Draft Risk Table: Appendix D to the 2024 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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Introduction

In December 2018, the SSC recommended that all groundfish assessment authors use the risk table when determining whether to recommend an ABC lower than the maximum permissible. In October 2023, the SSC requested that a draft risk table be developed for the Tanner crab. The following was used to complete the draft risk table, based on the template updated in 2023 to reflect only three levels of concern and implementing the SSC's December 2023 request regarding the labels for these levels:

	Assessment-related considerations	***Population dynamics considerations***	***Environmental/ecosystem considerations***	***Fishery Performance***
Level 1: Normal	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2: Increased concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types
Level 3: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. These considerations are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance considerations. Examples of the types of concerns that might be relevant in crab assessments include the following:

1. Assessment considerations—data-inputs: skipped surveys, lack of fishery-independent trend data; model fits: poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs; model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds; estimation uncertainty: poorly-estimated but influential year classes; retrospective bias in biomass estimates.
2. Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.
3. Environmental/ecosystem considerations—adverse trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.
4. Fishery performance—fishery CPUE exhibits a contrasting pattern to the stock biomass trend, unusual spatial patterns of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings.

Assessment considerations

The assessment model has been, and remains, a cause for concern regarding this assessment. While the model fits the fishery catch and bycatch data extremely well, it fails to achieve the dynamic range seen in survey biomass: underestimating the peaks and overestimating the valleys in a time series that exhibits decadal-scale variability. This inflexibility in the model points to constraints on processes in the model that should be allowed to vary with time, with natural mortality and survey selectivity as the most obvious candidates.

For this assessment, the effective sample size parameters for the Dirichlet-Multinomial likelihoods used to characterize fits to the 2013-2018 BSFRF SBS size compositions were fixed to their upper limits, with the implication that the true effective sample sizes were larger than the input sample sizes, to achieve model convergence and allow uncertainty estimates to be obtained. However, model convergence is a recurring issue with this assessment, and the models typically exhibit multiple local minima in the negative log-likelihood surface, requiring extensive jittering analyses to find the global minimum. Over time, several parameters have been fixed to an upper or lower bound to facilitate model convergence and allow uncertainty estimates to be calculated for model quantities.

These considerations are not new to the assessment, nor are the results for this year extreme.

Population dynamics considerations

Mature male biomass is currently used as the "currency" of Tanner crab spawning biomass for assessment purposes. However, its relationship to stock-level rates of egg production, a better measure of stock-level reproductive capacity, is unclear. Thus, use of MMB to reflect Tanner crab reproductive potential may be misleading as to stock health. Nor is it likely that mature female biomass has a clear relationship to annual egg production.

For Tanner crab, the fraction of barren mature females by shell condition appears to vary at decadal time scales (Rugolo and Turnock 2012), suggesting a climate driver. Clutch fullness quantifies the relative size (or absence) of the fertilized egg mass extruded by a mature female on her abdomen and reflects, in combination with her size, her contribution to the overall reproductive potential of the stock. Clutch fullness is thus a measure inverse to the fraction of barren mature females, which have no clutch. Decreases in clutch fullness may indicate reduced reproductive potential due to e.g., sperm limitation in males, lack of mating opportunities, or increased egg parasitism. Over the past two decades, clutch fullness (estimated from NMFS survey data) has tended to be higher for multiparous females than primiparous females in all size classes (Figure 1), although the differences tend to be small ($< 5\%$). 2023 exhibited the largest mean difference (27.5%) since 2005.

Tanner crab can be infected by a number of diseases and parasites, including black mat disease and bitter crab syndrome. Biological measurements on sampled Tanner crab captured in the NMFS EBS trawl survey include visual identification of infected or parasitized individuals. Because infection or parasitism may be expected to impact mortality through both direct and indirect effects, changes in the fraction of symptomatic crab may be indicative of changes in natural mortality not captured in the stock assessment. Thus, increases in the incidence of disease/parasitism would be cause for concern regarding stock health and potential bias in the assessment model. For males, the incidence of any signs of disease/parasitism by 5-mm size bin has generally been below 2.5% since 2005; small new shell males exceeded that limit in several years–with 2019 showing the highest incidence (Figure 2). Incidence values above 2.5% seem appear rather randomly (e.g., in 2021) for old shell males. For females, the highest incidence levels (~10%) are larger than those for males (Figure 3). The size distribution of incidence for old shell females exhibits a noticeable peak at ~60 mm CW in many years. Small new shell females exhibited relatively high incidence values in 2019, similar to that for small new shell males. In contrast, the prevalence of juvenile Tanner crab in the EBS survey specifically exhibiting visual signs of bitter crab disease in 2024, aggregated over size and sex, was in the "normal" range (Fedewa et al. 2024). Although it may be unrelated to the disease/parasitism incidence values shown here, the Tanner crab stock exhibited a dramatic decline in abundance across all size classes between 2019 and 2021 (Stockhausen 2023).

Clutch fullness returned to normal levels, after exhibiting low levels for primiparous females in 2023. However, the fraction of small crab exhibiting disease symptoms remained elevated, even though the aggregated prevalence of bitter crab disease in juvenile crab was in the "normal" range. The level of concern is thus considered "increased".

Environmental/Ecosystem considerations

Environmental Processes

During winter 2023/2024 and spring 2024, wind anomalies over the southern Bering Sea shelf opposed the mean currents and reduced transport of warmer waters from the south. In addition, stormy weather increased vertical mixing, which brought cooler water from depth. By June and July 2024, SST anomalies were reduced from as much as 1.52°C above monthly mean temperatures to as low as 1.52°C below monthly mean temperatures over the Eastern Bering Sea shelf (Lemagie and Bell 2024). While the average north-south component of the wind for winter 2023-2024 was almost exactly at the long term average, frequent changes in the storm track pattern and prevailing wind direction characterized the second half of the winter (Thoman 2024).

Sea ice formation was delayed due to warm SST anomalies in fall, as has been the norm since 2013. Eventually, the 2023-2024 average sea ice extent was slightly higher than 2022-2023. However, for the week of March 15-21, 2024, sea Ice thickness in most regions across the Bering Sea was slightly lower than the same week in 2023 (Thoman 2024).

Springtime temperature observations from the EcoFOCI survey over the southern shelf showed bottom temperatures averaged 2.52ºC at depth (300 m or 10 m off the bottom if shallower) and surface (top 5 m) temperatures averaged 2.782ºC. Mean sea surface temperatures were average to cool across the study region. The warmest bottom temperatures in spring 2024 were found near Unimak Pass and along the Alaskan peninsula, while the coolest temperatures were north of the Pribilof Islands, a typical pattern observed in the springtime (Axler and Rogers 2024).

Observations from the 2024 bottom trawl survey showed bottom temperatures were near the 1982-2024 time series average and slightly warmer than last year while surface temperatures were near the average but cooler than last year. The cold pool extent (area of 2°C bottom water) was near the time series average and 11% smaller than last year (Rohan and Barnett 2024).

Summer bottom temperatures in areas occupied by juvenile and adult Tanner crab were within normal ranges. The area occupied by male Tanner crab in the summer survey is high.

As of May 2024, bottom water pH and Ωarag, metrics of ocean acidification conditions, were both at their lowest point over the model record (since 1970; Pilcher et al. (2024)).

Overall, only the metrics for ocean acidification conditions were considered a potential matter for concern, while the transport and bottom temperature conditions were considered to potentially enhance larval retention and growth rates for early benthic instars, supporting a level of concern of “normal” for this component of the risk table.

Prey

Little information exists on trends specific to the abundance of Tanner crab prey on the EBS shelf. Chlorophyll *a* biomass provides an indicator of primary production and the April-May-June average over the outer EBS shelf may provide an index of prey abundance for Tanner crab larvae. Chlorophyll *a* concentration remains well below average in the south mid-outer shelf of the EBS (Fedewa et al. 2024). This suggests a less pronounced spring bloom and decline in large cell plankton like diatoms, which are a critical food source for crab larvae. Studies indicate that benthic invertebrates comprise an important component of adult Tanner crab diets, including brittle stars, sea stars, sea cucumber, bivalves, non-commercial crab species, shrimp and polychaetes. Summer benthic invertebrate density in the NMFS EBS shelf bottom trawl survey has been on a declining trend since 2010 (Fedewa et al. 2024), although it is not known whether the current levels are limiting or not.

Predators and Competitors

Pacific cod (*Gadus macrocephalus*) density in core Tanner crab habitats reached all time lows during the 2018-2019 marine heat wave but has increased annually since 2021 (Fedewa et al. 2024), suggesting the potential for increased predator-prey interactions and reduced survival of juvenile cohorts because Pacific cod is thought to account for a substantial fraction of annual mortality on Tanner crab (Livingston 1989; Aydin et al. 2007). The trends in biomass of Pacific cod in the

NMFS EBS shelf survey appear to have been negatively correlated (-0.186) with those of Tanner crab prior to 2010 (Figure 4), consistent with a role for predation by cod in regulating Tanner crab stock size . However, since 2010, the relationship is positive (0.759), which suggests that, if a relationship existed prior to 2011, its nature may have changed.

Despite depressed abundance of mature male Tanner crab from 2021-2023, mature male spatial extent increased and centroids of abundance have shifted northwest since 2023. Increased utilization of northern outer shelf habitats may increase competitive interactions with snow crab (Fedewa et al. 2024).

The level of concern is considered "normal".

Fishery performance

Fishery performance was based on recent trends in CPUE ("raw" kg/pot, not standardized) and spatial patterns of fishing effort in the directed Tanner crab fishery. As noted previously, ADF&G manages the Tanner crab fishery on a two-area basis, referred to here as East 166W and West 166W, with separate TACs set in each area. This year, total CPUE was higher than its long-term mean in the eastern area, but lower than its long-term mean in the western area. However, CPUE was higher in both ADF&G management areas than in 2022/23 (Figure 5).

CPUE was higher in the southwestern corner of the EBS shelf the past three years than it was prior to 2020/21 (Figure 6). It was concentrated along the southwestern Alaska Peninsula in 2023/24 more so than in 2022/23, but also extended more diffusely to the northwest along the outer shelf to Pribilof Canyon than was the case in 2022/23. CPUE in the eastern management area did not extend eastwards into Bristol Bay as it had in years when stock biomass was higher (e.g., 2013-2015).

Because NMFS survey catchability is less than 1, the ratio of the biomass of industry-preferred males caught in the fishery to the estimated biomass of those crab in the survey provides a conservative index of the level of exploitation of the stock by the fishery. Levels approaching 1 or larger might be cause for concern. The ratios in the western management area were among the highest in the time series in the past three years, while the ratios in the past two years were substantially smaller (see Figure 32 in main text).

Active vessels in the BSAI Tanner crab fisheries during 2023 was moderately below the time-series average, but unchanged from the previous year and on-par with fleet size over the last five years. Incidental catch of Tanner crab in EBS groundfish fisheries during 2023 was the lowest in the time-series history (Fedewa et al. 2024). No incidental catch occurred in the snow crab fishery because it was closed in 2023/24; little incidental catch occurred in the BBRKC fishery (see Table 8 in main text).

The level of concern is considered "normal".

Summary and ABC recommendation

The completed **DRAFT** risk table is:

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: Normal	Level 2: Increased concern	Level 1: Normal	Level 1: Normal

Because this is a draft risk table, no recommendations regarding an ABC buffer are made.

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Figures

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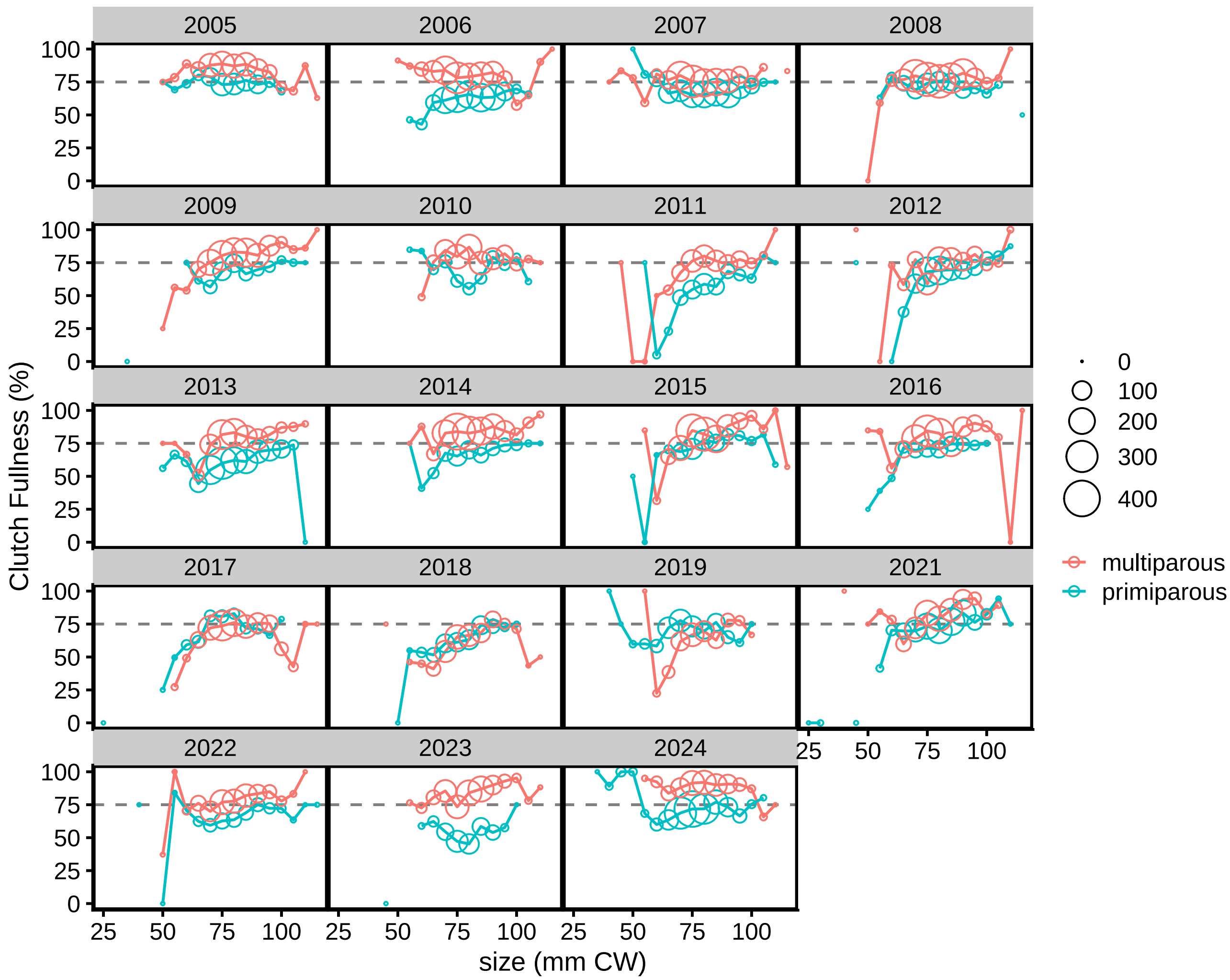

Figure 1. Annual size compositions by 5 mm size bin of mean clutch size for mature females by age (based on shell condition) from the NMFS EBS trawl survey, since 2004. Symbol size indicates the number of individuals sampled on which a ratio is based. For reference only, 75% clutch fullness is indicated by the horizontal dashed line. All “new shell” mature females were assumed to be primiparous (i.e., newly-matured and bearing their first clutch)) while “old shell” females were assumed to be multiparous (bearing their second or later clutch).

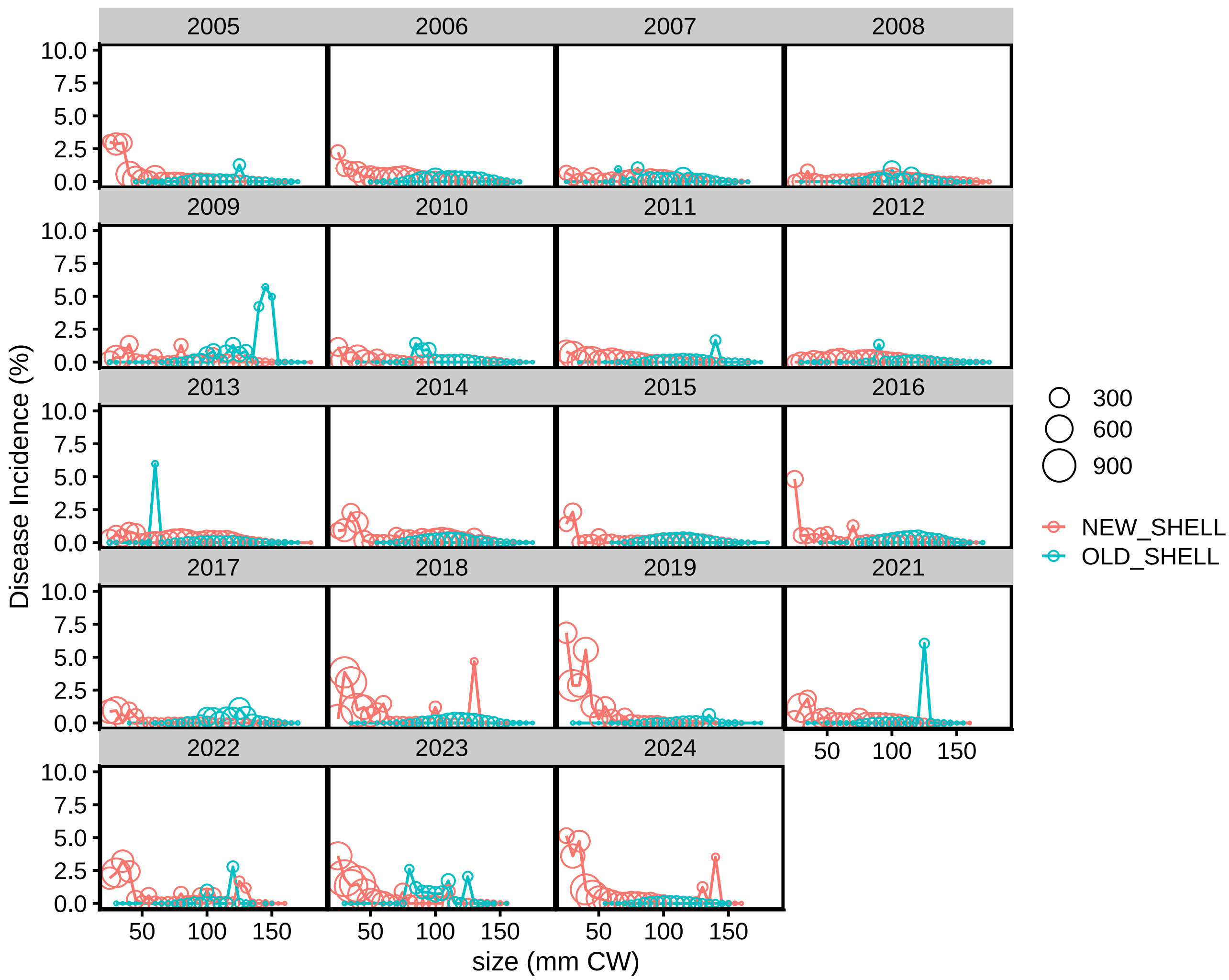

Figure 2. Annual size compositions by 5 mm size bin of disease/parasitism incidence for male Tanner crab, by shell condition, from the NMFS EBS trawl survey starting in 2005. Symbol size indicates the number of individuals sampled on which a ratio is based. Values do not reflect the degree to which any individual was infected/parasitized, only that an individual was classified as being infected or parasitized.

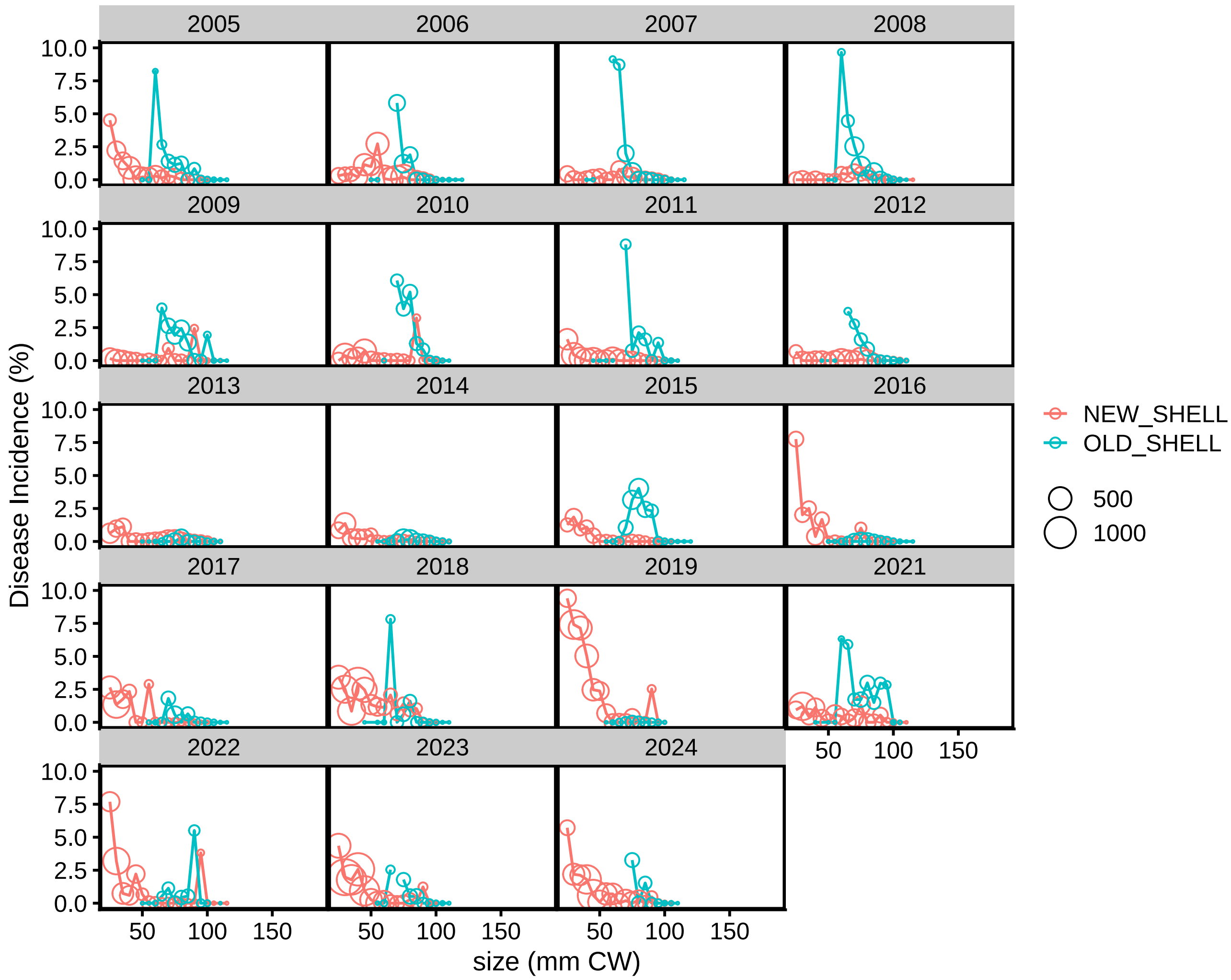

Figure 3. Annual size compositions by 5 mm size bin of disease/parasitism incidence for female Tanner crab, by shell condition, from the NMFS EBS trawl survey starting in 2005. Symbol size indicates the number of individuals sampled on which a ratio is based. Values do not reflect the degree to which any individual was infected/parasitized, only that an individual was classified as being infected or parasitized.

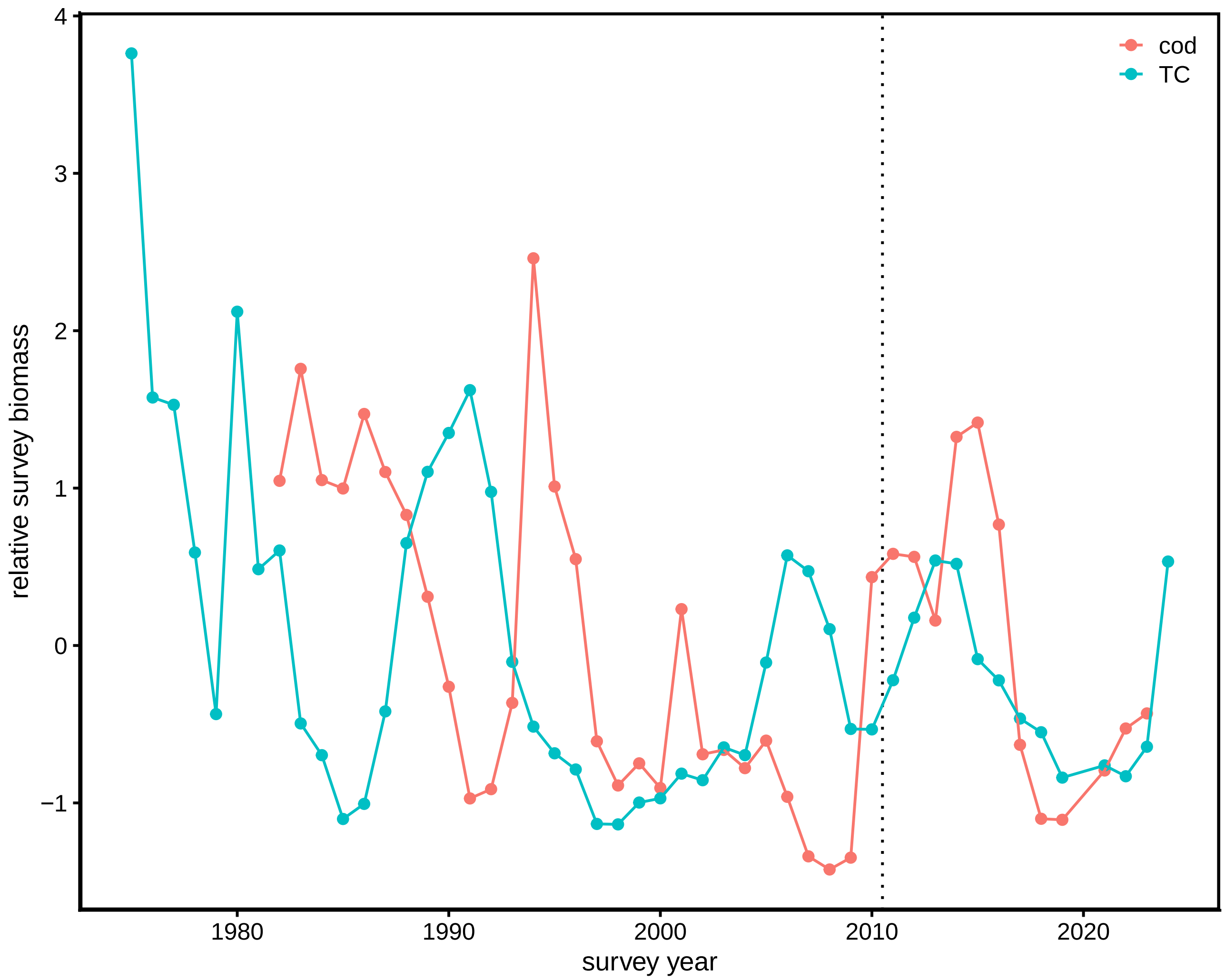

Figure 4. Relative trends in biomass for Pacific cod and Tanner crab (“TC”) in the NMFS EBS shelf survey. Vertical line indicates time of potential change in correlation between the time series.

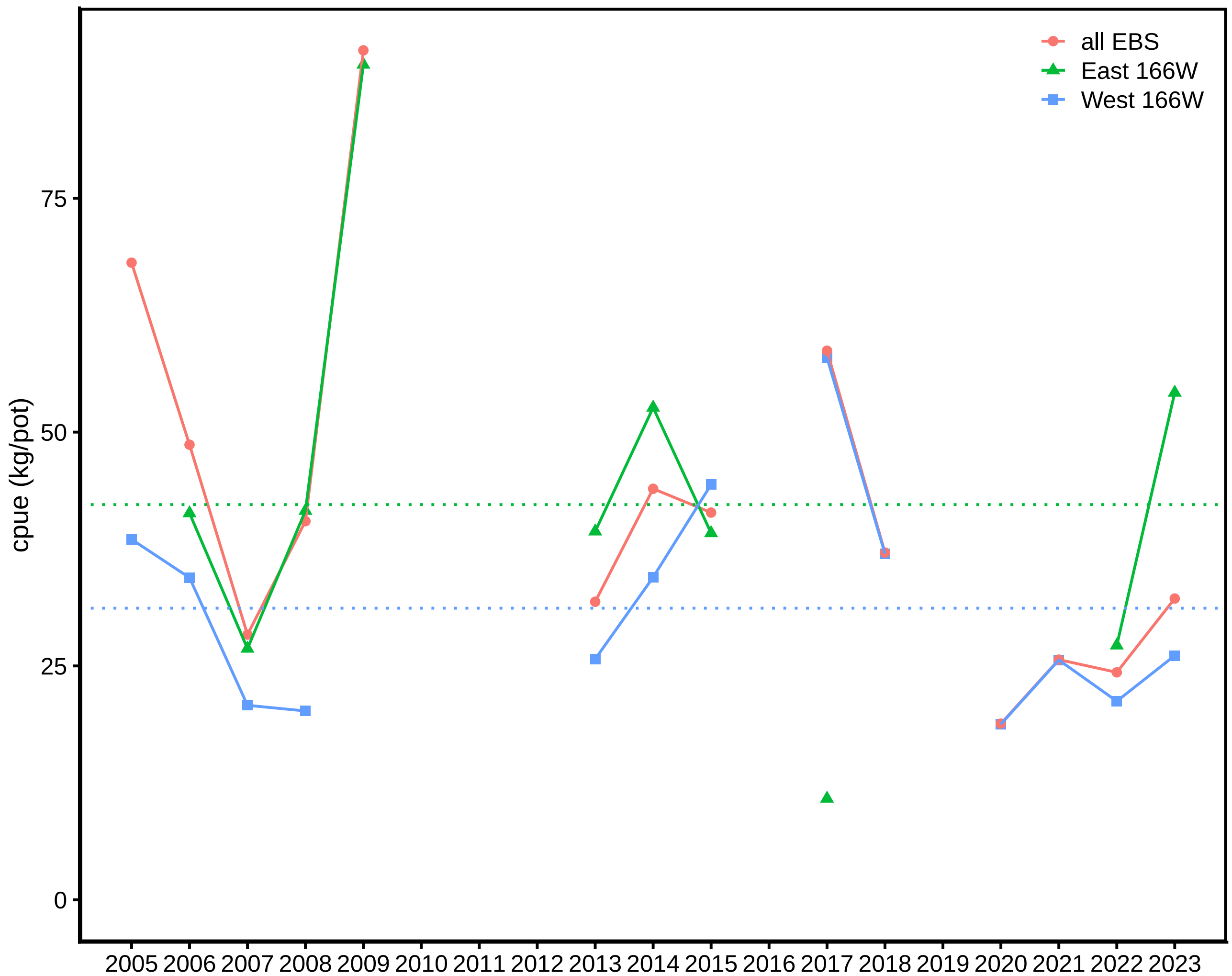

Figure 5. Trends in total CPUE (kg/pot) in the directed Tanner crab fishery, by ADF&G management area, since rationalization. The values labeled as 'all EBS'represent the CPUE for the combined areas. The dotted lines represent the longterm means for the two management areas.

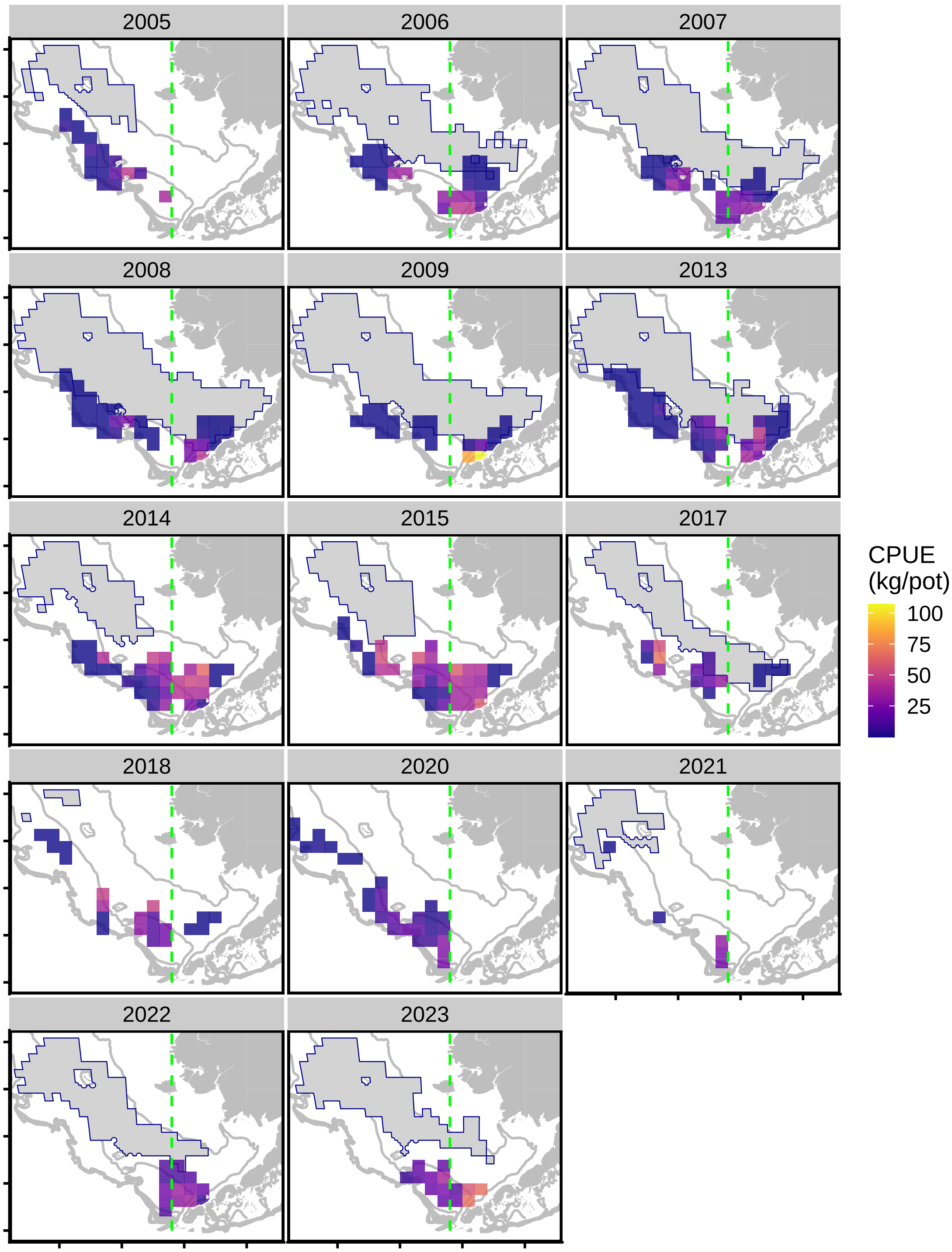

Figure 6. CPUE (kg/pot) in the directed Tanner crab fishery by ADF&G statistical area since rationalization. Lighter colors indicate higher CPUE. Results are shown only for statisitcal areas with more than 3 vessels reporting. The 166°W longitude line separating the two ADF&G management areas is indicated by the dashed line. The location of the cold pool at tbe time of the NMFS EBS trawl survey is indicated by the grey polygon.

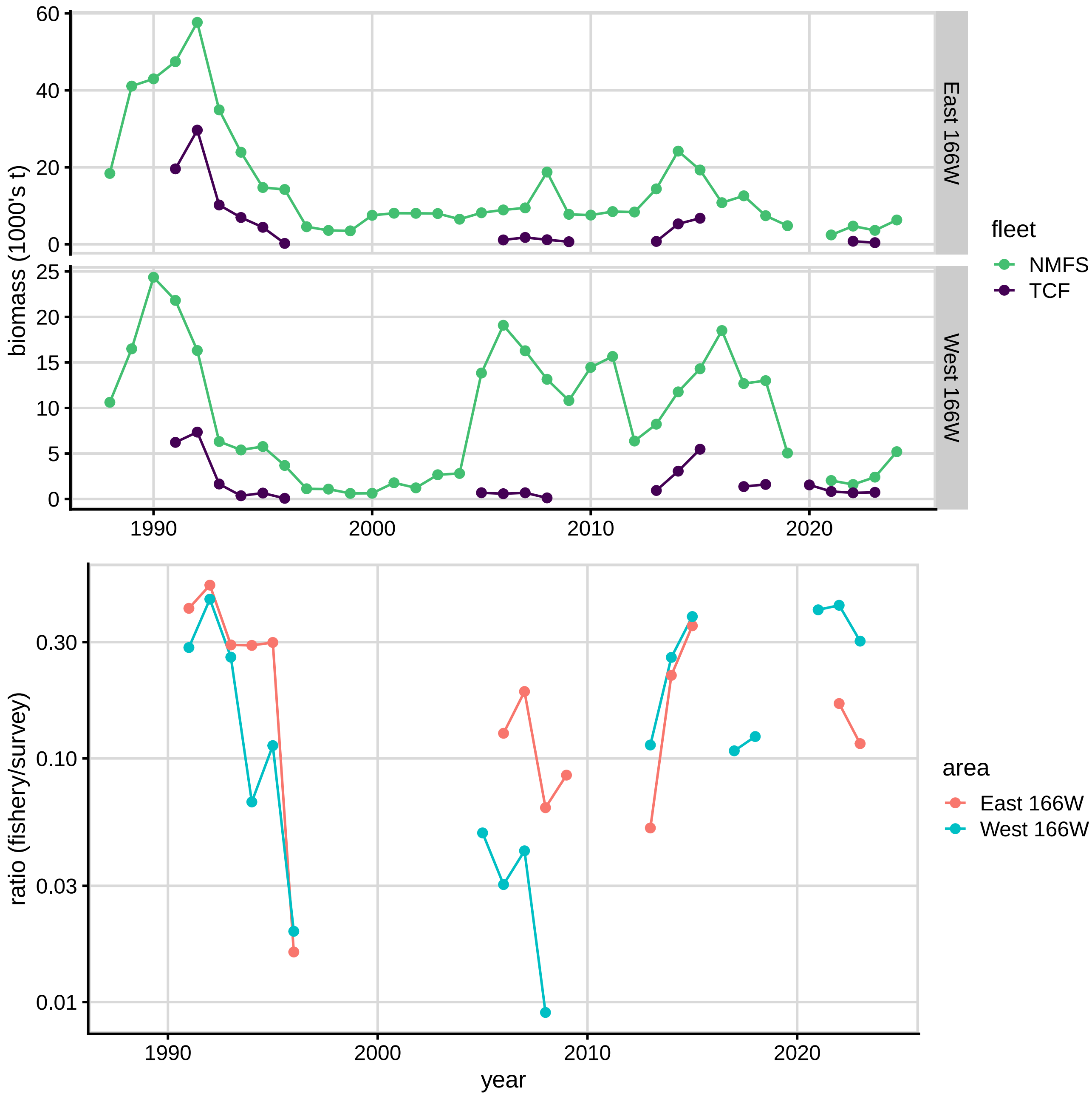

Figure 7. Comparison of the biomass of industry-preferred size males caught in the directed fishery ('TCF') and estimated from the NMFS EBS shelf survey. Upper plots: biomass, by ADF&G management area. Lower plot: ratios of fishery to survey biomass (log10 scale). The survey values correspond to the beginning of the fishery year.