

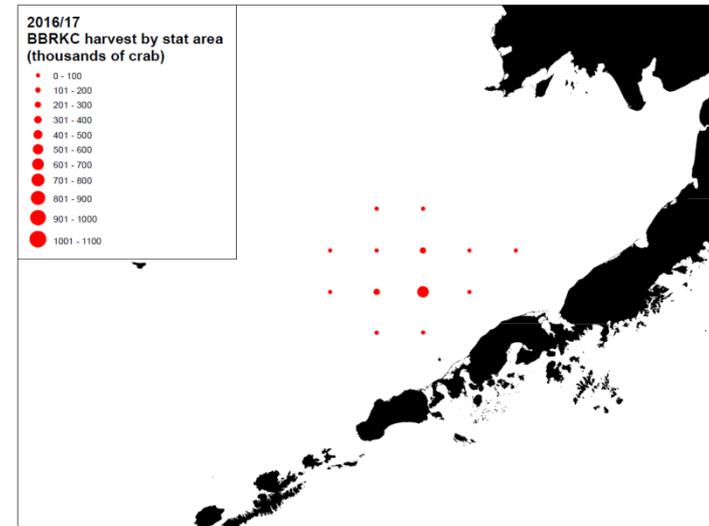
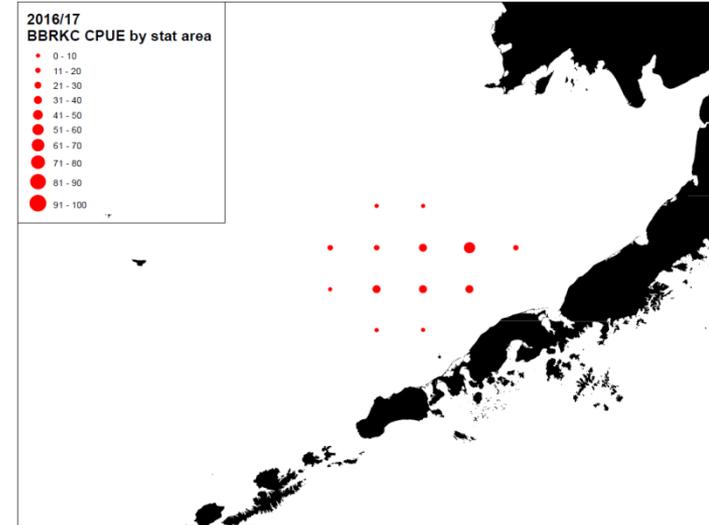
- **Possible explanation**: the population is patchy, highly aggregated
 - Fishing on “patches” of high density crab results in high CPUE, but does not necessarily reflect the overall population abundance as a whole
- **OR**...is the fleet becoming more efficient, better coordinated among vessels on the fishing grounds?
- How do we reconcile this?
 - Survey data is a June snap-shot of population spatial distribution, while the fishery occurs 4-5 months later



NOAA survey density (legal males 400 nm⁻²)

2016 survey shows broad spatial distribution, but catch us coming from a relatively small area.

Fishery CPUE



Fishery Harvest (1,000s crab)

Daily Fishing Logs (DFL_s)

Leah Sloan, PhD student-UAF



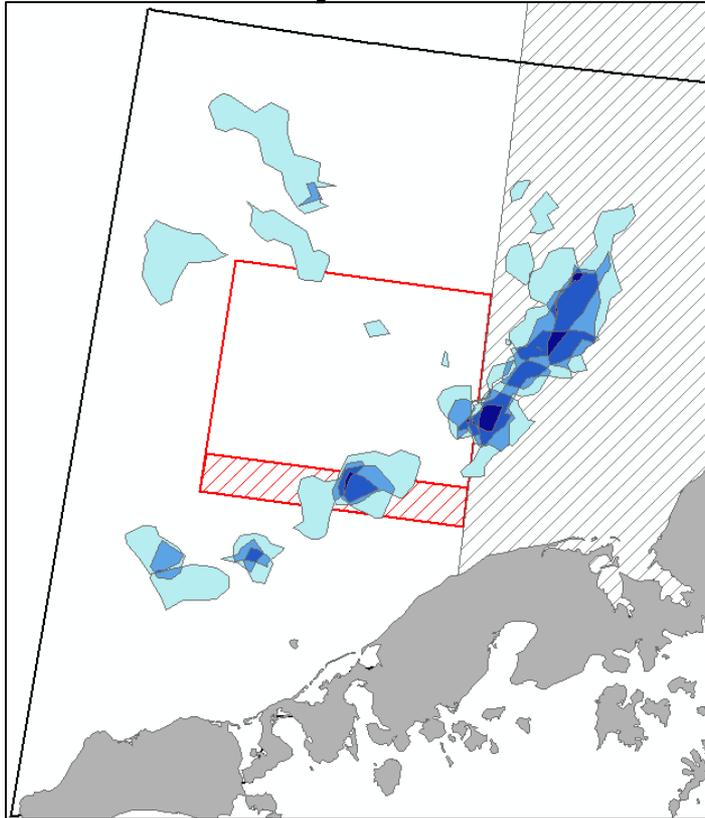
- Required since 2005
- Catch information in each DFL entry
 - Coordinates of first and last pot in each string
 - # pots per sting
 - # crabs caught per string
 - Date/time set and hauled
- Assumptions/ limitations in analyses
 - CPUE proxy for crab abundance
 - Coordinates of string midpoints used for all analyses
 - Data only for legal males
 - Only have data where fishing occurred

BBRKC DFLs

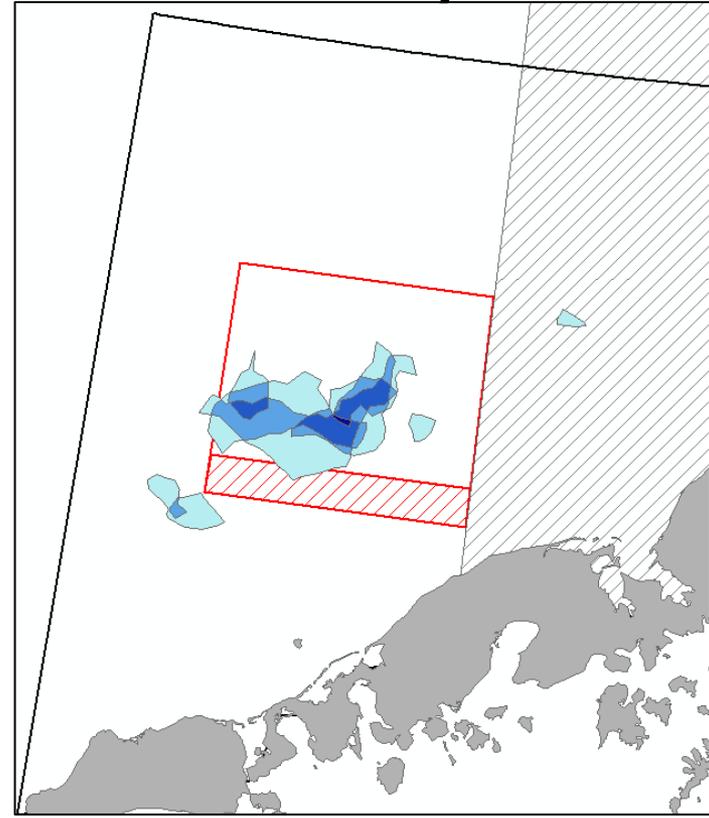
- **All DFLs digitized for 2005 - 2016**
 - **26,731 strings**
 - **17,227,454 crab**
- **Dataset represents >90% of all crabs caught**

Persistence of Hot spots

8 cold years



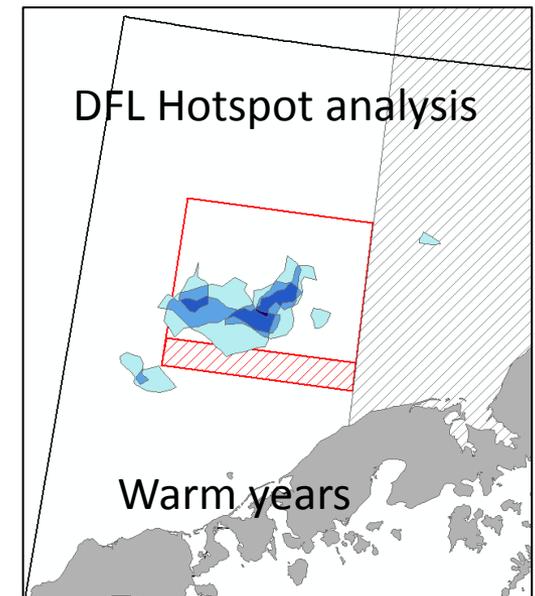
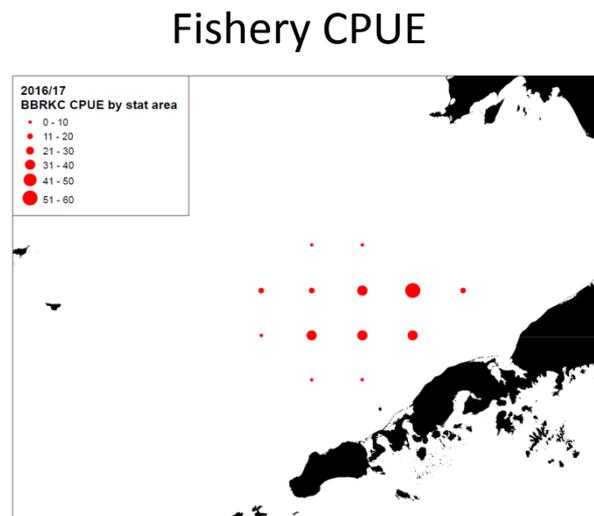
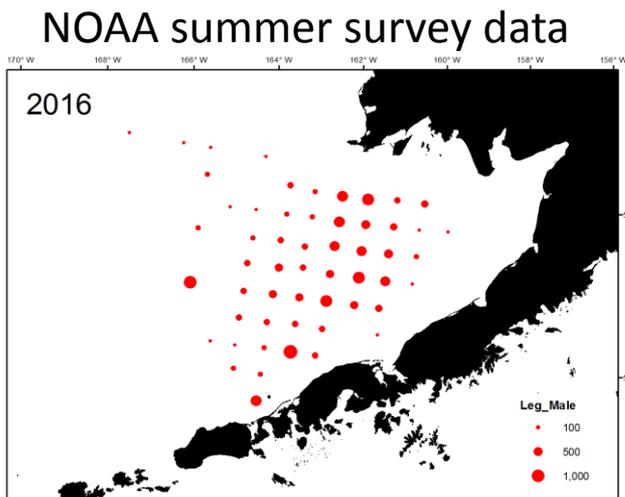
4 warm years



Appears that there may be an influence of oceanographic temperature and fishing performance/behavior.

The CPUE conundrum

- A disconnect between recent survey/assessment estimates and fishery performance
- How can we reconcile this?
 - Fishery CPUE currently not included in stock assessment model.....
 - Need better understanding of crab movement between the summer survey and the fishery..... tagging studies?



Tanner

Tanner Harvest Strategy Data Inputs

Population Biomass + Abundance (MFB, MMB, 5-inch males)

Considerations

- NMFS survey raw area-swept
- Stock assessment model survey
- Stock assessment model population

Sampling error, survey selectivity, etc., etc.

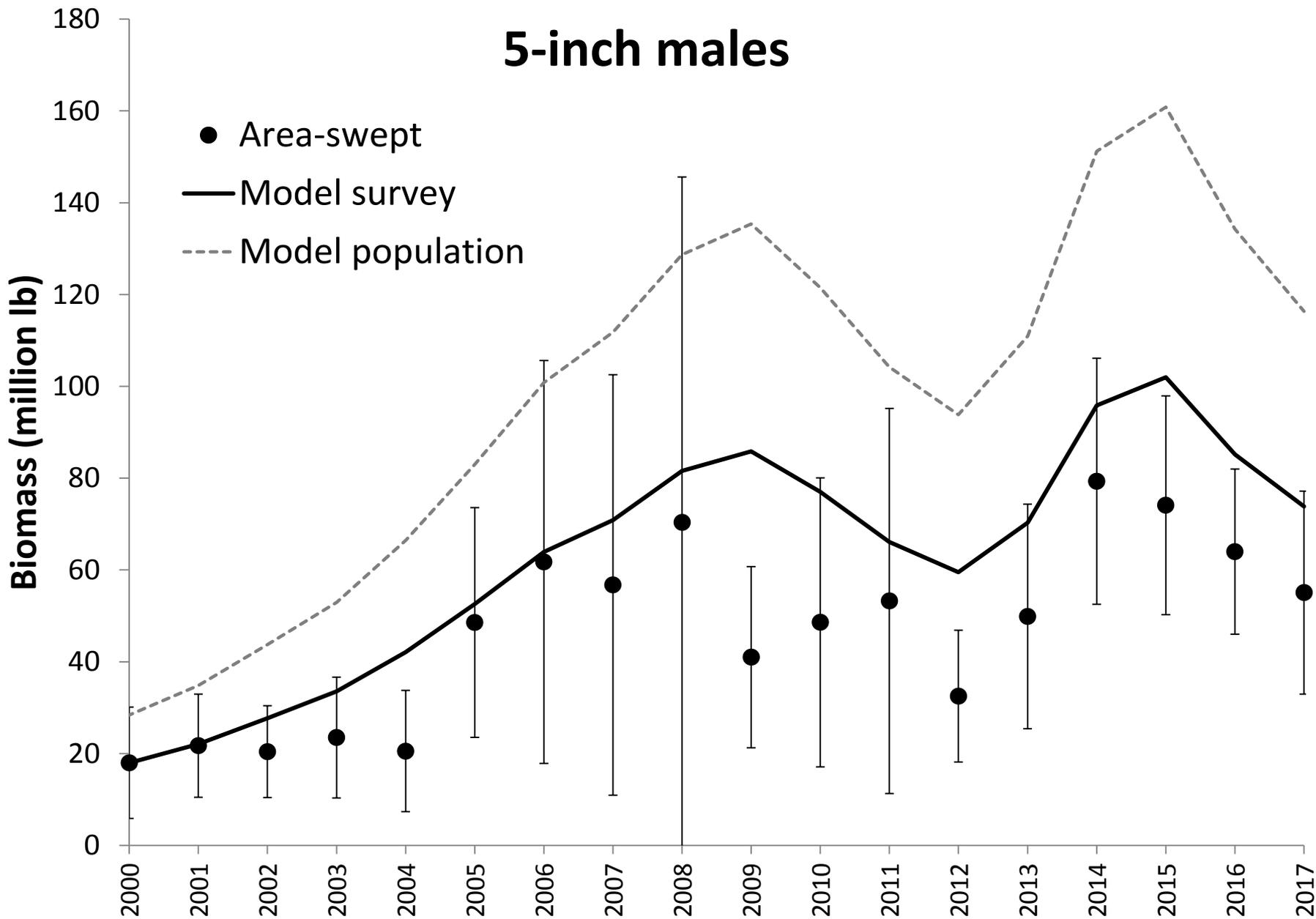
- Process error
- Estimates not partitioned by longitude
- Model fit for large males

Other model outputs relevant to the HS

- $F_{MSY} = F_{OFL} = 0.75$
- M (natural mortality) = 0.23
- Retained selectivity curve

In any given year we don't know what estimate is closer to the true population size

5-inch males



NMFS trawl survey

Over-estimation of 5 inch males

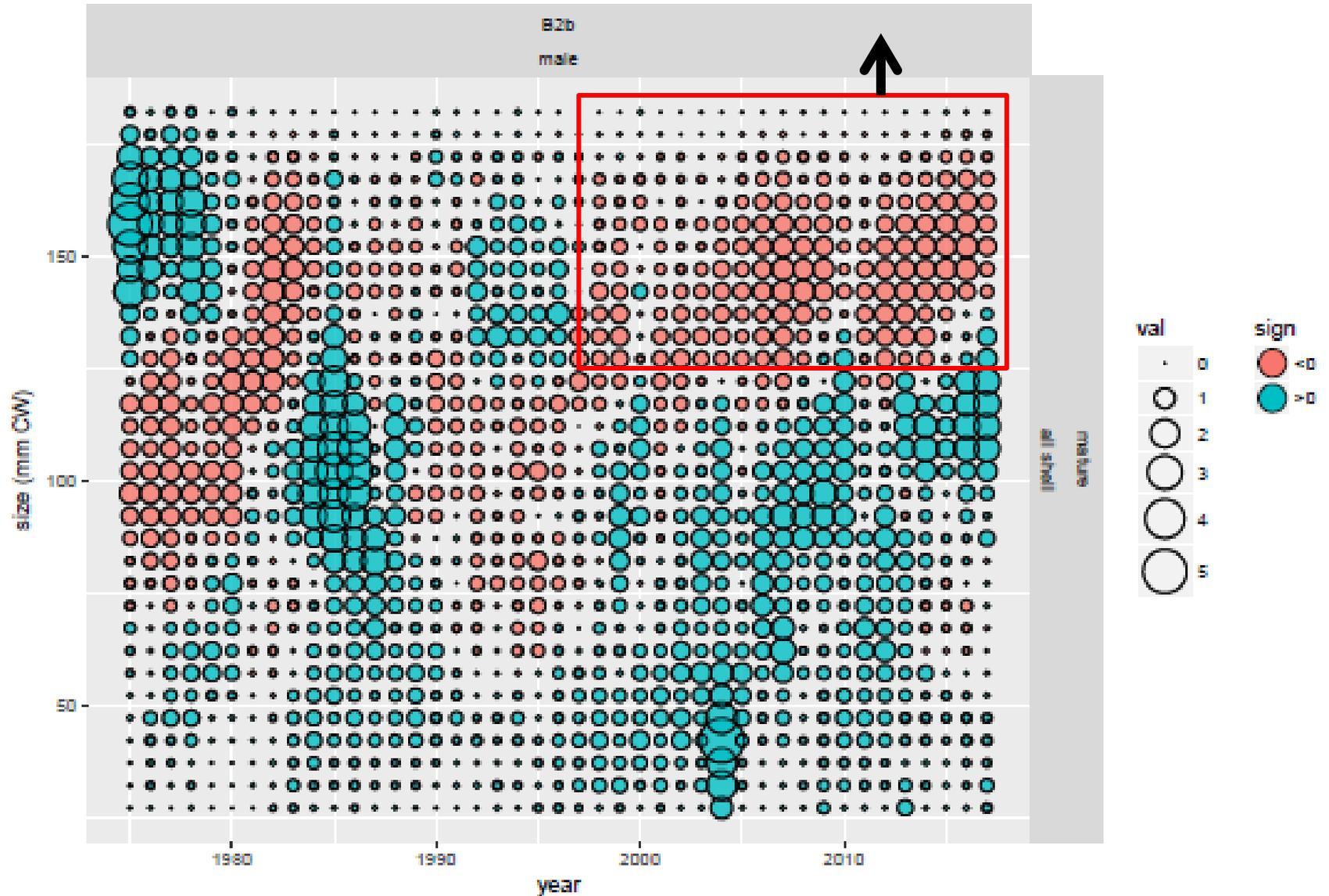


Figure 45: Pearson's residuals for proportions-at-size from the NMFS trawl survey for scenario B2b.

Structural issues with fitting the large males

From Sept 2017 CPT minutes: “***The current model consistently over-predicts abundance of large males in the NMFS trawl survey. This suggests some fundamental process is not being modeled appropriately (such as growth, mortality, or selectivity).***”

Addressing this issue should be a priority for future assessments. Some potential mechanisms to explore are whether the growth increment for the male molt to maturity is different than other molts, and whether the mortality of old males increases with age. Incorporation of chela height data into the model could help to inform which process is most likely.”

State has not used model survey or model population estimates for Tanner TAC setting because of this issue.

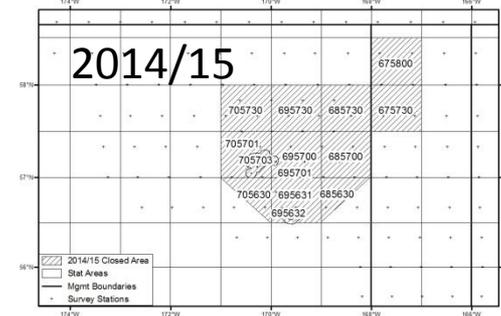
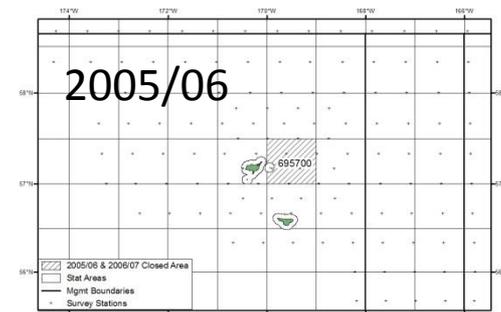
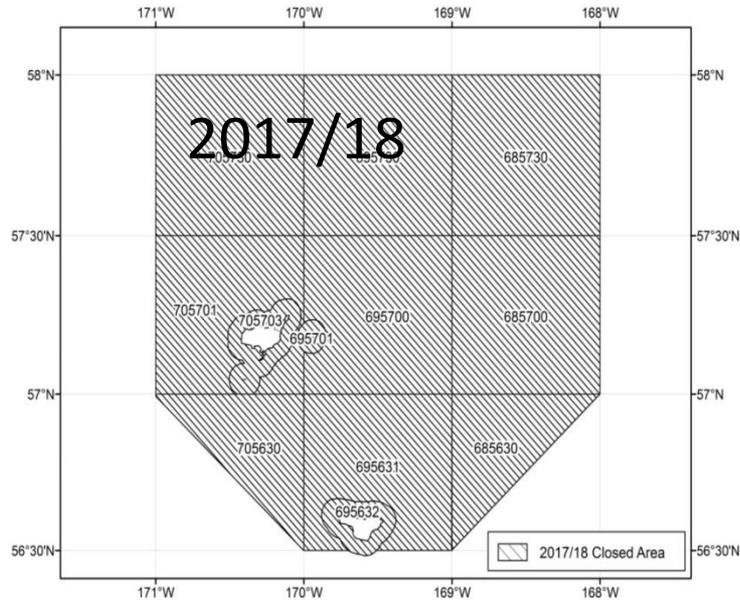
Stock structure uncertainty

*Tanner crab **stock structure** and the connectivity among Bering Sea subregions remains **poorly understood***

- Evidence suggesting east-west stock substructure:
 - Size-at-maturity
 - East-to-west decline in size-at-maturity has been established since 1980
 - Larval advection patterns simulated from ocean circulation model
 - Suggest subareas exist with high larval retention (e.g., Bristol Bay)
 - Genetics
 - Previously published genetic analysis suggesting eastern-western genetic differentiation, but what is the spatial scale? Smaller than regional?Needs closer look
 - Not single panmictic or open population
- Evidence suggesting single stock with connectivity among subregions:
 - Size-at-maturity
 - East-to-west variation in size at maturity may reflect environmental effects
 - Larval advection patterns simulated from ocean circulation model
 - Suggest varying degrees of connectivity and retention among subareas
 - Distribution of Tanner crab in the annual NMFS EBS trawl survey
 - Widely distributed over EBS surveyed area without discontinuity between areas

Closed areas to protect PIBKC from overfishing

- Pribilof District closed to commercial crab fisheries to protect PIBKC
- Area closure for all crab fisheries (i.e., snow crab and Tanner crab):



Effectively creating a crab sanctuary

- Size and shape has changed since 2005 in response to BKC bycatch
- How should this closure area be dealt with in TAC setting of other stocks?
- Conservation buffer?
- What about exploitation rate on the crabs outside the closure area?

Snow

Bering Sea Snow Crab

Three sets of estimates to consider:

1. **“Model observed” estimates (area-swept)**..... area-swept data using model-generated designation for maturity (chela and embryo data)
2. **“Model survey” estimates**.....the model fitted line based on observed (area-swept) estimates
3. **“Model population” estimates**.....the fitted line that accounts for survey selectivity (Q).....estimates of the underlying population..... “the population estimate if all crabs in the line of the survey trawl net were caught”

Sept ‘17 meeting minutes (bold italics added):

“The CPT ultimately concurred with the author recommended model run M17C.D17a for the 2017 assessment.The CPT, however, acknowledged that the unrealistic Q estimates for females in this model should be address in future assessments. ***As a result of the additional uncertainty in choosing the appropriate model runs and the large difference in OFL estimates between those model runs***, the CPT recommended increasing the ABC buffer from 10% (last year) to 20%.”

Harvest strategy data inputs: mature male biomass, mature female biomass, 4-inch male abundance

Snow crab state harvest strategy – Results for 2017/18

Computed 2017/18 TACs: area-swept and Model 17C estimates. Assumed old-shell fishery selectivity = 0.25 relative to new-s

| | Survey Observed (Area-swept Est.) | | Survey (Model Predicted) | | Population (Model Estimated) | |
|---|--------------------------------------|---------------|-----------------------------|---------------|---------------------------------|--------------|
| | TMB | MMB | TMB | MMB | TMB | MMB |
| 1983-1997 Average (millions lb) | 803.8 | 527.8 | 741.6 | 428.9 | 1,044.9 | 686.1 |
| 2017 Estimate (millions lb) | 420.6 | 185.1 | 567.0 | 242.9 | 669.5 | 341.3 |
| (2017 Est)/(1983-1997 Avg) | 52% | 35% | 76% | 57% | 64% | 50% |
| F_{MSY} = | | 0.3 | | 0.3 | | 0.3 |
| Exploitation Rate on MMB | | 0.146 | | 0.186 | | 0.165 |
| Computed TAC = Exp Rate X MMB (millions lb) | | 26.94 | | 45.15 | | 56.37 |
| Max TAC (58% cap on exploited legal males (million lb) | | 18.96 | | 44.08 | | 61.67 |
| TAC | | 18.961 | | 44.078 | | 56.37 |
| TAC: Millions of 4-inch legal at 1.27 lb avg wt | | 14.95 | | 34.75 | | 44.45 |
| TAC: % of area-swept estimate of 4-inch legal at time of survey | | 43% | | 99% | | 127% |
| TAC: % of model survey estimate of 4-inch legal at time of survey | | 18% | | 43% | | 55% |
| TAC: % of model population estimate of 4-inch legal at time of survey | | 13% | | 31% | | 39% |
| TAC: % of area-swept estimate of "ELM" at time of survey | | 58% | | 135% | | 172% |
| TAC: % of model survey estimate of "ELM" at time of survey | | 25% | | 58% | | 74% |
| TAC: % of model population estimate of "ELM" at time of survey | | 18% | | 41% | | 53% |

- High levels of uncertainty
- TAC exceeds ABC (50.1 mill lb) without even considering bycatch mortality.

How much weight should we give these comparisons?

Snow crab state harvest strategy – Results for 2017/18

Computed 2017/18 TACs: area-swept and Model 17C estimates. Assumed old-shell fishery selectivity = 0.25 relative to new-s

| | Survey Observed (Area-swept Est.) | | Survey (Model Predicted) | | Population (Model Estimated) | |
|--|--------------------------------------|---------------|-----------------------------|---------------|---------------------------------|----------------|
| | TMB | MMB | TMB | MMB | TMB | MMB |
| | 1983-1997 Average (millions lb) | 803.8 | 527.8 | 741.6 | 428.9 | 1,044.9 |
| 2017 Estimate (millions lb) | 420.6 | 185.1 | 567.0 | 242.9 | 669.5 | 341.3 |
| (2017 Est)/(1983-1997 Avg) | 52% | 35% | 76% | 57% | 64% | 50% |
| $F_{MSY} =$ | | 0.3 | | 0.3 | | 0.3 |
| Exploitation Rate on MMB | | 0.146 | | 0.186 | | 0.165 |
| Computed TAC = Exp Rate X MMB (millions lb) | | 26.94 | | 45.15 | | 56.37 |
| Max TAC (58% cap on exploited legal males (million lb) | | 18.96 | | 44.08 | | 61.67 |
| TAC | | 18.961 | | 44.078 | | 56.37 |
| TAC: Millions of 4-inch legals at 1.27 lb avg wt | | 14.95 | | 34.75 | | 44.45 |
| TAC: % of area-swept estimate of 4-inch legals at time of survey | | 43% | | 99% | | 127% |
| TAC: % of model survey estimate of 4-inch legals at time of survey | | 18% | | 43% | | 55% |
| TAC: % of model population estimate of 4-inch legals at time of survey | | 13% | | 31% | | 39% |
| TAC: % of area-swept estimate of "ELM" at time of survey | | 58% | | 135% | | 172% |
| TAC: % of model survey estimate of "ELM" at time of survey | | 25% | | 58% | | 74% |
| TAC: % of model population estimate of "ELM" at time of survey | | 18% | | 41% | | 53% |

- Accounts for 99% of area-swept estimate of 4 inch males
- High levels of uncertainty....females, 4-inch males
- **TAC approaching ABC (50.1 mill lb) when considering bycatch mortality.**

2017/18 TAC determined using observed (area-swept) estimates =

18.961 million lb

- Area-swept estimates more conservative (this year)
 - High levels of model uncertainty
 - Nearly 100% increase in TMB and MFB from 2016 to 2017.....seems implausible
 - Retrospective patterns in model estimates
 - Consistent with CPT feeling of model uncertainty (↑ in ABC buffer)
 - Lowest estimate of 4-inch males in the “observed” (area-swept) time-series
 - Continued declining fishery CPUE
 - Survey suggests much of the population is up north.....
May reduce availability due to sea ice.

2016 SAFE: Model 3b retrospective biases

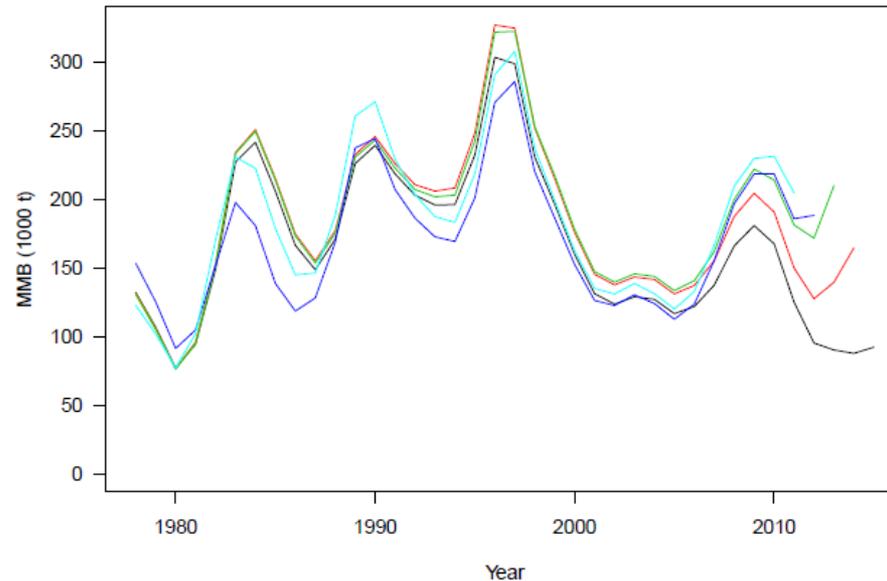


Figure 42: Retrospective pattern in MMB for chosen model

From 2017 SAFE: ***“Previous analyses suggest that retrospective biases may be a problem for the snow crab assessment*** (Szuwalski and Turnock, 2016). Retrospective biases can result from unaccounted for time-varying processes in the population dynamics of the model (Hurtado et al., 2015) and the retrospective bias in MMB for snow crab appears to result from an anomalously large estimate of survey MMB in 2014. This was likely caused by a change in catchability for that year and focused research on potential time-variation in important population processes for snow crab should be pursued to confront retrospective biases.”

Model uncertainty report card

| | |
|---|----------------------------------|
| a. <u>Uncertainty on model estimates due to: Stability of model estimates over last 5 years (this yr & prev 4) (changes in level and trend from year to year, effect on TAC)</u> | RANK |
| TMB MMB 4-in males | Moderate Moderate Moderate |
| b. <u>Uncertainty on model estimates due to: 5-yr trend in and level of current model compared to survey area-swept</u> | RANK |
| TMB MMB 4-in males | High Moderate High |
| c. <u>Uncertainty on 5-year trend in and level of survey area-swept estimates</u> | RANK |
| TMB MMB 4-in males | Moderate Low Low |
| d. <u>Uncertainty on model estimates due to: Trend in and level of current model and area-swept compared to fishery performance</u> | RANK |
| TMB MMB 4-in males | High |

| <u>Uncertainty on current model estimates and overall:</u> (consideration of a-d and the current model versus area-swept estimates for this year) | <u>Summary</u> | <u>Rank</u> |
|--|--|----------------------|
| TMB | Although high instability occurred for the last 5 assessments, the last 2 assessment are relatively stable (a), yet there is still a poor fit to "observed" values in last 5 assessments overall (especially for the FMB component; b), the "terminal-year-uptick" in "survey-predicted" TMB (a, b, and c) still exists, but is somewhat supported by the uptick in observed estimates, and the large effect on computed exploitation rate relative to the exploitation rate computed from the "observed" values. | Moderate-High |
| MMB | Although the "survey-predicted" values were unstable during the last 5 assessments, the last 2 are relatively stable (a), the 2016 assessment has corrected the problem of increasing trend that the 2015 assessment had and "survey-predicted" MMB has been brought to a lower level. Yet absolute values of model survey estimates are still higher than level of the "observed" values for 2016 and 2017 (b). Some uncertainty remains as to whether the 2016-to-2017 trend is better estimated by "survey-predicted" values (slight increase) or "observed" values (decrease; a, b, and c). | Moderate |
| 4-in males | Although the "survey-predicted" values were unstable during the last 5 assessments (a), the 2016 and 17 assessments have corrected the problem of increasing trend that the 2015 assessment had and "survey-predicted" 4-in male abundance has been brought to a lower level. However, it is alarming that the 2017 model survey estimates are more than double the "observed" values (b). Some uncertainty remains as to whether the 2015-to-2017 trend is better estimated by "survey-predicted" values (slight increase) or "observed" values (decrease; a, b, and c). CPUE has been in decline since 2007/08, but it is hard to argue that the "observed" values for 4-in males are more closely associated with CPUE than the "survey-predicted" values from the 2017 assessment. | High |
| OVERALL UNCERTAINTY ON MODEL FOR TAC COMPUTATION: | | MODERATE-HIGH |

Ranking uncertainty and thinking about buffers:

1. Rank overall model uncertainty: low, moderate, high, very high
2. **Low**: go with TAC computed by model survey estimates
3. **Moderate**: nudge TAC X% of the way down from model based TAC toward area-swept based TAC
4. **High**: nudge TAC Y% of the way down from model based TAC toward area-swept based TAC
5. **Very high**: abandon the above rules for TAC computation, come up with a new plan (e.g., close the fishery)

Bering Sea Snow Crab

Estimates of TMB, MMB, and number of 4-in CW males used in setting TAC:

Through 2005/06: area-swept estimates (all that was available)

2006/10 – 2009/10: model survey-predicted estimates

- Approval of model by CPT/SSC in fall 2006
- Survey-predicted estimates = population estimates; $Q = 1$

2010/11 – 2012/13: model population estimates with $Q < 1$

2013/14: model survey-predicted estimates

- Trend in model estimates versus area-swept & very low Q

2014/15: “observed” (area-swept) estimates

- Trend in estimates from previous models

2015/16: Mid-point between model survey-predicted estimates and area-swept estimates

- High uncertainty with model estimates for 2015

2016/17: 10% buffer on model survey estimate

- High uncertainty with model estimates for 2016

2017/18: “observed” (area-swept) estimates

- High uncertainty with 2017 model estimates
- Fishery performance

What's Next?

- Additional Research
 - Growth, maturity, movement, selectivity, stock structure, mating dynamics, natural mortality, recruitment mechanisms, etc., etc., etc.
- Model Improvements
 - Focus on specific areas for improvements (e.g., fit of large male Tanner)
- Harvest Strategy Updates
 - Better utilize model outputs (assessment + MSE)
 - Assess tradeoffs in conservation and optimum yield objectives
 - Re-assess spatial management
 - Must align with BOF 3-yr cycle



Ben's Plug for Annual ADF&G EBS Pot Survey

Looking for vessel/crew

Charter invitation to bid (ITB) out in late-Jan 2018

– Survey duration: ~25 days

Data needed for current year St Matt BKC assessment

– Timing: August 2018

For questions: vicki.vanek@alaska.gov; 907-486-1890

Up Next.....

Uncertainty in discard estimates

Estimating discards and problems with “legal, retained/not retained” categories in ADF&G at-sea observer data