EXAMINATION OF LENGTH-WEIGHT RELATIONSHIP IN DUNGENESS CRAB, *CANCER MAGISTER,* WITHIN WHIDBEY BASIN AND RECOMMENDATIONS FOR MORE ROBUST DATA COLLECTION

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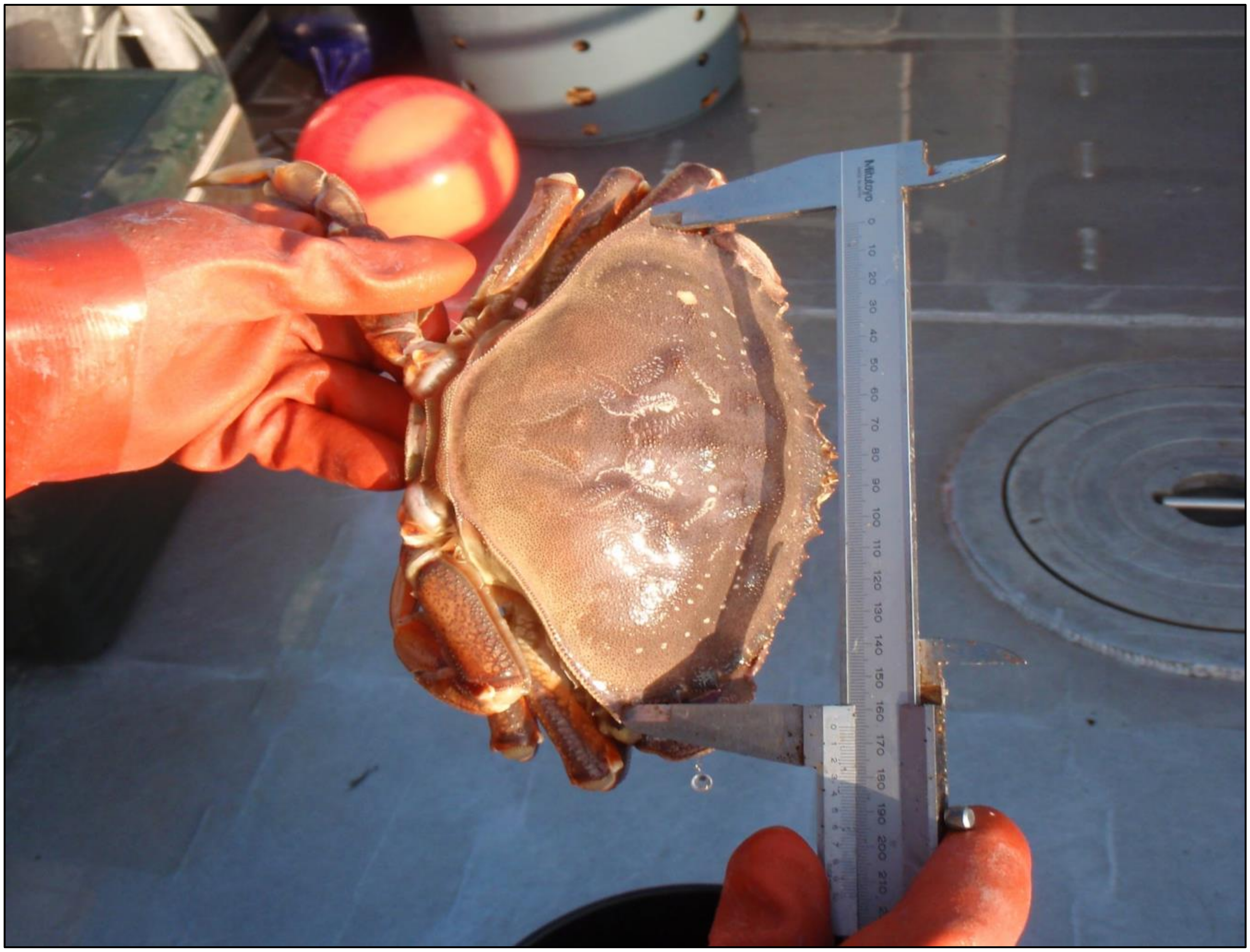

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ABSTRACT

The Dungeness crab, *Cancer magister*[1], fishery is co-managed by state and treaty tribe managers with annual quotas based off a running average of the most recent years catch and harvest allocations split evenly (i.e., 50/50) between co-managers. While tribal and state commercial harvest is recorded at the point of sale by weight, state recreational harvest uses mean crab weight to calculate the number of pounds harvested based on the number of crab taken. Currently, the mean crab weight used by the state, 816.5 g, is based off a Puget Sound-wide average. However, if mean crab weight differs by region, recreational harvest estimates should also, ideally, be adjusted by management region. Over 60% of the Swinomish Indian Tribal Community's harvest comes from Management Region 2 East (2E), where the mean weight of an individual crab has not been thoroughly quantified. In this pilot study, we targeted specific locations and hypothesized that mean weight of crab from two catch areas within 2E would be different from mean crab weight used by the state to estimate recreational harvest. Using test fishery data, we examined the mean weight of legal-sized male crab in Crescent Harbor and Similk Bay. Crab length-weight and length-width relationships were also quantified from these two areas. We found that the mean weight of legal-sized male crabs was 7.4 % heavier than the weight used by the state to estimate recreational harvest. These pilot study results demonstrate the need for a more comprehensive study on crab length-weight relationships throughout 2E and mean crab weight by management region; these data could be obtained through simple modifications to the current crab test fishing protocol.

Keywords: Dungeness crab, *Cancer magister*, length-weight, test fishery, Puget Sound, Salish Sea

[1] Scientists are currently debating if Dungeness crab belong in the genus "*Cancer*" or "*Metacarcinus*". Based upon the latest review paper, we have opted to utilize the name *Cancer magister* in this report (Rasmuson 2013).

INTRODUCTION

Dungeness crab, *Cancer magister*, is not only a culturally and economically-important species to the Swinomish Indian Tribal Community (SITC) but also supports an annual multi-million dollar fishery along the northeast Pacific coast (PSMFC 2014). Since the Rafeedie Decision in 1994 (US vs Washington state), the Dungeness crab fishery in Washington state has been co-managed by the Washington Department of Fish and Wildlife (WDFW) and the treaty tribes located in the state. Management of the fishery is based upon a 3-S strategy which regulates catch based on size, sex, and season with the aim of maintaining maximum sustainable yield (Fisher & Velasquez 2008). Since the 1970's, Dungeness crab harvest in Washington waters has increased consistently along with fishing effort. Although Dungeness crab populations appear to have remained relatively stable under current management practices, there is increasing concern regarding the long-term sustainability of the fishery given that total annual harvest (based on a five-year average) more than tripled between 1987 and 2013 (R. Conrad, Northwest Indian Fisheries Commission, unpublished data). Annual total allowable catch (TAC) for each region is based on a running average of the most recent years total catch. The TAC is allocated equally between the state and tribes; a large percentage of the state's allocation goes toward their recreational fishery. Catch accounting for tribal and state commercial harvest is recorded by weight at the point of sale, whereas state recreational harvest is based on a catch record card system to estimate the number of crab harvested. The state then uses a Puget Sound average weight of 816.5 g/crab to calculate total kilograms harvested based on the number of legally-sized male (LSM) crab taken.

The Dungeness crab fishery is particularly important to SITC and represents the Tribe's most economically-valuable fishery. Although SITC fishes in multiple management regions, over 60% of the tribe's annual harvest comes from Catch Reporting Areas (CRA) 24A and 24C within Management Region 2East (2E) (Figure 1). If the LSM crab in a given area exhibit different length to weight relationships or a different mean size than that used by WDFW, there could be overlooked management implications. For example, if mean crab weight differs by region then recreational harvest estimates should also, ideally, be adjusted by management region. This is especially true if the regions in question experience higher than average recreational fishing pressure. Although WDFW conducted creel surveys in 2015, providing data that implied higher recreational harvest rates in 2E, the precise harvest locations of the crab were not recorded (Velasquez 2015). Results from the creel survey further suggest that crab in 2E weigh more than crab in other regions, although crab weight was only calculated in this study and not measured.

Prior to opening the Dungeness crab fishing season in 2E the tribes conduct test fisheries to determine the condition and relative percent of hard-shell crab in each CRA. Swinomish's fishery-dependent test fishery allows for the collection of region-specific data on Dungeness crab populations. Field observations from these test fisheries, combined with the WDFW creel survey results, lead SITC staff to hypothesize that the 2E crab were slightly larger than crabs in other management regions. In order to determine whether the size of harvestable crab within an important Swinomish management area were in consonance with the current model for estimating recreational harvest, we examined data from three fishery-dependent test fisheries carried out over a span of three years. Because this initial effort was a pilot project, data were only collected from one area within CRA 24A (Similk Bay) and CRA 24C (Crescent Harbor). We also examined the current protocol for conducting Dungeness crab test fisheries to identify any gaps that could be addressed. The primary goals of this pilot project were to 1) analyze the mean size and weight of crab harvested in two important CRAs in 2E, develop a length-weight model, and compare results with the mean size and weight used by WDFW for recreational harvest estimates; 2) examine current methods used by SITC to conduct Dungeness crab test fisheries; 3) explore relevant questions which could be answered using fishery-independent versus fishery-dependent test fishing data; and 4) provide suggestions for modifications to the SITC Dungeness crab test fishing protocol in order to provide the most relevant and robust data possible to managers.

METHODS

Swinomish test fishing overview

Swinomish fishes for Dungeness crab in Management Regions 1, 2E, 2 West, and 3 (Figure 1). Fishing seasons in regions and sub-regions are set to ensure the fishery remains closed during peak molting periods. Based on the timing of peak molt, opening dates vary by region (e.g., June 1st in 2E or July 1st in Region 1). Prior to the opening of a management region, test fisheries are conducted to determine the relative percent of hard-shell to soft-shell crab. Test fishing protocol varies somewhat depending on the manager's intent. Fishery-dependent tests are carried out on commercial fishing vessels whereas fishery-independent tests are performed by researchers, are

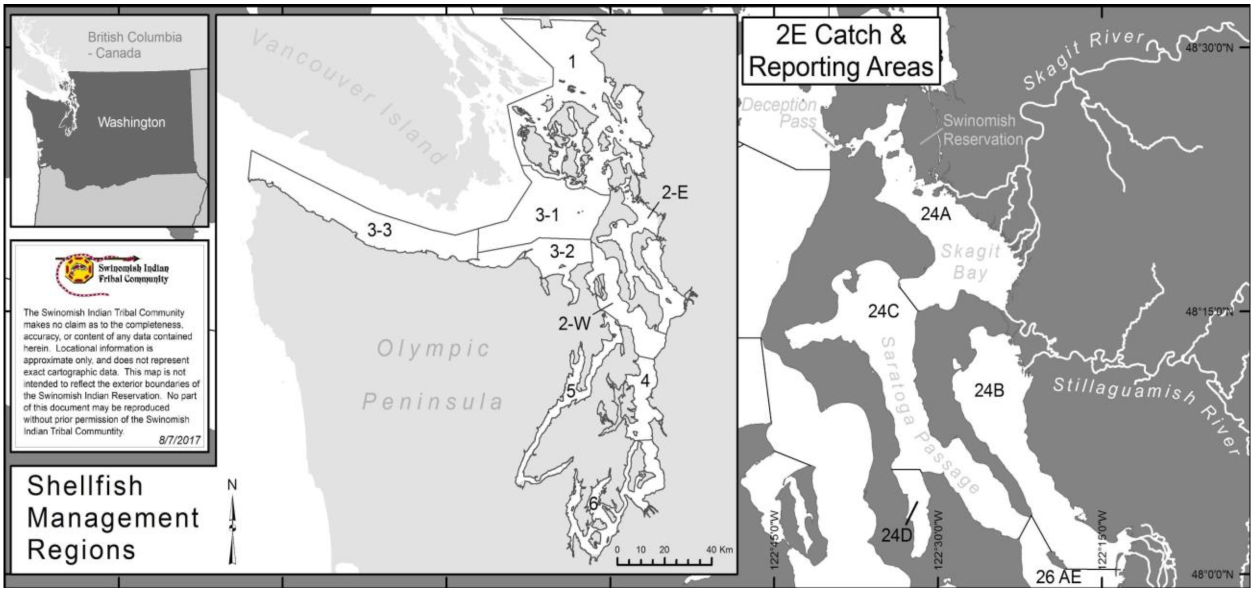

Figure 1. Location of the Swinomish Indian Reservation and Shellfish (Crab) Management Regions, including Catch and Reporting Areas in 2E (Whidbey Basin). Sub-regions 24A and 24C are particularly important to the Swinomish Tribe.

typically more targeted, and involve less gear. The biological criteria for opening a fishery is that 80% of all LSM crab are classified as stage 1 or 2-1 (Appendix A) of which a minimum of 60% of the crab are stage 1. These criteria are set in order to reduce handling mortality and provide a higher quality product for the commercial fishery.

Test fishery locations stratify data collection within a management region. Currently, SITC uses fishery-dependent test fisheries during which approximately 80 commercial pots are deployed using varying bait types and amounts within a CRA. Traps are set within a range of depths 9 - 55 m and left to soak for a minimum of 12 hrs (not to exceed 36 hrs). Sex, shell condition, depth, and location caught are recorded for each crab. The test fishery sample size for the first opening of the season must include a minimum of 300 LSM crab. In order to extend the end of a season, between 100 and 150 LSM crab must be sampled depending on the region.

Length-weight subsampling

We used data collected from May 2015-2017 test fisheries in 2E, which includes CRAs 24A and 24C (Figure 1). Data were specifically collected in Similk Bay (CRA 24A) and Crescent Harbor (CRA 24C) for this pilot project (Figure 2). For these particular test fisheries, crab pots were deployed at depths ranging from 8-20 m and 13-33 m in Similk Bay (24A) and Crescent Harbor (24C), respectively. Pots were left to soak for a 24 hr period before being hauled. Stage 1 and 2-1 male crab with a carapace length ≥158.75 mm were retained. Crab were held on test fishing vessels in plastic containers where they were allowed to dewater during transport. Upon return to port, a subsample of crab from these containers were weighed and measured to obtain a desired sample size (n ranging from 63-114 per container). Each crab was measured across the carapace at the widest point immediately in front of the tenth antero-lateral spine using vernier type calipers (± 0.02 mm) in order to determine carapace length. Carapace width was measured along a line perpendicular to carapace length from between the eyes to the posterior margin. Crab were then weighed using a Dune compact scale (± 2 g). Crab missing legs or claws were not weighed. An ordinary least squares regression model was used to examine the relationship between carapace length and crab weight within these two 2E sites. The mean weight of legal-sized male crabs was calculated for CRAs 24A and 24C as well as for the two areas combined and data were also combined across all years. An ordinary least squares regression was fitted to the relationship between carapace length and carapace width to estimate mean carapace width (R 2014).

RESULTS

Between the years of 2015 and 2017, 199 crab were sampled from 24A and 247 crab from 24C (total n =

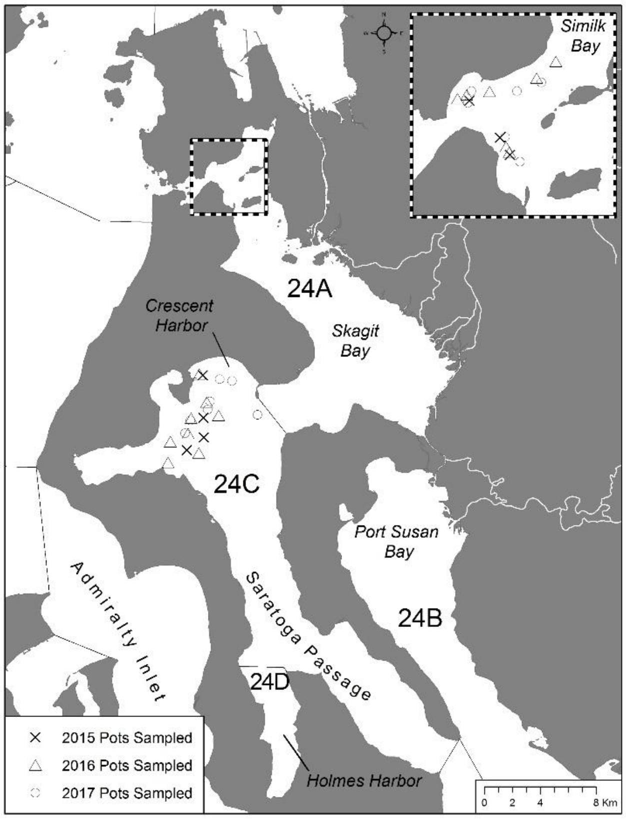

Figure 2. Crab length, width, weight sampling locations in Similk Bay and Crescent Harbor.

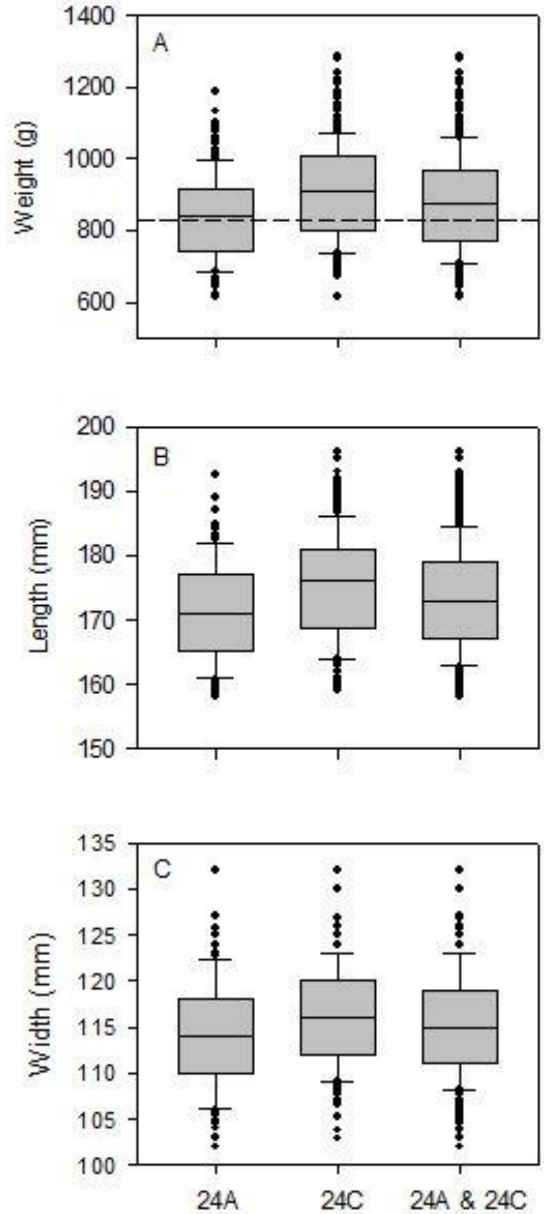

Figure 3. Box plots. A = Distribution of legal-sized male Dungeness crab, *Cancer magister*, weight by specific location within catch reporting areas in Swinomish Management Region 2 East (24A: n = 199; 24C: n = 247). Dashed line = 816.5 g weight used by Washington Department of Fish and Wildlife to estimate recreational harvest. B = Distribution of carapace lengths (24A: n = 199; 24C: n = 247). C = Distribution of carapace widths (24A: n = 127; 24C: n = 155). For all graphs, catch report areas 24A = Similk Bay and 24C = Crescent Harbor.

446 crab). The mean weight of a LSM crab in 2E was 877.0 g ± 6.3 SE, with mean weights in CRA 24A of 838.0 g ± 8.5 SE and 908.5 g ± 8.5 SE in area 24C (Figure 3). The mean carapace length of LSM crab in 2E was 173.6 mm ± 0.4 SE, with mean lengths in CRA 24A of 171.5 mm ± 0.6 SE and 175.2 mm ± 0.5 SE in area 24C (Figure 3). Regression analysis showed a linear relationship between crab carapace length and weight ($F_{1,\ 444} = 2895$, $p < 0.01$, $r^2 = 0.87$). The equation for the relationship [weight = 15.0(length) – 1726.6] can be used to predict the average weight of male crab within Crescent Harbor and Similk Bay based on carapace length (Figure 4).

The mean width of LSM crab in 2E was 114.0 mm ± 0.3 SE, with the mean width of LSM crab in 24A at 114.4 mm ± 0.5 SE and 116.0 mm ± 0.4 SE in 24C (Figure 3). Regression analysis revealed a linear relationship between carapace length and carapace width ($F_{1,\ 280} = 773.8$, $p < 0.01$, $r^2 = 0.73$). The equation for the relationship between carapace length and carapace width of LSM crab within Similk Bay and Crescent Harbor is [width = 0.58(length) + 14.5] (Figure 5).

DISCUSSION

Our results show that the mean weight of LSM crab in Similk Bay and Crescent Harbor (within CRAs 24A and 24C, respectively) is 7.4 % higher than the 816.5 g used by WDFW to determine recreational harvest. It is important to recognize that more widespread data collection throughout 2E is necessary before final conclusions regarding the mean weight of 2E crab can be determined. If future comprehensive results show that crab in these areas consistently weigh more than the current WDFW model assumes, it is likely that recreational harvest in 2E is underestimated. Both state and tribal commercial fisheries use shellfish CRAs for regional management of commercial harvest, however different CRAs are used for state recreational harvest. Importantly, Marine Area 8-1 (Appendix B) consists of the two CRAs presented here as well as CRA 24D (where data were not collected for this study) (Figures 1 & 2). The recreational crab fishery during summer of the 2016 season was estimated to have landed 250,086 crab from Marine Area 8-1 (WDFW Crab Recreational Catch Estimates) which, calculated at 816.5 g, represents 204,195.2 kg harvested. If an adjusted weight of 877.0 g were used instead, however, the recreational harvest for that period would amount to 219,325.4 kg (a difference of 15,130.2 kg). While the data presented in this study are only representative of two regions within these CRAs, our sites were selected because they are heavily fished by SITC and recreational crabbers. Indeed, of the nine marine areas monitored in a 2015 creel survey conducted by WDFW, areas 8-1 and 8-2 appeared to experience the greatest recreational fishing effort (Velasquez 2015). Thus, while we recognize this pilot study does not encompass samples taken systematically throughout all of 2E, these results are probably a good representation of mean crab weight from some of the more heavily fished areas in 2E.

In recent years it has been suggested that the minimum size of legal crab be raised, with proponents of the idea citing evidence that after a short period of stabilization an increase in minimum size could increase harvestable pounds without increasing TAC (D. Velasquez, personal communication). The legal minimum size has been raised in the past and if minimum size were to increase in the future it would likely also necessitate an increase in crab pot escape ring diameter. While the data presented here provide a length-width equation which could be used to examine the effects of escapement ring size on LSM crab in Whidbey Basin, it is also likely that there is considerable variability in length-weight relationships within different reporting areas. Given the possibility of such changes to the fishery, it is important that co-managers have sufficient data to determine the impacts these types of regulatory changes might have on local fisheries.

The southern Salish Sea is made up of the Strait of Juan de Fuca, the San Juan Islands, and Puget Sound (Moore et al. 2008, PSEMP Marine Waters Workgroup 2016). The complex hydrodynamics of the

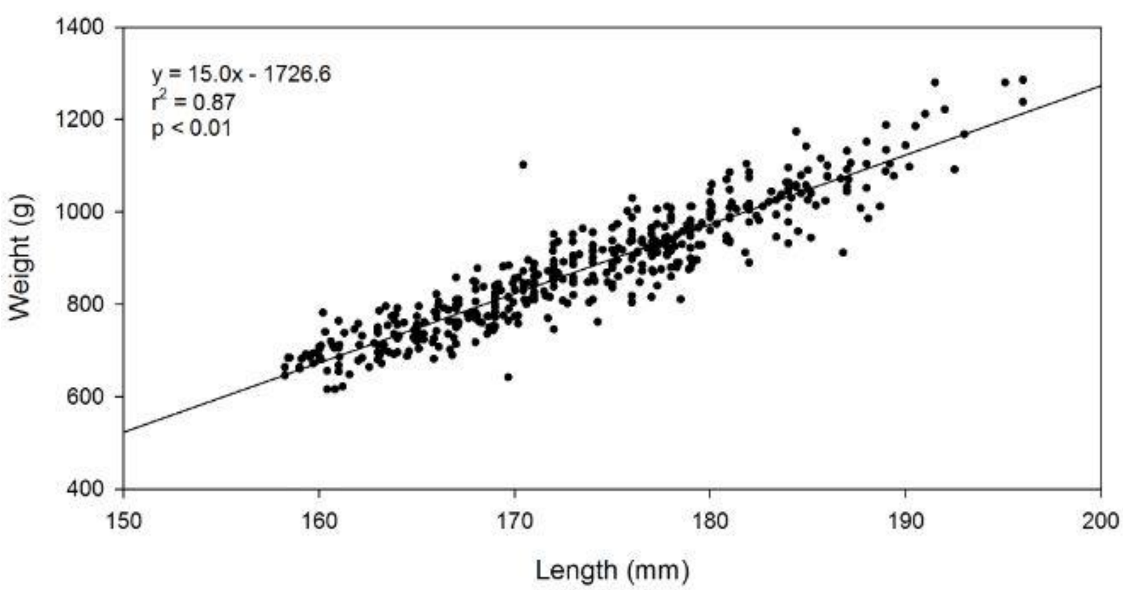

Figure 4. Length - weight relationship of legal-sized male Dungeness crab, *Cancer magister,* in Swinomish Management Region 2 East. Solid line shows ordinary least squares regression model, n = 446.

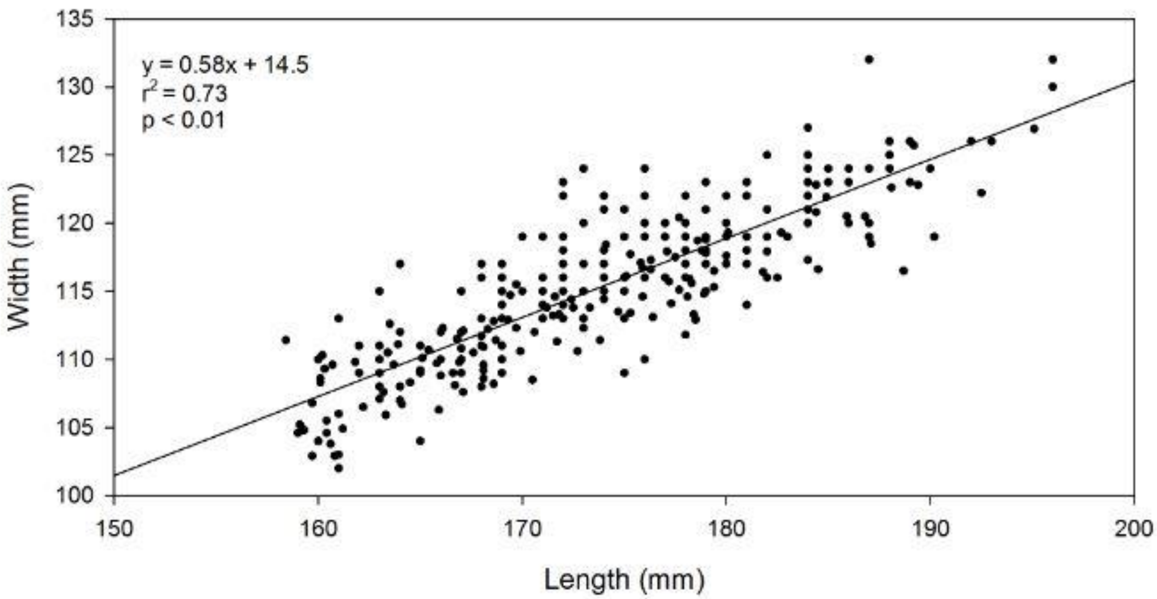

Figure 5. Length - width relationship of legal-sized male Dungeness crab, *Cancer magister,* in Swinomish Management Region 2 East. Solid line shows ordinary least squares regression model, n = 282.

southern Salish Sea, including the sub-basins of Puget Sound, may account for decreased population connectivity (Rasmuson 2013). This hypothesis is supported by the evidence of three distinct cohorts in the region: oceanic, Puget Sound, and Hood Canal (Dinnel et al. 1993). Yet, recent studies have only quantified genetic differentiation between Hood Canal crab and other areas of Puget Sound combined; there was no evidence of genetic connectivity among four other Puget Sound crab populations located in different sub-basins (Jackson & O'Malley 2017). This result is particularly interesting because our data suggest the crab in Similk Bay and Crescent Harbor may be slightly heavier than crab elsewhere in Puget Sound. Thus, we believe it may be worthwhile to expand a crab weight study to encompass the complete area of 2E. Although genetic connectivity may be strong within Puget Sound (except Hood Canal), there may be phenotypic differences in crab sub-basin populations that are important to understand to improve management of the fishery.

Although the current SITC protocol for conducting fishery-dependent crab test fisheries is sufficient for establishing the timing of fishery openings based on biological criteria agreed upon by co-managers, we believe additional data could be collected with the addition of a fishery-independent test fishery. Given the significance of this fishery to SITC, it is important that every effort be taken to ensure the most effective management practices possible. Some relevant questions and analyses that we feel could be addressed with modified survey methods are:

- Does mean weight of harvestable male crabs vary between and within CRAs throughout all of 2E and how does this compare to the WDFW mean weight used to estimate recreational harvest?
- What is the relative abundance of sex and size throughout CRAs fished by SITC?
- What portion of soft-shell crab are of a size class that might contribute to the fishery given time to harden their shell?
- Historically, morphological variation within CRAs has been qualitatively observed; how do characteristics such as crab width, length, and weight relate and how do these relationships vary spatially?

We suggest the following sequential data collection methods to answer the above questions [revised from Dunham et al. (2011)]. These recommendations could also provide more robust data should further management questions arise.

- Within each 2E CRA a pre-determined number of pots should be set at fixed depths (e.g., 10, 20, 30 m). Pots should be set approximately 100 meters apart and at the same location during each consecutive survey.

- Gear and bait as well as soak duration should be standardized so that catch per pot can be used as a measure of relative abundance.
- Upon collection, the entire catch from each pot should be placed in individual bins. Processing should take place on the boat and should involve determination of species, sex, length, width, weight, shell condition and bycatch. Data from malfunctioning traps would not be included.
- Record water quality parameters such as temperature and salinity at select pot locations to create profiles at survey depths.
- Surveys would need to be repeated annually at each of the sites to quantify variability within and between CRAs.

It is our opinion that standardized fishery-independent survey methods among co-managers of the Dungeness crab fishery in Washington would allow for more comprehensive and meaningful analysis of data throughout the region and place the fishery in the best possible position to adapt to potential unforeseen changes.

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Appendix A

Washington Department of Fish and Wildlife Dungeness Crab Shell Condition Stages

<u>Stage</u> <u>Shell Condition Description</u>

3-2 <u>Newly molted</u> - The exoskeleton feels like parchment, is very pliable and can be easily deformed without breaking. Endocuticle mineralization has begun.

3-1 <u>Recently molted</u> - The entire exoskeleton has begun to harden but can still be easily deformed. The dorsal side of the carapace will bend or crush under light pressure.

2-2 <u>Early intermediate phase</u> - This is the main period of tissue growth. The dorsal surface of the carapace continues to harden and is now only flexible at the posterior, left and right margins. The anterior ventral edge of the carapace and upper segment of the first walking leg are very flexible but will readily spring back into shape after pressure has been applied.

2-1 <u>Late intermediate stage</u>- Tissue growth continues. The dorsal side of the carapace is now hard. There is little to no flex left in the posterior dorsal edge of the carapace. The anterior ventral edge of the carapace and upper segment of the first walking leg are not yet firm. Additional tissue growth and endocuticle mineralization are needed to firm the exoskeleton at these points.

1-2 <u>Late hard shell stage</u> - The anterior ventral edge of the carapace and upper segment of the first walking leg are now firm when moderate pressure is applied. The color of the entire exoskeleton is beginning to darken and the crab is in prime quality for market.

1-1 <u>Pre-molt stage</u>- The color of the ventral surface of the exoskeleton is now dark yellow or brown. The crabs show signs of age; i.e. the exoskeleton may be damaged and may support sessile epifauna and may be starting to separate at the epimeral suture.

1-1M <u>Imminent-molt stage</u>- The color of the ventral surface of the exoskeleton is now dark yellow or brown. The crabs show signs of age; i.e. the exoskeleton may be damaged and may support sessile epifauna and may be starting to separate at the epimeral suture. <u>The shell is becoming flexible indicating imminent molting</u>.

Appendix B

Map showing Washington State marine management areas used for recreational Dungeness crab management.

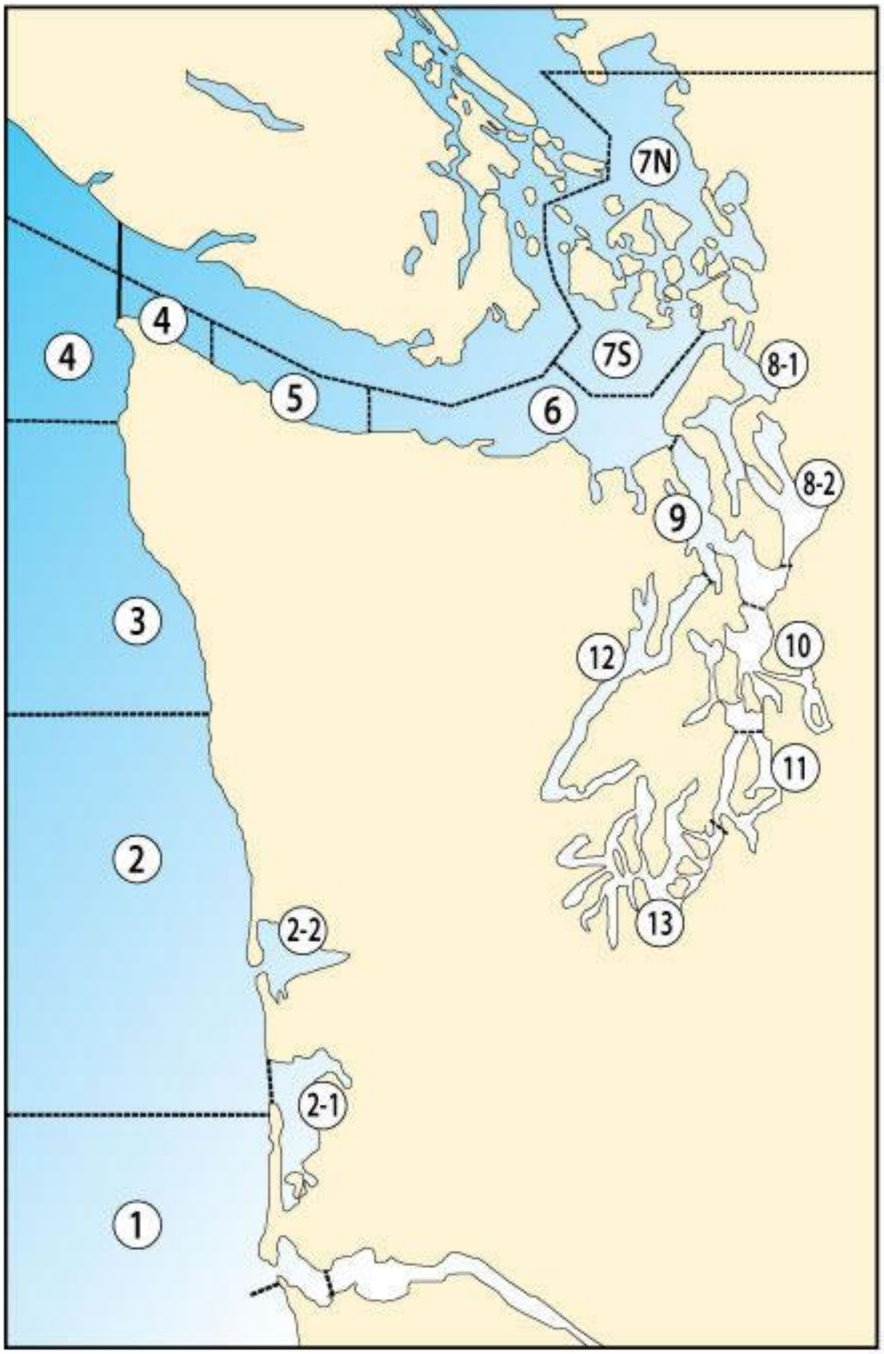

Image from: http://wdfw.wa.gov/fishing/shellfish/crab/