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Effect of the 2015 narwhal (*Monodon monoceros*) entrapment on the Eclipse Sound narwhal stock

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

A narwhal (*Monodon monoceros*) entrapment event of at least 249 whales occurred near the community of Pond Inlet, Nunavut in November 2015. We evaluated how this particular entrapment event may impact the Total Allowable Landed Catch (TALC) for Pond Inlet for future years, and modelled how these events may impact the Eclipse Sound narwhal stock over the next 100 years. To determine entrapment impacts on the TALC we modelled different magnitudes of entrapment, from 249 narwhals (minimum), up to 1,000 narwhals (maximum). Satellite tagging data in recent years have shown some mixing of the Admiralty Inlet and Eclipse Sound narwhal stocks. As a result of this potential mixing of narwhals, we modelled scenarios where 100% of the entrapment included whales only from Eclipse Sound, and another scenario where only 76% of the individuals were from Eclipse Sound, assuming the other 24% came from Admiralty Inlet (proportion of the stock that left Admiralty Inlet and entered Eclipse Sound in the fall based on 4/42 satellite tags). Potential biological removal (PBR) was calculated assuming the entrapment event exceeded mortality levels already included in the base level of natural mortality by varying proportions (20%, 40%, 60%, 80%, and 100%). A population model was also used to investigate the impact of frequent entrapments (every 3, 5, and 10 years) that range in magnitude anywhere from 200–1,000 narwhals to investigate the long term impact these events may have on the Eclipse Sound narwhal stock. Models were run with no error term and with an arbitrary process error of 0.05. Results from the PBR model indicated that in a worst case scenario, where the entrapment included 1,000 individuals all from Eclipse Sound, and where mortality is considered above the natural mortality already included in the PBR calculation, the TALC need only be reduced by 13 animals, from 134 to 121. When no error term was included in the population model, the model indicated that entrapment events of the magnitude previously seen in Eclipse Sound would not cause the stock to go extinct if the events occur every 3 years. The lower 90% confidence intervals, however, do suggest an extinction possibility if entrapments occur every 3 years, and indicate declines in stock size if the events occur every 5 or 10 years. Similar results were seen when an error term was included in the population model, except that entrapment events happening every 3 years would result in stock extinction within 100 years, and the median stock size declines even with entrapments only occurring every 5 or 10 years. In the event of a future entrapment, monitoring of the event and research on narwhal behaviour would aid in improving our understanding of the impacts of these events on narwhal stocks.

INTRODUCTION

Narwhals (*Monodon monoceros*) from the Baffin Bay population spend winter in the Davis Strait and Baffin Bay and migrate in the spring to their summering grounds. Narwhals tend to return to the same summering grounds year after year (Dietz et al. 2001, Heide-Jørgensen et al. 2002, Heide-Jørgensen et al. 2003, Dietz et al. 2008) and because of this site fidelity the summering aggregations are managed as individual stocks. There are four defined narwhal stocks in northern Canada, the Admiralty Inlet, Somerset Island, Eclipse Sound, and East Baffin Island stocks, and two putative stocks, the Smith and Jones Sound stocks (DFO 2015). Annual harvests occur across the Arctic and narwhal quotas are in place to manage and ensure sustainability of the hunt. Animals from the Eclipse Sound stock are hunted annually by Inuit primarily from Pond Inlet, Nunavut; however, some of these whales may also be hunted while on their migration route by other communities in Canada and Greenland (Heide-Jørgensen et al. 2013a).

On the wintering grounds narwhals are known to inhabit waters with ice coverage upwards of 95% (Laidre and Heide-Jørgensen 2011). However, when weather changes suddenly, or ice forms quickly in fiords or inlets used by narwhals in the fall or on the migration pathways, ice entrapments can occur. Ice entrapments are a natural source of mortality for Arctic whales and are included in the intrinsic rate of population growth used to manage sustainable harvest levels. Despite this, there is concern that large or trends towards more frequent entrapments may have impacts on the individual narwhal stocks. A large entrapment event occurred in 1924 in Admiralty Inlet, where 600 narwhals were entrapped (Degerbøl and Freuchen 1935). Following this, the largest entrapment event in Canadian history occurred in 2008 in Eclipse Sound near the community of Pond Inlet. The entrapment may have included > 1,000 whales, with 629 whales harvested (Laidre et al. 2012). Another large entrapment occurred near Pond Inlet in 2015, where at least 259 narwhals were harvested, and up to 1,000 were trapped. This was 7 years after the previous large entrapment, suggesting there could be an increase in the occurrence of these events, which may impact the abundance of the individual narwhal stocks. As a result, we evaluate how this particular entrapment event may impact the Total Allowable Landed Catch (TALC) for Pond Inlet for future years, and modelled how the stock may be impacted if events of this magnitude occur every 3, 5, or 10 years.

Aerial surveys conducted in 2013 estimated 10,489 (CV 24%) individuals in the Eclipse Sound narwhal stock (DFO 2015). This was a nearly 50% decline from a previous survey in 2004 which estimated the stock at 20,225 individuals (Richard et al. 2010). However, the Admiralty Inlet stock abundance estimate had a similar increase from 18,049 in 2010 (DFO 2012a) to 35,043 in the 2013 survey (DFO 2015). Satellite tag data from narwhals tagged in Eclipse Sound has shown that some whales are moving between the Eclipse Sound and Admiralty Inlet stocks and that at least one narwhal returned to a different summering region than where it was tagged after overwintering in the Davis Strait (Watt et al. 2012). Therefore, it is possible that the changes in abundance may be due to movement of narwhal between the two regions.

As a result of the potential mixing of narwhals between Admiralty Inlet and Eclipse Sound, we modelled scenarios for calculating TALC where 100% of the entrapment included whales only from Eclipse Sound, and another scenario where only 76% of the individuals were from Eclipse Sound, assuming the other 24% came from Admiralty Inlet. This portion was determined by taking satellite telemetry information that showed 4/42 tagged narwhals travelled from Admiralty Inlet into Eclipse Sound in the fall and may have been available for an early winter entrapment event (4/42 = 0.095) (Watt et al. 2012). Using this ratio as an assumption for the behaviour of the whole Admiralty Inlet stock, the number of Admiralty Inlet whales that could move to Eclipse Sound is calculated by taking the proportion of tags (0.095) multiplied by the abundance estimate for Admiralty Inlet (35,043; DFO 2015) for a total of 3,329 whales. If Admiralty Inlet whales move to Eclipse Sound, it would change the abundance of narwhal in Eclipse Sound from 10,489 (DFO 2015) to 13,818 (adding an additional 3,329 whales). Based on this, the proportion of Admiralty Inlet whales in the entrapment event may be 0.24 (3,329 whales divided by the total abundance estimate of 13,818). Thus, in our second scenario we estimate that 24% of the individuals in the entrapment event come from Admiralty Inlet, while 76% come from the Eclipse Sound narwhal stock.

It is possible that whales involved in the entrapment may have also come from stocks other than Admiralty Inlet or Eclipse Sound, but currently we have little satellite tag evidence to support modelling these scenarios.

Although the frequency of these entrapment events is unknown, we wanted to determine the long term impacts on the stock if these events are cyclical in nature. As a result, we used a population model to determine what the impact of entrapment events occurring every 3, 5, and 10 years would be on the Eclipse Sound stock size over the next 100 years, if we assume the number of whales involved in the entrapment that came from Eclipse Sound varied randomly every entrapment between 200–1,000 whales.

METHODS

BACKGROUND

On Thursday, 5 November 2015 the Mittimatalik (Pond Inlet) Hunters and Trappers' Organization (HTO) notified the DFO area office in Iqaluit of a possible entrapment of narwhal in the Eclipse Sound area. The initial estimate of the entrapment was ~1,000 animals. The discovery was made by a hunter who was on his way to Lavoie Pt. (N72.732, W80.225) on the west side of Eclipse Sound. As he was travelling by snowmobile he made a stop at a seal hole near Dufour Pt. (N72.760, W79.579). During the stop he put in a hydrophone to listen for marine mammal vocalizations – possibly to listen for seal activity. While doing this he heard the distinct vocalizations of narwhal. The presumption was that the whales were somewhere in the area and likely trapped because of the ice cover. The HTO was made aware of this discovery and a search was started by the HTO to find where the narwhal may be trapped. After almost a month of searching by snowmobile using hydrophones and visual sightings, narwhals were finally found on Wednesday, 2 December, at two small breathing holes in Eclipse Sound just north of Ragged Island / Cape Hatt (N72.62174, W79.82822). The number of narwhals entrapped was estimated at 250 or more. Hunters cut a third hole in the ice to spread out the whales and to improve the efficiency of the harvest. Harvesting by the HTO and Pond Inlet hunters started on Saturday, 5 December and ended on Thursday, 10 December. The total landed harvest was 229 narwhals, plus an additional 20 that were either killed by bears (n = 12) or lost (n = 8) while being harvested. DFO science sent two employees to collect skin and blubber from all harvested whales and other tissues (eye, embedded tusk, blood, liver, kidney, and muscle) from as many whales as time and temperature (approximately -53 °C) would allow.

POTENTIAL BIOLOGICAL REMOVAL (PBR) MODEL

We assume the minimum mortality of whales from the Eclipse Sound narwhal stock is 249 whales (harvested and lost whales), and calculate model estimates with three assumed upper limits of mortality; 300, 650, and our maximum mortality which was estimated as 1,000 whales from information from hunters.

Natural mortality from entrapment events is already included in the potential biological removal calculation (PBR; Wade 1998); however, given the magnitude of this event and the potential frequency of these large scale entrapments, we modelled different levels of entrapment mortality above that already included in the intrinsic rate of population growth. We used the same scenarios modelled by DFO (2012b) where entrapment mortality exceeded the base level of natural mortality by 20%, 40%, 60%, 80%, and 100% (the worst case scenario).

PBR was calculated following Wade (1998) (see below) for each scenario and the PBR was then divided by the loss rate (1.28 [Richard 2008]) to calculate a revised TALC for all possible scenarios.

$$PBR = 0.5 * R_{Max} * N_{Min} * F_R$$

Where:

N_{Min} = N / exp (z $\sqrt{}$ln (1+CV^2))

N for Eclipse Sound is 10,489 and the CV is 0.24 (DFO 2015). N changes with different estimates of entrapment mortality by taking N – mortality, but the CV remained at 0.24.

z = 0.842 for the 20^{th} percentile of the log-normal distribution of the estimated population size (Wade 1998).

R_{Max} = maximum rate of increase for the stock. The default for cetaceans when the rate is unknown is 0.04. It is then multiplied by 0.5 to simulate the effect of logistic density dependent growth.

F_R = recovery factor set to 1.0 for a healthy stock (Wade and Angliss 1997).

POPULATION MODEL

The model we used to determine how frequent entrapments would impact the Eclipse Sound narwhal stock was formulated from a model first described by Wade (1998) and later used to determine the effect of a flexible quota by Richard and Young (2015). The model uses a discrete form of the generalized logistic equation minus PBR. We also subtracted the entrapment event to simulate impacts of entrapments on the Eclipse Sound narwhal stock. In the model we assume the full TALC is taken every year, and PBR is recalculated every 5 years, since this is the proposed survey rate.

The model used here is:

$$N_{t+1} = N_t + N_t * R_{max}\left[1 - \left(\frac{N_t}{K}\right)\theta\right] - PBR - E$$

where:

N_t = stock size at year t; N_0 starts at 2013 with an abundance estimate of 10,489 (DFO 2015)

R_{max} = maximum net recruitment rate set as the default value for cetaceans of 0.04

K = the pre-exploitation size or carrying capacity of the stock – 25,000 for these simulated stocks (Richard and Young 2015)

θ = the density dependent shape parameter – 1 in this case for maximum net productivity at 50% K (logistic growth)

PBR_t = Potential Biological Removal in year t, calculated every 5 years between surveys, starting at t = 2015 (2 years after the initial abundance estimate to offset the PBR calculation with the estimated frequency of entrapments)

$$PBR_t = N_{min,t} * 0.5 * R_{max} * F_r$$

where:

$N_{min,t}$ = the 20% of the log-normal distribution of the estimated stock size an estimate $E(N_t)$ with a fixed CV of 30% (CV used is the same as that assumed in Richard and Young [2015])

$N_{min,t}$ = $E(N_t)$ / [exp(z*sqrt[ln(1+CV^2)])], which simply $E(N_t)$ / 1.280407 with z = 0.842 (standard normal variate for 20th percentile) and a CV = 0.3

The estimated $E(N_t)$ used to update $N_{min,t}$ and PBR is sampled from a log-normal distribution of mean N_t and CV of 30%, as follows:

$$E(N_t) = EXP(Log\left(\frac{N_t}{\left(1 + (CV^{0.5})\right)}\right) + Z^*((LOG(1 + CV^2))^{0.5}))$$

where:

z is a random normal deviate = (-2*Log(Uniform(0,1))*Cos(2*π*Uniform(0,1))

R_{max} = the maximum rate of increase for the population (0.04)

F_r = recovery factor = 0.5 or 1 depending if the scenario puts the starting population (N_t) below MNPL (0.5K or 12,500) then F_r = 0.5, or above MNPL then F_r = 1.

E = the magnitude of the entrapment (varies randomly among runs from a uniform distribution between 200 and 1,000 narwhals for each entrapment event independently).

We ran 10,000 iterations of the model to determine a median stock trajectory with 90% confidence intervals around the median. The model was run to project impacts of frequent entrapments on the stock over 100 years. The model was run with three entrapment frequencies, assuming an entrapment event every 3, 5, and 10 years. The model assumes that entrapment mortality is 100% above that already included in the natural rate of mortality accounted for in PBR, and the magnitude of entrapments varied completely randomly between 200-1,000 narwhals for each entrapment event (based on estimates from the 2008 and 2015 entrapment events). The model also assumed all whales (from 200–1,000) came from the Eclipse Sound narwhal stock and all perished in the event.

Due to a growing concern that deterministic models to not reflect natural variation in population processes (Dennis et al. 2006), we also ran models with an additional random parameter for process error (Hilborn and Mangel 1997) following:

$$(N_{t+1} = W_t + N_t * R_{max}\left[1 - \left(\frac{N_t}{K}\right)^{\theta}\right] - PBR - E)$$

where:

$$W_t = \exp\,(z * S_{pro} - \left[{S_{pro}}^2 \,/\, 2\right])$$

where:

S_{pro} = 0.05 (as described below), and;

z = a random normal deviate as defined above.

Since there is little evidence for what a realistic process error is for any marine mammal population, we used the same arbitrary process error (0.05) used by Richard and Young (2015).

This value is consistent with the hypothesis that population dynamics of long-lived narwhals are not highly variable (Richard and Young 2015).

RESULTS

POTENTIAL BIOLOGICAL REMOVAL (PBR) MODEL

Recalculations of PBR for the Eclipse Sound narwhal stock indicated that the effect of varying the maximum entrapment mortality had relatively little impact on the resulting TALC, regardless of whether the entrapment included whales only from Eclipse Sound (Table 1) or from both Eclipse Sound and Admiralty Inlet (Table 2). In the worst case scenario where all whales came from Eclipse Sound, 1,000 whales perished, and all mortality is considered in addition to that already included in the PBR calculation, the TALC went from 134 to 121, a difference of 13 narwhals (Table 1). If only 76% of the whales in the entrapment came from Eclipse Sound, in the worst case scenario, the TALC went from 134 to 125, for a difference of 9 narwhals (Table 2).

Table 1. Revised PBR and TALC resulting from different entrapment mortality estimates assuming all whales involved in the entrapment came from the Eclipse Sound stock. PBR was calculated after the entrapment event. The final column indicates the difference between the proposed TALC of 134 pre-entrapment and re-calculated TALCS that take into account different proportions of the 2015 entrapment mortality above natural mortality.

Entrapment Mortality for Eclipse Sound Narwhals*	Proportion of the 2015 entrapment mortality above the base level of natural mortality	N_{Min}	PBR	TALC (after losses)	Difference
249	0% - 0 animals	8,594	171	134	0
	20% - 50 animals	8,553	171	134	0
	40% - 100 animals	8,512	170	133	-1
	60% - 149 animals	8,472	169	132	-2
	80% - 199 animals	8,431	169	132	-2
	100% - 249 animals	8,390	168	131	-3
300	0% - 0 animals	8,594	171	134	0
	20% - 60 animals	8,545	171	134	0
	40% - 120 animals	8,496	170	133	-1
	60% - 180 animals	8,447	169	132	-2
	80% - 240 animals	8,397	168	131	-3
	100% - 300 animals	8,348	167	130	-4
650	0% - 0 animals	8,594	171	134	0
	20% - 130 animals	8,488	170	133	-1
	40% - 260 animals	8,381	168	131	-3
	60% - 390 animals	8,275	165	129	-5
	80% - 520 animals	8,168	163	128	-6
	100% - 650 animals	8,061	161	126	-8
1,000	0% - 0 animals	8,594	171	134	0
	20% - 200 animals	8,430	169	132	-2
	40% - 400 animals	8,266	165	129	-5
	60% - 600 animals	8,102	162	127	-7
	80% - 800 animals	7,939	159	124	-10
	100% - 1,000 animals	7,775	155	121	-13

*Assuming 100% of the whales came from ES

Table 2. Revised PBR and TALC resulting from different entrapment mortality estimates assuming 76% of the whales came from the Eclipse Sound stock and 24% of the whales came from Admiralty Inlet. PBR was calculated after the entrapment event. The final column indicates the difference between the proposed TALC of 134 pre-entrapment and re-calculated TALCS that take into account different proportions of the 2015 entrapment mortality above natural mortality.

Entrapment Mortality for Eclipse Sound Narwhals*	Proportion of the 2015 entrapment mortality above the base level of natural mortality	N_{Min}	PBR	TALC (after losses)	Difference
189	0% - 0 animals	8,594	171	134	0
	20% - 38 animals	8,563	171	134	0
	40% - 76 animals	8,532	171	133	-1
	60% - 113 animals	8,501	170	133	-1
	80% - 151 animals	8,470	169	132	-2
	100% - 189 animals	8,439	169	132	-2
228	0% - 0 animals	8,594	171	134	0
	20% - 46 animals	8,556	171	134	0
	40% - 91 animals	8,519	170	133	-1
	60% - 137 animals	8,482	170	133	-1
	80% - 182 animals	8,445	169	132	-2
	100% - 228 animals	8,407	168	131	-3
493	0% - 0 animals	8,594	171	134	0
	20% - 99 animals	8,513	170	133	-1
	40% - 197 animals	8,433	169	132	-2
	60% - 296 animals	8,352	167	130	-4
	80% - 394 animals	8,271	165	129	-5
	100% - 493 animals	8,190	164	128	-6
759	0% - 0 animals	8,594	171	134	0
	20% - 152 animals	8,470	169	132	-2
	40% - 303 animals	8,356	167	130	-4
	60% - 455 animals	8,221	164	128	-6
	80% - 607 animals	8,097	162	127	-7
	100% - 759 animals	7,972	159	125	-9

*Assuming 76% of the whales came from ES

POPULATION MODEL

The median stock abundance estimate for model runs without process error suggests the stock abundance remains relatively stable with entrapments every 5 and 10 years, and declines when entrapments occur every 3 years (Figure 1). When entrapment events were assumed to occur every 3 years, after 100 years the stock would be considered endangered, and the lower 90% confidence interval for the model suggests the stock may crash in approximately 60 years (Figure 1A). The median stock size remains relatively stable if entrapments occur every 5 years (Figure 1B), although the lower 90% confidence interval does suggest some decline in size. When entrapments occur every 10 years the median stock size actually increases, suggesting that the population growth rate is able to compensate for the mortality events; however, the lower 90% confidence interval does suggest a decline in stock size (Figure 1C).

Generally, the addition of process error resulted in a slightly lower stock size for all entrapment frequencies (Figure 2). In the case where entrapments occur every 3 years, the median stock size is predicted to hit 0 before 80 years, while the lower 90% confidence interval suggests extinction within 40 years is possible (Figure 2A). For entrapments occurring every 5 years with process error included in the model, the median suggests a slight decline in the stock over time, while the lower 90% confidence interval approaches a stock size of 0 in less than 60 years

(Figure 2B). When entrapments are assumed to occur every 10 years and process error is incorporated, the median stock decreases over time (Figure 2C). For the 10 year entrapment cycle, the lower 90% confidence limit suggests the stock goes extinct in approximately 100 years (Figure 2C).

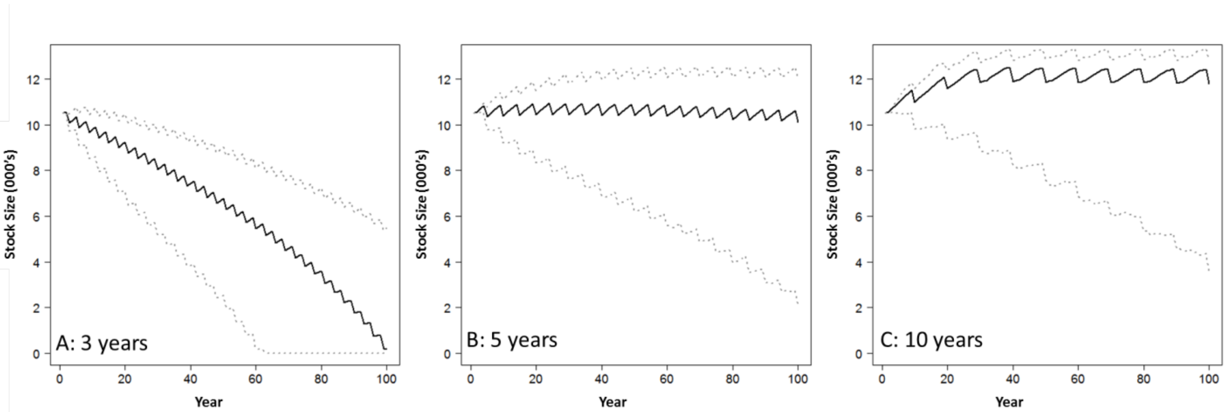

Figure 1. Stock abundance projections for the Eclipse Sound narwhal stock assuming entrapment events varying from 200–1,000 narwhals occur every 3 (A), 5 (B), or 10 (C) years. Black solid lines indicate median stock size over 10,000 iterations, while grey dashed lines indicate the 90% confidence intervals around the median.

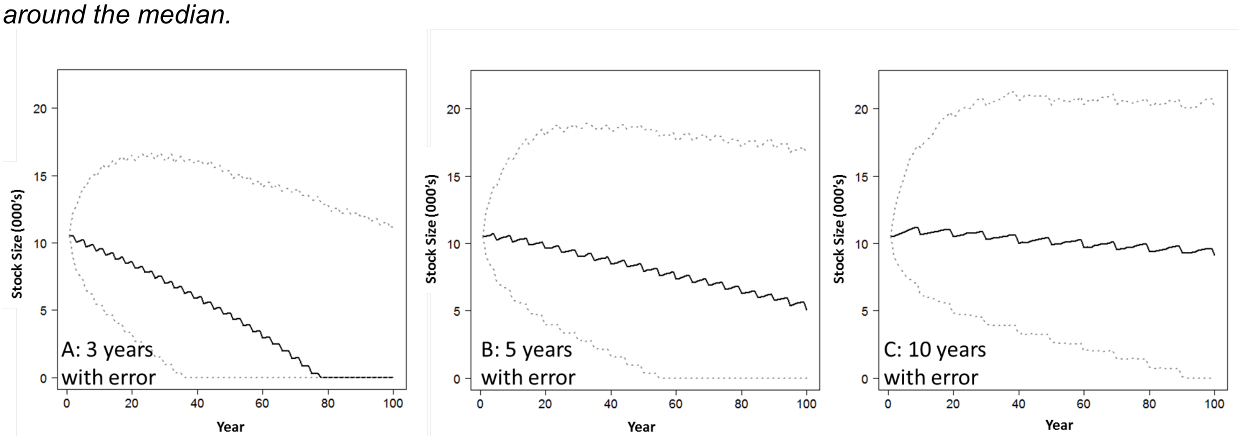

Figure 2. Stock abundance projections for the Eclipse Sound narwhal stock assuming entrapment events varying from 200–1,000 narwhals occur every 3 (A), 5 (B), or 10 (C) years with process error incorporated into the model. Black solid lines indicate median stock size over 10,000 iterations, while grey dashed lines indicate the 90% confidence intervals around the median.

DISCUSSION

The population modelling exercise without process error showed that entrapment events of this magnitude would have to be quite frequent (every 3 years or less), for the median stock size to decline over the next 100 years. However, the stock will not increase even when entrapments are only occurring every 5 years. At an entrapment rate of every 10 years, the median stock size suggests an increase, but it is difficult to interpret the amount of increase since we assumed a carrying capacity of 25,000 (which may not be accurate), and both the growth factor and the recovery factor change above 50% of the carrying capacity. We would caution interpretation of the magnitude of the increase, but it is evident that entrapments occurring every 10 years or more do not cause a decline in the Eclipse Sound stock. This suggests that if entrapments only occur every 10 years, the natural mortality rate already factored into the PBR calculation may already account for all mortality from these events. However, if the frequency of entrapments is every 3 or 5 years, the natural rate of mortality assumed in PBR may be exceeded. However, since PBR for this stock is ideally assessed every 5 years, we may be able to capture any entrapment events in the aerial surveys (depending upon the precision of the survey) and can then adjust PBR accordingly. If entrapments are occurring more frequently, surveys should also be conducted more frequently in order to capture the impacts of these events on the stock.

For the population model with process error incorporated, the confidence intervals are larger and chances of the stock going extinct are greater for all entrapment frequencies. We would caution that the process error selected is not based on biological data for any marine mammal populations, but comes from estimates for ungulates (Ahrestani et al. 2013) and therefore should be interpreted with caution. Another limitation of the population model is it currently does not incorporate the impacts of having a female biased entrapment. Without more information on birth rates, age at first reproduction, age structure of entrapped narwhals, and more evidence as to whether entrapment mortality is really greater for females versus males, or if males are just drowning while trying to escape, is needed to incorporate this parameter. However, we can assume that the long-term projections would be worse for the stock if reproductive females are making up the majority of the entrapment, as this could impact the maximum population growth rate in future years (currently assumed to be 0.04 for cetaceans). The 90% confidence intervals for the stock size estimates were quite large, and indicate our uncertainty with the population parameters used, as well as the variability in the size of the entrapments (200–1,000 whales) that may occur. Despite these limitations we believe the modelling exercise provides a useful framework for evaluating the impacts that frequent entrapments may have on the Eclipse Sound narwhal stock.

Entrapment events are natural sources of mortality for Arctic whales, although it is unlikely that all entrapments events would result in the death of every whale (some whales may survive long enough to escape or outlast the entrapment). Entrapments located and harvested by hunters may actually be increasing the mortality of whales since whales humanely harvested in these events are not currently considered part of the TALC. Whether or not these events are increasing in frequency or magnitude is difficult to determine. It is unlikely the 2015 entrapment would have been located had a hunter not used a hydrophone under the ice to hear the whales. An increase in the distance hunters can go from their communities as a result of gas powered snowmobiles has resulted in a greater expanse being monitored, and technologies, such as hydrophones, also increase the chances of finding an entrapment. Although detection of entrapments has likely improved, the incidence of entrapments as a result of unpredictable changes in climate and anthropogenic disturbances may also be increasing their incidence. Increased noise pollution caused by seismic surveys used to locate hydrocarbon reserves may also be linked to entrapment events (Heide-Jørgensen et al. 2013b). It is suggested the large 2008 entrapment event near Pond Inlet, may have occurred because whales left the summering region on their typical migration but were bombarded with noise which may have caused them to head back into the summering regions, which was eventually covered with ice and caused an entrapment (Heide-Jørgensen et al. 2013b). However, a direct link between seismic surveys and the entrapments could not be made. Although a consortium of oil companies (Petroleum Geo-Services Inc. (PGS), Multi Klient Invest AS (MKI), TGS-NOPEC Geophysical Company ASA (TGS), were granted a five-year license to conduct seismic surveys off the Canadian coast in Baffin Bay and Davis Strait (Speers-Roesch 2014), the companies decided to hold off on the surveys for 2015 since the communities were against the surveys and the dispute is currently in court (CBC 2015). Seismic surveying was ongoing off the east coast of Greenland (Gregoire 2015), but was unlikely to have impacted whales in Canada in 2015. Community members in

Pond Inlet suggested the entrapment may have been the result of shipping activity in Eclipse Sound, which may have interfered with the narwhal's typical migration pattern (L. Postma, pers. comm.). Currently there is little information on the interaction between ships and narwhals; however, this should be further investigated.

Changes in climate resulting in later freeze up dates, but more unpredictable ice formation may also cause ice entrapments. Of thirteen narwhals tagged in Eclipse Sound in August 1997–1999, all but one had left Eclipse Sound by October 1st (Dietz et al. 2001, Heide-Jørgensen et al. 2002). In contrast, of twelve narwhals tagged in the same region in August 2010–2011, only four whales had left the summering region by October 1st, with the majority leaving between October 4th and 16th (Watt et al. 2012). This is a difference in autumn migration start by over two weeks. However, this is still substantially earlier than the time frame for the entrapment, which was not until November. Why whales in 2015 remained in the summering region so long into the winter season is unknown; had satellite tags been implemented on narwhals that summer, we may have had some insight into their behaviour. For instance, if tags showed narwhals leaving the summer range, but returning again in October or November, this could provide evidence that some disturbance may have prompted them to return to their summering region.

Alternatively, narwhals may be choosing to stay in their summer regions longer for other reasons, such as abundant prey resources or to reduce predation risk. The body condition of narwhals in the 2015 entrapment appeared to be good, and a few narwhal stomachs (5-10) were inspected and found to contain an abundance of fresh squid, suggesting that narwhal were feeding throughout the entrapment. Narwhals may have chosen to stay in Eclipse Sound to take advantage of this prey source before their migration to the Davis Strait. In general, scientists know very little about entrapment events, and whether or not these events are always fatal is unknown. Future research on entrapment events is needed. In particular, monitoring of entrapments (e.g., controlled sampling and harvest over time to determine whale condition and health) or satellite tagging of narwhals would provide valuable information for determining what the whales are doing under the ice (i.e., are they feeding [deep diving], trying to scout for other holes [travelling far distances but then returning to the same breathing holes], etc.). Narwhals are very good at navigating in ice (Laidre and Heide-Jørgensen 2011), so it may have been possible for some to escape the entrapment.

The samples collected from the two entrapments in Pond Inlet included a greater proportion of females than males (> 80% female biased in 2008 [Watt and Ferguson 2011], and > 74% in 2015). It is hypothesized that males are able to dive longer and deeper than females and may have been able to escape the entrapment. In addition, females may be escorting their young who cannot dive for as long as adult whales, which may make females and young more vulnerable to entrapment events. Alternatively, adult males may actually head out of the summering region before females. In 2010, when whales were tagged in Eclipse Sound, the two large male narwhals (444 and 461 cm in length) were the first to leave the summering range, suggesting that females may delay migration, possibly to care for young in the calm of the fiords for longer, or to evade risk of predation. In 2011, the only tagged male did not leave the summering range until October at approximately the same time as the tagged females; however, this whale was only 310 cm in length with a very small tusk (20 cm in length) indicating it was still immature (Hay 1984, Watt et al. 2012). It is possible that large males may leave the summering region earlier. However, locals have found carcasses in spring (sex not indicated) indicative of winter entrapments (White 2012); males may drown while trying to escape and therefore not be captured at the entrapment site. Some hunters may prefer to hunt male narwhals to obtain a tusk while also collecting muktuk (P. Hall, pers. comm.). This may put less pressure on the stock since females of reproductive age and young whales (both females with no tusk and males with small tusks) are avoided. Entrapments, on the other hand, have potential to have a greater impact on the stock since females of reproductive age and their young appear to be more likely to be entrapped. However, although female biased entrapments have potential to negatively impact narwhal stocks, even the worst case scenario for the 2015 entrapment in Eclipse Sound did not result in a significant impact on the stock.

CONCLUSIONS

In summary:

- An ice entrapment event of over 249 narwhals occurred in Eclipse Sound in November 2015.
- This study assessed the impact of this entrapment on the proposed TALC, and the future abundance for the Eclipse Sound narwhal stock.
- Different scenarios were used to assess how different entrapment sizes (249, 300, 650, and 1,000 whales), with mortality levels exceeding the natural level of mortality by various amounts (20, 40, 60, 80, and 100%), would impact the PBR and resulting TALC.
- These scenarios were repeated to determine the impacts if the entrapment included individuals from both Eclipse Sound (76%) and Admiralty Inlet (24%).
- The results indicated that in a worst case scenario where the entrapment included 1,000 individuals all from Eclipse Sound, where all mortality was considered in addition to that already included in PBR, the TALC need only be reduced by 13 animals, from 134 to 121.
- A population model with and without process error was used to project future (up to 100 years) abundance estimates for the stock.
- Results of the population model without process error indicated entrapments occurring every 3 years would be detrimental to the stock, those occurring every 5 years would prevent stock growth, while those every 10 years may still allow the stock to increase in size, albeit with large confidence intervals.
- Results of the population model with process error indicated the Eclipse Sound narwhal stock declines at all entrapment frequencies (every 3, 5, and 10 years) investigated.
- If entrapments increase in frequency or magnitude the TALC may need to be revised, particularly given the concerns with entrapment events being female biased and therefore having potential to have a greater impact on stocks than hunting, which is typically male biased.
- In the event of an entrapment in the future, research should be undertaken to try to get a better understanding of these events and the impacts they have on narwhals.

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