How may an annual removal of humpback whales from Godthaabsfjord, West Greenland, affect the within-fjord sighting rate?

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ABSTRACT

Photo-identifications of humpback whales in the Godthaabsfjord area were collected from 2007 to 2012 and divided into individuals and number of sightings per individual. Monte Carlo simulations were performed on the sighting distributions of individual humpback whales to investigate the potential impact that local removals (e.g. ship strikes, subsistence hunt) could have on the sighting rate of humpback whales in Godthaabsfjord. Half of the sightings were based on the same six individuals during the six year period. Sighting rate was likely to drop regardless of when (spring, summer or autumn) an individual was removed due to the large degree of site fidelity of several humpback whales in Godthaabsfjord. Removals could affect the whalewatching industry in Godthaabsfjord where humpback whales constitute a key species. The least impact may be achieved by conducting the hunt outside the fjord system or minimising summer or autumn hunts within the fjord, as spring removals tend to have the least effect on summer sighting rates.

KEYWORDS: HUMPBACK WHALE; WHALING-ABORIGINAL; WHALEWATCHING; SIGHTING RATE; SITE FIDELITY; WEST GREENLAND

INTRODUCTION

From early spring to late autumn, humpback whales (*Megaptera novaeangliae*) come to West Greenland to feed on prey such as capelin (*Mallotus villosus*), sandlance (*Ammodytes dubius*) and euphausiids (Larsen and Hammond, 2004; Stevick *et al.*, 2006). Large aggregations of whales on the continental shelves of West Greenland have been linked to large densities of krill (Laidre *et al.*, 2010). Furthermore, the humpback whales also target food resources within fjords and bays and a limited number of humpback whales annually arrive to take advantage of the prey availability in Godthaabsfjord (64°11'N, 51°47'W; Fig. 1). Some individuals show a large degree of site fidelity returning to the fjord year after year, while others are seen a single year only. Generally, the whales do not remain in the fjord for the entire feeding period and their residence time seems highly variable (Boye *et al.*, 2010). This is also supported by a study of satellite tagged humpback whales, where individuals remained relatively stationary within an area for a maximum of a month and then moved up to hundreds of kilometres away to a different location, where they remained stationary again (Heide-Jørgensen and Laidre, 2007).

Humpback whales were, up until 1985, an important source of whale meat for the people of West Greenland. Commercial whaling of humpback whales was banned in 1966 but aboriginal hunters from West Greenland and the Lesser Antilles were allowed to continue the hunt (e.g. Martin *et al.*, 1984). In 1981 the abundance of humpback whales in West Greenland was estimated to be only 85–200 animals (Whitehead *et al.*, 1983) and in 1986 the International Whaling Commission (IWC) moratorium reduced the West Greenland quota on humpback whales to zero (IWC, 1986).

Since then, humpback whale abundance has increased rapidly in West Greenland with an estimated rate of 9.4% yr^{-1} and a current abundance estimate between 2,154 (CV = 0.36) and 3,272 (CV = 0.55) (Heide-Jørgensen *et al.*, 2012). This increase has resulted in an agreed quota for subsistence whaling as well as generating ecotourism. The West Greenland humpback whales now constitute a key species for the whalewatching industry. Around Nuuk, whalewatching takes place from smaller vessels within the protected waters of Godthaabsfjord. This is to avoid bad weather conditions or large swells on Fyllas Bank, Davis Strait, where whales are also present. The whalewatching operators in Nuuk are therefore dependent on the humpback whales being within the Godthaabsfjord area.

A recent study on site fidelity in humpback whales within the Godthaabsfjord (Boye *et al.,* 2010) raised the question of what happens to the sighting rate of humpback whales in Godthaabsfjord if individuals are removed from the fjord. Removals are most likely to happen through the subsistence hunt which was reopened in 2009. Since 2010 1–2 humpback whales have been taken yearly in the Godthaabsfjord area. In addition, ships strikes by large vessels are becoming more likely as oil and gas exploration in Greenland waters has resulted in increased shipping both offshore, along the coast and in the outer fjord system. The potential opening of an iron ore mine in the bottom of Godthaabsfjord would lead to an increase in marine traffic within the fjord system of significantly larger vessels than found previously. It is unknown whether the expected increase in noise levels and disturbance from anthropogenic activities could cause humpback whales to leave the Godthaabsfjord and feed in less exposed areas.

Ecotourism has become important in Greenland. This paper examines the possible effects that potential removals

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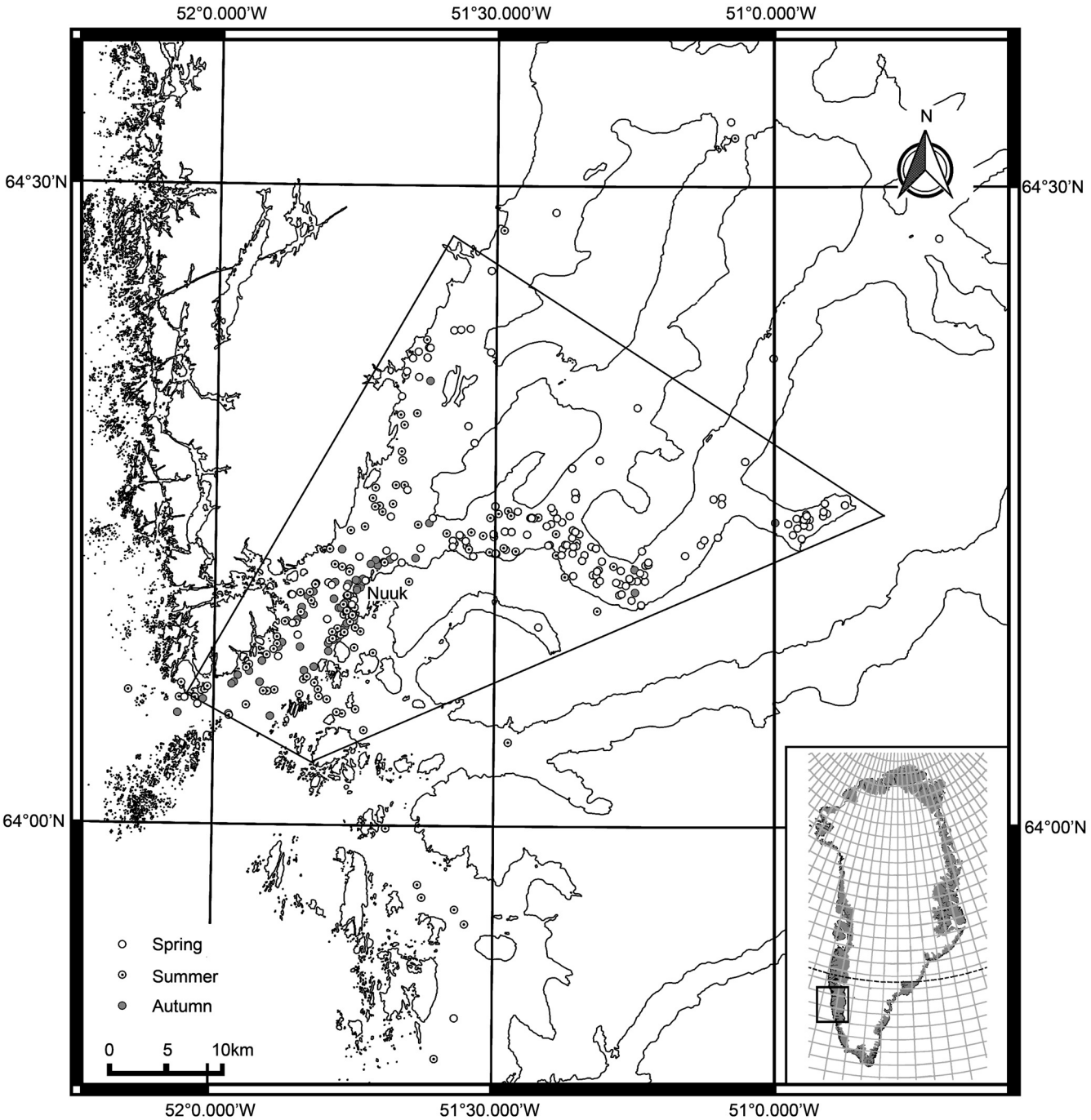

Fig. 1. The black frame indicates the area of effort by the researchers. Pictures from outside the effort zone have been supplied by locals and tourists. Map: Karl Brix Zinglersen, GINR, Coastline: Danish Geodata Agency.

of humpback whales from Godthaabsfjord could have on the sighting rate in the fjord. Assuming that individual whales' likelihood to be removed is proportional to the time they spend in the fjord, the impact on the sighting rate is analysed under the assumption that the number of whales that visit the fjord remains the same. Whilst this is unlikely for large removals, it is not unreasonable for realistic future removals of a single or a few animals per year, should it be from ship strikes or a direct hunt.

MATERIAL AND METHODS

Humpback whale fluke patterns along with the dorsal fin can be used for identification of individual whales (Katona *et al.*, 1979). In the period from 2007–2012 humpback whale identification photos were collected in the Godthaabsfjord area (Fig. 1) by researchers with help from local whalewatching boats. Whalewatching boats aim at areas with a high probability of finding whales, which precludes a quantification of effort. Additional photo-identifications were provided by the public. The researcher's effort on the water was from May to early October but locals and the whalewatching industry continued to provide photos until late October. Date, time and GPS position of the boat was noted for each photo, if available. Some photos only contained information on time and place (Godthaabsfjord). Photographs judged to be of suitable quality (Calambokidis *et al.*, 2000) were compared visually and sorted into individual whales by independent observers with

identification experience. Numbers of encounters of each individual in different years were also noted.

The density of whales was analysed by using the data on the number of whale encounters collected only from the research boat from May to early October and did not include photos from the public or whalewatching industry.

To investigate the potential impact that local removals could have on the sighting rate of humpback whales in Godthaabsfjord, Monte Carlo simulations were performed on the sighting distributions of individual humpback whales. Sightings were divided into the total number of spring (May and June), summer (July and August) and autumn (September and October) sightings per individual whale, with the total number of sightings summed over all individuals in each period giving an estimate of the relative sighting rate. One annual removal in either spring, summer or autumn was then assumed. It was also assumed that a removed whale would be replaced by a new whale drawn at random from the set of whales that had been seen in spring, summer or autumn. The probability that a given whale would be removed was set to be proportional to the relative sighting rate of that whale in the relevant season, so that harvest or potential ship strikes would target predominately the more resident individuals. The relative sighting rate, now given as the total number of sightings summed over the new distribution of individuals, would then decline over time because the distribution of individuals would change towards individuals with fewer sightings, while the total number of whales would remain the same. This made the relative sighting rate change over time, and this removal regime was simulated by 10,000 iterations over 50 years in order to estimate the development in the average of the relative sighting rate.

The estimated future sighting rates may be positively biased if caught individuals are not replaced; yet they might also be negatively biased if for example the integral of the number of whales in the fjord over a year is a function of ecological features, like the availability of food. In addition the estimates do not attempt to include the developments in the population of humpback whales in West Greenland, but attempt only to estimate relative sighting rates as a function of a change in the distribution of individual behaviour.

RESULTS

New individuals arrive in Godthaabsfjord each year (Table 1). However, within the period from 2007 to 2012 between 18.5% and 40% of the whales have been resighted for several years. There is a tendency for the resight rate to drop with time yet some individuals (8%) have been resighted during five to six years of the period and show a strong degree of site fidelity towards the Godthaabsfjord. It is also these individuals that appear to account for 50% of the encounters (Fig. 2). For instance, individuals with strong site fidelity have on average been photographed 4.3 ± 0.7 times (mean ± SE) annually whereas whales seen for a single year on average are photographed 2.1 ± 0.3 times in the given year they are present. The average for the single-year-individuals is drawn towards the higher end by two single individuals which were photographed 12 and 13 times during one year. If these two individuals are excluded, the average would drop to 1.7 ± 0.2 for whales seen for only one year in the fjord.

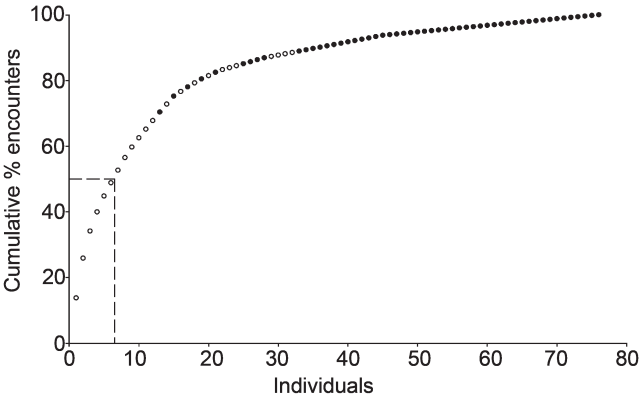

Fig. 2. The sighting rate of each individual. 50% of the encounters have during the past 6 years been based on the same 6 individuals. Open circles are individuals resighted in 2 or more years. Closed circles are individuals sighted for only one year.

May and early June are the months where most whales are seen in the fjord (Fig. 3). Sightings drop during summer and reach a minimum in August. In September, sightings increase again. Whales were also encountered during October and the public and whalewatching industry continued to provide photos during this month.

Fig. 4 illustrates the Monte Carlo simulation of one annual humpback whale removal in Godthaabsfjord. The potential relative sighting rate in spring, summer and autumn (Figs 4a–c) is shown in relation to an annual removal taking place during either spring (Fig. 4a), summer (Fig. 4b) or autumn (Fig. 4c). The potential relative sighting rate during summer is also shown (Fig. 4d) when a whale is taken in one of the seasons. According to the simulation the sighting rate will decline over time no matter what season a whale is removed.

Table 1

Site fidelity of humpback whales in Godthaabsfjord during the past six years. ID = number of whales identified, *N* = number of new individuals. Numbers in brackets are %.

				No. of whales seen in each subsequent year				
Year	No. of photos	ID	*N*	2008	2009	2010	2011	2012
2007	49	20	20	8 (40.0)	6 (40.0)	7 (27.0)	5 (24.0)	5 (18.5)
2008	143	20	12	–	6 (40.0)	10 (38.5)	7 (33.3)	9 (33.3)
2009	38	15	8	–	–	7 (26.7)	6 (28.6)	8 (29.6)
2010	68	26	13	–	–	–	9 (42.9)	9 (33.3)
2011	130	21	10	–	–	–	–	10 (37.0)
2012	85	27	13	–	–	–	–	–
Total	513	129	76	–	–	–	–	–

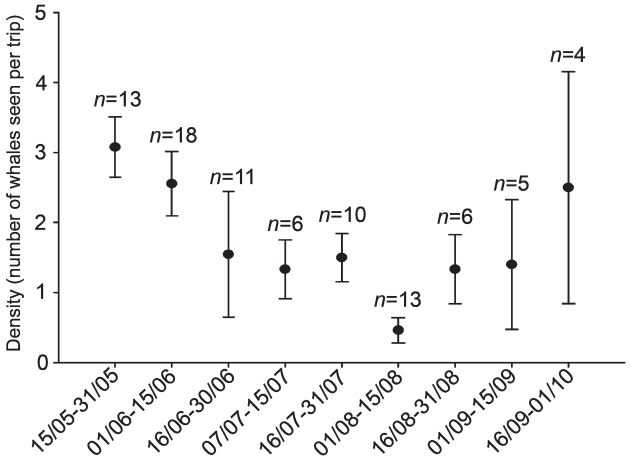

Fig. 3. The density of whales with SE. Most whales are spotted during late spring and early autumn. *n* = effort on the water in days in the given period.

However, there is a large difference in how much the sighting rate may drop. If one whale is removed annually during spring (Fig. 4a), then the sighting rate will gradually drop over a 50 year period and eventually stabilise at a sighting rate of 45% relative to the current spring sighting rate. In addition, the sighting rate during summer and autumn will also be affected by a removal in spring where annual sighting rates may drop to 65% and 55% for summer and autumn respectively relative to their current sighting rate. Autumn removals (Fig. 4c), show more or less the same pattern with the sighting rate dropping to 45% in autumn over a 40 year period and this causes the summer sighting rate to drop to 55% relative to the current sighting rate. Spring sightings will, however, be less affected by autumn removals as sighting rate only drops 20% and stabilises at 80% relative to the current spring sighting rate within a 20 year period. If removals take place only during summer (Fig. 4b) this will have a strong effect on both the summer and autumn sighting rates which may drop to around 40% and 45%, respectively. Again, this will not affect the spring sighting rate as much which drops to around 80% of its current sighting rate.

The main tourist season in Nuuk is during summer and only if whales are removed during spring is the decrease in sighting rate minimised; it stabilises at approximately 65% relative to the current summer sighting rate within a 50 year period (Fig. 4d).

DISCUSSION

The asymptotic sighting rate of the analysis is the same independently of the number of whales removed per year, but higher removals will result in a faster decline toward the asymptotic values. This constancy is obtained because it is assumed that the number of individual whales that visits the fjord will remain constant. While this may only be expected for very small removals, the analysis focuses on the effects caused by an expected change in the distribution of time-periods spend by individual whales in the fjord.

Looking at the density of whales, most encounters are during spring and autumn and fewest encounters during summer. Spring is the time period where the whales arrive from their winter breeding areas and the period corresponds to the spawning of capelin inside the fjords (Friis-Rødel and Kanneworf, 2002). The larger density during spring may therefore reflect an influx of individuals on their northward migration that target spawning capelin in the shallow waters. The higher density during autumn may reflect an influx of whales on their southward migration to the winter breeding areas.

Although new individuals enter the Godthaabsfjord area each year, many of the whales encountered are whales that

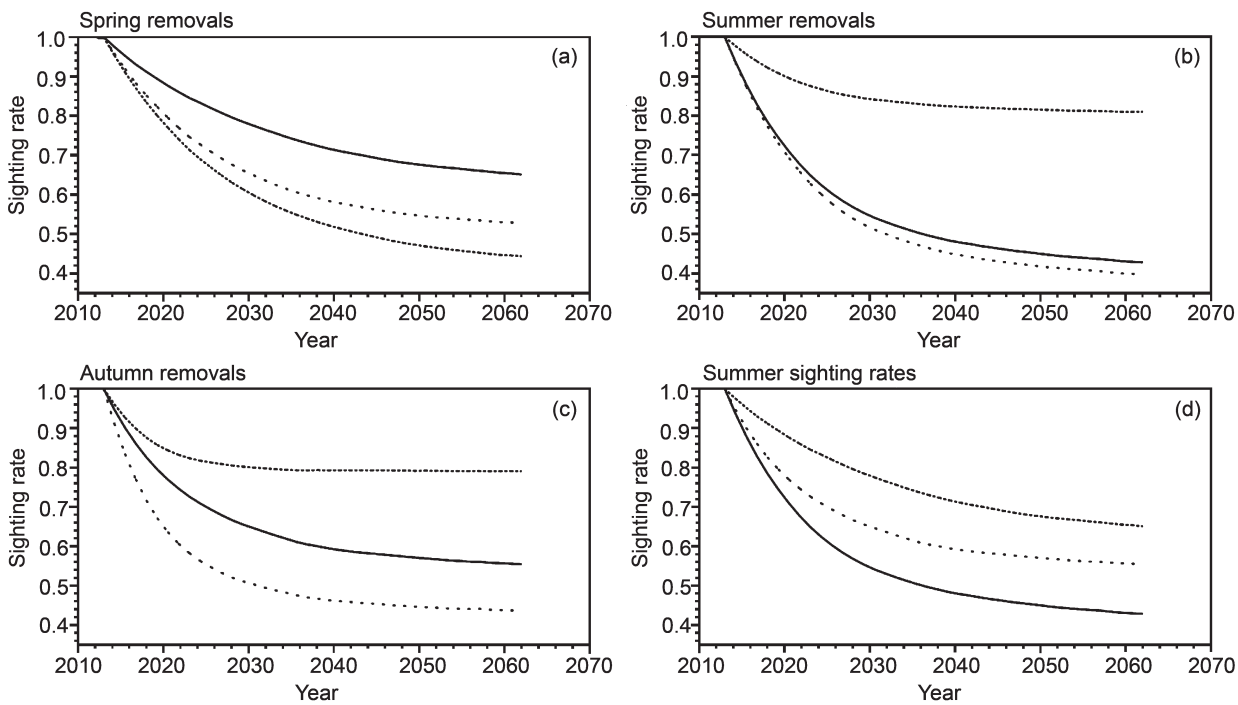

Fig. 4. Illustrates the simulation of removals of humpback whales under three different scenarios (A–C) along with an illustration of how summer sighting rates (D) could appear if whales were removed during different seasons. Spring (dotted line), summer (solid line) or autumn (dashed line). The simulation illustrates the removal of a single whale annually.

have been observed in the fjord in previous years. Whales with the largest site fidelity, i.e. whales that have been seen more or less every year since 2007, are encountered the most. It appears that just six individuals (of the total 76 whales that have been identified in the fjord so far) make up the basis of 50% of the encounters within the six year period. Therefore the most 'site faithful' individuals may be of considerable importance to the whalewatching companies as reflected in all the photos collected.

It is unlikely that photos of every whale entering/leaving the fjord are obtained. The vast majority of the photos collected are from the outer part of the fjord (Fig. 1) which either depict where most whales are present or where most boats are moving about. This means that the photos analysed represent the area used for whalewatching and represent the individuals present in that area.

The reason for the variable site fidelity amongst individuals is unknown but this may be maternally passed on to the calves (Weinrich, 1998). It is therefore a challenge to predict how, when and if new individuals become site faithful with time or if site faithful animals eventually become less site faithful. The simulation made here is based on the situation during the past six years and there is always the possibility that more years of data collection could alter the picture.

According to the simulation, the high site fidelity of individual whales in Godthaabsfjord will result in a decrease in sighting rate over time if humpback whales within the fjord are removed, despite the fact that new individuals arrive annually. If new individuals were encountered just as often as site faithful animals during a single season this would not be the case. But the fact that site faithful individuals are encountered more often and seen over a longer period within the fjord leads to a greater possibility for these animals to be hunted, struck by ships or by other means removed from the fjord. Eventually the yearly sighting rate would then decline over time because the distribution of individuals would change towards individuals that spend less time in the fjord system.

To reduce a decrease in sighting rate over time, several actions could be considered and some are already in use. Hunting of humpback whales most often takes place in spring or autumn when the weather is cold and the chance of destroying the meat in warmer temperatures is smaller. With the reopening of the subsistence hunt on humpback whales in West Greenland there has been an increasing concern and debate on how this might affect the whalewatching industry which relies on the presence of the whales and on the tourists. In Nuuk, whaling takes place within or in the vicinity of Godthaabsfjord as:

(1) the hunters are reliant on being close to the flensing areas to prevent long distance travelling and the risk of the meat being spoiled;

(2) the calmer waters within the fjord facilitates the hunt and reduces the risk of strike and loss; and

(3) long distance travelling would increase the fuel expenses.

However, if whales are not hunted during summer but are taken during the spring this may, according to the results presented here, facilitate a minimum in decrease of sighting rate in Godthaabsfjord. The density of whales within the fjord is larger during this period and the probability of striking a new (rather than site faithful) animal is greater. Furthermore, the whales are not always taken inside the fjord but occasionally just outside the fjord where individuals not associated with Godthaabsfjord may be encountered. According to the results, whaling within the fjord during autumn could have a larger negative impact on the summer sighting rate than hunting during spring. This could be explained by the identification data from spring and autumn which indicate that 41% of encounters during spring are of the six most site faithful individuals compared to 61% during autumn of the same six individuals. However, identification data during October are almost solely based on photos from the public and whale watching boats as very little effort on the water was carried out in October during this study and effort on the water during September was also low. If effort increases during autumn there is a possibility that whale density along with number of individuals encountered will increase further and that catches during autumn will have an equally low impact on the summer sighting rate as spring catches, however, the picture may also remain the same.

Ship strikes and entanglements account for unpredictable removals from the fjord. Entanglements are difficult to prevent and less controllable. Between one and five humpback whales have been entangled annually in West Greenland since 2001 (none in 2007) in fishing gear developed to catch cod or snow crabs (data from the Ministry of Fisheries, Hunting and Agriculture, Greenland Self Rule). In Greenland, the outcome of entanglements is lethal unless the whales are able to get free by themselves. Entanglements have also occurred in Godthaabsfjord.

Traffic from smaller outboard vessels is large within the fjord but has to our knowledge never resulted in any ship strikes fatal for whales or humans, although ship strikes have occurred. In contrast, the larger vessels involved in mineral exploration may pose a threat, as ships larger than 80m according to Laist *et al.* (2001) cause the most severe and lethal injuries. Shipping in relation to oil and gas exploration is already taking place from the mouth of the fjord to Nuuk harbour. Furthermore, the proposed Isua Iron Ore mine in the bottom of Godthaabsfjord may result in approx. 20 return ships trips a month within the fjord, divided into 330m bulk carriers (VLBC), 290m cargo ships, 170m tankers, 135m transport vessels and smaller 31m tug boats (Orbicon, 2013), increasing the possibility of ship strikes. Laist *et al.* (2001) found that most accidents occurred when speed exceeded 14 knots. To reduce the risk of ship strikes, regulations regarding speed of larger vessels entering the fjord could be implemented along with the use of marine mammal observers onboard the boats moving within the fjord. Finally, the risk of ship strikes could be further reduced if studies of humpback whale movements were conducted within the fjord to point out important travelling routes used by the whales or feeding hot spots. Restricted areas for large vessels moving within the fjord could then be established.

In summary, due to the large site fidelity of several individuals in Godthaabsfjord, sighting rate within the fjord is expected to drop over time if one individual is removed from the fjord annually even if the numbers of individuals that visit the fjord remain the same. This is despite a healthy

population of humpback whales along the West Greenland coast and the fact that new individuals enter the fjord every year. These results, however, depend on the assumption that the number of whales that visit the fjord will not increase. Most encounters of humpback whales occur during spring and autumn, corresponding to the influx of whales on their north and southward migration. The simulations of removals of whales from the fjord indicate that removals during spring will have the least effect on the summer sighting rate and hence the least effect on the whalewatching industry. Hunting takes places in either spring or autumn, where autumn hunting may result in a larger decrease in sighting rate than spring hunting. Ship strikes with lethal outcome are a new challenge which may be overcome by lowering speed and establishing restricted areas for heavy traffic within the fjord.

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REFERENCES

Boye, T.K., Simon, M. and Madsen, P.T. 2010. Habitat use of humpback whales in Godthaabsfjord, West Greenland, with implications for commercial exploitation. *J. Mar. Biol. Assoc. U.K.* 90(8): 1,529–38.

Calambokidis, J., Steiger, G.H., Rasmussen, K., Urbán R, J., Balcomb, K.C., Ladrón de Guevara P, P., Salinas Z, M., Jacobsen, J.K., Baker, C.S., Herman, L.M., Cerchio, S. and Darling, J. 2000. Migratory destinations of humpback whales that feed off California, Oregon and Washington. *Mar. Ecol. Prog. Ser.* 192: 295–304.

Friis-Rødel, E. and Kanneworf, P. 2002. A review of capelin (*Mallotus villosus*) in Greenland waters. *ICES J. Mar. Sci.* 59(5): 890–6.

Heide-Jørgensen, M.P. and Laidre, K. 2007. Autumn space-use patterns of humpback whale (*Megaptera novaeangliae*) in West Greenland. *J. Cetacean Res. Manage.* 9(2): 121–26.

Heide-Jørgensen, M.P., Laidre, K., Hansen, R.G., Burt, M.L., Simon, M., Borchers, D.L., Hanssen, J., Harding, K., Rasmussen, M.H., Dietz, R. and Teilmann, J. 2012. Rate of increase and current abundance of humpback whales in West Greenland. *J. Cetacean Res. Manage.* 12(1): 1–14.

International Whaling Commission. 1986. Chairman's Report of the Thirty-Seventh Annual Meeting. *Rep. int. Whal. Commn* 36:10–29.

Katona, S., Baxter, B., Brazier, O., Kraus, S., Perkins, J. and Whitehead, H. 1979. Identification of humpback whales by fluke photographs. pp.33–44. *In*: Winn, H.E. and Olla, B.L. (eds). *Behaviour of Marine Mammals, Vol. 3: Cetaceans*. Plenum Press, New York and London. i–xix+438pp.

Laidre, K., Heide-Jorgensen, M.P., Heagerty, P., Cossio, A., Bergstrom, B. and Simon, M. 2010. Spatial association between large baleen whales and their prey in West Greenland. *Mar. Ecol. Prog. Ser.* 402: 269–84.

Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S. and Podesta, M. 2001. Collisions between ships and whales. *Mar. Mammal Sci.* 17(1): 35–75.

Larsen, F. and Hammond, P.S. 2004. Distribution and abundance of West Greenland humpback whales *Megaptera novaeangliae*. *J. Zool. (London)* 263: 343–58.

Martin, A.R., Katona, S.K., Mattila, D., Hembree, D. and Waters, T.D. 1984. Migrations of humpback whales between the Caribbean and Iceland. *J. Mammal.* 65(2): 330–33.

Orbicon. 2013. ISUA Iron Ore Project – Environmental impact assessment (EIA) prepared for London Mining Greenland A/S. Final Version. Prepared by Orbicon. [Available at: *http://naalakkersuisut.gl/da/H%C3%B8ringer/Arkiv-over-h%C3%B8ringer/2012/~/media/B2799FE6392543138C3C8DB3682386FA.ashx*].

Stevick, P.T., Allen, J., Clapham, P.J., Katona, S.K., Larsen, F., Lien, J., Mattila, D.K., Palsbøll, P.J., Sears, R., Sigurjonsson, J., Smith, T.D., Víkingsson, G., Øien, N. and Hammond, P.S. 2006. Population spatial structuring on the feeding grounds in North Atlantic humpback whales *(Megaptera novaeangliae)*. *J. Zool.* 270: 244–55.

Weinrich, M. 1998. Early experience in habitat choice by humpback whales (*Megaptera novaeangliae*). *J. Mammal.* 79(1): 163–70.

Whitehead, H., Chu, K., Perkins, J., Bryant, P. and Nichols, G. 1983. Population size, stock identity, and distribution of the humpback whales off West Greenland – summer 1981. *Rep. int. Whal. Commn* 33: 497–501.