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Estimating the Economic Value of Narwhal and Beluga Hunts in Hudson Bay, Nunavut

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ABSTRACT. Hunting of narwhal (*Monodon monoceros*) and beluga (*Delphinapterus leucas*) in Hudson Bay is an important activity, providing food and income in northern communities, yet few studies detail the economic aspects of these hunts. We outline the uses of narwhal and beluga and estimate the revenues, costs, and economic use value associated with the hunt on the basis of the harvests in 2007. We also explore the effects of cost sharing and inclusion of opportunity cost of labour on model outputs. For the communities participating in each hunt, the average economic use value was negative (-$9399) for beluga and positive ($133 278) for narwhal. The corresponding per capita value estimates were -$1 for beluga and $44 for narwhal. Including the effects of cost sharing with one other hunting activity in the model increased the economic use values to $266 504 for beluga and $321 500 for narwhal. Narwhals provide a higher value per whale, in addition to a higher per capita total economic value to the community, compared to belugas because resources are shared among fewer communities. However, the beluga hunt overall provides greater revenue because more belugas are harvested. In keeping with literature on other hunting activities in the Arctic, our results indicate that the value of whales to communities is largely due to their food value.

Key words: hunting, narwhal, beluga, economic value, Hudson Bay, subsistence hunting, use value

RÉSUMÉ. Dans la baie d'Hudson, la chasse au narval (*Monodon monoceros*) et au béluga (*Delphinapterus leucas*) représente une activité importante en ce sens qu'elle est à la fois une source de nourriture et de revenu pour les collectivités du Nord. Pourtant, peu d'études se penchent sur les aspects économiques de cette activité. Nous faisons mention des utilités du narval et du béluga, puis nous estimons les revenus, les coûts et la valeur utilitaire économique liée à ces activités de chasse en fonction des récoltes de 2007. De plus, nous explorons les effets du partage des coûts et de l'inclusion du coût de substitution de la main-d'œuvre à l'égard des sorties de modèles. Pour les collectivités qui participent à chaque chasse, la valeur utilitaire économique moyenne était négative (-9 399 $) dans le cas du béluga et positive (133 278 $) dans le cas du narval. Les estimations correspondantes des valeurs par habitant étaient de - 1 $ pour le béluga et de 44 $ pour le narval. L'inclusion des effets du partage des coûts avec une autre activité de chasse au modèle a pour effet d'accroître la valeur utilitaire économique à 266 504 $ pour le béluga, et à 321 500 $ pour le narval. Les narvals donnent une plus grande valeur par baleine, ainsi qu'une valeur économique totale plus élevée par habitant pour la collectivité, comparativement aux bélugas car les ressources sont partagées entre un moins grand nombre de collectivités. Cependant, dans son ensemble, la chasse au béluga procure un revenu plus élevé parce qu'un plus grand nombre de bélugas est récolté. Conformément à la documentation publiée sur d'autres activités de chasse dans l'Arctique, nos résultats indiquent que pour les collectivités, la valeur des baleines réside principalement dans leur valeur alimentaire.

Mots clés : chasse, narval, béluga, valeur économique, baie d'Hudson, chasse de subsistance, valeur d'usage

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INTRODUCTION

Subsistence whaling has been an important activity for Native communities in the Canadian Arctic, as hunts hold cultural significance (Freeman, 2000; Nuttall, 2005; Stewart and Lockhart, 2005). Increasing human populations, combined with declines in marine mammal populations in Hudson Bay, reveal the importance of hunting to this region. Hunting and the use of "country foods" (i.e., foods hunted and gathered from the land) are important aspects of northern community life and contribute to reinforcing social and cultural relationships (Wenzel, 1991; Freeman, 2000; Nuttall, 2005). Not only does hunting provide a source of protein for people, but Inuit have also reported a lack of resistance to illness when not consuming country foods (Freeman, 2005). In Hudson Bay (Fig. 1), Inuit culture has been strongly linked to marine species throughout history (Stewart and Lockhart, 2005). A variety of species, including bowhead, beluga, narwhal, polar bears, walrus, seals, fish, and birds, have traditionally been hunted.

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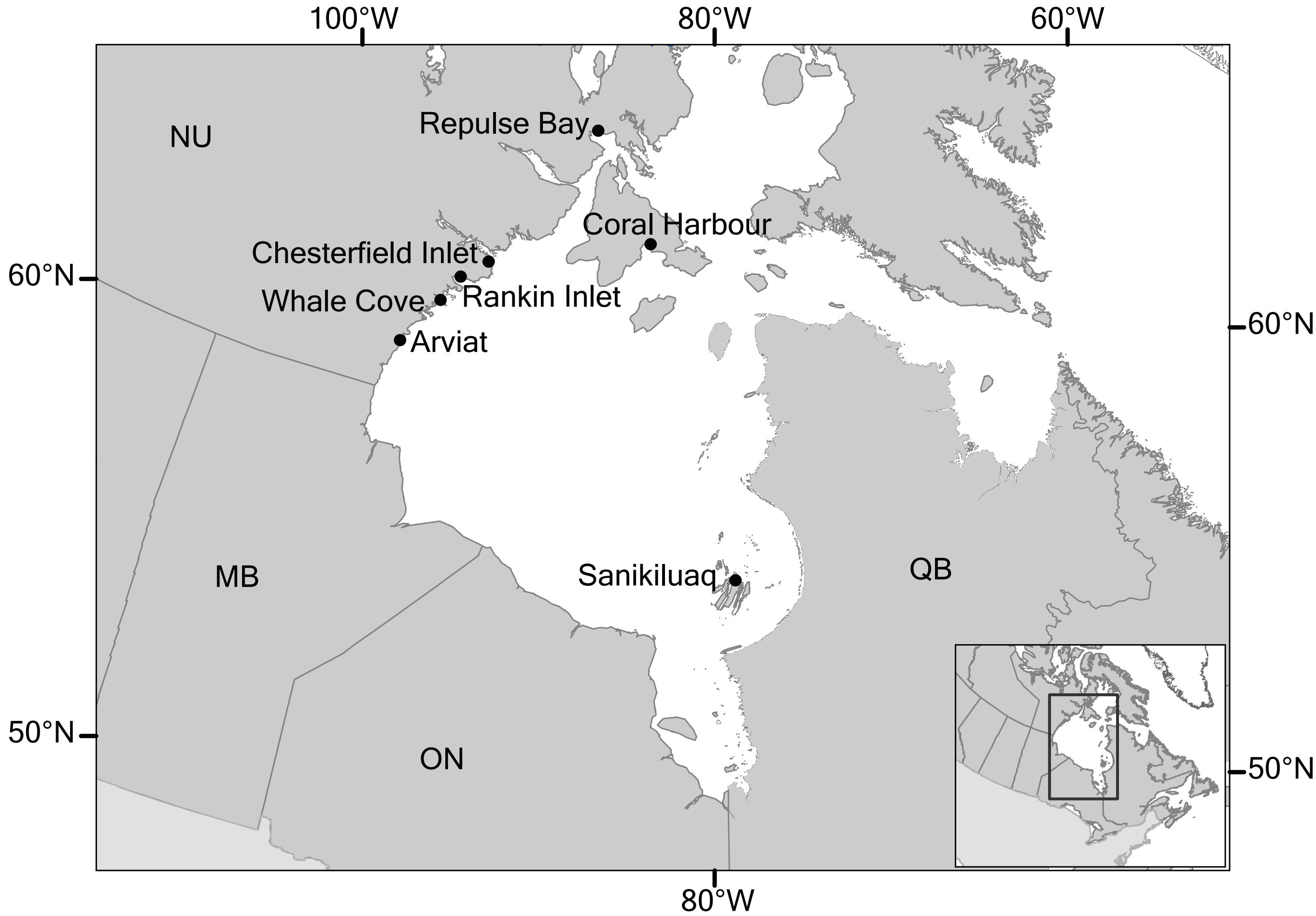

FIG. 1. Map of communities in the Nunavut portion of Hudson Bay that hunt narwhal or beluga. Nunavik, Ontario, and Manitoba communities are not shown.

The importance of northern species to Arctic communities has been recognized and studied for several years. The State of Alaska has included subsistence hunting as an economic sector in its studies of ecosystem importance (Colt, 2001), and the subsistence value of moose in Alaska has also been analyzed (Northern Economics Inc., 2006) in this context. Comprehensive assessments of polar bear hunting at various communities in the Canadian Arctic have assigned economic values to traditional and sport hunts and included different perspectives on hunting activities (Freeman and Foote, 2009). Analysis of seal hunting in Canada has also explored cultural and economic factors involved in hunting (Wenzel, 1991). Loring (1996) provided a summary of all summer hunting activities near Igloolik (a community north of Hudson Bay in Nunavut) in 1992, assigning an economic value of $6 million to all hunting activities for that year. Past research on narwhal and beluga harvests has focused on specific aspects of individual hunts, such as technical aspects of hunting in general (Weaver and Walker, 1988) and the economic importance of ivory from narwhals (Reeves, 1992a), rather than on comprehensive analyses. Unfortunately, such studies are not available for all species or communities involved in hunting. In this paper, we aim to provide an assessment of the economic factors involved in the hunting of two important whale species, beluga and narwhal, for communities in Nunavut, Canada.

The projected increase of community populations in Nunavut from 32 416 in 2010 to 44 581 in 2036 (Nunavut Bureau of Statistics, 2010) has the potential to increase pressure on marine mammal stocks in the area. While catches of beluga have remained relatively stable since the 1980s, narwhal catches increased in the late 1990s and have remained at this higher level (DFO, 1991, 1992a, b, 1993, 1994, 1995, 1996, 1997; Stewart and Lockhart, 2005; JCNB, 2009). In 2008, aerial surveys of the northern Hudson Bay narwhal population suggested a possible decline in abundance; however, these results were not conclusive because poor weather conditions during the 2008 surveys may have resulted in an underestimate of the population (DFO, 2010b). Narwhal is listed in Appendix II of the Convention on International Trade of Endangered Species of Wild Flora and Fauna (CITES). International shipment of narwhal parts or products therefore requires a CITES permit and a Non-Detriment Finding (NDF) issued by the exporting country. In December 2010, Canada did not issue a CITES NDF for the northern Hudson Bay narwhal population, so tusks from harvested northern Hudson Bay narwhal could no longer be exported internationally. The 2010 trade restriction did not affect narwhal hunting quotas, but it influenced the economic value of the narwhal hunt to northern Hudson Bay communities by effectively banning the sale of narwhal tusks except within Canada. In addition to this loss of economic potential, negative effects on the culture of these communities could result from climate change coupled with harvest and trade limitations (Nuttall, 2005). However, a 2011 aerial survey of the northern Hudson Bay narwhal population indicated greater abundance than estimates from previous surveys (Asselin et al., 2011). In 2012, therefore, Canada issued an NDF that retroactively authorized exports of northern Hudson Bay narwhal tusks originating from the 2010 and 2011 harvest years.

Of the three beluga stocks hunted within Hudson Bay, the eastern Hudson Bay population has declined in the past and has not shown a recovery; it has been listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (NAMMCO, 2005), while still enduring hunting pressure. Species distributions of narwhal and beluga are expected to contract poleward as a result of climate change, with negative impacts to hunters (Hovelsrud et al., 2008). Hudson Bay has already shown shifts in seasonal ice cover (Gagnon and Gough, 2005a, b), and because of its southerly location, it will likely be one of the first areas negatively affected by competing species, new predators, disease, and changes in food availability.

This paper presents the different aspects of the narwhal and beluga subsistence hunts in the Hudson Bay region, along with their economic ramifications for local communities. Commercial whaling, which was once important both nationally and regionally, no longer exists in Canada; therefore, in the context of this paper, hunting and whaling are limited to subsistence harvests. Beluga and narwhal were chosen for the focus of this study because they are hunted annually and landings are recorded. Analysis was limited to the Nunavut portion of Hudson Bay (Fig. 1) because the authors were members of an International Polar Year initiative focusing on Hudson Bay. We have based the model on communities on the Nunavut side of the bay because of our knowledge of the region. For each hunt, revenue, cost, and net economic value are estimated for 2007. For this study, we estimated use value, which we refer to as "economic value" throughout the paper. Our aim is to facilitate a better understanding of the contributions each hunt brings to the communities discussed in order to provide baseline information for comparison in the event of future changes in hunting patterns. Future geographic expansion of the model for additional Nunavut and Nunavik communities would be ideal, but is beyond the scope of this project. An Arctic-wide assessment of subsistence hunting economics revealed that studies are within the early stages of development, mostly focused on evaluating current knowledge (Nuttall, 2005). This paper aims to be useful in the context of current events and presents a model as a first step toward an overview of hunting economics. To develop a more comprehensive economic picture, however, further research will be needed.

METHODS

Using published and unpublished data combined with values provided by field researchers, we developed an economic model to estimate the total use value for beluga and narwhal hunts for 2007, the most recent year for which data were published on both narwhal and beluga catches (JCNB, 2009), when most communities were harvesting at or near their limit. For this analysis, we used Monte Carlo simulations whereby parameters for each equation are selected randomly from an assigned distribution to calculate total use value. Ranges for input parameters were assigned a uniform distribution to account for uncertainty, with the values presented in the sections below. Without prior information to generate distributions for each input parameter, the uniform distribution was selected to represent all parameter distributions within the model. While this choice is not ideal, continuing to build on our understanding will allow for more precise studies in the future. For each Monte Carlo simulation, one value per parameter is selected randomly from its assigned distribution in order to calculate the revenue or cost. This process is repeated for 10 000 iterations to generate a distribution of values for costs, revenues, total use values, and per capita use values. Similar methods have been used in other data-poor economic analyses, primarily fisheries economic analyses, such as the calculation of costs and revenues for fisheries in Indonesia (Bailey et al., 2008) or the contribution of fisheries to global employment (Teh and Sumaila, 2011). Estimates made using the Monte Carlo simulation approach are less precise than point estimates; however, they are also better at accounting for uncertainty. A drawback of this approach is that the parameter range, which is set by the user, limits the potential outcomes of the model: that is, each draw of the simulation is limited by the bounds on each parameter (Creal, 2009). We present this model as an estimate of economic costs and revenues based on the best available data and author assumptions, but we recognize the need for improved estimates in the future as data sets become richer.

Information on hunting activities was taken from published literature where available. In addition, both the authors and collaborators involved in biological sampling and observation of narwhal and beluga hunts in the communities provided estimates. Specific prices and costs for individual factors (fuel, meat replacement, narwhal tusk value, carving values) obtained in 2008 from Repulse Bay were used as representative of those in other Hudson Bay communities.

Carvings (narwhal and beluga) and narwhal tusks are sold primarily to the local Co-op, a locally owned and democratically operated northern business that operates as part of Arctic Co-operatives Limited, a larger network of 31 community-based business enterprises located throughout Nunavut and the Northwest Territories. Each independent Co-op purchases carvings from local artists, and Arctic Co-operatives Limited markets Inuit art both wholesale and retail, selling carvings to art dealers, distributors, and the general public (http://www.arcticco-op.com/index.htm). Some hunters may sell carvings or tusks to travelers directly for a higher price than the Co-op would pay. The prices of tusks and carvings that we used were based on the value a hunter/carver would receive for selling the piece to the Co-op, rather than on the higher price at which the Co-op generally would sell the piece. A portion of the additional revenue from such sales is redirected back into the Co-op or to other community programs; however, these added values that are generated are not available to us. Costs were first calculated under the assumption that the opportunity cost to hunt was zero. This assumption was then relaxed, and costs were re-assessed including an opportunity cost function.

Revenues and costs are calculated for the entire hunt and on a per capita basis. We chose the entire hunt approach to identify the scope of the use value for both hunts. We then calculated per capita use value to capture the sharing of resources among community members in a subsistence economy, which is an important value of Inuit culture (Wenzel, 2009a, b). All values are presented in Canadian dollars.

The Beluga Hunt

Belugas begin their annual migration into Hudson Bay in the springtime, traveling from Hudson Strait down the eastern and western coasts of Hudson Bay to their summering locations in eastern Hudson Bay, western Hudson Bay, and James Bay (DFO, 2001). Belugas hunted along these migration routes are used for the *muktaaq* (or thin layer of blubber with the skin attached), and a small portion of the meat is consumed or traditionally fed to dogs (Tyrrell, 2007). Communities in Hudson Bay generally do not consume large portions of muscle protein, although other Arctic communities often dry the meat and store it for later consumption (J. Orr, pers. comm. 2010). While non-indigenous people may consider this to be wasteful, to Inuit culture a partially flensed whale is not wasteful, since the remaining edible tissues and meat will be consumed by other animals (Freeman, 2005). Teeth and bones, more specifically vertebrae, are used for carvings. These carvings can be smaller pieces from individual teeth and bones, or larger pieces including more than one material.

Beluga Catch: The 2007 beluga catch, N_B, was set to 180 whales, according to reported catch data (JCNB, 2009). This total included catches from the following communities (number of whales harvested): Arviat (50); Chesterfield Inlet (12); Coral Harbour (7); Rankin Inlet (38); Repulse Bay (21); Sanikiluaq (52), and Whale Cove (10). Catches for Sanikiluaq were not available for 2007, so a five-year average from 2002 to 2006 was used as the 2007 catch in this community.

Beluga Revenue: The revenue from the beluga hunt is the sum of the value of the meat obtained from the *muktaaq* and other edible portions of the whale plus the income from the vertebrae and teeth, which are turned into carvings. The total revenue of beluga whales, TR_B, is calculated for all the whales harvested as:

$$TR_B = R_{Bm} + R_{Bc} \tag{1}$$

where R_{Bm} is the value of the meat, for which we essentially use the cost of replacing meat from the beluga whale with store-bought protein sources, plus the revenue from beluga carvings, R_{Bc}. This replacement value of meat, R_{Bm}, is further broken into:

$$R_{Bm} = N_B * w_B * e_B * c_{pB} \tag{2}$$

where w_B is the weight of an individual whale, e_B is the edible portion of the beluga, and c_{pB} is the replacement cost of other protein sources from the local store.

The revenue from beluga carvings is estimated as:

$$R_{Bc} = N_B * [(T_B * P_{Bt}) + (V_B * P_{Bv})] \tag{3}$$

where T_B is the number of teeth per beluga used for carvings, V_B is the number of vertebrae per beluga used for carvings, and P_{Bt} and P_{Bv} are the prices of carvings made from one tooth and one vertebra, respectively.

Beluga Cost: The cost of the beluga hunt is calculated for six communities combined (Arviat, Chesterfield Inlet, Rankin Inlet, Repulse Bay, Sanikiluaq, and Whale Cove). Baker Lake was excluded from the model, as there was only one year of reported hunts from 1977 to 2007 (JCNB, 2009). Costs here include both variable costs (bullets and fuel) and fixed costs (rifles and boats). The fixed cost estimate includes a term for depreciation. Costs are calculated on a per trip basis, and the number of beluga hunting trips, B_{trip}, depends on the number of hunters, M_B, the number of trips each individual takes, I_B, and the size of the hunting group, B_{gr}:

$$B_{trip} = \frac{M_B * I_B}{B_{gr}} \tag{4}$$

The per trip costs of the beluga hunt are broken into the cost of boats, C_{Bb}, the cost of guns, C_{Bg}, the cost of fuel, C_{Bgs}, and the cost of bullets, C_{Bbu}.

The cost of all boats per trip, C_{Bb}, is estimated as:

$$C_{Bb} = \frac{N_{bo} * \left(c_{bo} / T_{bo}\right)}{B_{trip}} \tag{5}$$

where N_{bo}, the number of boats, is represented as M_B/B_{gr}. The parameter c_{bo} is the cost of one boat, with a replacement time, T_{bo}. The cost of all guns per beluga trip, C_{Bg}, assuming each hunter has one gun, is estimated as:

$$C_{Bg} = C_R * \frac{M_B * c_{gu} / T_{gun}}{B_{trip}} \tag{6}$$

with c_{gu} as the cost of one gun, T_{gu} as the replacement time of a gun, and C_R as the percentage of hunters participating in the Canadian Ranger program. Canadian Rangers (2012) are a component of the Canadian Forces and are responsible for surveillance, patrols, reporting activities, and data collection. This program provides participants with guns, which in some cases they also use for hunting. This dual use of guns is further explained under "Model Inputs."

The cost of bullets per trip, C_{Bbu}, is estimated as:

$$C_{Bbu} = C_R * \frac{bu * M_B * I_B * c_{bu}}{B_{trip}} \tag{7}$$

where the total number of bullets used is dependent on the number of men hunting, M_B, the number of trips each hunter takes, I_B, the number of bullets used per hunter, bu, and the cost of each bullet, c_{bu}.

The cost of fuel per beluga hunting trip, C_{Bgs}, is estimated as:

$$C_{Bgs} = L^*c_{gs} \tag{8}$$

where L is the liters of fuel used per trip, and c_{gs} is the cost per liter of fuel.

The total cost for hunting beluga over all trips (TC_B) is the sum of the costs for the boat, guns, bullets, and fuel times the number of trips:

$$TC_B = B_{trip}^*(C_{Bb} + C_{Bg} + C_{Bbu} + C_{Bgs}) \tag{9}$$

Beluga Total Use Value: The total use value from the beluga hunt, Π_B, is calculated as the difference between total revenue and total cost:

$$\Pi_B = TR_B - TC_B \tag{10}$$

We also computed this value on a per capita basis, π_B, estimating the value of the hunt to every member of the community on the basis of the population size, B_{pop}.

$$\pi_B = \frac{\Pi_B}{B_{pop}} \tag{11}$$

The Narwhal Hunt

The narwhal hunted in Hudson Bay are part of the northern Hudson Bay stock. Historically, this population was believed to be part of the larger Baffin Bay narwhal population. However, recent studies indicate that, although winter ranges have the potential to overlap, Hudson Bay narwhal show summer site fidelity near Southhampton Island and Repulse Bay (COSEWIC, 2004; Westdal et al., 2010). Narwhal leave their winter range around May to begin migration to their summer location near Repulse Bay, where they stay until the beginning of September (Westdal et al., 2010). The narwhal hunt in Repulse Bay generally starts after the ice breaks up in mid June and continues until the whales leave the area (Freeman et al., 1998). In 2007, a year of unprecedented decline in sea ice allowed the narwhal to come close to shore, so the quota was easily reached (Cressey, 2007; Greer, 2007). During years of high sea ice, narwhal are hunted from the ice edge using snowmobiles, but after the ice is gone they are hunted from the open water using boats (Weaver and Walker, 1988). Snowmobiles were not included in this analysis because in the low-ice year 2007, boats were the primary tool for harvest of narwhals in Hudson Bay (DFO, 1998; Greer, 2007).

Narwhal have traditionally been hunted for *muktaaq*, which is highly prized in Native communities (Hrynyshyn, 2004; Freeman, 2005). In addition, tusks from the male narwhals are sold to the local Co-op, where they are picked up by art dealers to be sold in other locations. While females generally remain functionally toothless throughout life, a few do grow a full-length tusk. Males with two erupted tusks have also been reported. However, these are rare cases, estimated to occur in less than 1% of the population (Reeves, 1992a), and therefore this possibility was not incorporated into the model. Teeth and bones from both males and females are used for carvings and are sold to local tourists or to the Co-op for further distribution.

Narwhal Catch: Narwhals are typically hunted at three Hudson Bay communities: Repulse Bay, Rankin Inlet, and Whale Cove, with most, if not all, of the catches in most recent years from Repulse Bay. For 2007, the total catch, N_N, was reported as 81 whales: these included nine whales from Rankin Inlet, 72 from Repulse Bay, and none from Whale Cove (JCNB, 2009). As male narwhals have a higher value because of their tusks, catches were split into males, N_M, and females, N_F. Of the 72 whales reported from Repulse Bay in 2007, 41 were male (DFO, unpubl. data). The proportions of males and females in the 2007 catch from Repulse Bay (56% males, 44% females) were assumed to be representative of the Rankin Inlet catch as well.

Narwhal Revenue: Total revenue of narwhal, TR_N, for two separate uses, consumption in the form of narwhal meat and revenue from narwhals in the form of carvings, is calculated following the same method used for beluga.

$$TR_N = R_{Nm} + R_{Fc} + R_{Mc} \tag{12}$$

where R_{Nm} is the revenue from narwhal meat (males and females), R_{Fc} is the revenue from female carvings, and R_{Mc} is the revenue from male carvings. The carving revenue is calculated separately for males and females because of the male narwhal tusks. The revenue from the meat is calculated as the replacement cost of protein:

$$R_{Nm} = [(N_F{}^*w_{NF}) + (N_M{}^*w_{NM})]^*e_N{}^*c_{pN} \tag{13}$$

where w_{NF} and w_{NM} are the weights of female and male narwhal, respectively; e_N is the edible portion of narwhals; and c_{pN} is the cost of meat replacement per kg of narwhal meat.

The revenue from the female carvings R_{Fc}, which are carved from incisor teeth and vertebrae, is equal to:

$$R_{Fc} = N_F[(F_{to}*P_{to}) + (V_N*P_{NV})] \quad (14)$$

where F_{to} is the number of incisor teeth used for carvings for females, P_{to} denotes the price of the carvings made from teeth, V_N is the number of vertebrae used per whale, and P_{NV} is the price for a carving made from a vertebra. Prices of carvings for teeth and vertebrae, as well as the number of vertebrae used per whale, were the same for male narwhals.

For males the revenue is split into revenue from vertebrae and teeth, R_{Mvt}, and revenue from tusks, R_{Mtu}. Revenue from the male vertebrae and teeth was set to:

$$R_{Mvt} = N_M*[(M_{to}*P_{to}) + (V_N*P_{NV})] \quad (15)$$

using the same prices for carvings and teeth as for females. M_{to} is the number of teeth used for carvings from male narwhal.

Revenue from male tusks is estimated as:

$$R_{Mtu} = N_M*[(T_w*L_{tu}*P_{wt}) + (T_c*L_{tu}*P_{ct})] \quad (16)$$

where T_w is the percentage of tusks sold whole, P_{tu} is the price of whole tusks, and T_c is the percentage of tusks turned into carvings, set to (1-T_w), with the price of tusk carving, P_{ct}. It should be noted that both prices are dependent on the length of the tusk, L_{tu}.

Narwhal Cost: The narwhal total cost, T_{CN}, is calculated for the communities of Repulse Bay and Ranklin Inlet with the same basic equations used for the beluga hunt and the same ranges associated with costs of boats, guns, and bullets and with replacement times. Costs are calculated on a per trip basis, with the number of narwhal hunting trips, N_{trip}, estimated as:

$$N_{trip} = \frac{M_N * I_N}{N_{gr}} \quad (17)$$

where M_N is the number of narwhal hunters in the two communities, I_N is the number of individual trips each hunter takes, and N_{gr} is the size of narwhal hunting groups.

Our analysis of costs for individual boats, guns, and bullets, (c_{bo}, c_{gu}, and c_{bu}) used the same values as for the beluga hunt, as well as the same replacement time values for boats and guns (T_{bo} and T_{gu}).

The per trip cost of boats hunting narwhal, C_{Nb}, is estimated as:

$$C_{Nb} = \frac{N_{Nb} * \left(c_{bo} / T_{bo}\right)}{N_{trip}} \quad (18)$$

with the number of boats for narwhals, N_{Nb}, depending on the number of hunters and the size of hunting groups (M_N/N_{gr}).

The cost of guns per narwhal trip, C_{Ng}, is calculated assuming each hunter has one gun:

$$C_{Ng} = C_R * \frac{M_N * c_{gu} / T_{gu}}{N_{tr}} \quad (19)$$

The cost of bullets per trip:

$$C_{Nbu} = C_R * \frac{bu * M_N * I_N * c_{bu}}{N_{trip}} \quad (20)$$

used the same cost per bullet, c_{bu}, as for beluga hunting.

Finally the cost of fuel used per narwhal trip, C_{Ngs}, was set to:

$$C_{Ngs} = L*c_{gs} \quad (21)$$

where L is the number of liters of fuel used per trip and c_{gs} is the cost of fuel per liter.

The total cost of narwhal hunting (TC_N) is therefore calculated as the sum of the costs for the boat, guns, bullets, and fuel times the number of trips:

$$TC_N = N_{tr}*(C_{nb} + C_{Ngu} + C_{Nbu} + C_{ngs}) \quad (22)$$

Narwhal Total Use Value: The total use value for narwhals, Π_N, is calculated as the difference between the total revenue and the total cost of the hunt:

$$\Pi_N = TR_N - TC_N \quad (23)$$

and the per capita value, π_N, is calculated as:

$$\pi_N = \frac{\Pi_N}{N_{pop}} \quad (24)$$

where N_{Pop} is the population size of narwhal hunting communities.

Opportunity Cost

In the above cost functions, we assumed that the opportunity cost of labour (OC), essentially what the hunter must forgo in order to hunt, is equal to zero. This assumption was based on anecdotal evidence from other hunts such as polar bear hunting in Clyde River, where Inuit commented on taking on casual employment to cover the costs of hunting supplies and then quitting to go hunting (Wenzel, 1991). Other researchers have commented on the perception that hunters prefer hunting to alternative employment, even taking vacation time or missing work in order to hunt (B. Dunn and J. Orr, pers. comm. 2010). While jobs in some northern communities can be hard to obtain (Loring, 1996), past economic assessments have assigned a wage to hours worked to calculate the opportunity cost of hunting: for example, Foote and Wenzel (2009) used an opportunity cost of $12 an hour for polar bear hunting in Clyde River.

We performed a sensitivity analysis on the opportunity cost of hunting to determine how our assumption of opportunity cost equal to zero affected total cost and economic use value. Here, we calculate the opportunity cost per community from the average income and the time spent hunting. The median income for persons over 15 (In) is multiplied by the ratio of employed people (N_{em}) to the total number of people in the work force (employed and unemployed) (N_{lf}) in each community to give an average income per employable community member. This value is then multiplied by the number of hunters (N_{hun}) and number of days spent hunting (D_{hun}). OC per community is calculated for the whole season as:

$$OC = In * \frac{N_{em}}{N_{lf}} * N_{hun} * D_{hun} \qquad (25)$$

Income and employment numbers were obtained from census data from each community (Statistics Canada, 2006). The number of hunters is either M_B, for the beluga hunt, or M_N, for the narwhal hunt, while the number of days spent hunting each year is equal to the number of trips per hunter (I_B for beluga or I_N for narwhal). Opportunity cost for communities hunting both narwhal and beluga is calculated separately for each hunt.

Cost Sharing

Use values for beluga and narwhal hunting activities are calculated under the assumption that all costs are incurred for each hunting activity independently. For example, it is assumed that hunters purchase a boat and a gun specifically for the purpose of hunting beluga or narwhal. Rankin Inlet is a community that hunts both narwhal and beluga, as well as other species. It is almost certain that in this community gear is used for both hunts, thereby reducing the costs associated with each individual hunt. In other communities, it has been noted that boats, guns, and fuel may also be used to hunt a variety of species on the same trip (e.g., seals or ducks might be harvested on a trip intended primarily to search for beluga) (Loring, 1996). We therefore re-assessed all communities under the new assumption that whale-hunting costs are shared with other hunting activities. In this analysis, costs of boats, guns, and fuel were shared; however, the cost of bullets was not, as a bullet can be used only once.

Model Inputs

Parameter values used for model inputs and references are summarized in Table 1. Single estimates rather than ranges were used to express catch statistics because data were provided as single estimates (JCNB, 2009). Proportions of male vs. female narwhals were taken from Fisheries and Oceans Canada catch records for Repulse Bay, where the majority of narwhal are caught (DFO, unpubl. data). The same proportion of male to female narwhals was applied to catches from Rankin Inlet.

Composition of body weight for narwhal has been noted as 30%–35% blubber, 25% muscle, and 10% skin (Reeves and Tracey, 1980). A summary of edible weights from the 1960s to the early 1980s (Ashley, 2002) indicates upper limits of 45% of body weight for beluga *muktaaq* with some muscle and 37% for narwhal *muktaaq* and some muscle. Reeves (1992b) listed multiple sources and values of use, ranging from 6.9% to 45.7% of body weight for narwhals and from 14% to 76% for belugas, although he noted that these ranges were higher than the values he observed. Using the average weight for a narwhal (Heide-Jørgensen, 2002) and the amount of *muktaaq* taken from harvested whales (Wenzel, 1991, 2009b), we calculated that *muktaaq* accounted for 5.9% to 7.8% of their body weight.

For belugas, we used the known amount of *muktaaq* from 20 to 30 whales (2268 kg) traded between Nunavut and Nunavik (Tyrrell, 2007), along with the average beluga body weight of 725 kg (DFO, 2002; NAMMCO, 2005), to calculate the percentage of body weight consumed as *muktaaq*, which ranged from 10.5% to 15.6%. More recent research on belugas has estimated lower ranges, from 8% to 10% of body weight consumed (Hrynyshyn, 2004). Estimates from field researchers were much lower, at 5% to 12% of body weight being consumed as *muktaaq* or muscle (Jack Orr, pers. comm. 2010). Taking into account the possible exaggeration in earlier studies of the upper ranges for the edible weights for both species, we set the edible portions (to include *muktaaq* and some muscle) for both belugas (e_B) and narwhals (e_N) to the range of 5% to 25% of the body weight.

The cost of replacing a kilogram of meat from narwhal (c_{pN}) or beluga (c_{pB}) was based on the values of a variety of alternative protein sources (e.g., chicken, steak, and ground beef). The replacement cost of meat has been calculated for other hunting activities in Canada and Alaska in the past. Replacement values for other harvested animals have ranged from \$8.8 per kg for moose in Alaska for 2005 (Northern Economics Inc., 2006) and from \$8.50–\$10.00 per kg for polar bear meat in the 1980s and 2002 (Foote and Wenzel, 2009; Wenzel, 2009b). The lower estimates of replacement value for polar bears were for communities using the meat as dog food, and therefore, these figures reflect the cost of dog food. In 1990, the country food store in Iqaluit sold narwhal *muktaaq* for \$17.60 to \$18.99 per kg and beluga *muktaaq* for \$15.40 per kg, as they were imported from other communities; however, prices are expected to have increased since then (Reeves, 1992b). Our replacement values, which are based on a variety of chicken, beef, pork, and seafood, both fresh and canned, are higher. While beluga and narwhal meat may be used as dog food, our replacement values consider meat substitutes regardless of their use for human or dog consumption. Replacement costs of narwhal and beluga, c_{pN} and c_{pB}, were set to the range of \$6.90 to \$39.00 per kg in our model. These values were based on the cost of various protein sources collected from the local Co-op in Repulse Bay in 2008.

For beluga carvings, the number of teeth per beluga, T_B, used for carving was set at 0–2 teeth per whale. Younger

TABLE 1. Parameter inputs for model equation. Parameters with multiple sources were combined to provide a distribution, while parameters with no literature estimates were estimated by field researchers.

Parameter	Lower range	Upper range	Description	References
N_B	180	180	# Beluga	NAMMCO, 2005; JCNB, 2009
w_B	600	1100	Weight of beluga (kg)	Brodie, 1971
e_B	5	25	Edible portion of beluga (% body weight)	Reeves, 1992b; Ashley, 2002; Hrynyshyn, 2004; Tyrrell, 2007
c_{pB}	6.9	39	Replacement cost of meat ($ per kg)	Value obtained in 2008 from Repulse Bay[1]
T_B	0	2	Teeth per beluga	Estimated value[2]
V_B	0	2	Vertebrae per beluga	Estimated value[2]
P_t	20	200	Price of carving for 1 tooth ($)	Value obtained in 2008 from Repulse Bay
P_v	60	250	Price of carving for 1 vertebrae ($)	Value obtained in 2008 from Repulse Bay
M_B	10	40	# of beluga hunters (% of community)	Estimated value[2]
B_{pop}	7364	7364	Population of all beluga communities	Statistics Canada, 2006
B_{gr}	1	5	Beluga hunting group size	Estimated value[2]
I_B	10	15	Trips per beluga hunter (# trips/year)	Estimated value[2]
c_{bo}	3000	20000	Cost of boat ($)	Estimated value[2]
N_N	81	81	# narwhal	JCNB, 2009
N_f	35	35	# female narwhals	DFO, unpubl. data
N_m	46	46	# male narwhals	DFO, unpubl. data
w_{NF}	800	1000	Weight of female narwhal (kg)	Garde et al., 2007
w_{NM}	1500	1800	Weight of male narwhal (kg)	Garde et al., 2007
e_N	5	25	Edible portion of narwhal (% body weight)	Wenzel, 1991, 2009a; Reeves, 1992b; Ashley, 2002
c_{pN}	6.9	39	Replacement cost of meat ($ per kg)	Value obtained in 2008 from Repulse Bay[1]
F_{to}	0	2	Teeth per female narwhal	Estimated value[2]
M_{to}	0	1	Teeth per male narwhal	Estimated value[2]
V_N	0	2	Vertebrae per narwhal	Estimated value[2]
L_{tu}	2.5	8	Length of tusks (feet)	Weaver and Walker, 1988; Reeves, 1992a; Garde et al., 2007
T_w	95	100	% of tusks sold whole	CITES, 2004
R_{wt}	100	180	Revenue per foot from whole tusk ($)	Value obtained in 2008 from Repulse Bay
P_{ct}	60	200	Price per foot of tusk carving ($)	Value obtained in 2008 from Repulse Bay
M_N	20	50	# of narwhal hunters (% of community)	Greer, 2007; Estimated value[2]
N_{gr}	1	5	Narwhal hunting group size	Greer, 2007; Sloan, 2008; Estimated value[2]
N_{pop}	3459	3459	Population of narwhal communities	Statistics Canada, 2006
I_N	5	10	Trips per narwhal hunter (# trips/year)	Estimated value[2]
T_{bo}	4	10	Boat replacement time (years)	Wenzel, 1991; Estimated value[2]
c_{gu}	700	1200	Cost of gun ($)	(www.cabelas.ca)
T_{gun}	2	10	Gun replacement time (years)	Wenzel, 1991; Estimated value[2]
C_R	0	45	% of hunters in Canadian Ranger program	DFO, unpubl. data
b_u	1	10	Bullets per hunter (per trip)	Estimated value[2]
c_{bu}	2	3	Cost per bullet ($)	Value obtained in 2008 from Repulse Bay
L	20	100	Gas per trip (liters)	Value obtained in 2008 from Repulse Bay
c_{gs}	0.9	1.1	Cost of gas per trip ($)	Value obtained in 2008 from Repulse Bay

[1] Collected values were used in conjunction with data from other studies (Reeves, 1992b; Northern Economics Inc., 2006; Foote and Wenzel, 2009; Wenzel, 2009a).

[2] Values estimated by authors with assistance of northern field researchers (Jack Orr and Blair Dunn).

belugas caught have smaller teeth that are not generally used for carvings, and older whales can have prominent wear patterns in their teeth that make them unsuitable for carvings; therefore, teeth are extracted only from certain whales. In general, only larger vertebrae are used for carvings. Teeth and vertebrae are either collected as they are found (from previous hunts) or are left in the sun to bleach for years before being used for a carving (Jack Orr, pers. comm. 2010). The number of vertebrae per beluga, V_B, used for carving was set at 0–2, as many hunters do not collect the vertebrae, and not all vertebrae are suitable for carving. Narwhal incisor teeth are used for carving along with narwhal vertebrae. In male narwhals, the upper left incisor erupts into a tusk that can be sold whole or used for carving. Female narwhals have two incisor teeth (F_{to}) available for carvings, with the model range set at 0–2. Males have one incisor tooth (after the tusk erupts); therefore, M_{to} was set to a range of 0–1. The number of vertebrae taken from narwhal, V_N, was also believed to be low and was set at 0–2 vertebrae per whale, using the same reasoning as for belugas. The distribution of vertebrae and teeth remained uniform, although only discrete values were used for sampling (values of 0, 1, or 2 only). Teeth and vertebrae are used on their own to make small carvings, or as part of a more elaborate carving that can include parts of various media from a variety of animals. The price of one carved tooth for beluga or narwhal, P_t, can range from $20 to $60 as part of an earring set, or up to $200 if it contributes to a more elaborate carving. Prices of vertebrae carvings (P_v) were set to the range of $60–$250, depending on the quality and size of the carving.

For males, additional revenue is generated from tusks, and its value depends on the length of the tusk. Measurements of narwhals harvested in Pond Inlet in 1982–83 show a tusk range of 136 to 236 cm (4.46 to 7.74 feet) (Weaver and Walker, 1988). Maximum lengths up to 202 cm

TABLE 2. Community data from Statistics Canada (2006).

Community	Median income ($)	# people employed	# people in labor force	# men age 15 and up
Arviat	15 200	535	615	600
Chesterfield Inlet	21 184	140	160	105
Coral Harbour	14 029	250	310	215
Rankin Inlet	26 389	1010	1125	805
Repulse Bay	10 912	180	275	250
Sanikiluaq	14 368	205	250	240
Whale Cove	16 352	90	100	95

(6.63 feet) have been reported in Greenland (Garde et al., 2007), with rare reported cases of tusks longer than 243 cm (8 feet) (Reeves, 1992a). In our model, the range for tusk length, L_{tu}, was set at 2.5 to 8 feet (76 to 243 cm). Tusks are either sold whole or used for carvings. Recent reports based on exporting records (CITES, 2004) estimate a high ratio of whole tusk sales to tusk carvings, suggesting that relatively few tusks are used for carvings. Therefore T_w, the percentage of tusks sold whole, was set at 95% – 100%, with the remaining 0% – 5% used as carvings. The price for a whole tusk is the amount a hunter would receive if the tusk were sold to the local Co-op store. In 2008, Repulse Bay hunters were paid $100 per foot for tusks up to six feet long plus $15 per inch for every additional inch; this value was used for prices of whole tusks, R_{wt}, in our model. Tusks that are turned into carvings are estimated to generate prices (P_{ct}) ranging from $60 to $200 per foot, depending on the size and quality of the carving.

Costs for each hunt depend on the number of hunters participating. The 2006 census data indicate that Aboriginal men over the age of 15 numbered 2310 in the beluga-hunting communities and 1150 in the narwhal-hunting communities (Statistics Canada, 2006). We assumed that 10% – 40% of those 2310 men hunt belugas, M_B, and 20% – 50% of those 1150 men hunt narwhals, M_N. Although women help with processing and are considered important to the overall hunting activity, they generally do not participate in the actual hunt. We therefore used the number of men in these communities to estimate the hunters. In Repulse Bay, the hunting season for narwhal is shorter than that for belugas in other communities. In 2007 specifically, the narwhal quota was reached before the end of the season, making this a successful hunt with a large community involvement (Greer, 2007). Because of the short hunt season and high demand for narwhal, we set a higher proportion of participants for narwhal hunting in the model, M_N. The estimated number of trips taken by each hunter per year was set to 10 – 15 for belugas, I_B, and 5 – 10 for narwhals, I_N, because of the shorter narwhal season. Group sizes of hunting trips were observed to be 2 – 4 hunters for the 2007 narwhal hunt in Repulse Bay (Greer, 2007); for the model, however, the range for both hunts (B_{gr} and N_{gr}) was extended to 1 – 5 hunters.

Gear costs were set to the same ranges for both hunts. According to the narwhal hunting records, a range of guns is used. The most common calibers, in order of frequency of use, are .303, .338, .375, 6.5 mm, and .308, and the least common caliber is 458 (DFO, unpubl. data). The same gun types and proportions were assumed for beluga hunting. The cost of each gun, c_{gu}, ranges from roughly $700 to $1200 as based on prices for .338 and .308 caliber rifles from Cabelas Canada, where a number of hunters purchase their guns (www.cabelas.ca). The .303 caliber rifles used for hunting are provided by the Canadian Ranger program. Community members, including hunters, can enroll in the Canadian Ranger program to assist the Canadian Forces in protecting their communities if necessary, and in return they receive a .303 caliber rifle and 200 rounds of ammunition each year, as well as clothing. Therefore, the cost of these rifles, 55% of the guns used to hunt narwhal in 2007 (DFO, unpubl. data), are not fully incurred by the hunters themselves; rather, the hunters earn the guns by participating in the Canadian Ranger program. The number of guns used by Canadian Rangers (C_R) was set to 0% – 45% of all guns, which lowered the total gun costs for the hunt. Wenzel (1991) noted replacement times of 4.3 years for guns used in polar bear hunts, 6.9 years for boats, and 4.7 years for boat motors. In the model, we assumed a range of replacement times for guns, T_{gun}, from 2 to 10 years. For boats used in the hunts, the cost, c_{bo}, was set at $3000 – $20 000 (J. Orr, pers. comm 2010), with a replacement time, T_{bo}, of 4 – 10 years.

Community population size, income, and employment rates were taken from the 2006 Canadian census (Statistics Canada, 2006): this information is presented by community in Table 2. Population for all beluga hunting communities, B_{pop}, was 7364 people, and that for all narwhal hunting communities, N_{pop}, was 3459 people.

RESULTS

Beluga

The total revenue to the participating communities from the beluga hunt ranged from $57 667 to $1 995 473, with a mean value of $601 154 (Fig. 2). Carvings from teeth and bones contributed an average of $50 156 to this total, and meat an average of $550 997, which identifies meat as the major contributor to beluga value. The total cost of this hunt ranged from $52 090 to $3 763 073, with a mean value of $593 949 (Fig. 2). Boats had the highest cost per trip, followed by fuel, guns, and then bullets. Economic value for beluga ranged from -$3 709 037 to $1 915 904, with a mean

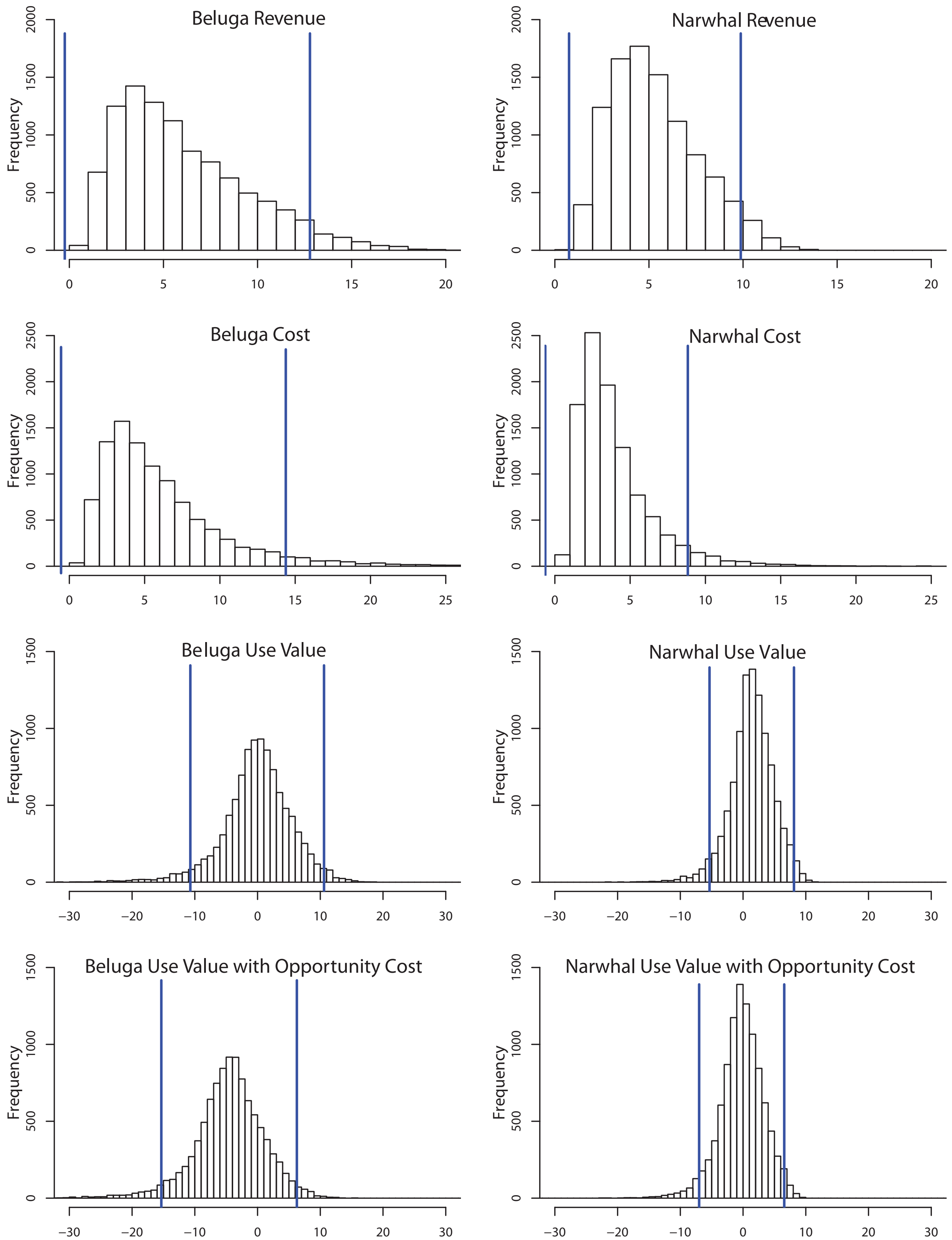

FIG. 2. Distributions (and 95% confidence intervals, represented by vertical lines) of draws for each value in the Monte Carlo simulations of total revenue (TR), total cost (TC), total use value (Π), and total use value including opportunity cost (Π + OC) for the beluga and narwhal hunts. All values are presented in hundreds of thousands of Canadian dollars (CDN$100 000). Note that both horizontal and vertical scales differ from graph to graph.

value of -$9399. The per capita economic value ranged from -$503 to $220, with a mean value of -$1.

The opportunity cost of beluga hunting ranged from $217 973 to $718 212, with a mean value of $445 514. When incorporating the opportunity cost into the total cost estimate, the mean total economic value decreases to -$454 859 with the range -$4 210 558 to $1 407 560. Inclusion of opportunity cost decreases the per capita value of beluga hunting to -$61.

When cost sharing from other hunting activities is incorporated into the model without opportunity cost, the mean economic value of the hunt increases to $266 504 for cost sharing with one other hunting activity (two hunting activities altogether) and to $487 184 for cost sharing with nine other hunting activities. The mean per capita economic value increased to $36 when costs were shared with one other hunting activity and $69 when shared with nine other hunting activities (Fig. 3). However, inclusion of opportunity cost decreased the per capita economic value, which now ranged from -$24 (for cost sharing with one other activity) to $5 (with nine other hunting activities).

Narwhal

The total revenue for the narwhal hunt ranged from $81 267 to $1 413 947, with a mean value of $529 928. Average revenue from meat was $366 100, with tooth and vertebra carvings from female narwhal generating an average of $9339, and tusks, teeth, and vertebrae from the male narwhals, an average of $154 487. The total cost ranged from $58 273 to $2 279 463, with a mean value of $376 821. As in the case of belugas, boats had the highest average cost, followed by fuel, guns, and then bullets. The economic value ranged from -$2 120 367 to $1 193 315, with an average value of $133 278. The per capita economic value ranged from -$602 to $348, with a mean value of $44 (Fig. 2).

The opportunity cost of narwhal hunting ranged from $69 763 to $288 113, with a mean value of $160 013. When we included opportunity cost, mean economic value decreased to -$26 735, with a range of -$2 301 919 to $1 025 006, and the mean per capita value decreased to -$7.

The economic value and the per capita economic value increase when costs of the narwhal hunt are shared with other hunting activities. The mean economic value increases from $133 278 to $331 500 when costs are shared between two hunting activities (narwhal hunting plus one more) and to $472 077 when costs are shared with nine other hunting activities. Similarly, the per capita economic value increases from $44 per person to $96 for two hunting activities and continues increasing to $137 when costs are shared among 10 hunting activities (Fig. 3). However, with opportunity cost considered, these per capita values decrease to $46 for cost sharing with one other activity and $90 for sharing with nine other activities.

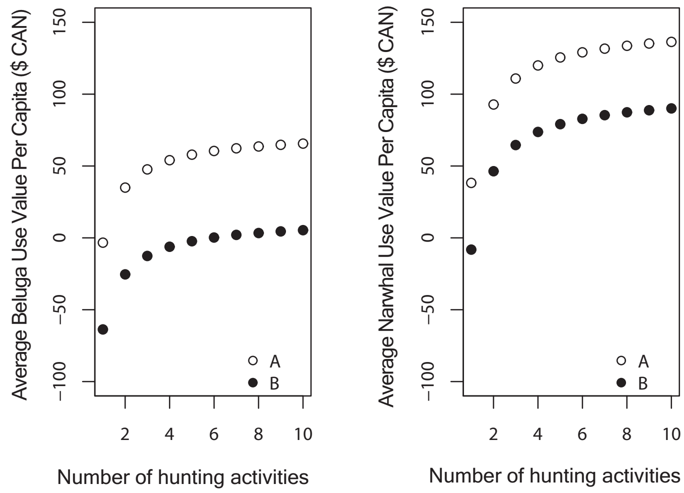

FIG. 3. Average per capita use value for beluga and narwhal hunts under two conditions. (A) Open circles indicate values for cost sharing with one to nine other hunting activities. (B) Filled circles show the same cost sharing, but with economic values recalculated to include opportunity cost. The category "two hunting activities" means the beluga hunt or the narwhal hunt plus one additional hunting activity.

Opportunity Cost and Cost Sharing

Table 3 identifies the average economic value when costs are shared with other hunting activities, while Figure 3 shows the corresponding mean per capita values. Although narwhal has a higher value when calculating hunting activities, beluga hunting has a higher value when we take cost sharing into account.

Value per Community

While all calculations are based on the assumption that all communities invest the same costs and receive the same revenues, in reality this is not the case. On the basis of total revenue and the number of whales landed, the value from each hunt for each community (Table 4) was estimated using mean revenues of $3163 per beluga and $6542 per narwhal. Ignoring costs for a moment, results indicated that Repulse Bay generated the highest revenue, to which the narwhal hunt contributed nearly half a million dollars. Not only does this community benefit from the majority of narwhal catches in Hudson Bay, but the added value of hunting belugas also generates a disproportionate amount of revenue in Repulse Bay compared to other communities.

DISCUSSION

In 2007, the total revenue from beluga hunts was higher than that from narwhals, but overall, the narwhal hunt has a higher net economic value. The main reason for this difference is the higher cost of hunting belugas. As the costs of guns, boats, bullets, and gas were constant between the two hunts, the discrepancy in total costs stems from the number of hunters and the number of trips taken for each of the

TABLE 3. Effects of cost sharing and opportunity cost on total economic value. Columns 2 and 4 present mean total economic values of the beluga hunt, Π_B, and the narwhal hunt, Π_N. Columns 3 and 5 show these same values recalculated to include the opportunity cost of each hunt.

Number of hunting activities	Π_B ($)	Π_B including opportunity cost ($)	Π_N ($)	Π_N including opportunity cost ($)
1	-9399	-454 859	133 278	-26 735
2	266 504	-179 009	321 500	161 486
3	358 454	-87 059	384 240	224 227
4	404 429	-41 084	415 611	255 597
5	432 014	-13 499	434 433	274 419
6	450 404	4 890	446 981	286 967
7	463 540	18 025	455 944	295 930
8	473 392	27 877	462 666	302 653
9	481 054	35 540	467 895	307 881
10	487 184	41 670	472 077	312 064

TABLE 4. Contribution of beluga and narwhal hunts to each community.

Community	Beluga landed (#)	Beluga revenue ($)	Opportunity cost beluga hunting ($)	Narwhal landed (#)	Narwhal revenue ($)	Opportunity cost narwhal hunting ($)
Arviat	50	158 150	67 855	–	–	–
Chesterfield Inlet	12	37 956	16 674	–	–	–
Coral Harbour	7	22 141	20 924	–	–	–
Rankin Inlet	38	120 194	163 282	9	58 878	136 960
Repulse Bay	21	66 423	15 326	72	471 024	12 803
Sanikiluaq	52	164 476	24 204	–	–	–
Whale Cove	10	31 630	11 917	0	0	10 119

hunts. Narwhal hunting is more focused compared to beluga hunting, as individual hunters are eager to be part of the community quota before it is filled. When considering the revenue generated per whale, narwhals are more valuable at $6542 per whale on average compared to $3163 per whale for belugas. While some of this value can be attributed to tusks from male narwhals, the weight of the whale is also important, considering that the weight for narwhals used in the model was higher than that for belugas. In the case of narwhals, the value of meat (*muktaaq* and muscle) is higher than that of carvings and tusks. While male narwhals have a higher use value (higher body weight and additional revenue from tusks), the value of meat contributes roughly 70% of the total use value of narwhals in this model.

In these communities, 50% to 60% of people over age 15 earn an income, with median incomes ranging from $10 912 in Repulse Bay to $26 389 in Rankin Inlet (Statistics Canada, 2006). Using Repulse Bay as an example, the economic use value (not including cost sharing or opportunity cost) per whale equates to $38 per beluga and $1890 per narwhal. Repulse Bay thus generates $136 878 from hunting whales, as the distribution of catches is not even across communities (Table 4). Repulse Bay has the lowest median income of all communities, at $10 912 with 375 wage earners, yet the highest value from whaling. The value from whales is equivalent to 3.3% of the income of each wage earner, meaning that each wage earner would have to increase his or her annual income by that percentage to make up for loss of income if whaling were to cease. The value from whales would be a lower percentage of income in other communities, where incomes are higher and contributions of value from whales are lower (because of smaller catches).

When we take time spent hunting (opportunity cost) into account, the per capita use values of $44 and -$1 for narwhal and beluga decrease to -$7 and -$61. In our model, costs of obtaining and operating gear are high enough to negate the value of meat and crafts derived from the whales. For the polar bear hunt in Clyde River, gear costs range from 44% to 80% of a hunter's income, and these high costs limit a person's ability to participate in hunting activities (Wenzel, 2009b). Hunters who are employed (wage earners) are better able to afford and maintain hunting equipment (Wenzel, 1991). Analyses of hunting for other species have also identified low economic use values. Economic analysis of seal hunting in Clyde River in the 1980s identified revenues of $1133 per hunter (not per capita), but once costs were considered, hunting operated at a deficit (Wenzel, 1991). The subsistence economic value of moose (meat only) was calculated to be $633 per hunter in 2005 (Northern Economics Inc., 2006); again, this value would be lower if calculated on a per capita basis. One analysis of multiple subsistence hunting activities in Alaska identified an economic value close to zero when opportunity costs were included (Colt, 2001). Although the narwhal and beluga hunts produce substantial revenues, the per capita economic values show that if we also consider investments of gear and time, participating in hunting activities is a time-consuming and costly endeavor.

There are perceptions that hunting activities in the Canadian North are based on financial desire (Wenzel, 1991), although both the model results presented here and in past economic studies indicate there may be other motivations. It has been noted that money is necessary to facilitate hunting activities, rather than being their end goal (Nuttall, 2005).

Anthropological literature outlines the cultural importance of hunting activities, as well as views on animals as a resource (Wenzel, 1991; Freeman and Foote, 2009; Schmidt and Dowsley, 2010), although these aspects are not quantified in this analysis. It is likely that the high cultural values of these hunts (and others) drive hunters to participate in hunting activities despite the low financial returns. One important cultural aspect of the hunt is resource sharing. The concept of sharing food between individuals, families, and communities is crucial to cultural stability in northern communities (Berkes and Jolly, 2001; Nuttall, 2005). It has been reported that this system of sharing is a socially (not economically) based norm (Nuttall, 2005).

Although hunting activities contribute only a small fraction of the total income to the community, these activities will almost certainly continue to take place because of the cultural and community values associated with them. The hunting and sharing (distribution) of country foods, as well as other resources, are culturally significant exercises in many northern communities (Wenzel, 1991; Nuttall, 1992, 2005). It is estimated that 96% of Inuit households share food with the community (Tait, 2001). In addition, the community participation necessary to land and process a whale and the celebration of the hunt are core cultural features of these communities (Freeman, 2005). The value of participating in hunting activities (non-use value) is that it provides intangible benefits and a source of identity to Inuit hunters (Wenzel, 1991; Reeves, 1992b). So while the use value of these hunts is sizable when looking at the hunt as a whole, or on a community basis, the total value to the individual hunter (use value plus non-use value) is likely much higher than what our current data and model can possibly capture. In this regard, the total value of beluga and narwhal hunts to community members may be underestimated in our study.

There are likely other reasons why people would continue to hunt. First, costs could be lower in reality, as previously mentioned, through cost sharing with other hunting activities. Second, subsidies also lower hunting costs, as they are shown to do with fishing (Sumaila and Pauly, 2006; Sumaila et al., 2010). Third, opportunity costs are more likely to be overestimated within the model, rather than underestimated.

Continued building on the current model to include additional variables for both costs and revenues will further expand our understanding of hunting activities and affect the model in many ways. Outside of their value as food and arts and crafts, values from hunting activities include the previously mentioned cultural values, added health benefits, and values to scientific research. In the model, we assigned the next best available proteins, such as beef, pork, or chicken from the local store, as substitutes for *muktaaq.* However, in nutritional terms, these may not be practical substitutes. Marine mammal blubber and skin contain high levels of retinol (a form of vitamin A), vitamin B, vitamin C, and polyunsaturated fats, in addition to being high in protein, while marine mammal muscle is high in iron and zinc (Geraci and Smith, 1979; Kinloch et al., 1992; Hidiroglou et al., 2008). Diets with higher contributions of country foods and polyunsaturated fats protect against cardiovascular disease, whereas store-bought foods have lower values of polyunsaturated fats (Kinloch et al., 1992). The differences in nutritional value between country foods and store-bought foods should be considered a limitation of this modeling exercise. Harvesting of animals also benefits scientific research: hunters collect samples of fat, muscle, and other organs and send them to researchers for analysis. Genetic analysis of these samples and the information they provide on the diet and health of the whales can prove valuable for stock management.

Estimates of the costs associated with hunting will need to be expanded for more precise economic values of both hunts. Including the additional costs of equipment maintenance, camping gear (stoves, tents, food for multi-day trips), and processing gear (knives, equipment for drying meat) will result in lower economic values than presented in this paper. However, factors such as cost sharing would still lower costs and result in higher economic values, as presented. Although values were presented as though all costs (fixed and variable) were incurred solely for the purpose of the individual hunts, this idea is not representative of hunting in the North. Repulse Bay, for example, participates in both the narwhal and the beluga hunts. If hunting activities were combined using the same gear, and narwhal were hunted only opportunistically during "beluga hunting trips," then in theory we might assume no costs associated with the narwhal hunt, because in this case narwhal would be considered a non-target species. Hunting activities in the North also target a variety of other species, such as seals, caribou, polar bears, birds, fish, and shellfish. It is almost certain that some degree of cost sharing is occurring already. Figure 3 illustrates the increase in economic value due to cost sharing. Both hunts show an asymptotic shape, indicating that the greatest increases are happening when costs are shared between two and four activities, which is likely already occurring in reality.

The issue of subsidies has not been fully addressed in the model. We have incorporated the fact that discounts on guns and bullets are offered to some members of the community, as information from harvested narwhals indicates that the majority of guns used for hunting (and bullets) were obtained from the Canadian Ranger program. Other subsidies are known to exist for hunters; however, we do not know the magnitude of their value or how these subsidies filter down to the hunters. Information regarding numerous programs available through Nunavut Tunngavik Inc. (NTI) aimed to assist Nunavut hunters is available online (http://www.tunngavik.com/programs-and-benefits/frequently-asked-questions/hunters-harvesters/). Various programs under NTI offer subsidies, such as the Nunavut Harvester Support Program (NHSP). These harvester support programs in various regions have had a positive effect on country food production (Hedican, 1995; Dorais, 1997; Chabot, 2003). The NHSP and other programs offer hunting gear at a subsidized cost or money to purchase gear through the local HTO, thereby lowering the costs associated with hunting. Equipment draws and lotteries (through the local Co-op, for example) also provide some hunters with equipment at little or no cost. Furthermore, since carvings and tusks are generally sold through the local Co-op before they are further distributed at higher prices, the Co-op generates revenue from these sales. While the amount of revenue is unknown, the Co-op re-invests its profits in community programs, thereby adding value to the community through these sales. It is also possible for individual hunters/carvers to sell their products directly to art dealers or travelers generating additional revenue directly.

We believe that the opportunity cost calculated within the model is possibly an overestimate; however, more research would be needed to improve current values. For example, hunters may hunt after working hours or on the weekends, when these trips do not interfere with work, which would lower the opportunity cost. In addition, members of the community have been known to leave work when whales were present in nearby areas, forgoing work for hunting. This choice implies that hunting activities are more important than earning a wage, emphasizing the cultural value of the hunt.

While values in this model are derived from hunting, it would be possible to generate revenue through other avenues, such as whale watching. It was estimated that in 2003, more than 13 million people globally participated in whale watching, spending over $1.6 billion USD (Cisneros-Montemayor and Sumaila, 2010). Yet the notion that whaling and whale watching cannot coexist must be taken into account. Locations where tourism infrastructure already exists have the greatest potential for revenue from whale watching activities (Cisneros-Montemayor et al., 2010), but even in northern communities that lack a significant flow of tourists, potential exists for the opening of whale watching endeavors. More research is needed to identify the scope of these possibilities, including the potential desire of northern communities to participate. Polar bear hunting activities combine sport-based "trophy hunts" for non-Natives with traditional hunts (Dowsley, 2010), indicating that some communities may be willing to participate in multiple activities to generate revenue.

Perhaps what is most informative regarding this model is that the revenue generated from both hunts averages just over CDN $1.1 million for the 2007 year, with most of the revenue generated as edible products. While this figure is considered an underestimate for reasons previously mentioned, its total value pales in comparison to the landed value of marine commercial fisheries within Canada, which for 2007 was $1.96 billion (DFO, 2011). In the case of the narwhal hunt, it is often implied that hunting activities are driven by potential profits from male narwhal tusks. However, for the communities specified in this model, males accounted for only 56% of catches (from Repulse Bay), indicating they were not the sole targets of the hunt, at least for the 2007 season.

If the harvesting of whales is not possible in the future (because of biological limitations), the economic ramifications will affect not only Hudson Bay communities, but also those in other areas of Nunavut and Nunavik. The ban on trading narwhal products outside of Canada has likely affected Hudson Bay communities, yet this lost revenue appears small compared to the costs associated with hunting. As the preliminary details of these hunts have been presented here, more research is needed to gain a better understanding of various aspects of these activities in northern communities.

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