Crab Handling Mortality in Directed BSAI Crab Fisheries

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Alaska Department of Fish and Game
Crab Plan Team Meeting
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Why is handling mortality important?

- Discarding (target species) and bycatch (non-target species) occurs in BSAI crab fisheries
- Once returned to the ocean, a portion of those crab die
- Catch accounting: Estimates of discard/bycatch mortality is needed to estimate total fishery mortality
- “Overfishing” occurs when total fishery mortality exceeds the OFL
- Assumptions about what portions of discards/bycatch die affect estimates of total fishery mortality
- NOTE: Retained catch: deadloss rate very low ~<2%

Sources of handling mortality

- Injuries: physical trauma of dumping and sorting on deck
- On-deck anoxia
- Temperature stress (freezing)

Short-term mortality

- Can be studied and estimated relatively easily

Long-term effects

- "*Individuals that incur damage to sensory structures during handling may survive well in captivity but in the wild may be eaten or may fail to obtain enough food, leading to delayed mortality*." (van Tamelen 2005)
  - Increased predation
  - Decreased ability to feed or mate
  - Increased mortality during molting
    - Some evidence of this for Tanner crab (eyestalk freezing)
  - Cumulative effects of repeated capture?
- **More difficult to estimate**

Current handling mortality rates

BBRKC

- Directed fishery: 20%
- Tanner fishery: 25%

- Snow
  - Directed fishery: 30%
  - Tanner fishery: 30%
- Tanner
  - Directed fishery: 32.1%
  - snow fishery: 32.1%
  - BBRKC fishery: 32.1%
- AIGKC
  - Directed: 20%

Why are we talking about this?

- Oct + Dec 2021 Council tasked staff to prepare discussion paper in response to ongoing decline of BBRKC and 2021/22 fishery closure
- Discussion paper presented to Council in April 2022 and addressed 4 topics:
  1. Provide the best available information on Bristol Bay red king crab molting/mating annual cycle and how the seasonality of this overlaps with fisheries and the effects these interactions may have.
  2. Evaluate boundaries used for the BBRKC survey, stock assessment, PSC limits, and directed fishery.
  3. Provide the best available information on bottom contact by pelagic trawl gear and the impact it may have on BBRKC stocks.
  4. Summarize mechanisms used in other council managed fisheries to create flexible, responsive spatial management measures for all gear types and how they might be applied to protect BBRKC.

Why are we talking about this?

- April 2022 Council Meeting Motion

D1 BBRKC Information
Council motion
April 9, 2022

The Council requests that each Bering Sea sector with crab mortality (directed crab fishery, Pacific cod sectors, AFA pollock, and A80) present the following to the Council in October 2022 as applicable:

- voluntary measures for implementation in 2023 and beyond to avoid BBRKC and reduce crab mortality in the non-directed fisheries
- measures in the directed crab fishery to reduce discard mortality of BBRKC
- description of research that would inform development of more flexible and effective spatial management measures; gear modifications to reduce impacts on the BBRKC stock, or to evaluate unobserved mortality in the trawl sector

Why are we talking about this?

- April 2022 Council Meeting Motion

The Council requests an expanded discussion paper that includes:

1. Analysis of the impacts of annual or seasonal closures to pelagic trawl, groundfish pot, and longline gear in the RKCSA including impacts on target catch, fishery timing relative to crab mating/molting, crab avoidance, and other PSC and non-target species.
2. Tables for all sources of BBRKC mortality across federal fisheries:
   - for the pot, longline and trawl groundfish fisheries, total estimated PSC in Registration Area T in numbers, proportion of total PSC in Zone 1, proportion of total PSC in RKCSA, estimated PSC mortality, and estimated proportion of the PSC that are female. Information should also be provided on fishery timing in relation to BBRKC molting and mating, estimated bottom contact of the gear, observer coverage rates, and assumed discard mortality rates.
   - for the directed BBRKC fishery and the Tanner fishery in the eastern subdistrict, estimated mortality presented in a revised version of Table 3-3 from the April 2022 discussion paper that contains total retained catch, total discards, discard mortality, proportion of discards that are female, observer coverage rate, and assumed discard mortality rate.
3. A discussion of scientific information needed to create dynamic closed areas, such as seasonal or annual shifting closed areas, to protect mature female BBRKC.
4. Information needed to allow the A80 sector to create rolling hotspot closure systems to avoid and reduce BBRKC PSC as well as the potential tradeoffs of doing so on encounter rates of halibut.
5. Provide information on the impact of groundfish predation on BBRKC.
6. Analysis of the impacts of:
   - prohibiting fishing for Pacific cod with pot gear in Area 512
   - establishing a PSC hard cap for the under 60' fixed gear sector and over 60' pot sector

The council requests the expanded discussion paper go to the SSC for review and comment if that can be accomplished without delaying council review and action.

Handling mortality is a big part of this

Why are we talking about this?

- Asked to provide a history of discard/bycatch handling mortality rates for directed crab fisheries

- What is being done to estimate these numbers?
- What should be done?

Disclaimer

- The following is from my own investigations, not guaranteeing that it covers all information.

What has been used

From: Zheng, Jie (DFG) <jie.zheng@alaska.gov>
Sent: Friday, November 6, 2020 1:52 PM
To: Daly, Ben J (DFG) <ben.daly@alaska.gov>
Subject: Re: 20% handling mortality rate

Hi Ben,
The 20% is my assumed value. There are several handing mortality rate studies on red king crab, and the estimated handling mortality rates are about 10% or less. Considering the uncertainties and potential factors not considered in these factors, I assumed 20% to be a reasonable value.

For Tanner and snow crabs, under Jack and Lou, handling mortality rates were assumed to be 100%. However, there are some studies showing that it is much lower than 100%, so the CPT took an average of 0 and 100% to make it 50%. Later, the CPT lower the values less than 50%, but above 20%. It is reasonable to have Tanner and snow crab handling mortality rates to be above red king crab's 20% because of lower temperatures during Tanner and snow crab fisheries.

I gave talks about this in the past and have a slides on it. When I found the slides, I would email them to you.

Cheers,
Jie

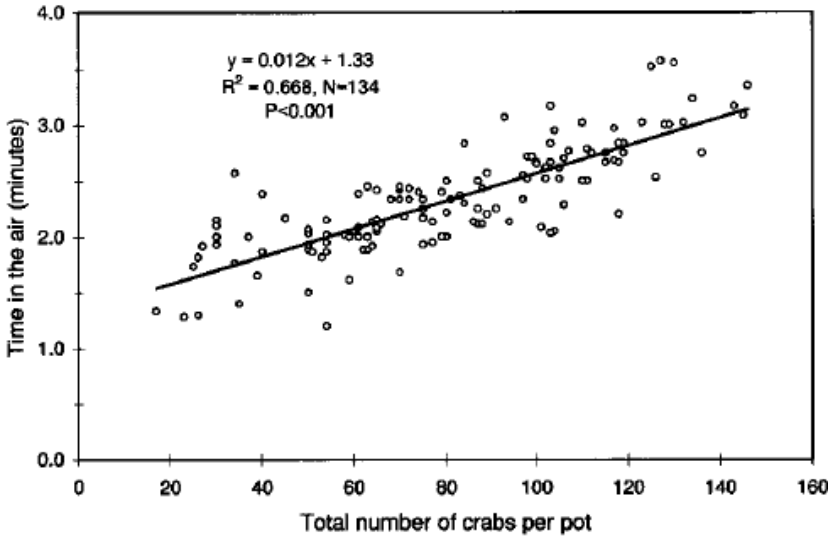
Research in 1990s + 2000s

1. Carls, M.G., and C.E. O'Clair. 1990. Influence of cold air exposures on ovigerous red king crabs (*Paralithodes camtschatica*) and Tanner crabs (*Chionoecetes bairdi*) and their offspring. Pp.329-343. *In* Proc. Int. Symp. King & Tanner Crabs, Alaska Sea Grant Rep. 90-04.
2. Stevens, B.G. and R.A. MacIntosh. 1993. Estimation of mortality rates for king crab captured in finfish trawl and crab pot fisheries. Presented at the NMFS Stock Assessment Workshop, Woods Hole, MA, July 19-22, 1993.
3. Watson, L.J. and D. Pengilly. 1994. Effects of release method on recovery rates of tagged red king crabs *Paralithodes camtschaticus* in 1993 Bristol Bay commercial fishery. ADF&G, RIR No. 4K94-40.
4. Zhou, S., and T.C. Shirley. 1995. Effects of handling on feeding, activity and survival of red king crabs, *Paralithodes camtschaticus* (Tilesius, 1815). J. Shellfish Res. 14: 173-177.
5. Zhou, S., and T.C. Shirley. 1996. Is handling responsible for the decline of the red king crab fishery? Pp. 590-611. In Proc. High Latitude Crabs: Biology, Management, & Economics. Alaska Sea Grant College Rep. 96-02.

Research in 1990s + 2000s

6. MacIntosh, R.A., B.G. Stevens, J.H. Haaga, & B.A. Johnson. 1996. Effects of handling and discarding on mortality of Tanner crabs (*Chionoecetes bairdi*). Pp. 576-589. In Proc. High Latitude Crabs: Biology, Management, & Economics. Alaska Sea Grant College Rep. 96-02.
7. Warrenchuk, J.J. and T.C. Shirley. 2002. Effects of windchill on the snow crab (*Chionoecetes opilio*). Pp. 81-96. In Proc. Crabs in Cold Water Regions: Biology, Management, & Economics. Alaska Sea Grant College Rep. 02-01.
8. Warrenchuk, J.J. and T.C. Shirley. 2002. Estimated mortality of snow crabs Discarded during the Bering Sea Fishery in 1998. Alaska Fishery Research Bulletin 9: 44-52.
9. Van Tamelen, P.G. 2005. Estimating handling mortality due to air exposure: development and application of thermal models for the Bering Sea snow crab fishery. Trans. Amer. Fish. Soc. 134: 411-429.
10. Pengilly, D. and S. Gish. 2005/2006. Estimating mortality due to handling injuries in red king crab from tag recovery data. Presented at 2005 Crab Interagency meeting and 2006 TCS meeting.

Results: RKC



Zhou and Shirley 1995 + 1996

- Lab studies, Fishery data
- Five treatments: handling once, twice, three times, modified handling, & control. Dropping distance: 3 m.
- No significant differences in righting responses, feeding rates, weight gain, CL increment, or long-term (4 months) mortality rates among 5 treatments of mature female, juvenile female, & juvenile male red king crabs.
- Incidence of injuries increased with number of times handled.
- Estimated mortality rates during 1990-1993 fisheries was minimal (**0.02%)**
- "*Deck impacts, aerial exposure, and water impact should have minimal, effects on discarded female and sublegal red king crab,* if *these crabs are handled in the normal manner which we have described*."

Results: RKC

Stevens, B.G. and R.A. MacIntosh. 1993. Estimation of mortality rates for king crab captured in finfish trawl and crab pot fisheries. Presented at the NMFS Stock Assessment Workshop, Woods Hole, MA, July 19-22, 1993.

- **5.2% for king crabs**, 11% for Tanner crabs 2 days after handling.

Watson, L.J. and D. Pengilly. 1994. Effects of release method on recovery rates of tagged red king crabs *Paralithodes camtschaticus* in 1993 Bristol Bay commercial fishery. ADF&G, RIR No. 4K94-40

- **No different recovery rates** (27.1% vs 27.4%) between placing release (control) and dropping crabs overboard from the level of the vessel rail to the sea surface of tagged red king crabs. I.e., no different handling mortality rates.

Results: RKC

Pengilly, D. and S. Gish. 2005/2006. Estimating mortality due to handling injuries in red king crab from tag recovery data. Presented at 2005 Crab Interagency meeting and 2006 TCS meeting.

- **Leg crush injuries reduces survival**
  - Crabs suffering a leg crush injury have ~77% survival relative to uninjured crabs during the 1-3 week period after receiving the injury.
  - Those that survived the short-term period after receiving survived at same rate as uninjured crabs.
  - Results could be applied to estimated frequency of "major" walking leg injuries in bycatch to estimate bycatch mortality due to those injuries.
  - - 1% to 4% incidence in bycatch estimated for leg injuries of this type

- **Rostrum break has only minor effect at most in reducing survival**
  - Results may (?) apply to broken spines, which can be a common injury (Zhou and Shirley 1996), but difficult to get estimates of incidence from

Results: cold air exposure

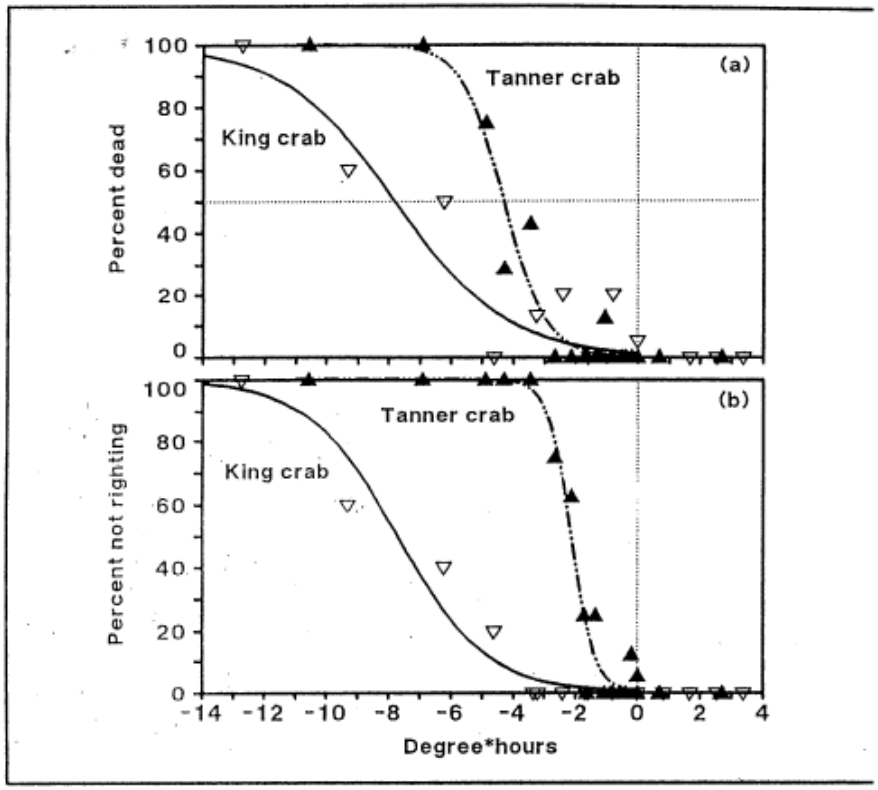


Figure 3a.--Percent mortality 128 days after aerial emersi as a function of exposure (°h). 3b.--Percent crabs n righting immediately after emersion as a function of °h.

Carls and O'Clair 1990

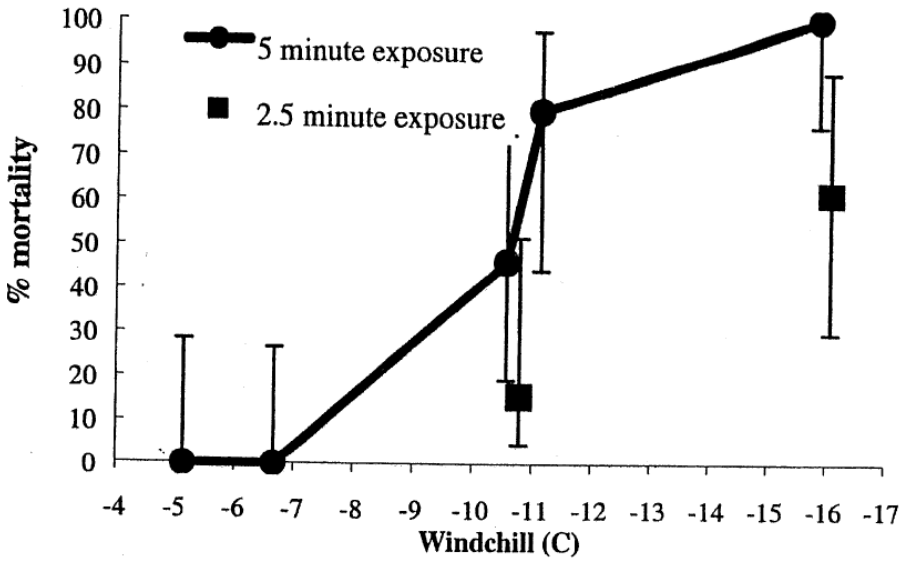


Figure 1. Percent mortality of C. opilio exposed to windchill treatments. Error bars indicate 95% confidence limits.

Warrenchuck and Shirley, 2002

Higher mortality at colder temperatures

Results: cold air exposure

Warrenchuk and Shirley 2002

1998 EBS snow crab:

- No relationship between retained catch deadloss and windchill at time of capture
- Estimated 2.6% handling mortality due to major injuries
- Estimated mortality of discarded snow crabs: 3.9% by the windchill model & 19.6% by the temperature & wind speed model
- **Overall estimated handling mortality 22.2%** (19.6% + 2.6%)

Results: cold air exposure

van Tamelen 2005: Cold air exposure on EBS snow crab

- Heat budget models, calibrated with observed temperatures of living snow crabs exposed to cold air. Applied to lab results and temperature data from 1979 to 2001.
- Estimated handling damage rates for snow crabs from 1979 to 2001: **0-30%** .

What has been used

1. Early years: did not consider bycatch and its mortality. E.g., Balsiger 1974; Katz, Balsiger, Schappelle & Spinker 1977; Reeves & Marasco 1980; Somerton 1981.

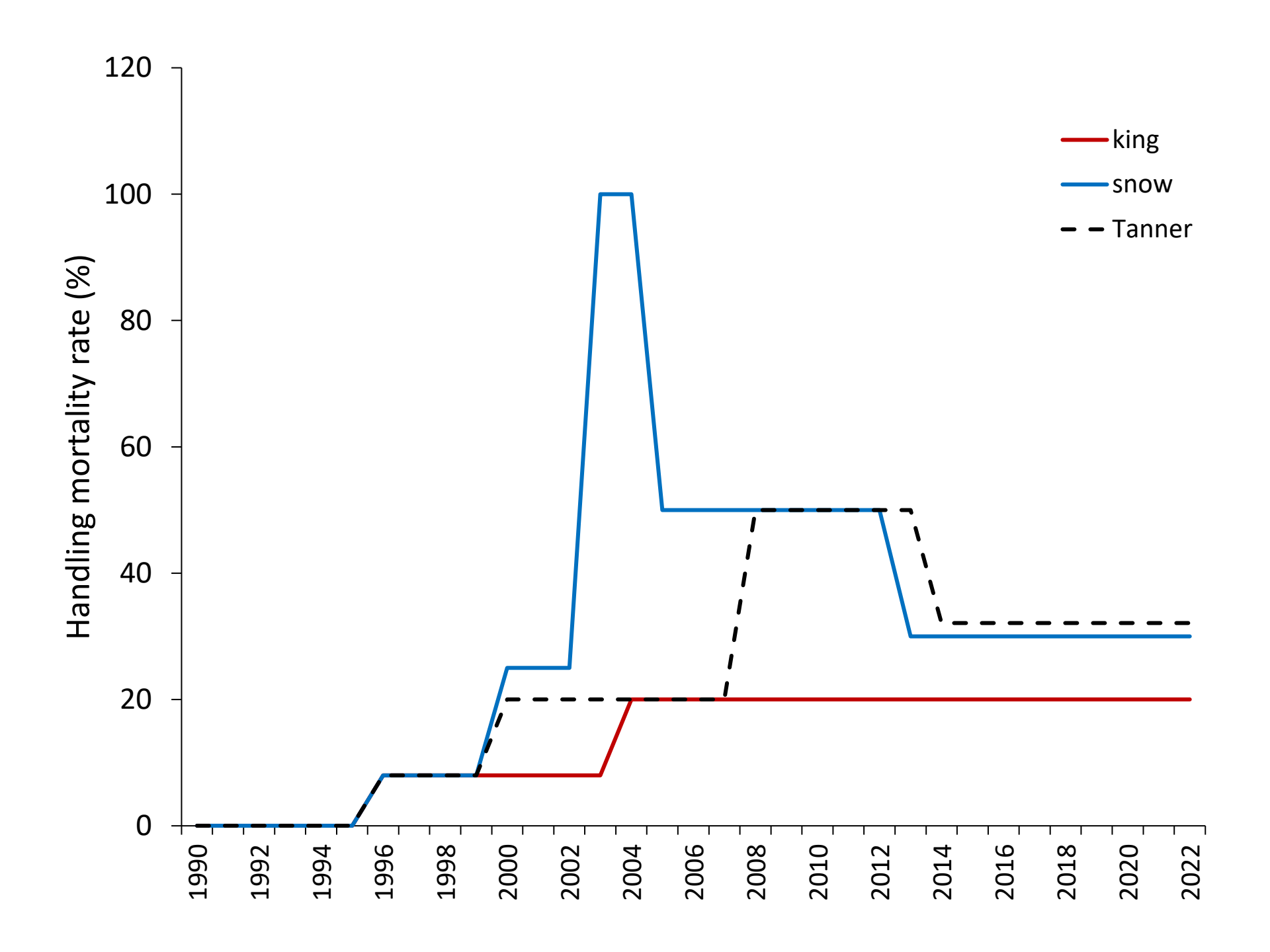
2. 1990s + 2000s:

   - 1996: CPT (NPFMC 1996): 8% for king, Tanner & snow crabs;
   - 2000, 2005: CPT (NPFMC 2000, 2005): 8% for king crabs, 20% for Tanner and 25% for snow crabs.
   - 20% for king and Tanner crab state harvest strategies (Zheng 2003; Zheng et al. 1996, 1997a, 1997b; Zheng & Kruse 1999a, 1999b, 2000a, 2000b; Zheng & Pengilly 2003; Kruse et al. 2000);
   - 25% for snow crab state harvest strategy (Zheng et al. 2002);
   - Snow crab models: 25% (Turnock 2002 & earlier), 100% (Turnock 2003, 2004), & 50% (Turnock & Rugolo 2005-2008);
   - Tanner crab OFL: 50% (Rugolo & Turnock 2008).

2005 SAFE: page 5-5

So what are the population impacts of bycatch?

By applying mortality rates estimated from scientific observations to the number of crabs taken as bycatch, it is possible to estimate the relative impacts of bycatch on crab populations. Discard mortality rates have been established in previous analysis (NPFMC 1999), and may be species or fishery specific. Bycatch mortality rates in trawl, dredge, and fixed gear fisheries for all crab species were set at 80% , 40%, and 20% respectively. For crab fisheries, mortality rates were averaged across different fisheries. Rates used were 24% for *C. opilio*, 20% for *C. bairdi*, and 8% for blue king crab and red king crab. The


120
100
80
60
40
20
0
Handling mortality rate (%)
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
king
snow
Tanner

Stoner et al., 2008; Stoner 2009

RAMP: Reflex action mortality predictor

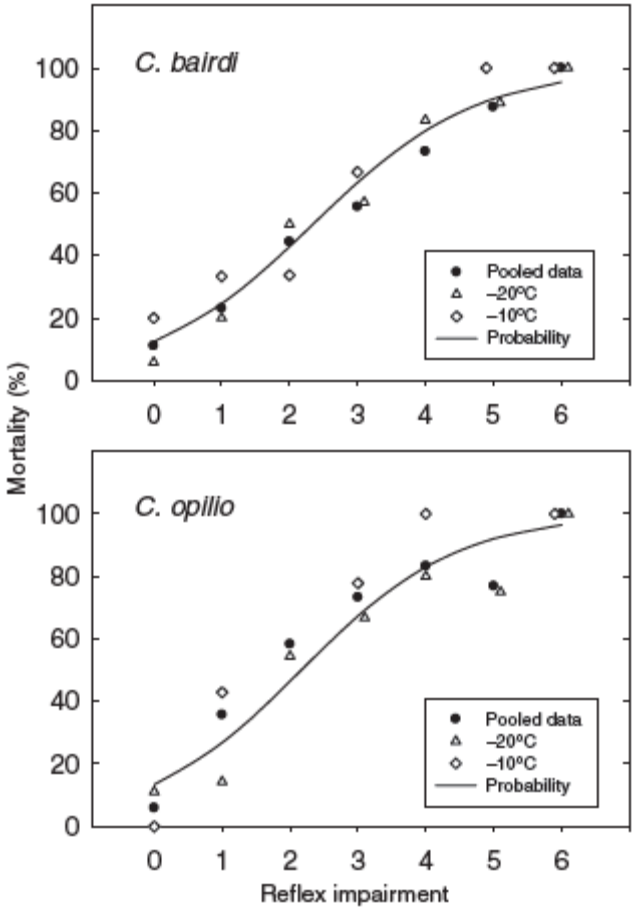
Table 1

Reflexes identified as useful for assessing stress in *Chionoecetes* spp. "Test" is the manipulation required to elicit a stereotypic positive response. No response was recorded when no motion was detected in response to repeated testing (modified from Stoner et al., 2008)

Reflex	Test	Positive response	Lost response
Leg flare	Lift crab by the carapace, dorsum up	Legs spread wide and to near horizontal orientation in strong crabs	Legs droop below horizontal, with no attempt to raise them
Leg retraction	While holding crab as above, draw the forward-most walking legs in the anterior direction	Legs retract in the posterior direction, or present resistance to the motion in weakened crabs	No resistance to the manipulation occurs
Chela closure	Observe for motion or hold the chelae in the fingers	Chelae open and close with or without manipulation. In weakened crabs the chelae may close slowly, or show low resistance to manual opening	No motion is detected in the chelae under manipulation
Eye retraction	Touch the eye stalk with a blunt probe, or lift the eye stalk from its retracted position	Eye stalk retracts in the lateral direction below the carapace hood, or shows resistance to lifting	No motion or resistance to manipulation occurs in the eye stalk
Mouth closure	If closed, attempt to open (extend) the 3rd maxillipeds with a sharp dissecting probe. If open, draw the maxillipeds downward	3rd maxillipeds retract to cover the smaller mouth parts. The maxillipeds droop open or move in an agitated manner in weakened crabs	No motion in the maxillipeds occurs
Kick	With the crab in ventrum-up position, use a sharp dissecting probe to lift the abdominal flap away from the body	One or more legs or chelipeds move quickly in the ventral direction, particularly in males. Motion in the hind most legs is retained in weakened crabs	No motion in the legs or chelipeds occurs

RAMP: Stoner et al., 2008; Stoner 2009

- Means to estimate short-term (<2 weeks) mortality by scoring 6 reflex responses of captured crab prior to being discarded
- Applied to snow + Tanner crab
- 80% accurate in predicting mortality



Dan Urban Research

- Applied RAMP during 2010-2012 **snow** crab fisheries
  - Over 19,000 crab evaluated
  - Estimated discard mortality was 4.5%
  - Strongly correlated to air temperature
- Applied relationship to historical 1991-2011 temps and historical handling mortality rate estimated at 4.8%

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ICES Journal of Marine Science; doi:10.1093/icesjms/fsv004

Discard mortality rates in the Bering Sea snow crab, *Chionoecetes opilio*, fishery

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Urban, J. D. Discard mortality rates in the Bering Sea snow crab, *Chionoecetes opilio*, fishery. – ICES Journal of Marine Science, doi: 10.1093/icesjms/fsv004.

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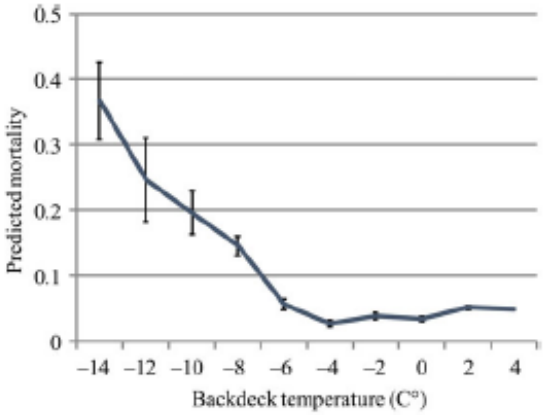
Fish and invertebrates that are unintentionally captured during commercial fishing operations and then released back into the ocean suffer mortality at unknown rates, introducing uncertainty into the fishery management process. Attempts have been made to quantify discard mortality rates using reflex action mortality predictors or RAMP which use the presence or absence of a suite of reflexes to predict discard mortality. This method was applied to snow crab, *Chionoecetes opilio*, during the 2010 – 2012 fisheries in the Bering Sea. Discard mortality in the fishery is currently assumed to be 50% in stock assessment models, but that rate is not based on empirical data and is widely recognized to be in need of refinement. Over 19 000 crab were evaluated using the RAMP method. The estimated discard mortality rate was 4.5% (s.d. = 0.812), significantly below the rate used in stock assessment models. Predicted discard mortality rates from the 2010 to 2012 study were strongly correlated with the air temperature at the St Paul Island airport in the Pribilof Islands. Using this relationship, the discard mortality rate from 1991 to 2011 was estimated at 4.8% (s.d. = 1.08).

Keywords: Alaska, Bering Sea, *Chionoecetes opilio*, discard mortality, RAMP, reflex action mortality predictor, snow crab.



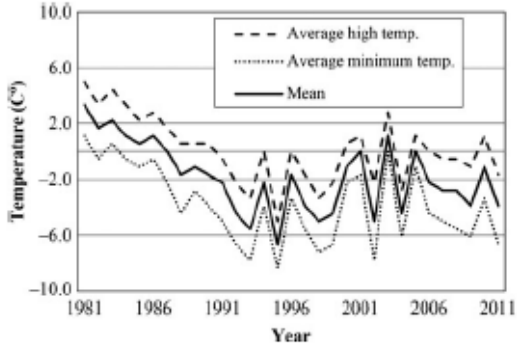


Figure 2. The average daily temperature at the St Paul airport in the Pribilof Islands from 1981 to 2011 for the days when the Bering Sea snow crab fishery was occurring.

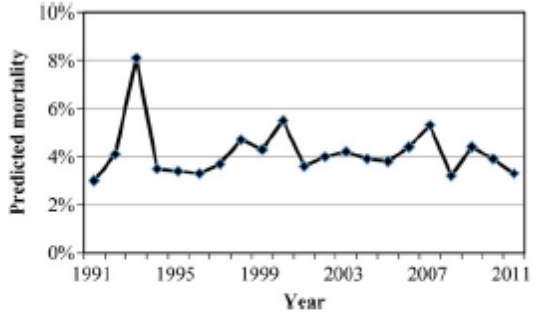


Figure 3. Estimates of historical snow crab discard mortality rates based on the relationship between predicted discard mortality and the temperature at the St Paul airport in the Pribilof Islands when the discards were occurring.

Snow crab: Dan Urban research, May **2013** CPT Meeting

- Acknowledgement by CPT about difficulty in determining true handling mortality (unknown long-term effects)
- At the time, snow crab assessment assumed 50% handling mortality in directed fishery
- RAMP study provided evidence to suggest 50% too high: CPT agreed
  - CPT considered range of options: 20%, 25%, 30%
  - **Settled on 30%**: derived by summing the highest estimate due to freezing (0.08) with the highest estimate of injury rates (0.12) to capture the short-term mortality and multiplying that sum by 1.5 to provide an estimate that includes long-term mortality. Since there is no information on long-term mortality, the CPT agreed that the best first-order estimate of the long-term mortality is 50% of the short-term mortality.
- At the time, CPT recommended 30% handling mortality not be applied to Tanner crab
  - No Tanner data
  - Stoners work suggested that Tanner crab may have higher handling mortality

Tanner crab: Dan Urban research, May **2014** CPT Meeting

- RAMP scores >10,000 Tanner crabs from six vessels during the 2013/14 Tanner fishery
- Discard mortality rates for Tanner crab higher than those for snow crab at most temperatures
- At the time, assessment used 50%,
  - CPT considered 3 options: 32.1%, 23.3%, and difference in mort rate curves
  - **Settled on 32.1%** for all pot fisheries: derived by summing the average estimate based on back deck RAMP scores taken across a range on temperature (0.114) with the highest estimate of injury rates (0.10) to capture the short term mortality and multiplying that sum by 1.5 to provide an estimate that includes long-term mortality. Since there is no information on long-term mortality, the CPT agreed that the best first order estimate of long-term mortality is 50% of the short-term mortality.
  - Same logic as snow crab

Dan Urban Research: king crab

- Attempted to develop RAMP-based approach for RKC + GKC
- RAMP not useful for king crab
- GKC thought to be more hardy that RKC, but no data to confirm

Fish Tickets: Deadloss ~<2%

- Could inform short-term mortality
- But retained catch deadloss likely underestimates handling mortality
  - Retained crab likely biased towards good condition, more robust (larger) crab
  - Doesn’t inform long-term mortality
  - Regulatory discards (females, sublegals) subject to repeated capture within as season or across seasons
  - Predation by fish as crab descend through water column or are lethargic at bottom

Summary

- Short-term mortality mostly due to time out of water, air temperature, injuries, with freezing more of a factor for snow and Tanner given the fishery timing
- Difficult to estimate long-term handling effects
  - Creates uncertainty in determining true handling mortality rate
- Snow + Tanner: based on RAMP approach
  - Short-term mortality ~20%
  - RAMP useful for snow + Tanner, not so much for king crab
- King crabs: mostly based on research done in 1990s and 2000s
  - Short-term mortality <6%
- Current approach: buffer estimated short-term mortality rates to account for long-term effects