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Systematic Review and Critique of the Contributions of Traditional Ecological Knowledge of Beluga Whales in the Marine Mammal Literature

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ABSTRACT. In this study we systematically review and critique literature containing Traditional Ecological Knowledge (TEK) of the beluga (*Delphinapterus leucas*) as a case study to gain insights into TEK's contributions to the marine mammal literature over the past four decades. We reviewed multiple searchable online databases, collected both academic and grey literature, and categorized it by geographic and disciplinary focus, as well as by the contribution of TEK to the source. Of the total 137 papers retained in the final analysis, 67% referred to the Canadian North, particularly the Hudson Bay subregion. Articles that included informal or anecdotal representations of TEK of belugas were the most prevalent. The number of papers containing TEK of belugas increased rapidly between 1975 and 2004 but appears to have leveled off since then. Biological papers represented the largest disciplinary focus (72%), followed by papers on management or co-management. This review showed that although knowledge of Indigenous peoples has made substantial contributions to the understanding of beluga, there is a lack of explicit collection, documentation, and use of TEK in the literature on belugas and particularly in the literature on beluga management.

Key words: beluga whales; Traditional Ecological Knowledge (TEK); *Delphinapterus leucas*; Arctic; systematic literature review

RÉSUMÉ. Dans cette étude, nous avons passé en revue de manière systématique la littérature existante sur les connaissances écologiques traditionnelles (CÉT) des bélugas (*Delphinapterus leucas*) et nous l'avons critiquée en tant qu'étude de cas dans le but de mieux comprendre la contribution des CÉT aux connaissances existantes sur les mammifères marins au cours des quatre dernières décennies. Différentes bases de données consultables en ligne ont été examinées, puis des articles publiés dans des revues scientifiques et des écrits provenant de la littérature grise ont été recueillis, après quoi ceux-ci ont été classés par emplacement géographique, discipline, ainsi que par leur utilisation des CÉT. Au total, 137 documents ont été retenus pour les analyses finales, dont 67 % faisaient référence au nord du Canada, en particulier la sous-région de la baie d'Hudson. Les articles contenant des informations non publiées ou des anecdotes sur la représentation des CÉT sur les bélugas ont figuré parmi les articles les plus abondants. Les documents contenant des CÉT sur les bélugas ont augmenté rapidement entre 1975 et 2004, mais leur nombre semble s'être maintenu depuis. Les articles de biologie ont représenté la majorité des documents (72%), suivis de ceux axés sur la gestion ou la cogestion. Cette revue de la littérature montre que bien que les connaissances des peuples autochtones aient contribué à une compréhension nettement meilleure des bélugas, il y a un manque de rigueur dans la manière de recueillir, de documenter et d'utiliser les CÉT dans la littérature sur le béluga, particulièrement la littérature celle axée sur la gestion.

Mots clés : bélugas; connaissances écologiques traditionnelles (CÉT); *Delphinapterus leucas*; Arctique; revue systématique de la littérature

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INTRODUCTION

Marine mammals, particularly cetaceans, are difficult and expensive to study and monitor (Laidre et al., 2008; Simmonds and Eliott, 2009). Arctic marine mammals are particularly difficult to study because of their remote locations and the challenging environmental conditions often present (Huntington et al., 2005; Laidre et al., 2008). These challenges result in a lack of access to observational data for key species and at specific, often critical, times of the year, leaving significant gaps in the understanding of species ecology and behaviour. These gaps are demonstrated in the recent International Union for the Conservation of Nature (IUCN) "Red List," which classifies more than 50%

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of cetacean species as "Data Deficient" (Simmonds and Eliott, 2009). Several populations of the three cetacean species that are year-round residents in the Arctic—narwhal *Monodon monoceros*, beluga *Delphinapterus leucas*, and bowhead *Balaena mysticetus*—are designated as endangered, threatened, or of special concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), which highlights the need for increased understanding of these and other marine mammal species in the Arctic in order to formulate management plans and address conservation concerns (COSEWIC, 2011). Of particular importance for science-based management are accurate life histories, population estimates, stock/population designations (spatial structure), and knowledge of distribution and migratory routes (Adams et al., 1993; Olsen et al., 2014). Current science-based conservation measures are hindered by incomplete information about Arctic species' life history traits and distribution (Laidre et al., 2008; Ragen et al., 2008; González-Suárez et al., 2009; Simmonds and Eliott, 2009). These issues are even more pertinent in light of climate change because Arctic warming is predicted to affect distribution, migration, abundance, reproductive success, prey abundance and distribution, and survival (Learmonth et al., 2006; Simmonds and Isaac, 2007; Simmonds and Eliott, 2009). These changes may result not only from in situ changes in habitat conditions, but from new competitive and predation forces as southern marine mammals (e.g., killer whales, *Orcinus orca*) expand their ranges northward (Higdon et al., 2012; Hammill, 2013).

A source of information that has been gaining recognition in marine mammal science, as reflected in the academic literature, is Traditional Ecological Knowledge (TEK). Defining TEK is challenging and there are a multitude of definitions (for a review of these refer to Furgal et al., 2006 or Houde, 2007); however, for the purpose of this paper TEK is defined as "knowledge gathered and maintained by groups of people, based on intimate experience with their environment" (Huntington et al., 2004:21). These knowledge bodies exist the world over and are common in places where people still live closely connected with their environment. One such place is the Arctic (Berkes et al., 2007), where TEK has been featured in Arctic research since the mid-1960s (Wenzel, 1999). In the past two decades, published documentation of TEK has increased exponentially and is gaining attention and recognition, as demonstrated by its inclusion in policies such as Canada's Species at Risk Act (SARA) and Oceans Strategy and those of the IUCN (Berkes et al., 2001, 2007; Government of Canada, 2002; Furgal et al., 2006).

Given the challenges in understanding marine mammals, knowledge from Indigenous peoples can make unique and significant contributions in several areas (e.g., monitoring, research, and management). The temporal and spatial scales at which Indigenous peoples are observing and interacting with the Arctic environment, and the ways in which they do so, mean that TEK can often provide complementary or additional temporal and spatial perspectives to scientific understanding. When used to observe a species or phenomenon at a similar scale, TEK can also increase the confidence in results and understanding from science (Gagnon and Berteaux, 2009). In Sanikiluaq, Nunavut, located in the Belcher Islands of Hudson Bay, traditional knowledge of the environment and environmental change has been used as a foundation for continued monitoring and research in the region (Gilchrist et al., 2006). Further, TEK has contributed new information and insight about marine mammals, generally in the fields of biology and ecology, and specifically in regard to estimating population numbers, defining stock structure, managing bowheads and belugas in Alaska, and redefining stock status of bowheads in Canada (Huntington, 2000a; NWMB, 2000; Fernandez-Gimenez et al., 2006; COSEWIC, 2009). More broadly, Indigenous approaches to resource management focus on strategies that promote resilience, such as multiple species management, and on maintaining sources of ecosystem renewal that can be more adaptive to unexpected events or ecological surprises (Berkes et al., 2000). Table 1 contains further examples of TEK contributions to marine mammal science.

The systematic literature reviews widely used in many disciplines are designed to synthesize a topic to increase understanding and illustrate trends occurring in the literature over time (Mulrow, 1994). For example, two earlier reviews of TEK studies found an overall lack of attention to methods (Davis and Wagner, 2003; Furgal and Laing, 2012). These reviews found that very few articles provided a detailed description of methods (timeframe, instruments for collection, such as semi-directive interviews, and number of participants), and even fewer described how they selected local experts to be participants. It is important to identify and understand trends in the representation and contributions of TEK to the marine mammal literature in order to improve its use and better recognize the contributions of Indigenous peoples.

The purpose of this study was to review and critique the literature of TEK on belugas systematically in order to 1) assess the contributions of TEK to the marine mammal science literature and how they have been represented; 2) examine the marine mammal literature over time to assess how the contributions and attributions of TEK have changed, and; 3) consider the geographic focus (e.g., Greenland) and disciplinary focus (e.g., management of beluga) of papers and how these have changed over time.

METHODS

We conducted a systematic review of academic journal articles and grey literature on TEK of beluga using methods similar to those of Furgal et al. (2010). Academic journal articles had typically undergone an anonymous or blinded external review by experts in the field before publication. Grey literature articles came from such sources as government, industry, organization and private consulting reports, and theses, which had undergone varying processes of peer

TABLE 1. Selected examples of Traditional Ecological Knowledge (TEK) contributions to marine mammal science and conservation in the Arctic (adapted from Fraser et al., 2006).

Species	TEK contributions	Reference
Bowhead Whale (*Balaena mysticetus)*	Information on seasonal movement, distribution, and abundance of bowheads. Indications of population viability through increases in number of young seen.	Noongwook et al., 2007
Bowhead Whale (*Balaena mysticetus*)	Knowledge of migration behaviour of bowhead whales (that they travel through pack ice and farther offshore) changed survey methods and significantly increased population estimates (from 2000–3000 to 6000–8000).	Huntington, 2000a
Beluga Whale (*Delphinapterus leucas*)	Discussion of the effects of beaver dams on fish distribution (and consequently, belugas) increased understanding of the factors affecting beluga distribution.	Huntington, 1998
Narwhal (*Monodon monoceros*)	Information on critical habitat, identification of two morphs and trends in size of narwhal stocks.	Furgal and Laing, 2012

TABLE 2. Categories used to group articles based on their representation of TEK.

Category	Explanation
TEK study	Intentional explicit (primary) collection or use of TEK (or both) in the introduction or methods, as well as TEK in the results of the paper.
TEK content	Implicit inclusion or anecdotal or informal collection of TEK (not clearly stated in the methods or introduction); e.g., a personal communication from a hunter. Also includes papers that discuss primary collection of TEK, but do not directly include it. Papers describing interviews focused solely on monitoring the harvest were considered as papers with TEK content, rather than TEK studies, given the lack of an ecological focus.
TEK reference	Papers that included TEK through reference to another study (often one of the "TEK studies") or papers with more general references to TEK (e.g., to the importance of including TEK).

review. Websites and webpage content were excluded. We searched the literature using one online search engine, Google Scholar; two agency websites, Government of Canada and Aboriginal Portal; and three online indexes: Web of Science; the Arctic Science and Technology Information System (ASTIS) at the Arctic Institute of North America, University of Calgary; and the Circumpolar Health Bibliographic Database at the University of Manitoba. To capture all reports that include TEK of beluga, different keyword combinations were used. Keywords for beluga ("beluga" and "white whale") were used in combination with different keywords for TEK: "Indigenous Knowledge," "Inuit Knowledge," "Traditional Knowledge," "Traditional Ecological Knowledge," "Traditional Environmental Knowledge," and "TEK." To ensure full capture of beluga TEK, we also searched reference sections of the articles we collected to capture papers that contained a significant amount of TEK about beluga but were not found by the online search, which often occurred when the article was not available online.

All papers that contained "beluga" and "TEK" were included, and the full source was gathered for sources published up to the end of 2012. To be included in the analysis, an article needed to have beluga as a primary focus (i.e., appearing in either the title, keywords, abstract, or executive summary). The use of TEK could be explicit (i.e., a TEK study) or it could be implicit, such as a reference to what Inuit field guides reported about where to find beluga as reported in the context of a peer-reviewed study. TEK needed to come from people, either directly or indirectly, but could not simply be inferred (e.g., archaeological studies of harvesting).

We categorized all articles by source (academic journal or grey literature), contribution of TEK acknowledged in the article, geographic focus, and field of study. The data were analyzed for trends in the contributions of TEK to the literature over time, both within categories and overall. Fisher's exact test was used to examine categorical differences using a significance level of 0.05. Each paper was classified as using one of three types of TEK presentation: a TEK study, TEK content, or references to TEK (Table 2). Each of these categories was treated as mutually exclusive; therefore, if a paper fell into two categories (e.g., having TEK content and references), it was put into the category of greater TEK contribution (i.e., TEK content). Geographic focus was categorized by country, and Canada was further delineated using Environment Canada's Canadian Ice Service (CIS) categorization of western and eastern Arctic, dividing at Somerset Island, and Hudson Bay (CIS, 2015). Geographic focus categories were not mutually exclusive, so it was possible for a paper to fall into more than one category if the study included multiple regions. Articles were also classified by four fields of study: methods, biology, management and co-management, and hunting and resource use (Table 3). Again, an article could fall into more than one category. For example, a government science article on harvest advice for beluga was categorized as biology as well as management and co-management, as it draws heavily from and adds to the ecological understanding of beluga to inform science-based management models. The line between the biology and the management and harvesting categories is drawn where the article shifts from being about the species to being about human–beluga interactions.

TABLE 3. Categories used to group articles by field of study.

Field of study	Explanation
Methods	Suggested methods; framework development; methodological critiques.
Biology	Articles that focus on developing or enhancing biological and ecological understanding of beluga (e.g., topics such as feeding ecology, genetics, behavioural studies, ecologically focused monitoring, and wildlife health). Biology papers could draw on a variety of sources, including harvest statistics.
Management and Co-Management	Articles that focus on influencing human behaviour in relation to beluga; e.g., management and conservation plans (or critiques of such plans) and integration of TEK into management plans.
Harvesting / Hunting / Resource Use	Papers that focus on the relationship or interactions between Inuit (or other Indigenous groups) and beluga, e.g., traditional hunting practices.

RESULTS

A total of 137 papers were retained in the analysis after the application of inclusion and exclusion criteria (e.g., beluga needed to be the primary focus) and removal of duplicates (online Appendix 1). Papers spanned the time period from 1976 to 2012, and 57% of all papers were grey literature. Papers were more frequently categorized as TEK content articles (46%) than as TEK studies (27%) or TEK reference articles (27%) (N = 137; Fisher's exact test, $p < 0.05$). The earliest paper found in the literature search, a TEK study by Read and Stephansson (1976), is an example of the type of contributions that Inuit made to the overall understanding of beluga, notably regarding their distribution and migratory routes. TEK content articles often added hunters' voices to an article and attributed specific contributions in the article to that knowledge holder. For example, several studies cited personal communication with hunters or highlighted how hunters or guides contributed to the project (e.g., by identifying study areas; Rugh et al., 2000).

The distribution of grey and academic literature was similar within each of the TEK categories except the TEK content category, where there was a bias towards grey literature. The grey literature, which contained informal or anecdotal representation of TEK, accounted for 75% of TEK content articles and 34% of all articles (N = 63 and 137, respectively) (Fig. 1).

The total number of papers that contain TEK of beluga increased rapidly and significantly between 1975 and 2004, with numbers appearing to level off through the 2000s to approximately 35 papers every 5 years (Fig. 1). Between 1995 and 2012, the number of papers in the TEK studies category remained fairly constant.

The geographic focus of articles was unevenly distributed, with 67% of the papers focused, at least in part, on Canada (Fig. 2) (N = 137). Within Canada, more than half of the articles were focused on the Hudson Bay subregion. Alaska (27%) and Hudson Bay (36%) were most frequently the regions of focus, while papers focusing on Russia and Greenland (each 3%) were least common (Fisher's exact test, $p < 0.05$).

A significant majority (72%) of papers retained in the analysis focused on beluga biology compared to 26% on management and co-management (N = 137). Significantly fewer papers looked at hunting and resource use (15%), and even fewer papers dealt with methods (2%) (Fisher's exact test, $p > 0.05$).

The earliest published TEK studies found in this review were in the fields of biology. However, the beluga TEK literature published since the 1990s has increasingly focused on management or co-management (see Figs. 3 and 4). For articles with either an ecological or a management focus, there was a marked increase in the number of papers with some contribution from TEK, although TEK was not the focus of the article. This TEK content category increased considerably between 2000 and 2004 and has remained relatively stable over the last 10 years. Papers in the fields of biology that referred to TEK also increased markedly in 2000 and remained a significant source of all contributions until 2012. A similar trend was not observed in the fields of management and co-management. TEK references in the latter fields were the least represented of all of categories of TEK contributions.

The publication of TEK studies differed between papers focused on beluga biology and those focused on beluga management. TEK studies with biological focus increased in total number of publications in the 1990s and then decreased slightly in the 2000s. Publication of TEK studies focusing on beluga management also increased, but not until a decade later. The number of papers focusing on biology peaked in 2000; after which the TEK content and TEK reference papers remained fairly consistent and evenly distributed through the 2000s until 2012. For papers with a focus on management, 2000 was also the year of marked increase, primarily in the TEK content category, with very few papers on beluga published in the TEK reference category.

DISCUSSION

Systematic literature reviews are invaluable tools to identify research trends and provide an opportunity for reflection within a field of study. This review highlighted some of the contributions TEK has made to the marine mammal literature, examined how these contributions have changed over time, and illustrated the geographic and disciplinary focus of this literature to date. These results raise issues and questions related to representation and attribution of TEK. Further, they have been shaped and given

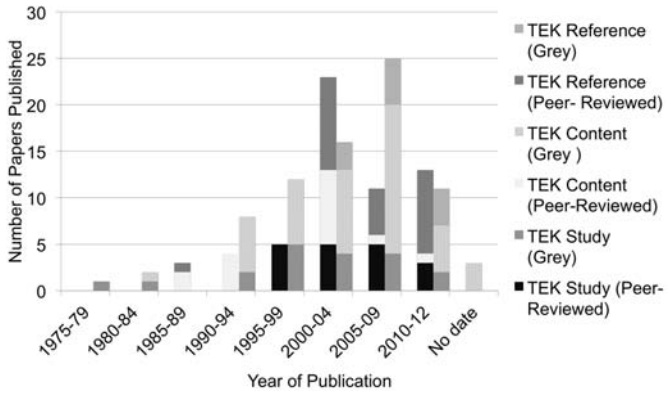

FIG. 1. Number of papers in peer-reviewed and grey literature publications (1975–2012), by TEK representation category (TEK studies, articles with TEK content, articles with TEK references).

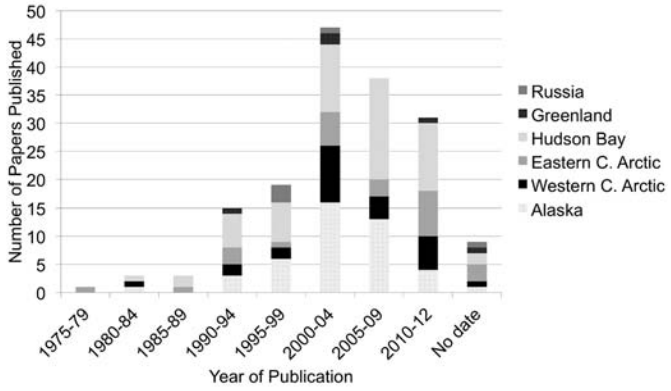

FIG. 2. Number of beluga TEK papers published (1975–2012), by geographic focus. The sample size for this figure is greater than the total number of papers because the geographic focus of some papers included multiple regions.

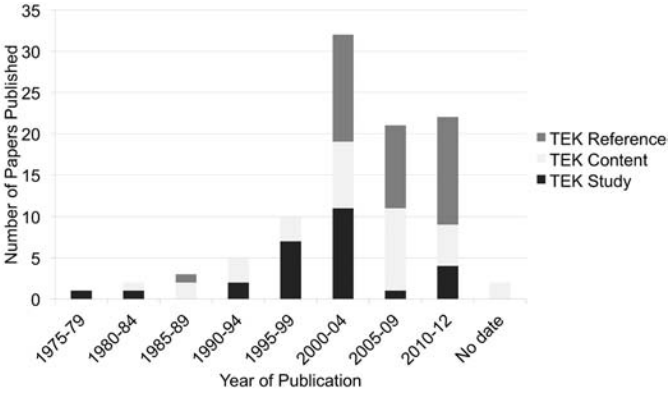

FIG. 3. Number of papers published in the field of biology (1975–2012) with contributions from TEK of beluga.

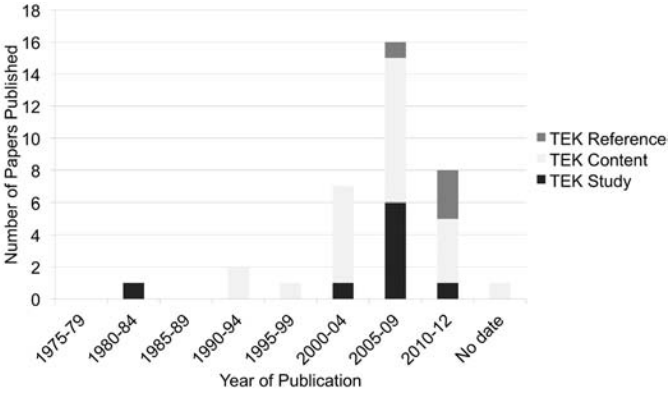

FIG. 4. Number of papers published in the fields of management and co-management (1975–2012) with contributions from TEK of beluga.

relevance by the current political landscape in the North (e.g., land claim agreements and associated co-management bodies).

TEK has made substantial contributions to the marine mammal literature, both formally, through the 37 TEK studies that intentionally documented the knowledge of Arctic Indigenous peoples, and informally, through the information about beluga contributed by Inuit hunters and guides to numerous studies, represented by the 63 TEK content articles captured in this review. Some of these papers then went on to inform seminal beluga literature. For example, the TEK study by Read and Stephansson (1976) then went on to inform some of the first assessments of the status of beluga (e.g., Reeves and Mitchell, 1987).

In this review, we observed several broad trends in the literature. The first was the marked increase in the number of publications with contributions from TEK of beluga over the past three decades, with very few papers published in the 1980s, the greatest increase in the 1990s, and an apparent leveling off in the 2000s. This pattern likely reflects an overall increase in recognition for the potential contribution from TEK and a resulting increase in attention to, interest in, and documentation of TEK (Huntington, 2011) and related policy changes. Recognition of the value to monitoring and management discussions of contributions from people living in close connection with their environment has increased since the 1980s (e.g., "Earth Summit" [UNEP, 1992]). Changes in policies giving recognition to this value have created space for more formalized documentation and reporting of Inuit Knowledge (IK) in the science literature and by northern communities themselves (McDonald et al., 1997; Furgal et al., 2006; Bocking, 2011). However, almost half of the increase in TEK contributions came from papers in which TEK was implicitly included as anecdotal or informal knowledge (e.g., personal communications from hunters). Possible explanations for this anecdotal treatment of TEK are insufficient attention to research design and methods in local observation and knowledge studies, or a failure to recognize and appreciate the potential contribution of TEK, or both (Davis and Wagner, 2003).

The dominance of grey literature in all sources identified and retained for the analysis is perhaps not surprising given the ease of production and dissemination of grey literature in comparison to journal articles. However, it indicates the importance of also searching that body of literature when looking for sources of TEK on beluga and possibly other marine mammals. While some grey literature is well cited (e.g., McDonald et al., 1997), much of it receives very

little attention despite its potential for valuable contributions (e.g., Thomsen, 1993). This neglect is likely due in part to difficulties in access (e.g., not available online) and journal restrictions surrounding citable sources, and it may reflect the quality of some grey literature sources. However, this is not the case for all grey literature, as some is readily available, e.g., through the DFO Canadian Science Advisory Secretariat (CSAS), and undergoes some form of peer review.

Nearly two-thirds of all sources focused on Canada. The dominance of papers on Hudson Bay likely reflects the interest in beluga stocks in that region. Of the seven populations of beluga currently recognized in Canada, the two currently assessed as endangered (the Eastern Hudson Bay and Ungava Bay stocks) are both located in that region (COSEWIC, 2004). Given their status, these stocks receive a large amount of research and assessment attention (e.g., increased frequency of aerial surveys). For example, the Department of Fisheries and Oceans Canada (DFO) has produced seven science advisory reports related to harvest advice for this population since 2010. The large number of TEK articles reporting on Alaska could also be due to the status of the Cook Inlet population, which was recently declared endangered, under the United States Endangered Species Act. Many of the Alaskan papers focused on this population, probably as a result of research focus in the region. This focus also reflects the policy support afforded to TEK through structures such as the Alaska Beluga Whale Committee (ABWC), a co-management board that has TEK as one of its priority areas of research (Fernandez-Gimenez et al., 2006). The underrepresentation of Russia and Greenland in the analysis may be the result of limiting our review to articles in English. Or it may reflect a lack of political or legal necessity to consider TEK in those jurisdictions, which means that less TEK is documented and published.

Some of the earliest contributions from TEK on beluga were in the field of biology. TEK studies that focused on biology grew rapidly in the 1990s; however, a similar trend was not observed in management-focused papers until the 2000s. This pattern may represent an evolution in the field as some authors who initially documented TEK of beluga (e.g., Huntington, 2000b) then went on to focus on its inclusion in management and other applications (e.g., Fernandez-Gimenez et al., 2006). It may also represent a shift in the broader political landscape. For example, the implementation of land claims (e.g., the Inuvialuit Final Agreement signed in 1984) and the establishment of wildlife boards, e.g., the Alaska Beluga Whale Committee (1988) and the Nunavut Wildlife Management Board (NWMB; 1993), created a demand for TEK to be documented to inform management decision making and subsequently raised questions about how to incorporate TEK into the process (e.g., Fernandez-Gimenez et al., 2006; Gislason, 2007).

Management and biologically focused papers with contributions from TEK increased in the 2000s, particularly in terms of implicit or informal inclusion of TEK. This trend was particularly pronounced for management-focused papers, many of which were government advisory reports that frequently included resource user perspectives or anecdotal evidence from TEK. While references to sources that included TEK showed a similar increase in papers focused on biology, a similar trend was not observed for papers with a management focus—perhaps for lack of applicable sources to cite. Perhaps this lack indicates that management-focused articles are an area of opportunity where TEK or TEK holders could be more rigorously included.

Papers which make reference to TEK are likely underrepresented in this study because TEK references were not actively collected but were included if they fit the criteria. Other studies may exist that refer to TEK about beluga but did not meet the search criteria because this was not stated. The TEK reference section also lags behind the other categories because of the relatively few published articles. However, the numbers of articles in this category will likely increase.

The potential of attaching value to the different representations of TEK may be problematic since each category has strengths and challenges and serves a particular purpose in a publication. For example, TEK content articles sometimes add hunter-attributed contributions. The greatest potential problem in these cases is the lack of purposeful and rigorous use of appropriate methods (i.e., opportunistic documentation) and the associated challenges (i.e., lack of verification with the contributor). Although the purpose of this review was not to analyze the methods used, a surprising number of papers did not report methods used for TEK collection or inclusion in their study. In articles including TEK content, it was often difficult to determine how the information was gathered and which aspects of the results came from TEK. For example, Asselin (2010) in her thesis cited personal communications with a hunter to support the hypothesis that Pacific herring (*Clupea palasii*) were the factor driving belugas to aggregate at an ice edge. While the hunter originated this idea, Asselin et al. (2012) did not include his statement in the peer-reviewed publication resulting from the same research, mainly because they could not contact the hunter to confirm the statement and obtain clear permission to cite it (N. Asselin, per. comm. 2014). This example points to the importance of documenting TEK as well as to the lack of systematic and recognized ways of including oral sources in peer-reviewed publications. The present review also gathered other studies that appeared to have done some form of TEK collection, but did not report the methods. For example Kishigami (2005) mentions that Inuit hunters were interviewed about beluga management, but that is the extent of the reporting of the interview and analysis process. This failure to report methods, as similarly noted by Davis and Wagner (2003) and Furgal and Laing (2012), is one reason that papers with TEK content were the largest TEK category, though some TEK studies also had similar methodological challenges. The failure to apply standard qualitative research methods, which include stating the limitations of results, to this work may be responsible for some of the unfair critiques of TEK

that discredit the content and inadvertently disempower the knowledge holders (Davis and Ruddle, 2010; Furgal and Laing, 2012).

In all cases, and particularly for sources that reference TEK, one of the most significant issues is proper attribution to knowledge holders (e.g., Elders, hunters, practitioners). This issue is not unique to the group of papers that reference TEK, but is part of the ongoing discussion in the literature about what constitutes authorship. In academia, recognition of contributions is given through authorship, and the documentation and use of TEK pose specific challenges that call into question a fundamental assumption that underpins this paradigm. Even in papers that drew strongly from Inuit understanding of a species, the contributions are quickly disassociated from the original knowledge holder and become associated with the article authors. Co-authorship with knowledge holders or communities is one potential solution, but also comes with its own set of challenges, especially in regard to meeting standardized academic practices for authorship. Castleden et al. (2010:29) argue that the collective ownership of IK and Indigenous autonomy "demand different or amended inclusionary authorship guidelines" (e.g., amount of written versus other intellectual contributions) rather than traditional criteria for authorship and suggest that Indigenous partners should have the opportunity to choose how their contributions are acknowledged at the outset of the research project.

Arctic beluga populations are a species that provides the opportunity for meaningful contributions from TEK to support greater common understanding. Several conditions create this context: large and widespread populations with many opportunities for human interactions; endangered populations that urgently require improved understanding; and resources of great importance for Arctic Indigenous peoples with significant cultural, health, and economic value. Such conditions are facilitated in part by legislative requirements, particularly for species at risk, which necessitate the consideration of TEK (defined as Aboriginal traditional knowledge) in assessing population status and implementing recovery measures (SARA; Government of Canada, 2002). While the formalization of Aboriginal traditional knowledge inclusion is still relatively new, COSEWIC's Aboriginal traditional knowledge "Process and Protocol Guidelines," which were approved in 2010, outline an approach, including several ethical considerations, for the gathering and inclusion of Aboriginal traditional knowledge in the COSEWIC assessment process (COSEWIC, 2012). While this context does not exist for all Arctic species, similar opportunities exist for polar bears (*Ursus maritimus*) and several other species. Challenges still remain when it comes to decisive integration of knowledge in practical applications (e.g., species management) (Dowsley and Wenzel, 2008).

The settlement of land claims across the Canadian North is creating, and in some cases legislating, increased opportunities for contributions of TEK to the management of Arctic wildlife species. For example, one of the most recently settled claims, the Nunavik Inuit Land Claims Agreement (NILCA) (Government of Canada, 2008), specifically articulates the value and necessitates the inclusion of Nunavik Inuit knowledge under the wildlife management objectives:

> 5.1.3 (f) recognizes the value of Nunavik Inuit approaches to wildlife management and Nunavik Inuit knowledge of wildlife and wildlife habitat and integrates those approaches with knowledge gained through scientific research; …

Though wildlife management boards, frequently co-management boards, are obligated to consider TEK, one of the challenges of including TEK in assessments is the difficulty in finding such documentation (Lawson et al., 2006). However, this is frequently more of an issue for non-Aboriginal managers than for Aboriginal Canadians on co-management boards and speaks to some of the power dynamics at play (Nadasdy, 2005). While some wildlife boards have undertaken this work themselves (e.g., NWMB, 2000), the capacity of boards to do so, in addition to other more urgent responsibilities in resource-constrained environments, can be a barrier and significant challenge. Additionally, knowledge holders may be reluctant to share TEK because of concerns about how and by whom it may be interpreted, considered, and used in decision making processes, and the implications of these concerns can further complicate TEK collection (Nadasdy, 1999; Fernandez-Gimenez et al., 2006; Gagnon and Berteaux, 2009). However, documentation of TEK for its meaningful inclusion into evidence-based decision making and management remains an essential part of the solution. Further research is also required on the processes used for the consideration and inclusion of both science and TEK in species management.

The knowledge of Arctic Indigenous peoples has made important and significant contributions to the understanding of beluga, particularly in the field of biology. An increase in published sources, both grey and peer-reviewed, has been seen predominantly in the last two decades and primarily focused on the Canadian Arctic. This increase in published sources documenting TEK, presenting TEK content, or referring to TEK sources reflects a number of trends in the recognition of and attention to TEK, or to the context within which TEK exists today. There is great potential for increased contribution of TEK, particularly in the context of wildlife management. Significant opportunities for improvement remain in regard to how to present and recognize these contributions properly and responsibly, and there is a pressing need for increased documentation of TEK, using rigorous and attentive methods, in order for this potential to be fully realized.

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APPENDIX 1

The following table is available as a supplementary file to the online version of this article at:
http://arctic.journalhosting.ucalgary.ca/arctic/index.php/arctic/rt/suppFiles/4543/0
TABLE S1. List of sources included in the review including categorization.

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