Research Description - Estimating unobserved snow crab mortalities relative to crabs observed in bycatch – Craig Rose - FishNext Research

The topic of **unobserved mortality** of crabs that encounter bottom trawls, but are not caught and remain on the seafloor, has received considerable attention, most recently in discussions of recent declines in Bering Sea snow crab stocks and potential actions to promote their recovery. Research that I led to assess such mortality has received interest, particularly to provide multipliers to estimate unobserved mortality from the observed crab bycatch. While there are many limitations and caveats to such an application, the data from our studies provide the best existing basis for such an estimate. However, the project's final research report did not make such an estimate and the related values were presented in graphical form. Here, I will provide calculations of such estimates and their associated caveats. Last Spring, I discussed this research at Alaska Bycatch Taskforce and Crab Plan Team meetings (see https://meetings.npfmc.org/CommentReview/DownloadFile?p=35d4163e-d8c6-439a-a981-bfd05c385b6e.pdf&fileName=PPT_Reserach%20estimating%20unobserved%20mortality.pdf for the CPT presentation) and provided the raw data to the AFSC stock assessor. While detailed results, by size or footrope sector or with uncertainty ranges, are not provided here, these simple average results were calculated to serve pending deeper analyses.

Research Projects on Unobserved Mortality of Crabs

As leader of the AFSC Conservation Engineering Program through 2013, I led several research projects with the goal of working with the trawling industry to understand, quantify, and find ways to reduce unobserved mortality of crabs encountering bottom trawls. Work funded under NPRB Project 0711, in collaboration with Bering Sea bottom trawlers, developed methods to capture crabs after non-capture trawl contacts (here termed 'recapture') and to relate their probability of survival to how many reflexes each crab was missing (Stoner et al. 2010). To assess and adjust for any additional damage from capture and handling, we also captured crabs with a 'control' net, that crabs entered directly, without encountering any trawl components. Those methods were then used to estimate mortality rates of crabs after non-capture contacts with different bottom trawl components, as well as to assess designs intended to reduce crab mortality (Figure 1 - Rose et al. 2013, Hammond et al. 2013). In addition to estimating mortality rates, these studies showed that mortality rates could be reduced by raising trawl components above the seafloor and reducing footrope weight. This included the sweep modifications (Rose et al. 2010) that were implemented in regulations for all Alaska flatfish trawl fisheries.

The capture nets used in NPRB-0711 (Figure 2) did not cover the whole area behind/under the trawl footrope and crabs caught in the trawl net itself were not counted or assessed. Thus, that study could not assess the proportion of crabs caught or escaping under the trawl. Industry collaborators also indicated that the conventional footrope design tested was much heavier and had much less clearance beneath the net than designs they were currenting using.

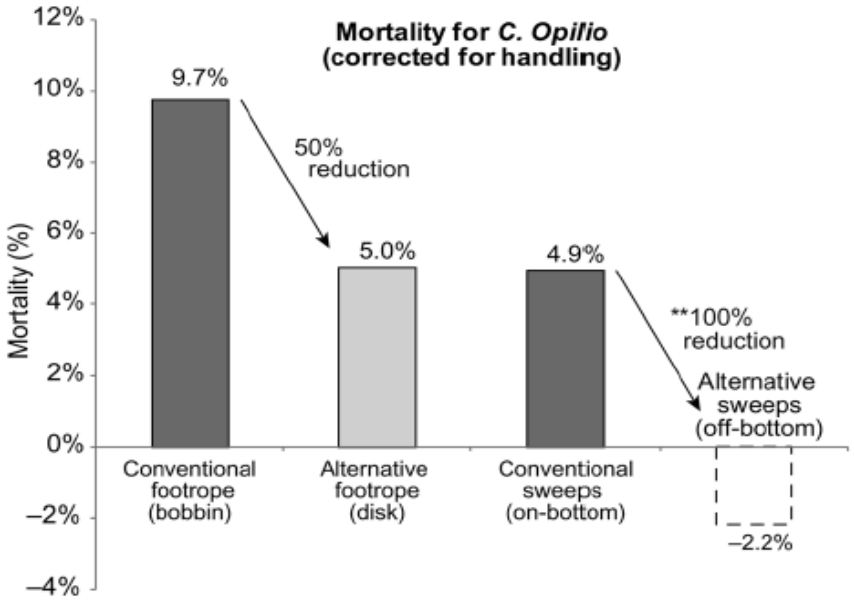

Figure 1 – Estimated mortality rates for conventional and modified trawl footropes and sweeps (from Hammond et al. 2013, NPRB 0711).

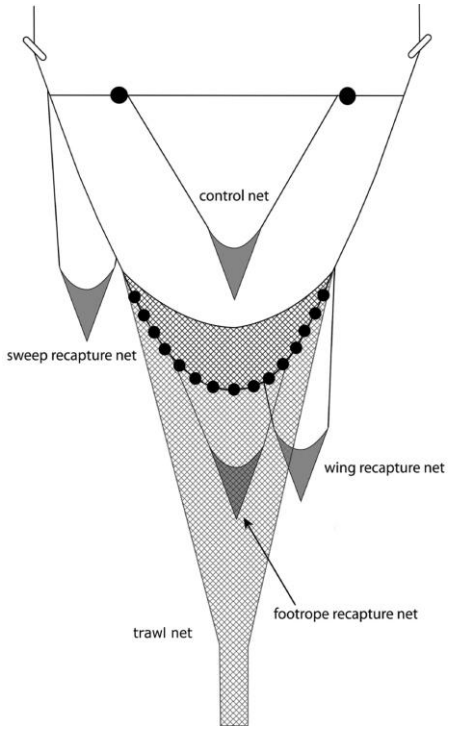

Figure 2 – Recapture nets used during NPRB Project 0711 to assess the mortality rates of crabs during non-capture encounters with bottom trawls. (Note: No more than 2 of these nets were fished during the same tow, and the control net always was fished separately. From Rose et al. 2013 NPRB 0711)

Our subsequent study (NPRB 1117) used under-trawl nets designed to cover the entire area behind the trawl's footrope (Figure 3) and tested three footrope designs more similar to those used at that time. 'Control' capture was achieved by removing the footrope and floating the leading edge of the trawl net above the seafloor. The results of that work were only published in the final NPRB report https://projects.nprb.org/#metadata/d8beeb60-31c0-406b-981a-8f4a0883e925/project, which only displayed the mortality rates and percent of crabs caught in graphical form (Rose et al. 2014).

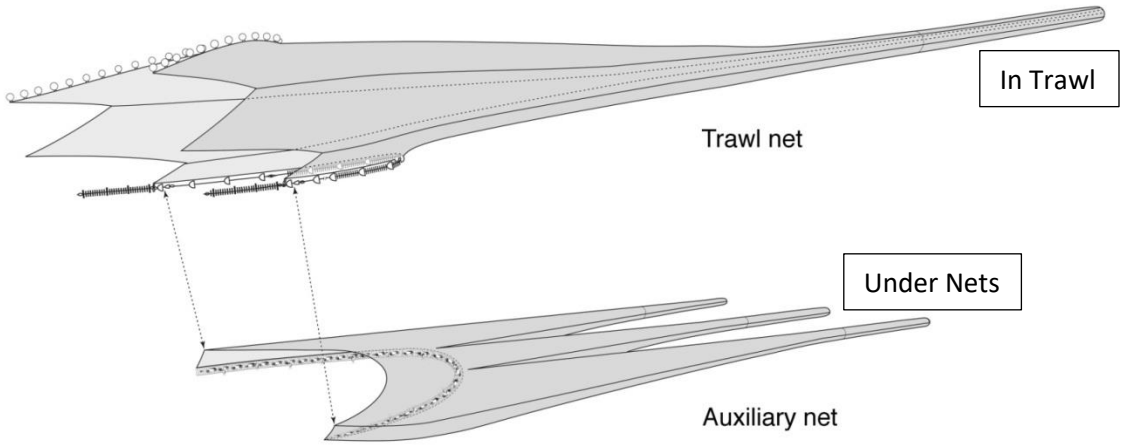

Figure 3 – Recapture (auxiliary) nets used during NPRB Project 1117 to assess the mortality rates of crabs during non-capture encounters with bottom trawls and the proportions of crabs caught and escaping under the trawl net.

Three different footrope designs (Figure 4) were used during the 2012 and 2013 study trips, with 16 tows of the 16" footrope, 23 tows of the raised 16" footrope, and 20 tows of the 24" footrope. Nine tows were made in the control configuration, where recaptured crabs only experienced capture and handling stressors. All crabs in each net (left, center and right under-nets and the trawl codend) were categorized by species and sex, measured for carapace width, and assessed for losses of six reflexes to estimate mortality probability.

Figure 4 – Four footrope designs used to study unobserved mortality of Bering Sea crabs: Left - 16" bobbin and disk, Middle -16" footrope raised by inserting 21" disks, Right – 24" disks and bobbins.

Starting with the numbers of crabs in each net and the average mortality probability for each of those crabs, calculations of a multiplier between observed crab caught and unobserved mortalities proceeded in four steps (Table 1):

1) Estimating a multiplier between observed snow crabs caught and number of snow crabs under the trawl by dividing the total number caught in the under-nets by the number caught in the codend.
2) Calculate the average mortality probabilities for snow crab in the under-nets and the control net.
3) Adjust average mortality probabilities for capture and handling stressors to isolate the effects of trawl footrope contact. To correct mortality estimates for handling damage, we assumed that gear and handling mortalities were independent and sequential. That is, where both processes occur together for the recaptured crabs (m_{g+h}), the gear mortality (m_g) occurs first and only those crabs not killed by the gear (1- m_g) are vulnerable to capture and handling mortality (m_h), resulting in Equation 3:

   $$m_{g+h} = m_g + ((1 - m_g) * m_h) \quad (3)$$

   This equation was solved for m_g, resulting in Equation 4:

   $$m_g = (m_{g+h} - m_h) / (1 - m_h) \quad (4)$$ (Rose 1999)

   [m_{g+h} is the raw under-net mortality from Step 2 and m_h is the control mortality]
4) Multiply the adjusted mortality rate by the Multiplier to estimate numbers from Step 1 to estimate the number of unobserved crab mortalities per crab observed in the catch.

Estimates ranged from 0.3 to 9.5 unobserved crab mortalities per crab observed in the catch. Multipliers were higher for males than females and lowest for the 24" footrope.

Notes

These multiplier estimates do not include crabs encountering sweeps, which cover most of the seafloor fished by trawls. Mortality rates for snow crabs encountering the required raised sweeps were slightly less than, but not significantly different those captured in control nets (Hammond et al. 2013), indicating no significant mortality of snow crabs encountering raised sweeps.

Similar calculations could be made for Tanner crab, but king crabs were not included in this study.

Estimates are likely to have wide uncertainty ranges, which were not calculated here.

Bottom trawl footrope designs vary widely and are not systematically documented. At the time of these studies (2013), A80 captains noted that the 24" design was in the range of practice at the time and that the trend was toward footropes with more clearance beneath and less weight. They particularly noted that the 'conventional' footrope design tested in 2008-2009 (Hammond et al. 2013, Rose et al. 2013) had little space beneath and was more heavily weighted than their footropes.

Escape and mortality rates will vary with how footropes are rigged onto the trawl. Even though the 24" footrope used in 2013 had much more clearance below it, which should have provided more escape opportunities, it captured a higher percent of crabs than the smaller footropes (16" and 16" raised with 21" disks) used in 2012. This was attributed to a rigging difference that put the front edge of the 2013

net at the height of the middle of the footrope disks, while the net height during 2012 was even with the top of the footrope.

Table 1 - Estimating unobserved mortality of snow crab, those encountering a trawl but not captured, from the number of captured crabs. The multiplier considers both the proportion of crab caught and the mortality rates for escaping crab. Data is from experiments conducted in 2012 and 2013 (NPRB project 1117).

Snow crabs in test nets	**Females**		**Males**		**Combined**	
Footrope design	**Under Nets**	**In the Trawl**	**Under Nets**	**In the Trawl**	**Under Nets**	**In the Trawl**
24" bobbins	717	73	986	78	1703	151
16" bobbins	1390	18	958	10	2348	28
Raised 16" bobbins	882	18	515	4	1397	22

Raw multiplier (under/in)	**Females**	**Males**	**Combined**	
24" bobbins	10	13	11	Multiply observed bycatch numbers by this value to estimate how many uncaught crab encountered the footrope (unobserved).
16" bobbins	77	96	84	
Raised 16" bobbins	49	129	64	

Raw Mortality rate	**Females**	**Males**	**Combined**	
24" bobbins	5.2%	8.9%	7.4%	Average mortality rates for crabs caught under the net or in the control net.
16" bobbins	5.2%	10.6%	7.4%	
Raised 16" bobbins	6.7%	12.4%	8.8%	
Control Net	2.1%	5.4%	2.9%	

Adjusted Mortality rate	**Females**	**Males**	**Combined**	
24" bobbins	3.1%	3.7%	4.5%	Under-net mortality rates adjusted for the effects of capture and handling, using the mortality rates of crabs caught in under-nets without passing footrope gear (Control).
16" bobbins	3.2%	5.4%	4.6%	
Raised 16" bobbins	4.6%	7.4%	6.0%	

Multiplier with mortality	**Females**	**Males**	**Combined**	
24" bobbins	0.3	0.5	0.5	Multiply observed bycatch numbers by this value to estimate how many crab died after unobserved footrope encounters during that fishing effort.
16" bobbins	2.4	5.2	3.9	
Raised 16" bobbins	2.3	9.5	3.8	

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