INTRODUCTION: WALRUS OF THE NORTH ATLANTIC

The walrus is the largest arctic pinniped. It occurs as two subspecies; the Pacific walrus, *Odobenus rosmarus divergens*, occupies the waters off western Alaska and eastern Siberia, the Bering and Chukchi Seas and the Bering Strait, while the Atlantic walrus, *Odobenus rosmarus rosmarus*, ranges, discontinuously, from eastern Arctic Canada to west and east Greenland, to Svalbard and Franz Josef Land. The Laptev Sea walrus, *O.r. laptevi*, was nominally a subspecies for a time, but is now thought to be the westernmost population of the Pacific walrus (Lindqvist et al. 2008).

Walruses are easily recognized by their long ivory tusks. They feed benthically in relatively shallow water and haul out onto ice and land to rest. These features make them attractive to hunters both to fill subsistence needs and for profit. Their gregarious nature and low reproductive rates—a mature female has one calf approximately every three years—make walrus populations vulnerable to over exploitation. Their reliance on sea ice, traditional haulout sites on land and beds of bivalves in shallow water for food, also put walruses at risk from other anthropogenic disturbances including climate change, disturbance via increased development in the Arctic and damage to their food through contamination or physical disruption.

The North Atlantic Marine Mammal Commission (NAMMCO) has had an interest in Atlantic walruses since it's inception in 1992. The Commission's first review of this subspecies in 1993 led to a compilation of current knowledge (Born et al. 1995) and stimulated subsequent management and research activities. Recognizing the progress in these undertakings, NAMMCO requested an updated assessment in 2004. Dr. E.W. Born, then of the Greenland Institute of Natural Resources, hosted a meeting of the NAMMCO's Scientific Committee Working Group on the stock status of walruses in the North Atlantic and adjacent seas in November 2009. The chapters in this volume arise largely from that meeting. They are grouped into sections on Stock Identity, Population Size, Population Assessment, and New Methods.

Within the range of the Atlantic walrus there are many groups that represent populations or smaller units (stocks). Populations comprise animals with a greater likelihood of breeding with others in the group than with walruses outside the group. Stocks are subdivisions within a population that are largely defined by their interaction with humans (i.e. hunting by areas). A continual problem in wildlife management is discerning which animals are being discussed; which stock or population do they belong to and what degree of linkage exists between them and other areas or groups? Section 1 in this volume addresses this question.

Shafer et al. (Chapter 1) examined walrus stock affinities within Canada. They analysed samples from six of the seven recognized stocks of walruses within Canada using microsatellite methods; no samples were available from the seventh stock that occurs in Hudson Bay. They found significant genetic differentiation among stocks which Bayesian clustering analysis suggested were elements of two larger genetic clusters. One, a High Arctic population contains the Baffin Bay, West Jones Sound and Penny Strait–Lancaster Sound stocks. The other, a central Arctic population contains both North and Central Foxe Basin stocks as well as the Hudson Bay–Davis Strait stock. The two large-scale populations were moderately differentiated but were not completely isolated, based on contemporary movement evidenced in assignment tests. There was some genetic evidence that suggests that the two Foxe Basin stocks are distinct from Hudson Bay–Davis Strait, but also that there is no difference between the two Foxe Basin stocks, indicating the need for more information about the walruses in Hudson Strait.

The relatedness of West Greenland and eastern Canadian walruses has been examined using microsatellite techniques (Andersen et al. Chapter 2). The authors of this chapter examined recent samples from West Greenland vs Southeast Baffin Island and Hudson Strait as well as Northwest Greenland vs northern Baffin Bay. Walruses in West Greenland and at Southeast Baffin Island did not differ from each other but both differed from Northwest Greenland and Hudson Strait walruses. The conclusions are that there are subunits within the range of walruses in the Hudson Strait–Davis Strait–Baffin Bay region and that one unit is the Southeast Baffin Island–West Greenland group. The authors also noted that this group may receive some, but likely very limited, input from Hudson Strait. These genetic data indicate walrus movement south into Hudson Strait from SE Baffin and a need for further sampling within this area in Canada.

Genetic data provide indirect information on which walruses occur in which area. However, non-breeding animals will leave no genetic markers and genetic evidence will always lag by one generation, the results of the previous mating. The deployment of biotelemetric tracking devices or "tagging" provides more direct information on movements and was the approached used to address long-standing questions about the relationship between walruses found in West Greenland and those in the eastern Canadian Archipelago (Dietz et al. Chapter 3). Satellite-linked tags deployed on walruses on their wintering grounds at Store Hellefiske Banke, Central West Greenland and also on their summering grounds off the coast of Southeast Baffin Island, Canada confirmed that walruses moved between these two areas. Eight of the 31 tagged walruses moved from West Greenland to Baffin Island, departing Greenland between 7 April and 17 May and taking, on average, 7 days to swim the 400 km across Davis Strait. In addition, one flipper tag deployed on a male walrus off South Baffin Island was recovered on a walrus that was hunted at Store Hellefiske Banke, documenting that the reverse migration also takes place. Four of the walruses tagged in central West Greenland went north past Disko Island in the spring. Contact was lost with all of these animals, but one which had gone as far as the Upernavik area had turned south and continued towards Baffin Island before transmissions ceased, suggesting a rather complicated migration pattern. This study also indicated that the tagged walruses showed a strong affiliation with the Store Hellefiske Banke, which provides a shallow, accessible feeding ground, regardless of the sea ice cover present.

Most studies of animal movements involve tagging animals where they normally occur, with new range information being gleaned if they go someplace previously unknown to science. Born et al. (Chapter 4) had an opportunity to turn this approach around when they were able to study a walrus that appeared outside the 'normal' range. An adult male Atlantic walrus that appeared in the Faroe Islands was fitted with SPOT-5 satellite-linked transmitter in February 2010. Born and his colleagues were able to obtain data from this animal until 25 April 2010. In this period, the walrus foraged and rested around the Faroes and then it swam over 2,200 km to the island of Prins Karls Forland in the western Svalbard Archipelago during a period of about 25 days. Genetic analysis placed this walrus in the Svalbard–Franz Josef Land subpopulation, indicating that it returned to its site of origin.

Benjamin Franklin once asked "What signifies the knowing of names if you know not the nature of things?" This NAMMCO volume now turns its attention to the 'nature' of the stocks and populations identified (Section 2). It is important to know the size of the population (or stock) to be able to assess past management practices and to make predictions about the sustainability of current and proposed management actions. But estimating the number of walruses is not an easy task. Walruses occupy large areas but, on land or ice, tend to be found in groups. Not all of the walruses in an area will be seen by observers; some will be submerged. Additional logistic complexities involve getting to where the walruses actually are at a given time, which can be challenging given their remoteness, and typical weather and sea ice cover in the Arctic.

There have been several attempts to estimate the size of walrus populations in Canada at haulouts, essentially colony counts, to estimate the minimum population size and various methods have been applied to address detection and availability biases. These methods are detailed in Stewart et al. (Chapter 5). Counts were made at terrestrial haulout sites in the Penny Strait–Lancaster Sound (PS-LS) and West Jones Sound (WJS) stocks in 1977 and 1998–2009. The Minimum Counted Population (MCP) was similar in 1977 (565) to recent years (557) for the PS-LS stock. The MCP for the WJS stock was 404 in recent surveys compared to 290 in 1977. However, there were no statistically significant trends over time in either group. Stewart et al. also calculated bounded-count estimates for comparison to move from a count to an estimate of population size. They used broad-scale behavioural data to estimate the proportion of the total stock that could be considered countable, in the absence of concurrent satellite tag data. For the PS-LS stock, adjusted MCP was 672 in 2007 and 727 in 2009. For WJS, the best estimates were the adjusted MCP of 503 in 2008 and the adjusted bounded count of 470 in 2009.

Stewart et al. (Chapter 6) applied similar methods, as well as data from 3 concurrently deployed satellite tags to calculate minimum population counts for walruses in the eastern Ellesmere Island area. Aerial surveys were conducted in August of 1999, 2008, and 2009. Because three of nine tags deployed in July 2009 in nearby Kane Basin were transmitting from the survey area and because surveys on 9 and 20 August 2009 were the most extensive, these surveys are the main focus of this paper. There were, at the time, no known terrestrial haulouts in the area—2009 was the only year in which the survey area was largely ice-free; walruses were observed on the ice and in water during this survey effort. The MCP was 571; when adjusted for animals not hauled out the estimate for the area was 1,250 walruses.

Direct counts were used by Stewart et al. (Chapter 7) to determine the MCP in summer around SE Baffin Island. Aerial surveys examined the coast from the NE corner of Hudson Strait to Isabella Bay during late summers of 2005 through to 2008. The MCP ranged from a minimum of 716 (in 2006) to a maximum of 1056 (2007). Several approaches were again taken to derive a population estimate from these surveys: the largest MCP, adjusted using published maximum estimates of the proportion of walruses hauled out concurrently, produced an estimate of 1,420 walruses; adjusting with data from four concurrent satellite tags produced an estimate of 2,102 using the simple proportion of 'tags dry' at the time of the counts and 2,502 using the proportion of time dry immediately preceding the survey. The authors concluded that there were 2,100–2,500 walrus present in Hoare Bay in late summer 2007, while noting the estimates are likely negatively biased estimators of the population of walruses around SE Baffin Island.

Heide-Jørgensen et al. (Chapter 8) conducted visual line-transect aerial surveys in the springs of 2006, 2008 and 2012 to estimate the number of walruses on the south and north wintering grounds in Central West Greenland. Using satellite-tag data from 24 walruses tagged in northern Baffin Bay in May and June of 2010 to 2012, they adjusted their observed counts for the availability of walruses on sea ice and walruses submerged below a detection threshold. They also adjusted for walruses that should have been visible to the surveyors but that were missed by the observers. The estimates of abundance were all roughly similar: 1,105 in 2006, 1,137 in 2008 and 1,408 in 2012. The combined information in Chapters 3, 7 and 8 clearly show that most walrus that spend the winter in West Greenland move west to Baffin Island in the summer but that some portion of the group summering in Canada remains there in winter. While the population estimates presented here infer about half the walrus remain in Canada, the surveys are not directly comparable and the extent of the summering area in Canada has not yet been delineated or surveyed.

In addition to knowing how many animals there are in a population, it is important to know how that population has responded, and might respond in the future, to management practices. Section 3 in this book includes four papers that use abundance estimates to assess the status of the populations and how those assessments are used in managing walrus removals. In the first, Lydersen and Kovacs (Chapter 9) summarize recent studies on walruses in Svalbard (a population that is free from hunting pressure) spanning most of the topics reported *de novo* for other regions earlier in this volume. Data from satellite-relay data loggers showed adult male walruses moved into areas of >90% ice concentration in winter, going as far as 600 km into dense ice. Breeding areas were identified by the season of occupancy and diving behaviour. After the breeding season, tagged males returned to the coast of Svalbard to the previous year's summering area. Data from the SRDLs (Satellite Relay Data Loggers) were used to adjust an aerial survey of walruses at all known haul-out sites in the Svalbard Archipelago. The estimated number of walruses was 2,629 in August 2006. Biopsy samples of blubber from adult male walruses were analyzed for fatty acids (FAs). Although the blubber showed vertical stratification, as seen in many other marine mammals, differences between layers were less pronounced than other pinnipeds, perhaps because the thick dermis offers some insulating value and affects the FA composition of the outer blubber in this species. The FA composition of the inner blubber closely resembled the lipids found in the walruses main prey: *Mya truncata* and *Buccinum* spp. Analysis of skin biopsies for organochlorines (OCs) found a significant relationship between OC levels in skin and blubber and a related study showed a significant decrease in levels of PCBs and DDE in walruses in Svalbard from 1993 to 2002–04. Between-individual variation in OC levels appeared to be diet-related, with individuals that had high OC levels having FA compositions in the inner blubber that closely matched seal tissues, while those with low levels matched those typical of the walruses more usual invertebrate prey. Historical sex-distribution of walruses in southern Svalbard was investigated based on mandible measurements of individuals hunted during the 19^{th} century. The analyses showed that female walruses were once more common in south-eastern Svalbard than they are today.

Witting and Born (Chapter 10) examined historical and recent dynamics of the three Atlantic walrus populations in Greenland using age- and sex-structured population dynamic models. They fit exponential growth, density-regulated growth, and selection-delayed dynamics to recent abundance estimates, age-structure data, and historical catches, integrated with data in a Bayesian framework. For the Baffin Bay walrus, analysis of the overall historic decline was compromised by incomplete catch reporting before the 1950s. But, it was clear that the population did decline by 40% from the 1960s to 2005, increasing subsequently when catches were decreased. The 2012 abundance estimate was 1,400 individuals with an annual growth rate of 7.7%. The authors estimated that West Greenland/Baffin Island walrus numbers declined by 80% from 7,000 in 1900 to 1,350 in 1960 then increased to 3,100 by 1993. A minor decline followed between 1994 and the early 2000s. Quotas were introduced at this time and models indicated a subsequent increase to 3,900 by 2012. For East Greenland, the 2012 estimate of 1,400 marks a recovery from 1888, the year prior to our first historical catches by European sealers. The authors note uncertainty in the historical trajectory, but also point out that the model estimates show a continued increase from a reliably known low in 1957.

Witting and Born were able to use compiled historical data for their modelling of the Greenland walrus populations. Until now, there has been no comparable compilation for Canada. Stewart et al. (Chapter 11) combed archaeological, historical (e.g., Hudson's Bay Company journals) and recent catch records and analysed catches according to year, data source (whaler, land-based commercial, subsistence, etc.) and population or stock. They compiled an impressive data set spanning centuries of walrus hunting in all of the eastern Canadian Arctic. Numbers of walruses landed, estimates based on products such as hides and ivory, as well as aggregate tallies, such as Peterhead boatloads, indicated a minimum landed catch of over 41,300 walruses in the eastern Canadian Arctic between 1820 and 2010. Historically, walrus hunting increased as bowhead (*Balaena mysticetus*) whaling declined. Land-based traders continued the commercial hunt until regulatory changes in 1928 reserved walruses for use by aboriginal people in the North. The sources, quality and completeness of catch data varied greatly with time, location and the different hunt types. The authors note that their estimates are negatively biased because this variability prevented extrapolating walrus catches to the whole whaling fleet, interpolating to fill gaps in various records, and accounting for under-reporting and animals that were killed and lost. Stewart and co-authors also provide caveats for each type of data examined. The authors have also made available a great deal of supplementary material, which can be accessed online via the *NAMMCO Scientific Publications* website, http://septentrio.uit.no/index.php/NAMMCOSP/index.

Much of the research conducted on walrus populations has been to support management decisions. As Wiig et al. (Chapter 12) note, 'walrus management' is actually directed at managing human activities. These authors review the history of such management decisions in the four range states: Canada, Greenland, Norway (Svalbard) and Russia which have permanent populations of Atlantic walruses. Subsistence hunting continues in Arctic Canada and Greenland while walruses have been completely protected from hunting in Svalbard (Norway) in 1952 and Russia in 1956. Since about 1950 Canada and Greenland have both increased protection of walruses. One large challenge in both countries is the variable and sometimes high rates of struck and lost animals. In addition to hunting pressure, the authors considered other human activities that impinge on walrus populations and the degree to which protection afforded to walruses and their habitat relies on the rigor of the Environmental Impact Assessments (EIAs) associated with developments. They noted that basic information is often lacking and enforcement remains a challenge. The authors note that while there is ongoing cooperation between Canadian and Greenlandic scientists on assessments of shared populations of walruses, there is currently no formal agreement between the two range states on co-management of shared stocks. International agreements have varying impacts on walrus management, but they do help to identify illegal trade and encourage sustainable management.

Several of the foregoing chapters have made reference to 'tagged' walrus. Attaching an instrument package to something as large as a walrus, which is surrounded by equally large associates, is not a straightforward process. The final section contains two papers on recent developments in the chemical immobilization of walrus. Acquarone et al. (Chapter 13) examined almost 70 immobilizations of 41 different individuals using etorphine HCl. The success rate (full immobilization) was 84% while 9% were insufficiently retrained and 7% died. Mortalities were not correlated with the doses of agonist, doses of antagonist, or to the times of injections. The mortality rate of the animals that were the subject of this study was similar to a number of other studies reviewed by these authors. Repeatedly immobilized animals showed no change in their response to the drugs.

Immobilization with etorphine HCl causes apnea in walrus, lasting about 13 min in the Acquarone et al. study and this drug is clearly unsuited to prolonged chemical restraint. In a study complementary to that of Acquarone and his co-authors, Griffith et al. (Chapter 14) explored methods to chemically restrain walrus for longer periods. Six adult (1050–1500 kg) animals were initially injected remotely with etorphine, then restrained for up to 6.75 h using meditomidine. The authors note apnea was still induced by IV injection of meditomidine. In all cases, the effects of the meditomidine were reversed with IM injections of atipamezole and doxapram.

While the collection of papers in this book demonstrates real progress since the previous NAMMCO review, much remains to be done. Virtually all authors note caveats associated with their results. Many areas remain unsampled for genetic data. The logistics of surveying walrus are daunting and converting counts into realistic estimates to account for animals not accounted for in the surveys and various biases result in abundance estimates still containing many uncertainties. Wiig et al. commented that:

> *"International cooperation in information sharing has had clear benefits for management of walruses in the past. The maintenance and expansion of this international sharing will be to the best for the management of Atlantic walruses in the future."*

One can hope that the raft of international co-authorships of the majority of papers in this volume is but a first step in that international sharing of information to reduce those uncertainties.

—Robert E.A. Stewart, Kit M. Kovacs and Mario Acquarone

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