Exempted Fishing Permit #2019-01:

Final Report
May, 2021

Biological sampling of incidentally-caught red king crab (*Paralithodes camtschaticus*) in the Bering Sea and Aleutian Islands yellowfin and rock sole fisheries

EFP Applicants:
Cory Lescher (M.S. Candidate) and Dr. Bradley Harris
Fisheries, Aquatic Science, and Technology (FAST) Laboratory
Alaska Pacific University
4101 University Dr
Anchorage, AK 99503

Collaborators:
Mr. John Gauvin, Alaska Seafood Cooperative
Dr. Noëlle Yochum, RACE Division, Alaska Fisheries Science Center, NOAA

EFP # 2019 - 01

This exempted fishing permit (EFP) authorized selected vessels participating in the 2019 Eastern Bering sea bottom trawl catcher/processor sector to conduct experimental fishing to provide detailed information on two primary aspects of trawl-bycaught red king crab (RKC) in the yellowfin and rock sole fisheries: an exploration of RKC catch estimation accuracy by comparison of census to observer sub-sampling and extrapolation and an examination of vitality metrics to predict delayed discard survival for RKC. This report includes 1) a summary of project objectives, initial exemptions requested, problems encountered, and improvised solutions; and 2) a full report on the single EFP objective carried out.

Summary of project objectives (Purpose and Goals)

The overall goal of this project was to enhance our understanding of RKC catch rates and vitality metrics in the groundfish trawl fishery. Primary objectives of the project were to:

1. Collect basic biological data from bycaught RKC to examine key characteristics of interest to the industry and managers (sex, size, shell condition, clutch assessment for females).
2. Use whole-haul census of RKC to make empirical estimates of haul-level sampling variance from sub-sample estimates.
3. Examine how RKC PSC rates are influenced by haul characteristics and environmental variables.
4. Examine potential vitality metrics and/or environmental and biological variables that can be used to predict delayed discard mortality.

Exemptions requested

Exemption for comparison of whole-haul and subsampling:

The requested exemption was to delay discard of red king crab for a longer period than under normal discarding operations to conduct the whole-haul assessment and gather individual crab-specific biological data. The estimated additional per crab handling time was 1 – 2 minutes, with large hauls (e.g. >200 crab) potentially requiring additional time to complete data collection. The exemption applied to up to five Amendment 80 vessels performing standard fishing practices between January and April 2019 in the Bering Sea yellowfin sole and rock sole fisheries. Selected vessels could participate in the EFP for up to four trips each resulting in up to 40 fishing days per vessel, providing a total expected sample size of up to 200 hauls.

Exemption for at-sea crab vitality pilot study:

The second requested exemption was to hold RKC on board for a longer period than under normal discarding operations in order to assess their survival. The estimated additional per-crab holding time was 72 hours (in circulating sea water). The exemption applied to two Amendment 80 vessels for up to two fishing trips each between January and April 2019. Given the on-deck tank capacity and the aim of a 72-hour holding period, we anticipated holding up to 96 crabs for each vessel per trip or 384 crabs total in on-deck tanks for observation. At the end of each crab's 72-hour holding period, the crab were to be returned to the sea.

Problems

The EFP proposal was presented to the NPFMC Council in October of 2018 and final EFP granted for field work to begin January of 2019. Due to unforeseen circumstances resulting from the government shutdown in December and January 2018-2019 the final signed copy of the permit was delayed, and fieldwork was postponed to February. More importantly, the vessels working under the whole-haul and subsampling component of the EFP had planned to fish for rock sole and other species in Zone 1, where we expected RKC encounters to be sufficiently high to support the proposed work. Unfortunately, the abundances of both Pacific cod and halibut were very high in Zone 1, and these vessels had to move to other areas where RKC catches were very low or zero. Concerned that the project would not encounter enough RKC for the census study to provide meaningful results, we submitted a request to the NMFS Alaska Regional Office for an immediate amendment to expand the scope of the EFP to include snow and Tanner crab. No changes were requested for the vitality component of the EFP. Unfortunately, it was determined by NMFS that the request was outside the scope of the application and EFP as issued and such a modification would have required an additional formal application and review. Thus, due to the upcoming field work and inherent time constraints of the application process, the request was not approved.

As anticipated, very few RKC were encountered by the participating vessels and to salvage the census study we opted to revise our data collection methods to allow the complete census of snow and Tanner crab in a manner that did not require an EFP. This entailed counting all snow and Tanner crab on the belt without handling or removing them from the factory sorting line. An unfortunate consequence of this approach was that biological data from snow and Tanner crab could not be collected but this did allow for a complete census of catches per haul. As this work was not conducted under the EFP it is not presented here. Analyses of the snow and Tanner crab census data are underway and we plan to provide a report to the Council in the future.

This report is therefore singularly focused on the RKC vitality work which was recently published in the journal *Fisheries Research* (Lescher et al. 2021).

<u>Identifying RKC-specific vitality metrics:</u>

A suite of 14 candidate vitality metrics were identified based on RKC kinesiology, physiology, and ecology; metrics used for other crab species (Stoner et al., 2008; Hammond et al., 2013; Rose et al., 2013; Yochum et al., 2015, 2016); and observations provided by commercial crab fishermen. In August 2018, these candidate metrics were explored using a series of metric-specific stimulations on 14 adult RKC (hereafter called crab) at the Alaska Fisheries Science Center laboratory in Kodiak, Alaska.

Laboratory crab were evaluated individually for responses to each candidate vitality metric. Evaluations were conducted a) immediately after removing crabs from seawater tanks (8°C), and b) after crab were housed in a dry tote (18°C) for twenty five minutes. The latter tests were conducted to determine whether individual metrics were sensitive to air exposure. Metrics determined to be overly sensitive to air exposure were eliminated as viable alternatives for further testing. This process was repeated twice per crab over a two-day period. Vitality metrics were selected for further field testing if each crab gave clear and consistent involuntary responses to the stimulation on every assessment.

The seven metrics chosen for field trials (Table 1) were tested on post-capture adult RKC collected from six hauls over the course of two commercial groundfish bottom trawl fishing trips on the F/V Cape Horn targeting flatfish (yellowfin sole, *Limanda aspera* and Northern rock sole, *Lepidopsetta polyxystra*) in February and March of 2019. No modifications were made to fishing operations and the vessel utilized its standard flatfish trawl gear for this study. Vessel data, fishing specifications, and environmental conditions were recorded on the haul-level. Live crab were collected on deck from the trawl alley while the codend was being emptied and from the sorting belt immediately prior to the regulatory point of discard in the factory. We aimed to assess crab from the catch without overly impeding the pace of commercial fishing operations.

Crab were held in four (100- x 100- x 70-cm deep) plastic tanks secured to the ship's trawl deck, each supplied with a continuous flow of seawater pumped at a rate to maintain ambient surface seawater temperature and dissolved oxygen levels. An important objective of field testing was to include crab in various states of stress and injury (e.g., undamaged, cracked carapace, missing limbs) for assessment and monitoring. All crab were sexed; weighed; measured for carapace length; and assessed for shell condition, female clutch fullness, clutch condition, and egg development following Donaldson and Byersdorfer (2005). Visible injuries were categorized as follows: autotomized limbs, broken limbs not autotomized, broken rostrum, cracked carapace, crushed carapace, other injury, or no visible injury; and vitality metrics were assessed one at a time following the order presented in Table 2. Each crab was first tested for their response to six of the vitality metrics (all except self-righting), then individually marked with a zip tie-affixed plastic identification tag, and finally, placed in a tank to test their ability to self-right in seawater (the final metric). Tanks were limited to 12 or fewer crab at a time.

Each crab selected for vitality sampling was given a vitality score equal to the number of vitality metric responses absent upon assessment, from zero (no absent responses, unimpaired) to seven (all responses absent, impaired). Observed responses were marked as “present” regardless of the strength of the response. All crab were reassessed and scored at 2, 4, 6, 12, 24, 48, and 72 hours after the initial vitality assessment. Following the final (72 hour) assessment, the plastic identification tag was removed, and the crab was released back to sea. Dead crab (abdominal flap, mouth parts and appendages hanging free from the body when removed from tank) were removed from the tank and discarded at the time of the assessment.

<u>Results</u>

In total, 37 RKC (10 male, 27 female) were collected from the deck and 18 (10 male, eight female) were collected from the factory over two fishing trips. Males (n=20; weight range: 1.30kg – 5.30kg; weight mean: 3.61kg; carapace length range: 111mm – 185mm; carapace length mean: 159mm) were generally larger than females (n=35; weight range: 0.78kg – 2.64kg; weight mean: 1.70kg; carapace length range: 101mm – 153mm; carapace length mean: 126mm). This is consistent with previously reported size-based sexual dimorphism (Donaldson and Byersdorfer, 2005). Of the 55 assessed crab, four had an initial vitality assessment score of zero (i.e., no responses absent), 12 had a score of one, 13 a score of two, 11 a score of three, seven a score of four, six a score of five, two a score of six, and no crabs had a score of seven (i.e., most impaired, see the left-most panels in Figure 1). The time series of scores for each crab throughout the holding period is presented from left to right in Figure 1. Crab collected from the factory had higher initial scores (mode score three, range score two to six) than crab collected from deck (mode score one, range score zero to five). All factory crab had an initial vitality score of two or greater, whereas almost half (43%) of crab collected from deck had initial vitality scores less than or equal to one (Figure 1).

During the study, six crab died (one male, five female; four deck, two factory). All six were relatively small individuals with a mean carapace length of 113 mm and mean weight of 1.37 kg, and each had an initial vitality score of four or higher. Of the remaining 49 live crab, 39 (80%; 32 deck, seven factory) responded to all seven metric-specific stimuli (i.e., score zero) by the six-hour assessment, and 46 (94%; 32 deck, 14 factory) had recovered to score zero at the 72-hour assessment. Three crab (one deck, two factory) received scores greater than zero (one, one, and three) at the 72-hour assessment and two had scores lower than their initial assessment consistent with recovery. Regardless of whether a crab lived or died, there were no individuals that demonstrated a progressive increase in scores over time, suggesting an overall decrease in impairment over the course of the assessment period.

Crab sampled from the factory sustained both higher levels of initial impairment and more severe injuries (e.g., broken rostrum and crushed carapace) than those sampled from deck. During the initial assessment, 11 (20%) of the 55 crab had one or more injuries present. All but one of the injured crab were collected from the factory and two subsequently died (broken rostrum score six and crushed carapace score five).

Fishing variables (e.g., tow duration, total catch, CPUE) and environmental data (e.g., seafloor water temperatures, ambient air temperature) for all hauls are presented in Table 3. However, the relatively small number of crab deaths (n=6) observed in our study precluded meaningful analyses relating fishing and environmental conditions to RKC discard mortality. Although our review of the literature found no previous studies examining factory-induced stress and injury to crabs, our findings were consistent with our expectations that higher levels of impairment would be found in crab sampled from the factory, compared to those sampled from the deck. This expectation was based on the presumed effects of being dumped into and held in the vessel's stern a tank for a period of time with significant tonnages of groundfish and effects of the conveyor belts that transports catches into the factory from the stern holding tank. However, this did not translate to a substantial disparity in observed mortality rates in crab collected from the two locations (10.8% deck mortality and 11.1% factory mortality), likely due to small sample size. Likewise, while the preponderance of mortality events appeared to have occurred in smaller individuals and females, our small sample size prevented us from establishing a conclusive relationship between mortality and individual size or sex (e.g. Figure 2).

While investigating specific physiological mechanisms linking injury and impairment to mortality was beyond the scope of this study, we met the goals outlined in this EFP to examine potential vitality metrics that can be used to predict delayed discard mortality. Our results provide evidence supporting the utility of the RKC-specific vitality metrics that were developed through laboratory testing and input from commercial fishermen. Our work provides a methodological foundation and applied information to assess impairment and mortality from fisheries interactions in RKC, a necessary step to establishing RKC-specific discard mortality rates. In addition, the vitality metrics selected and evaluated for this study could be used to look further into the effects of the point of discard (i.e., 'on deck' compared with 'in the factory') on mortality rates of bycaught RKC. Metrics explored in this study were promising and if applied in future field trials may inform a predictive relationship between impairment and survival outcomes. This would be beneficial to update post-release mortality rate estimates used for this fishery, which have not been reassessed since 1987 (Stevens, 1990). Fishery management currently uses discard mortality rates from the 1987 study which does not account for recent fishing gear modification (e.g., lighter footrope materials and wider footrope bobbin spacing). This research along with additional supplemental information is published in the journal Fisheries Research (see Lescher et al., 2021).

References:

Donaldson, W., Byersdorfer, S., 2005. Biological Field Techniques for Lithodid Crabs, Biological Field Techniques for Lithodid Crabs. Alaska Sea Grant, University of Alaska Fairbanks. https://doi.org/10.4027/bftlc.2005

Hammond, C.F., Conquest, L.L., Rose, C.S., 2013 Using reflex action mortality predictors (RAMP) to evaluate if trawl gear modifications reduce the unobserved mortality of Tanner crab (*Chionoecetes bairdi*) and snow crab (*C. opilio*). ICES. J. of Mar. Sci. 70, 1308–1318, https://doi.org/10.1093/icesjms/fst085.

Lescher C., Yochum N., Harris B.P., Nathan Wolf N., John Gauvin J. In press. Selecting Species Specific Vitality Metrics to Predict Red King Crab (Paralithodes camtschaticus) Discard Survival, Fisheries Research. https://doi.org/10.1016/j.fishres.2021.105964

Rose, C.S., Hammond, C.F., Stoner, A.W., Eric Munk, J., Gauvin, J.R., 2013. Quantification and reduction of unobserved mortality rates for snow, southern Tanner, and red king crabs (*Chionoecetes opilio*, *C. bairdi*, and *Paralithodes camtschaticus*) after encounters with trawls on the seafloor. Fish. Bull., U.S. 111, 42–53. https://doi.org/10.7755/FB.111.1.4

Stevens, B.G., 1990. Survival of king and Tanner crabs captured by commercial sale trawls. Fish. Bull., U.S. 88, 731–744.

Stoner, A.W., Rose, C.S., Munk, E.J., Hammond, C.F., Davis, M.W., 2008. An Assessment for Two Alaskan Crab Species, Tanner Crab (Chionoecetes bairdi) and Snow Crab (C. opilio), Based on Reflex Impairment. Fish. Bull. 106, 337–347.

Yochum, N., Rose, C.S., Hammond, C.F., 2015. Evaluating the flexibility of a reflex action mortality predictor to determine bycatch mortality rates: A case study of Tanner crab (Chionoecetes bairdi) bycaught in Alaska bottom trawls. Fish. Res. 161, 226–234. https://doi.org/10.1016/j.fishres.2014.07.012

Yochum, N., Stoner, A.W., Sampson, D.B., Rose, C., Pazar, A., Eder, R., 2016. Utilizing reflex impairment to assess the role of discard mortality in “Size, Sex, and Season” management for Oregon Dungeness crab (Cancer magister) fisheries. Can. J. Fish. Aquat. Sci. 74, 739–750. https://doi.org/10.1139/cjfas-2016-0029

<u>Tables and Figures:</u>

Table 1

Vitality metrics previously assessed on other crab species (*), those considered based on consultation with crab fishermen (a), those evaluated on unimpaired crab in a laboratory setting (**), and those selected to test at sea (***).

Reflexes	Metrics from literature (*) and fishermen input (a)	Metrics evaluated in the laboratory	Selected RKC metrics to test at sea
Leg flare	*	**	
Leg retraction	*	**	
Leg wrap	*a	**	
Leg curl	*	**	
Chela closure	*	**	***
Eye retraction	*	**	
Maxilliped control	*	**	***
Abdominal flap kick	*	**	
Antennae stimuli	*	**	
Defensive posture	A	**	***
Self-right in water		**	***
Skydiver	A	**	***
Mandible closure	*	**	***
Abdominal flap slack	A		***

Table 2

Seven vitality metrics specific to red king crab (*Paralithodes camtschaticus*) selected for this study and tested (in the order listed) at sea, including the assessment method and criteria for determining if the response was present or absent. Weak responses were considered present.

Reflex	Method	Present	Absent
Mandible closure	A probe gently attempts to pull mandible forward	Mandible not moved from resting position	Mandibles are easily manipulated
Maxilliped control	If closed, a probe is used to stimulate and open (extend) 3rd maxillipeds; if open, use probe to manipulate 3rd maxillipeds downward	Crab returns maxillipeds to resting position tucked in front of mouth; the maxillipeds move in an agitated manner in weakened crab	No motion in the maxillipeds or initiated movement occurs
Chela closure	A probe is placed within the grasp of crab's open chela or the chela is manipulated if closed	Chela closed tightly, or shows resistance to manipulation	Chela does not close and/or no motion is detected under manipulation
Defensive posture	Gently pull outward and straighten legs or chelipeds	Legs and chelipeds tuck back in front of body	Crab unable to return legs or chelipeds to tucked position
Skydiver leg flare	Lift and hold crab while supporting underside of carapace with dorsum up	Legs and chelipeds outstretched in a splayed "skydiver" flare parallel to the ground	Legs droop more than 45 degrees from body, or hang limp
Abdominal flap slack	Crab is held vertically with both hands supporting underside of pereiopods at the coxa and abdomen facing sampler	Maintains tightly closed abdominal flap. Fecund females may have slight gap due to clutch size, yet maintains pressure keeping flap "closed"	Abdominal flap hangs loose from body, or has a gap of more than 1/8th inch
Self-right in water	Crab placed upside down in sea water tank	Self-rights $\leq$ 60 seconds	Unable to self-right during assessment period

Table 3

Information for each tow from which red king crab RKC, were collected, assessed, and held, including: tow duration, target species catch (Northern rock sole, *Lepidopsetta polyxystra*, NRS and yellowfin sole, *Limanda aspera*, YFS), total catch weight (metric tons), catch per unit effort (CPUE), fishing depth, seafloor water temperature , range of ambient air temperature recorded at the St. Paul weather station, and total number of RKC, of those collected, that died during this study.

Tow No.	Duration (hr:min)	Target Catch	Total Catch (mt)	CPUE (mt/hr)	Depth (m)	Seawater Temp (°C)	Air Temp (°C)	No. RKC Collected	No. RKC Died
1	1:55	NRS	5.4	2.8	59	4.2	19-34	9	0
2	3:30	NRS	7.2	2.0	46	3.9	19-34	14	0
3	3:15	NRS	43.8	13.5	44	4.1	22-38	3	1
4	2:15	YFS	17.6	7.8	59	3.6	32-41	18	1
5	2:30	YFS	15.0	6.0	57	3.7	32-41	8	1
6	3:20	YFS	36.6	11.0	57	3.2	31-38	3	3

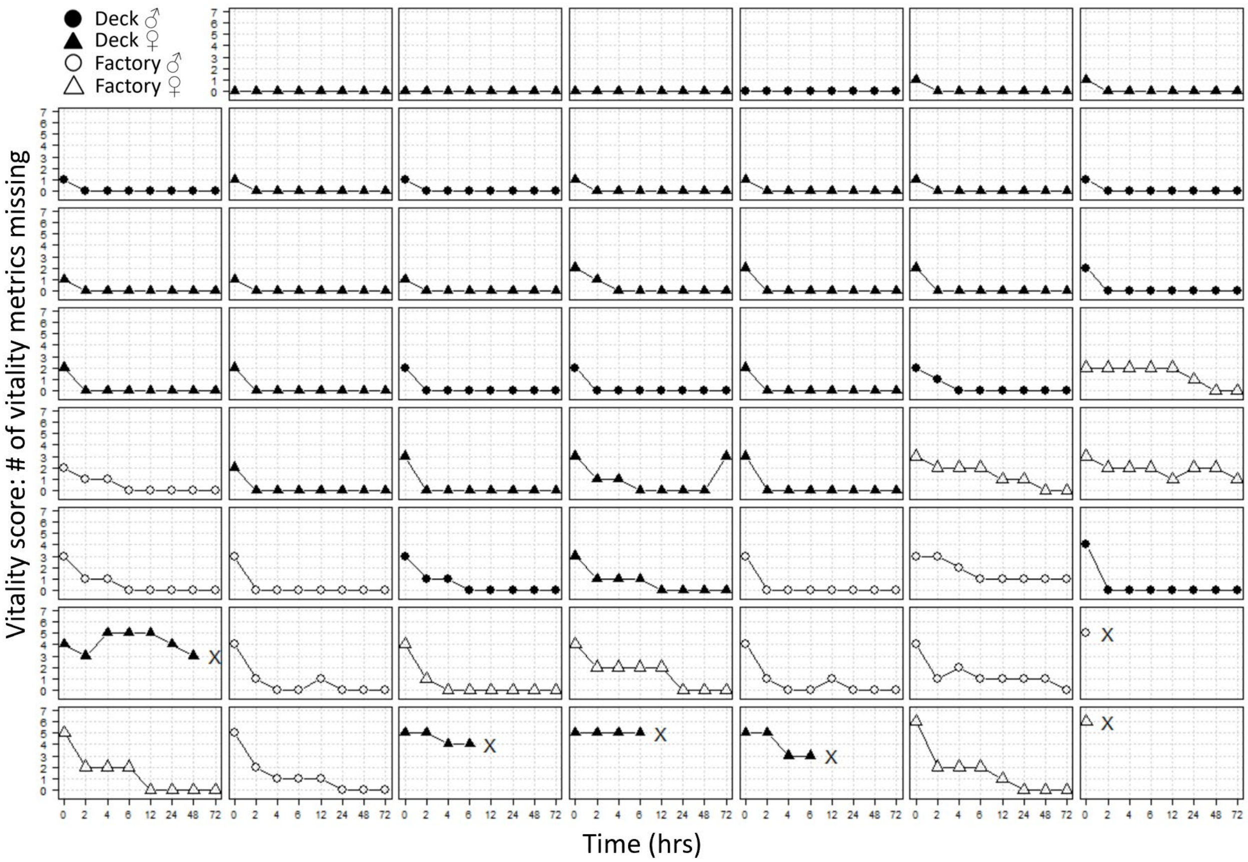

Fig. 1: Fifty-five red king crab (*Paralithodes camtschaticus*; one crab per plot) and their vitality scores (y-axis) reflecting number of vitality metrics absent, plotted over the 72-hour assessment period (x-axis). Plots are ordered by vitality score upon initial vitality assessment from least impaired (top left) to most impaired (bottom right), sex (male ♂ = circle, female ♀ = triangle) and location of collection (deck = solid, factory = hollow). The six crab that died are denoted with an "X" at the assessment during which they were found dead in the holding tank.

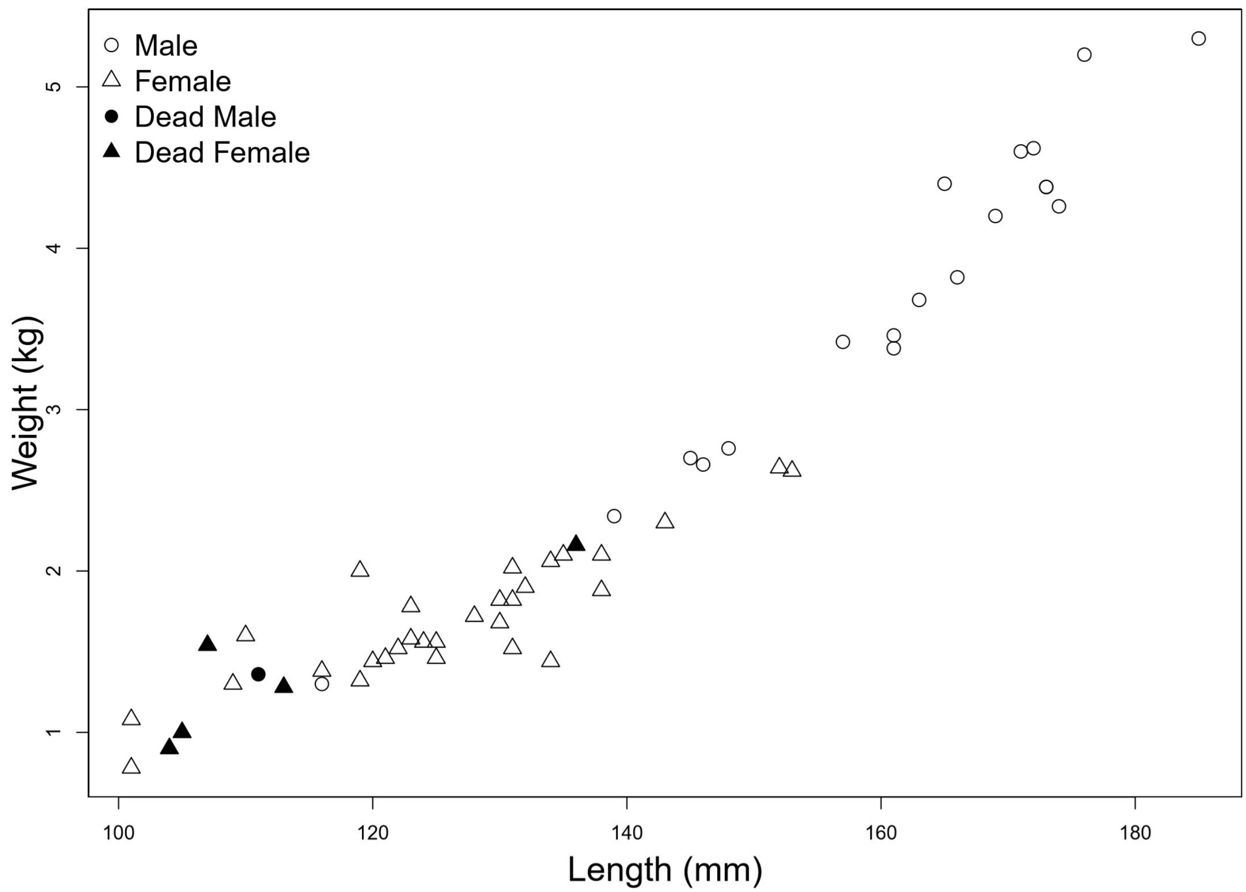

Fig. 2. Length weight relationship of the red king crab encountered from this study by sex, males (circles) trended larger than female with just two males smaller than the average female. Crab that died within the 72-hour holding period (n=6) are shown with solid shapes for both male and female.