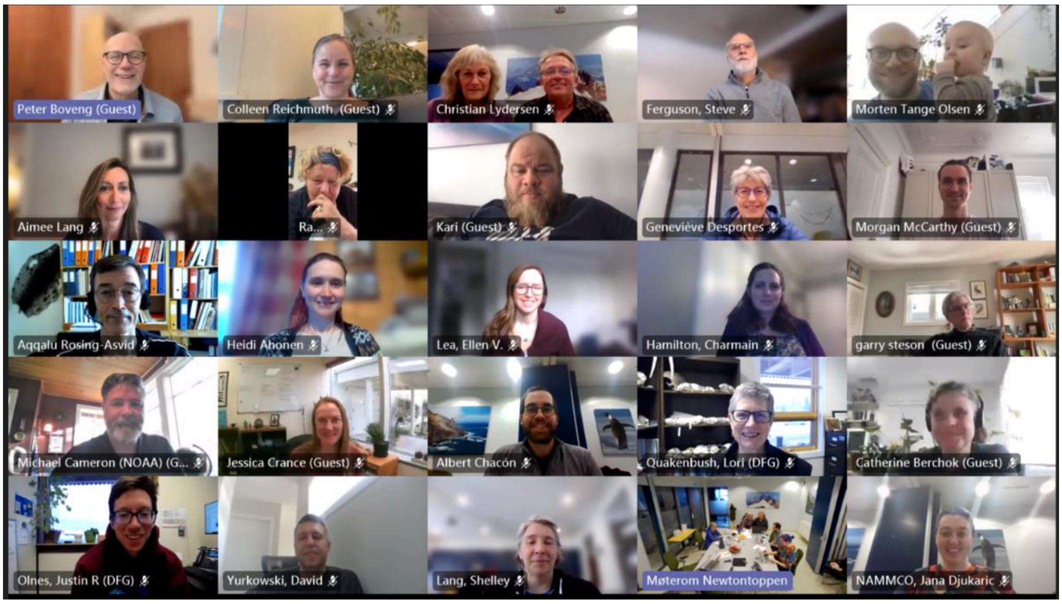
NAMMCO Panarctic Bearded Seal Workshop



21-23 March 2023

Video Conference

REPORT

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EXECUTIVE SUMMARY

The NAMMCO Panarctic Bearded Seal Workshop (BSWS) was held online on March 21 – 23, 2023. The meeting was co-chaired by Peter Boveng (NOAA Alaska Fisheries Science Center) and Christian Lydersen (Norwegian Polar Institute). The purpose and objectives of this Workshop were:

Purpose:

- To review new information since 2010 (Cameron et al. 2010) and, based on all the information available, assess the status and trends of the species throughout its range and identify threats and critical knowledge gaps.

Objectives:

- Consider new knowledge from 2010-present (since the Cameron et al. 2010 review of bearded seals)
- Examine progress in defining stock structure by exploring:
    - Outcomes of new genetic analysis; and
    - Other data informing stock structure (e.g., Indigenous knowledge, distribution and movements, hunting patterns, vocalisations, etc.).
- Review and assess population/stock abundance, trends, status, health, and condition.

Bearded seal populations/stocks on a circumpolar scale

Genetics

Results from an ongoing circumpolar genetic study on bearded seals were presented at the Workshop, strongly supporting the division between the Atlantic and Pacific bearded seal subspecies (Figure 1). Within the Atlantic, preliminary results pointed to the following genetic units:

1) Svalbard-East Greenland-South Greenland
2) Hudson-Davis Strait
3) Northwest Greenland (Melville Bay)

Additional structure was considered possible between Hudson and Davis Strait seals, and samples from Melville Bay were expected to cluster with those from the Canadian High Arctic (Grise Fjord and Resolute), but additional data and analyses were needed to determine that.

Currently, there is no evidence supporting different genetic units in the Pacific, but the Workshop agreed that with more genetic sampling and analysis, separated genetic units might eventually be identified there.

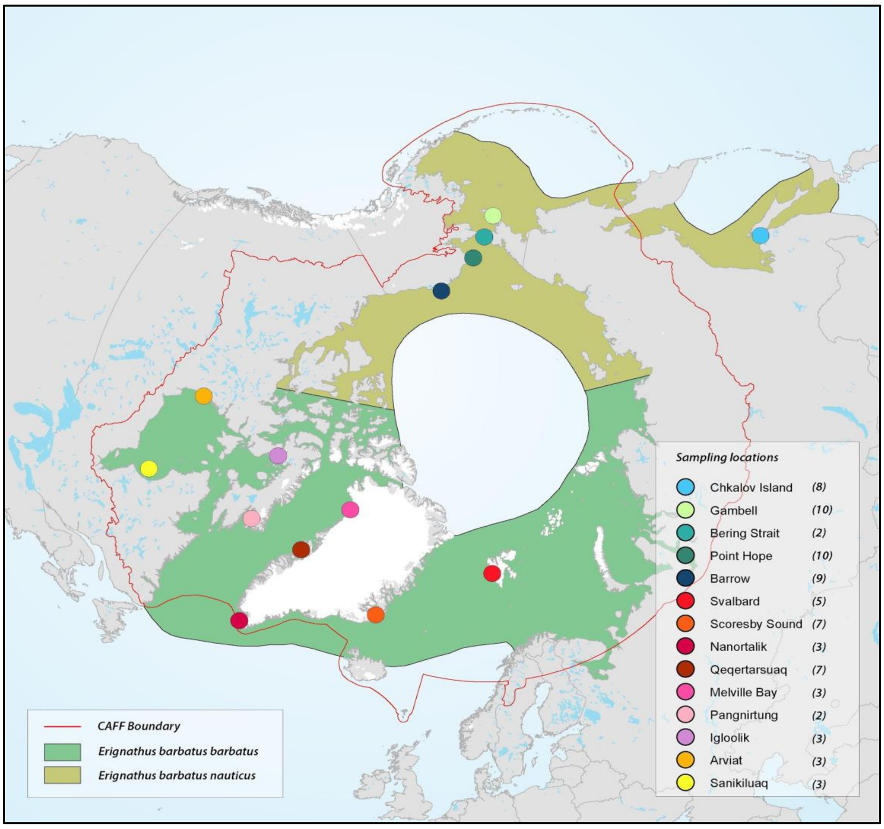

Figure 1. Global distribution of the bearded seal (*Erignathus barbatus*), showing the range of the two recognized subspecies: Pacific (*E. b. nauticu*s) and Atlantic (*E. b. barbatus*). Filled dots indicate sampling locations used in the ongoing circumpolar genetic study at the University of Copenhagen (source: Map provided by CAFF. Sampling locations provided by Morgan McCarthy and Morten Tange Olsen).

Movements and acoustics

Results from tagging studies presented at the Workshop indicate that juvenile bearded seals in Alaska are associated with nearshore and shallow waters of the continental shelf and that their movements are correlated with sea ice changes. Juvenile seals prefer intermediate ice concentrations and in years with more widespread intermediate ice, they would be also more dispersed. While they haul out on both sea ice and land, their haul out durations on land are usually shorter. Acoustic monitoring of bearded seal populations in the eastern Chukchi and northern Bering seas revealed that bearded seal calling activity increased from September to February, reaching its peak from March to June before abruptly ceasing. The timing of this cessation aligned with an earlier sea ice retreat each year, indicating a correlation.

In the Baffin Bay area, bearded seals show a migration pattern closely tied to ice conditions. An increase in catches occurs on the Greenland side of Baffin Bay when the eastward expanding pack ice reaches the region in January. This high catch rate continues until May, with the area with highest catches following the open water moving northward along the coast until late June-July, when bearded seals are primarily caught on the Canadian side of Baffin Bay.

In Svalbard, bearded seals are found in coastal waters around the archipelago and occupy drift-ice areas during the spring mating period. Mother-pup pairs have small home ranges during the nursing period, with pups gradually spending less time hauled out and more time diving as they develop. Adult seals exhibit individual movement patterns and are considered generalists, with 50% home ranges covering about 20 km². They primarily dive and spend minimal time hauling out, except during peak moult. Passive acoustic monitoring in Svalbard has revealed local variation in the vocal behaviour of male bearded seals. The vocal season varies, with the shortest duration happening/being in Kongsfjorden (west Svalbard) and the longest in northeast Svalbard. A higher abundance of vocalising bearded seals has been identified in the north and east of Svalbard, and vocalisations resembling those of the White Sea population have been recorded. Vocal activity is lower in Kongsfjorden, suggesting a local population decline or distribution shift, which does not align however with the presence of sea ice.

Hunting and Local Knowledge

Bearded seals in Alaska are sustainably harvested by Alaska Natives under the US Marine Mammal Protection Act. Annual harvest estimates reach around 6,700 seals, with participation and use of seal products showing stable or declining trends. Factors affecting the numbers of seals struck and lost are poorly documented. In Svalbard, bearded seal hunting is permitted with restrictions, resulting in varying but low annual numbers (2-34). In Greenland, the number of bearded seal catches has declined from around 2,000 in the early 1990s to approximately 1,000 in recent years, particularly in southeast and southwest Greenland, potentially influenced by reduced ice transport with the East Greenland current and decreased consumption of seal meat.

Combining Indigenous and local knowledge with technological tools provides information on bearded seal behaviour, habitat use, and abnormal conditions. Group interviews conducted in coastal communities in Alaska yield detailed information about movements and habitat use, including rare behaviours like bearded seals hauling out on land and traveling up rivers. Indigenous knowledge also confirmed that yellow blubber in old bearded seals is a normal characteristic, providing important context for harvested seals with yellow blubber because there has been no adequate scientific explanation for this relatively common occurrence.

Bearded seal abundance, condition and population status

Abundance

The U.S. has conducted aerial surveys in the Bering, Chukchi, and Beaufort Seas between 2012 and 2021 to estimate seal densities, with over 500,000 bearded seals estimated in the Bering and Chukchi Seas. Close-kin mark-recapture methods using genetic samples from harvested seals (N= 1,759) are being employed to improve abundance estimates and demographic parameters. The current estimate is approximately 232,000 bearded seals, but including heterogeneity in adult male breeding success increases the estimate to around 409,000. Future steps include refining the model and increasing sampling for better precision.

Limited data is available from Southwest Greenland, Northeast Greenland, and the South-Eastern part of Greenland, but multiple surveys have been conducted in Central-West Greenland, providing potential abundance data on bearded seals from 1981 to 2022. Published estimates exist from surveys in the North Water polynya, yielding an estimate of 6,000 bearded seals in both 2010 and 2014. However, despite the availability of survey data for abundance estimation, the Workshop was informed that no specific timeframe has been set for estimating the abundance of bearded seals in Greenland.

A synthesis of bearded seal abundance and density estimates from aerial surveys (1958 to 2022) across the Canadian Arctic was presented at the Workshop, revealing densities ranging from 0.02 to 0.24 bearded seals per km^2. Higher densities were observed in the Beaufort Sea and Baffin Bay-Davis Strait areas compared to other regions (Hudson Bay Complex and High-Arctic Archipelago and Ellesmere Island).

Growth, vital rates, and energetics

Information from Canada, presented at the Workshop, indicates stable bearded seal stocks in the Canadian Arctic, with most hunting taking place in Nunavut, particularly the Baffin Region. Local bearded seals average around 210 cm in length. A sampling program in Newfoundland collected data from 485 bearded seals between 1979 and 2021, revealing size and weight variations. Changes in growth and condition may be linked to ecosystem shifts and declining sea-ice in the north-western Atlantic Ocean.

In Alaska, subsistence harvest data has provided some insights on population trends and biological parameters. Comparing measurements and reproductive rates between different decades, female bearded seals had varying growth rates, with a recent period of above-average growth. Adult blubber thickness was generally average or above, with occasional exceptions. Pregnancy rates increased significantly in the 2010s, and the age of maturity decreased. A higher proportion of pups were harvested in the 2010s, indicating favourable conditions for growth and survival. Overall, these indicators do not show sustained declines, contrary to predictions of population decline due to climate change causing a reduction in sea ice.

In Svalbard, peak pupping occurs in early May. Pups are born weighing around 37 kg and during nursing, they grow at a rate of 3 kg/day, reaching over 100 kg in weight. Mothers have an average parturition mass of 369 kg, but experience a daily mass loss of 4 kg during lactation. Male and female bearded seals have body lengths of 231 and 233 cm, respectively, with corresponding body masses of 270 kg for males and 275 kg for females. Male body condition declines from May to August due to breeding and moulting, while females experience a drop in body condition from May to June during lactation. Sexual maturity is reached at 6 years for males and 5 years for females.

Direct physiological data from captive bearded seals presented at the Workshop showed that bearded seals have low mass-specific energy demands and little seasonal variation in metabolic costs associated with moult. Their resting metabolic rates are consistently low throughout the year, whether in water or during haul out, and during moulting and non-moulting periods. Ongoing research aims to measure differential metabolic costs during resting, swimming, and diving activities. Despite their polar distribution, bearded seals have the lowest measured resting metabolism among phocid seals.

Other issues

Health, shipping threats and climate change

The decline in sea ice poses a threat to bearded seals, impacting their population and health. Increased exposure to harmful algae blooms (HABs) and neurotoxins is a growing concern. However, studies have shown that bearded seals in Alaska have lower contaminant concentrations compared to other regions. Traditional uses of bearded seals by Indigenous communities include food, oil, and various by-products, and efforts are being made to collect further data on bearded seal life history, contaminants, and diseases. Although bearded seals generally appear healthy, the Workshop noted that they have been affected by two unusual mortality events in Alaska over the last decade.

The diminishing sea ice in the Arctic has led to increased shipping activity, including the use of global shipping routes and regional shipping to coastal communities. Bearded seals are exposed to higher levels of vessel traffic, particularly in the summer months and within specific regions. The risk of collisions or displacement is considered low, but noise disturbance from shipping could have negative impacts, especially during the spring mating season. Currently, shipping traffic is low during this critical period, but increased year-round vessel traffic could pose a greater threat. The extent of bearded seals' avoidance of high ship traffic areas is not yet fully understood.

The reduction in sea-ice cover in Svalbard and the northern Barents Sea region is impacting bearded seals. Declining land-fast sea ice extent, influenced by the West Spitsbergen Current, creates poorer ice conditions and allows Atlantic fish and invertebrate species to migrate to high latitudes. Bearded seals have adapted by using glacier ice but will face challenges as glaciers retreat. While some seals have been observed hauling out on land, there is no evidence of pupping or nursing on land yet. Disease risks and pollution levels are a concern, with antibodies for *Brucella* and *Toxoplasma gondii* found in bearded seals. Reduced sea ice cover also affects food availability, as competition from walruses increases. Harbour seals are also expanding their distribution and displacing bearded and ringed seals in certain areas. The cumulative impact of these factors on bearded seal demographics is not well understood, but their adaptability, specialized habitat use, and diverse diet may aid in their adaptation to a changing Arctic ecosystem. However, uncertainties remain regarding diseases, pollutants, and the breeding system of bearded seals in the face of these changes.

Management zone delimitation

The Workshop participants aimed to delineate management units for bearded seals based on genetic and other lines of evidence, such as tracking and vocalisation studies. They recognised the need to identify both demographically independent and ecologically significant populations for conservation purposes and two maps with potential management zones based on genetics and other evidence were generated (Figure 2). Efforts to increase sample size for genetic analysis were recommended, along with proposals for in-depth genetic studies in the North Atlantic area (see below), and obtaining abundance estimates and conducting surveys in the Atlantic Arctic were highlighted as priorities. The Workshop emphasised the importance of considering multiple lines of evidence and the need to improve genetic data resolution, as genetic similarity alone does not necessarily indicate movement between areas.

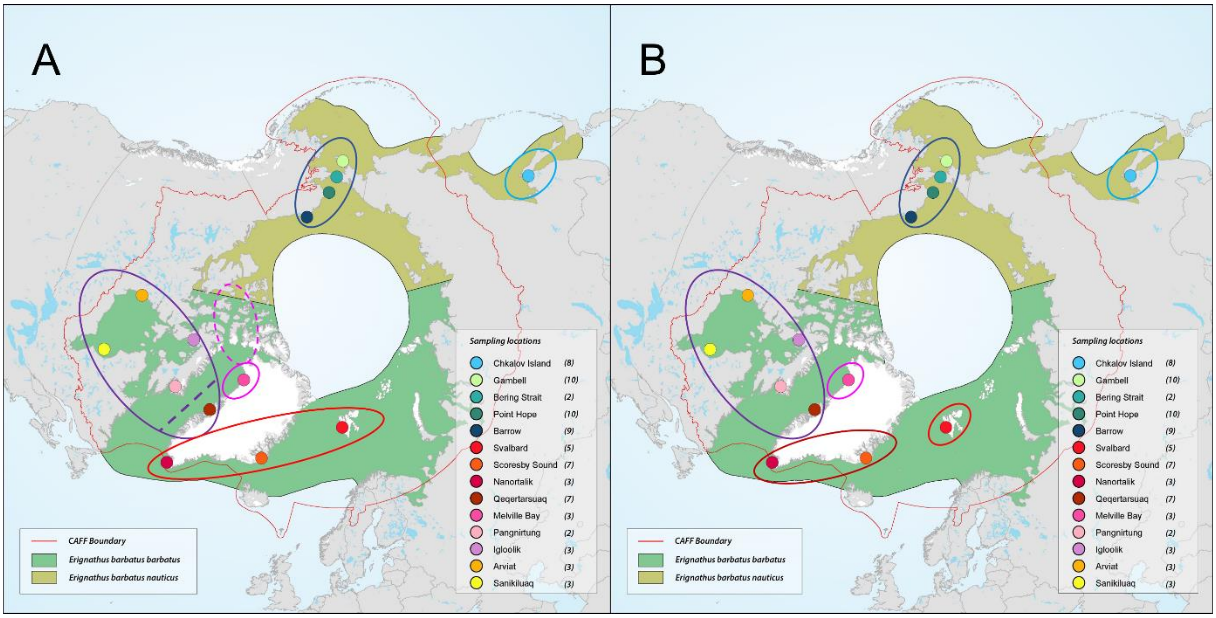

Figure 2. Management zone delimitation for bearded seal in the Panarctic, based on preliminary results from ongoing genetic analyses (A) and non-genetic (e.g., tracking and acoustics) studies (B). Dashed lines indicate potential boundaries not confirmed by preliminary results but expected with additional sampling.

Recommendations for priority actions

Theme	Recommendations
Management zone delimitation	• Use available genetic information and other lines of evidence (e.g., movement patterns) to produce a map with potential management zones, indicating information on catch data within their boundaries. • Make efforts to collect more samples and increase coverage for the circumpolar genetic analyses.
Circumpolar genetic analyses (sampling)	• Prepare a proposal for an in-depth genetic analysis in the North Atlantic area (specifying number of samples needed and where they should be collected) and apply for funding through NAMMCO (Norwegian funding). • Try to obtain DNA from Russian seal bones or other material in museum collections elsewhere, to provide samples from Russian waters. Old material from past Russian expeditions might be available in museums in the USA and Norway. • Establish a provisional group to coordinate samples for genetic analyses.
Fill population data gaps	• Conduct modelling with external covariates to determine seal density-habitat relationships. Extrapolate such relationships to other areas with missing population data to make abundance estimates. However, more research on ecological differences between Pacific and Atlantic bearded seals should be done before extrapolating habitat modelling results. • Collaboration between groups in the USA, Canada (DFO) and Greenland (GINR) to combine survey data. • Transboundary Canada-Greenland seal tagging project. • Identify unsurveyed areas where surveys should be conducted, prioritising those with substantial catches or sources of mortality. • Timely analysis of Greenland existing survey data.
Metabolism and moulting	• Investigate wind chill - haul out interaction during moulting season. • Consider information on metabolism and moulting process and their consequences for bearded seals in a changing Arctic.
Impact of predation/pathogens on bearded seal populations	• Investigate effects of predation on bearded seals across their range, to assess vulnerability of Arctic predator-prey systems under climate change. • Continue and expand screening for pathogens in bearded seals.
Abundance estimation in Greenland	• West Greenland and Melville Bay (key hunting areas) as major priority, to get abundance estimates. • Start with most recent surveys, then work backwards in time.
Close-Kin mark recapture models	• Investigate possibilities to obtain population structure/geographic patterns using this genetic method. • Follow developments of current CKMR projects.

MAIN REPORT

1. WELCOME FROM THE CO-CHAIRS AND OPENING REMARKS

The Co-chairs of the meeting, Christian Lydersen (Norwegian Polar Institute, NP) and Peter Boveng (NOAA Alaska Fisheries Science Center) welcomed the participants (Appendix 1) to the NAMMCO Panarctic Bearded Seal Workshop (BSWS), looking forward to three days of talks and productive discussions. Lydersen introduced participants from the NAMMCO Secretariat and NP (together in one office) The rest of participants agreed to introduce themselves when taking the floor.

Lydersen indicated that this Workshop had originally been planned as a NAMMCO-CAFF meeting, but due to the restrictions in the Arctic Council activities linked to the Russia-Ukraine war, it was decided that NAMMCO take the lead of the BSWS organisation. However, the scope, purpose and objectives of the Workshop were kept unchanged:

Purpose

- *To review new information since 2010 (Cameron et al. 2010), and, based on all the information available, assess the status and trends of the species throughout its range and identify threats and critical knowledge gaps.*

Objectives

- *Consider new knowledge from 2010-present (since the Cameron et al. 2010 review of bearded seals)*
- *Examine progress in defining stock structure by exploring:*
    - *Outcomes of new genetic analysis; and*
    - *Other data informing stock structure (e.g., Indigenous knowledge, distribution and movements, hunting patterns, vocalisations, etc.).*
- *Review and assess population/stock abundance, trends, status, health, and condition.*

The format, agenda and list of participants were also retained. Lydersen reminded participants of the specific topics to be addressed each day of the Workshop and noted that the main recommendations would be prepared at the end.

Use of this Report

Due to the challenges of convening an international workshop online and across multiple time zones, time was a limiting factor in the selection of the presentations. The emphasis in many of the presentations was on new findings, work in progress, review of key topics, syntheses, or reports that are not yet widely available. This approach was enabled by a recent NAMMCO review of bearded seal literature published since 2010 (Sherdin et al. 2022). This workshop report should not be cited as an original source for any of the results reported herein. Original sources of citable findings are listed after each of the presentations, where available.

2. ADOPTION OF AGENDA

The Workshop's agenda was adopted without modification and can be found in Appendix 2.

3. APPOINTMENT OF RAPPORTEURS

NAMMCO Scientific Secretary, Albert Chacón, was appointed as the primary rapporteur, with assistance from other members of the Secretariat. A shared Word document was also made available to all participants, for them to make notes during the meeting. All participants were also requested to provide summaries of the information they presented.

4. BEARDED SEAL POPULATIONS/STOCKS ON A CIRCUMPOLAR SCALE

4.1 GENETICS

4.1.1 Circumpolar genetic data

Morgan McCarthy presented "Circumpolar population genomics of bearded seals".

Author's summary:

Bearded seals represent the sole extant species within the genus *Erignathus* and are further divided into *Erignathus barbatus nauticus* and *Erignathus barbatus barbatus*. While these subspecies designations have been debated on a morphological basis (Kosygin & Potelov, 1971; Manning, 1974), complementary analyses of acoustic (Risch et al., 2007) and genetic (Davis et al., 2008) evidence report support for the delineations. Being the only genetic study to have previously investigated bearded seal population structure with 13 microsatellite markers, Davis et al. (2008) did not establish any substructure within subspecies, though unique acoustic signals point towards the possibility that there may be finer scale population structure across the bearded seal range. Cameron et al. (2010) indicate the Okhotsk Sea population may represent a distinct population segment (DPS), as the Kamchatka Peninsula could act as a physical barrier between the Okhotsk and Bering Seas, though this has not previously been tested with genetic methods. While there are reported acoustic differences between regional populations that may be indicative of population substructure, it was noted that these regional vocalisations could be the result of adapting vocalisations to the surrounding environment (Risch et al., 2007). Uncertainties in the number of appropriate DPSs for optimal conservation actions, based on morphological and acoustic signals alone, highlight the need to incorporate genomic information to provide better-informed conservation recommendations. Here, we sequenced 84 whole genomes from bearded seals across a large portion (with gaps in the Russian range) of their circumpolar distribution, resulting in 70 high quality genomes.

Preliminary results based on ~ 2 million SNPs indicate population structure between the Pacific (*E. b. nauticus*) and the Atlantic (*E. b. barbatus*) subspecies, clearly separating animals from the Pacific and Atlantic oceans and supporting the subspecies designations. Within the Atlantic, there was a strong structure between the northwest and northeast Atlantic, and evidence for a distinct population in northwest Greenland. Bearded seals in Svalbard clustered with those from South and East Greenland, whereas seals from West Greenland clustered with those from nearby Canada (Baffin Island, Hudson Bay). Finally, there was a subtle isolation-by-distance gradient from the Hudson Bay to Davis Strait, within the northwest grouping. While the sample size representing the Sea of Okhotsk was small, it separated out from the Beringia populations within the North Pacific.

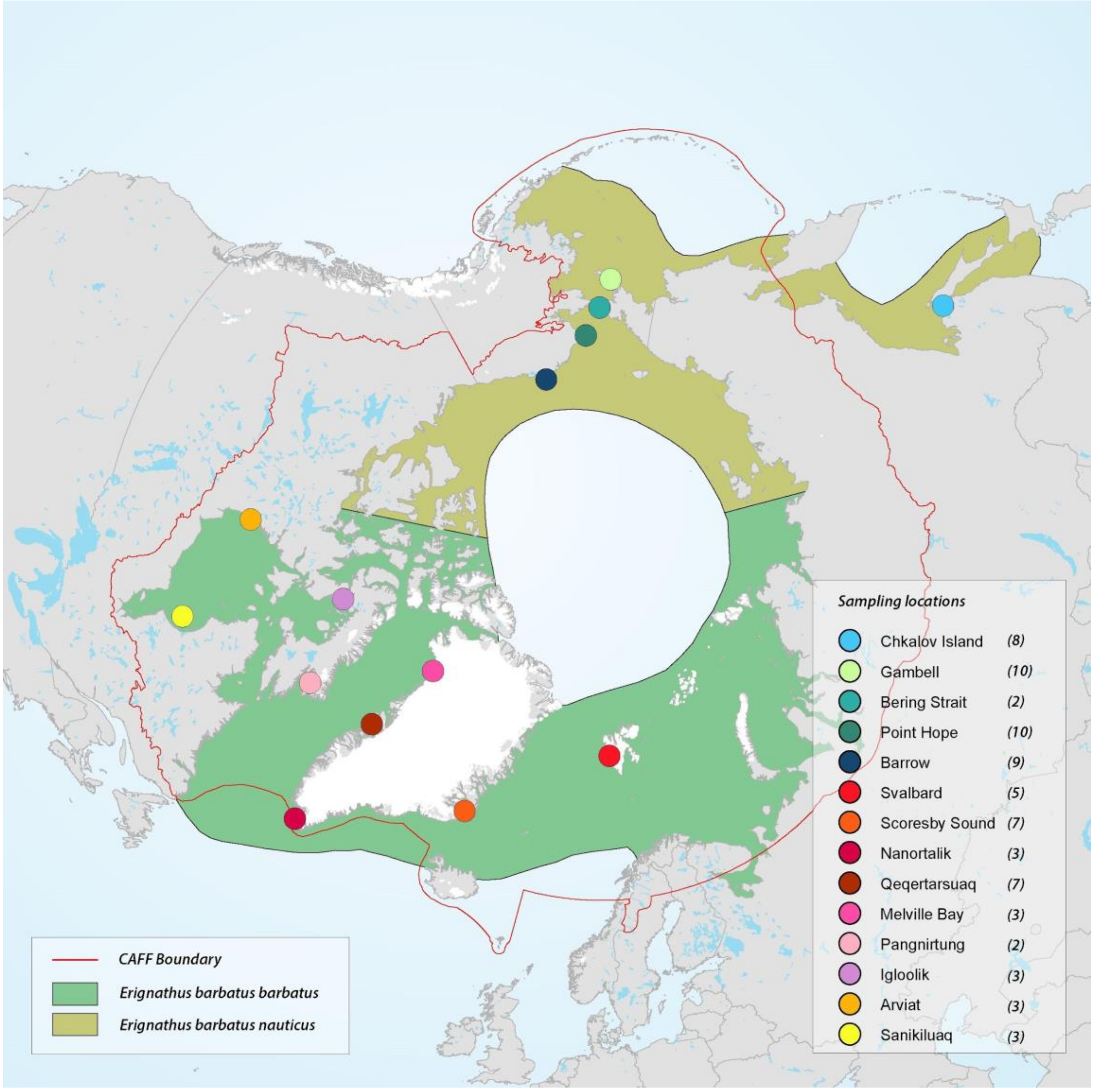

Figure 1. Global distribution of the bearded seal (*Erignathus barbatus*), showing the range of the two recognized subspecies: Pacific (*E. b. nauticus*) and Atlantic (*E. b. barbatus*). Despite the solid lines delimiting the boundaries between subspecies, such boundaries are to be determined with further genetic analyses. Filled dots indicate sampling locations used in the ongoing circumpolar genetic study at the University of Copenhagen (source: Map provided by CAFF. Sampling locations provided by Morgan McCarthy and Morten Tange Olsen).

Overall, differentiation was the highest between Pacific and Atlantic populations and the lowest within populations of the same subspecies. The Pacific population had a slightly higher heterozygosity than the Atlantic one, suggesting a larger estimated effective population size in the Pacific and/or that it may have been the founder (ancestor) of the Atlantic population. The East Atlantic subpopulation had lower heterozygosity than the West Atlantic one. Based on the available data, the Pacific and Atlantic subspecies split was calculated to have happened around 200,000 years ago (during the Penultimate Glacial Period; PGP), just after an increase in population size during the mid-Pleistocene. Increasing ice cover during the PGP time might have separated the ancestral Pacific population from the Atlantic one.

Discussion:

The Workshop welcomed the preliminary results from the circumpolar genetic analyses, noting that finding strong differentiation between Atlantic and Pacific samples supports current subspecies division. However, obtaining samples from the regions between the two subspecies is needed to better define the geographic border between them.

The Workshop participants agreed that sample size needed to be increased to detect further genetic differences among populations within the same subspecies, for example between Hudson Bay and the Davis Strait. It was also confirmed that additional samples from the Okhotsk Sea and Labrador areas were available and would be provided to support ongoing analyses.

Based on the presented results, the Workshop participants agreed that different management units could now be defined for the North Atlantic, but not for the North Pacific. Further discussions on management zone delimitations were postponed to the general discussion item 4.6.

4.1.2 Population structure in the North Pacific

Aimée Lang presented "Evaluating population structure in North Pacific bearded seals".

Author's summary:

Although bearded seals (*Erignathus barbatus*) are currently abundant and broadly distributed, concern for this species, which is an important subsistence resource for Alaska Native communities, has arisen given projections of diminishing ice in the future. Given that the impact of climate warming is unlikely to be uniform across the range of bearded seals, a better understanding of population structure is needed to assess the potential for localised depletion. To evaluate population structure in North Pacific bearded seals, we (1) sequenced the mitochondrial DNA control region for 177 bearded seal samples collected between March and May in the Bering and Chukchi Seas and 10 samples collected from the Sea of Okhotsk, and (2) conducted 'genotyping by sequencing' to discover and genotype Single Nucleotide Polymorphisms (n=3185 SNPs after quality control and filtering) in 99 samples collected during spring months from seals in the Bering and Chukchi Seas. No significant differences between geographic areas were detected in the SNP analysis, and clustering analyses both with and without *a priori* information on the geographic location of sampling failed to identify distinct clusters. A small but significant difference in mitochondrial DNA haplotype frequencies was found between seals sampled in the Bering Sea and those sampled in the south-eastern Chukchi Sea, but no significant differences were found between the other strata. While little evidence of population structure among North Pacific bearded seals was detected in our study, it is of note that in highly abundant species, such as the bearded seal, we would expect to find small effect sizes even when gene flow is limited. Additional study incorporating larger numbers of samples, increased geographic coverage, and a more powerful marker set is warranted.

Discussion:

Given the low evidence of population structure in the Bering and Chukchi seas, it was asked whether the quality of the samples could be affecting such results and what could be done to improve that. Several factors, from suboptimal storage conditions to deterioration during shipping were suggested to reduce the quality of the samples. It was, however, noted that, even with low quality samples, DNA could still be extracted albeit using more expensive methods. In this study, samples with a high proportion of missing data, which could be the result of low sample quality, were removed prior to analysis to avoid biasing the inference of population structure. However, this resulted in smaller sample sizes for some areas, particularly for the Sea of Okhotsk, and reduced power to detect population structure if present.

4.2 MOVEMENT DATA

4.2.1 Satellite tracking in Alaska

Justin Olnes presented "Bearded seal movement studies in Alaska using satellite telemetry".

Author's summary:

Bearded seal movements in Alaska have been studied using satellite telemetry. Since 2014, 27 bearded seals have been captured by the Alaska Department of Fish and Game as well as by collaborators and they were fit with transmitters. Seal tagging involves partnerships with Alaska Native hunters. Subadults and adults are very difficult to capture in Alaska, therefore the tagged sample is primarily of juvenile bearded seals (<2 years old). Only one of the 27 captured seals was an adult bearded seal. As with other ice-associated seals, juvenile bearded seals tend to make south-north movements with increasing and decreasing sea ice extent. Seals were typically nearshore (<50 km from land) and in relatively shallow water (~30 m), remaining on the continental shelf of the Bering, Chukchi, and Beaufort seas. Juvenile bearded seals prefer intermediate ice concentration, and have some association with the ice edge, or marginal ice zone. However, in years where intermediate ice is more widespread, juveniles were more widely dispersed. We also documented instances where juveniles spent significant time away from land and in open water for weeks at a time. Juveniles primarily made benthic dives and spent half their time near the sea floor. Juveniles hauled out on both sea ice and land, but haul out durations on land tended to be shorter than on sea ice. Data from one adult male showed limited movements centred around Barrow Canyon, a productive area in the northeast Chukchi Sea. The adult bearded seal also primarily made benthic dives and hauled out on land.

Discussion:

To the question of why adults were hard to capture during the study, Olnes informed that adults were, in general, more wary of boats due to being hunted in Alaska, making them more difficult to approach. Lydersen noted that bearded seals in Svalbard were easy to approach, despite them also being hunted. However, a common observation in both Alaska and Svalbard was that, once captured, bearded seals of all age classes were docile and easy to handle.

Relevant citations:

Olnes, J., J. Crawford, J. Citta, M.L. Druckenmiller, and L. Quakenbush. 2020. Movement, diving, and haul out behaviors of juvenile bearded seals in the Bering, Chukchi and Beaufort seas, 2014–2018. Polar Biology https://doi.org/10.1007/s00300-020-02710-6

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Cameron, M.F., Frost, K.J., Ver Hoef, J.M., Breed, G.A., Whiting, A.V., Goodwin, J., and P.L. Boveng. 2018. Habitat selection and seasonal movements of young bearded seals (Erignathus barbatus) in the Bering Sea. PloS ONE 13: e0192743. https://doi.org/10.1371/journal.pone.0192743

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Hamilton, C.D., Lydersen, C., N., Born, E.W., Boveng, P., Brown, T.H., Fisk, A., Folkow, L.P., Frost, K.J., Glazov, D.M., Granquist, S.Heide-Jørgensen, M.P., Hussey, N.E., Kalinek, J., Laidre, K.L., Litovka, D.I., London, J.M., Loseto, L.J.D., Nilssen, K., Nordøy, E.T., Quakenbush, L., Rosing-Asvid, K.E.W., Shpak, O.Von Duyke, A.R., Yurkowski, D.J., and K.M. KovacsDiversity and Distributions 00: 1-25.

4.2.2 Distribution, diving and feeding behaviour in bearded seals

Kit M. Kovacs presented "Bearded seals, Svalbard, Norway: distribution, diving and feeding".

Author's summary:

Bearded seals can be found in all coastal, shallow waters surrounding the Svalbard Archipelago. Additionally, they occupy drift-ice areas north and east of the archipelago (at least during the spring mating period when their vocalisations are heard continuously).

Bearded seal pups start swimming and diving with their mothers when they are a few hours old. Mother-pup pairs remain in relatively small home-ranges during the nursing period, that lasts just over three weeks. If drift ice blows offshore, mothers bring their pups back to the coast. Diving in the first weeks of life, when pups are thin requires active swimming (with lateral acceleration) both to leave the surface and to return to it. When pups are fatter, toward the end of nursing, significant effort is required to get to depth, but returning to the surface occurs through natural buoyancy. Young pups spend approximately half of their time hauled out – but this drops to only a few hours out of the water over the first two months of life. Time spent at the surface also changes over this same period from 10 h a day to approximately six h per day, which then remains quite constant through the first year of life. Development of diving skill is rapid in the first 50 days of life. Time spent diving increases exponentially as does average dive depth (50 – 60 m) and maximum depth. The deepest dives recorded for pups were circa 350 m – but such deep dives were rare. After the initial exponential increase in dive depth, pups dove less deeply as they got more experience. Pups over 300 days of age had an average dive depth of 25 m. A few pups remained in their natal area, but most spread along the coast, becoming established in fjords along the west and north coasts of Spitsbergen. First-passage time analyses showed that pups spend most of the time in their first year of life within fjords.

Adult bearded seals are quite steadfast and follow very set movement patterns at the level of the individual, but patterns vary markedly between individuals. This general pattern extends across the type of areas occupied, the water masses in which they dive, distances from the coast, distances to glaciers, average dive depths etc. In short, bearded seals in Svalbard can be described as a generalist species, comprised of specialist individuals. Fifty-percent home ranges encompass an average of 20 km^2. All tagged animals spent some time in front of glaciers, where ice is available for resting. They hauled out only 5% of their time on average, but this increased to 20% of their time during peak moult in July. Diving occupied an average of 75% of their time and they were at the surface (in the water) 20% of the time.

Only a single stomach content analysis study has been conducted in Svalbard on bearded seals. It showed that bearded seals eat a wide variety of prey including fish and benthic invertebrates. The iron-coloured faces of many bearded seals in the archipelago confirms that these individuals feed in soft-bottom substrates with high iron content (which adheres to the surface of the hair on their faces and fore-flippers when it oxidises onto the hairs when the animal is at the surface). Captive feeding studies confirm that bearded seals use both suction and water jetting to access difficult-to-reach prey. Isotopic studies of the whiskers of pups suggest that maternal diets vary with sea ice conditions, with higher prevalence of offshore prey (pelagic fish) in heavier ice years and more shallow, benthic invertebrate prey in lighter ice years. This study also confirmed that individuals tend to specialise, but that there is a lot of variation between individuals. A comparative feeding niche study suggested that bearded seals feed at a trophic level that is higher than walruses and baleen whales, but lower than ringed seals and other animals that are considered top predators.

Bearded seals have been tracked in only a few locations across their broad range. Thus, hot-spot analyses to date provide little information for conservation planning for this ice-associated Arctic endemic species.

Relevant citations:

Hamilton, C.D., Kovacs, K.M. and Lydersen, C. 2018. Individual variability in diving, movement and activity patterns in adult bearded seals in Svalbard, Norway. Scientific Reports 8: 16988Fedak, M.A., Freitas, C., Hindell, M.A. and Kovacs, K.M. 2019. Behavioural ontogeny of bearded seals *Erignathus barbatus* through the first year of life. Marine Ecology Progress Series 627: 179-194.

Hamilton, C. D., Lydersen, C., Aars, J., Acquarone, M., Atwood, T., Baylis, A., Biuw, M., Boltunov, A. N., Born, E. W., Boveng, P., Brown, T. M., Cameron, M., Citta, J., Crawford, J., Dietz, R., Elias, J., Ferguson, S. H., Fisk, A., Folkow, L. P., Frost, K. J., Glazov, D. M., Granquist, S. M., Gryba, R., Harwood, L., Haug, T., Heide-Jørgensen, M. P., Hussey, N. E., Kalinek, J., Laidre, K. L., Litovka, D. I., London, J. M., Loseto, L. L., MacPhee, S., Marcoux, M., Matthews, C. J. D., Nilssen, K., Nordøy, E. S., O'Corry-Crowe, G., Øien, N., Olsen, M. T., Quakenbush, L., Rosing-Asvid. A., Semenova, V., Shelden, K. E. W., Shpak, O. V., Stenson, G., Storrie, L., Sveegaard, S., Teilmann, J., Ugarte, F., von Duyke, A. L., Watt, C., Wiig, Ø., Wilson, R. R., Yurkowski, D. J. and Kovacs, K. M. 2022. Marine mammal hotspots across the circumpolar Arctic. Diversity & Distribution, doi: 10.1111/ddi.13543.

Hindell, M.A., Lydersen, C., Hop, H. and Kovacs, K.M. 2012. Pre-partum diet of adult female bearded seals in years of contrasting ice conditions. PLos ONE 7(5): e38307.

Kovacs, K.M., Krafft, B. and Lydersen, C. 2020. Bearded seal (Erignathus barbatus) pup growth - body size, behavioral plasticity and survival in a changing climate. Marine Mammal Science 36: 276-284. doi.10.1111/mms.12647.

Marshall, C.D., Kovacs, K.M. and Lydersen, C. 2008. Feeding kinematics, suction and hydraulic jetting capabilities in bearded seals (Erignathus barbatus). Journal of Experimental Biology 211:699-708.

Watanabe, Y., Lydersen, C., Sato, K., Naito, Y., Miyazaki, N. and Kovacs, K.M. 2009. Diving behavior and swimming style of nursing bearded seal pups. Marine Ecology Progress Series 380: 287-294.

4.2.3 Satellite tracking in Greenland

Aqqalu Rosing-Asvid presented "Bearded seals movements and catch statistics around Greenland".

Author's summary:

Bearded seals are caught in the Canadian part of the Baffin Bay during the summer, but catches in that part of the Baffin Bay cease in the fall when sea ice expands towards west Greenland. A strong increase in catches in the south-eastern corner of Baffin starts when the eastward expanding pack ice reaches the area around January. Catches remain high there until May and the survey conducted in March/April shows a high concentration around the hunting area. In May-June a wedge of open water penetrates northwards along the coast. The area with high catches then moves northward with the open water, but in late June-July the pack ice begins to retreat towards Canada and the catches in west Greenland drop significantly, whereas they start to catch bearded seals on the Canadian side.

This indicates that their migration patterns are linked to the changes in ice conditions during winter. There are also local/stationary bearded seals in Greenland, but seals with such a behaviour are not likely to survive the hunt if they stay close to a settlement. Tracking of bearded seals confirm that local non-migrating bearded seals, live in the uninhabited part of Melville Bay and in Southeast Greenland and they are also likely to be widespread in other uninhabited parts of Greenland. Catches in Greenland have dropped from about 2,000 bearded seals in the early 1990s to around 1,000 in recent years. The drop is mainly seen in southeast and southwest Greenland and might, to some extent, be related to declining ice transport with the east Greenland current and declining use of seal meat due to a strong decline in the number of sledge dogs in southeast Greenland.

Discussion:

Rosing-Asvid informed that meat and skin from young harp seals and ringed seals were generally easier to sell and the hunt was mainly focused on these species. Regarding the dynamics of seals seasonally crossing Baffin Bay, it was clarified that pupping was seen along the Greenland coast especially in the Upernavik area (Northern West Greenland). The sea ice retreat towards Canada in the following months and catches decrease on the Greenland side of Baffin Bay, but increase on the Canadian side.

4.3 HUNTING STATISTICS

4.3.1 Greenland

Catch statistics for Greenland were presented under the previous item 4.2.3.

4.3.2 Alaska

Olnes presented "Subsistence harvest of Bearded Seals in Alaska".

Summary:

As with other ice-associated seals in Alaskan waters, bearded seals are harvested for subsistence by Alaska Natives. A provision in the US Marine Mammal Protection Act allows for the sustainable harvest of bearded seals by Alaska Natives. This is the primary source of human-caused mortality for bearded seals in Alaska. Harvest data are typically collected using household surveys. A local surveyor is hired to survey a certain number of households in a community, from which a community-level harvest total can be estimated. Surveys are approved by the community beforehand, and the results must also be approved by the community before they are shared. Collecting annual harvest data is a significant challenge, as more than 50 communities may hunt bearded seals. The current best estimate is that ~6,700 bearded seals are harvested annually in Alaska, and this is thought to be sustainable. Trends from one region in Alaska show stable or declining participation in hunting and using bearded seal products. The rate of struck and loss is not well documented and factors that affect the likelihood of losing a struck seal are also poorly documented.

Discussion:

It was noted that the use of bearded seal products had been declining in parts of Alaska, Greenland and in Labrador. Different job opportunities, reduced time for hunting, and changing weather patterns making hunting more dangerous, were suggested as potential reasons for such a decline. However, bearded seals remain a very important resource throughout much of coastal Alaska.

Lydersen informed the Workshop that bearded seals in Svalbard could be hunted (sport hunt) without any set quotas. However, seals are protected from the 1st of December to the 31st of January (polar night) and from the 28th of April to the 4th of June (nursing period). In addition, the hunt is only performed in a small area around the main settlement (Longyearbyen) and it is mandatory to have an annual big game shooting license to participate. The numbers shot should be reported to the Governor of Svalbard. Hunting statistics are only available from 2003-2022 in Svalbard and vary between 2 to 34 animals per year. Quakenbush noted that there are no prohibitions on native subsistence hunting of bearded seals in US waters, even for reproductive females, as long as there is no waste.

Relevant citations:

Olnes, J., Quakenbush, L.T., Nelson, M., Simon, A., Burns, J., and the Ice Seal Committee. 2022. Trends in the subsistence harvest of ice seals in the Yukon-Kuskokwim Delta region, Alaska, 1962–2018. Arctic 75: 449-461.

Ice Seal Committee. 2019. The subsistence harvest of ice seals in Alaska – a compilation of existing information, 1960-2017. 86 pp.

Nelson, M.A., Quakenbush, L.T., Taras, B.T., and the Ice Seal Committee. 2019. Subsistence harvest of ringed, bearded, spotted, and ribbon seals in Alaska is sustainable. Endangered Species Research 40: 1-16. https://doi.org/10.3354/esr00973.

4.4 ACOUSTICS

4.4.1 Chukchi Sea

Jessica Crance presented "Year-round distribution of bearded seals, *Erignathus barbatus*, throughout the Alaskan Chukchi and northern Bering Sea".

Author's summary:

The Marine Mammal Lab has been deploying passive acoustic recorders throughout the eastern Chukchi and northern Bering seas since 2010 to monitor marine mammal populations. Here, we will present data on bearded seal presence and phenology from year-long deployments at nine sites over four years (2012-2016), totalling 13,275 days (~75,000 hours). Bearded seal calling activity was present at every site in every year. Calling activity, defined as the percentage of intervals per day with calls (PIC), increased from September through February and reached 100% PIC from March through June, at which point calling ceased abruptly regardless of ice cover. The timing of this cessation of calling occurred earlier each year, corresponding with an earlier sea ice retreat. The sustained calling detected overwinter at all locations suggests that this is more than just a few animals that are remaining in the Chukchi Sea. Preceding this main pulse was a smaller peak in calling that progressed southward, corresponding with the fall migration of bearded seals to the Bering Sea.

Discussion:

To the question of whether there was any prospect for getting call counts from some of the records, Crance informed that it could be possible to get some minimum number of calls per hour, but due to time and funding limitations, she limited their analysis to only presence or absence. The use of other measures to obtain call counts (e.g., AI/ML algorithms) were being investigated.

Relevant citations:

Crance, J.L., Berchok, C.L., Kimber, B.M., Harlacher, J.M., Braen, E.K. and Ferguson, M.C., 2022. Year-round distribution of bearded seals, *Erignathus barbatus*, throughout the Alaskan Chukchi and northern Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, *206*, p.105-215.

4.4.2 Svalbard

Heidi Ahonen presented "Acoustic presence in time and space in Svalbard, Norway".

Author's summary:

Male bearded seals produce elaborate vocalisations to attract females and to compete with other males during the mating season, making it possible to monitor breeding populations of this species using passive acoustic monitoring (PAM). Previous studies of the acoustic behaviour of Svalbard's bearded seals have all been conducted in Kongsfjorden. Although these studies have given important baseline information regarding seasonal vocal presence, male site fidelity and mating tactics, studies involving additional locations within the archipelago are needed. Since 2008, the Norwegian Polar Institute has established extensive PAM network around Svalbard, making it possible to investigate spatial and temporal distribution of vocalising bearded seals in a much larger area. Results from the data processed so far show bearded seal vocal presence at two Svalbard fjords (Kongsfjorden and Rijpfjorden) and at three offshore locations northeast of Svalbard Archipelago (Atwain, M1 and M2, Figure 2). Furthermore, two vocalisation types that had not been previously reported in Svalbard were recorded; these resemble call types reported for the White Sea population. Vocal season was found to be the shortest in Kongsfjorden (March – June) and the longest in northeast Svalbard locations M1 and M2 (November – July). Interestingly, sea ice cover in the study years was present throughout the vocal season at Atwain, M1, M2 and Rijpfjorden, while in Kongsfjorden there was a mismatch between the peak in vocal activity and the time when sea ice was present. These results show that bearded seals vocalise a longer period than previously thought in Svalbard and that the abundance of vocalising bearded seals in the north and east of Svalbard is considerably higher than anticipated. Vocalisation (trill) rate seemed to be considerably lower in Kongfjorden than previously observed for this area, suggesting presence of fewer males or less breeding activity taking place in this fjord. It is not currently known if bearded seals in Kongsfjorden are less vocal because individual animals have shifted their distribution northward or whether there has been a population decline locally. Lastly, it was interesting to discover that bearded seals in Svalbard do make use of the drift ice around the archipelago for breeding. This might provide the species with some respite from the reduction in shore-fast ice that is taking place because of increased influx of Atlantic Water and warmer air and ocean temperatures.

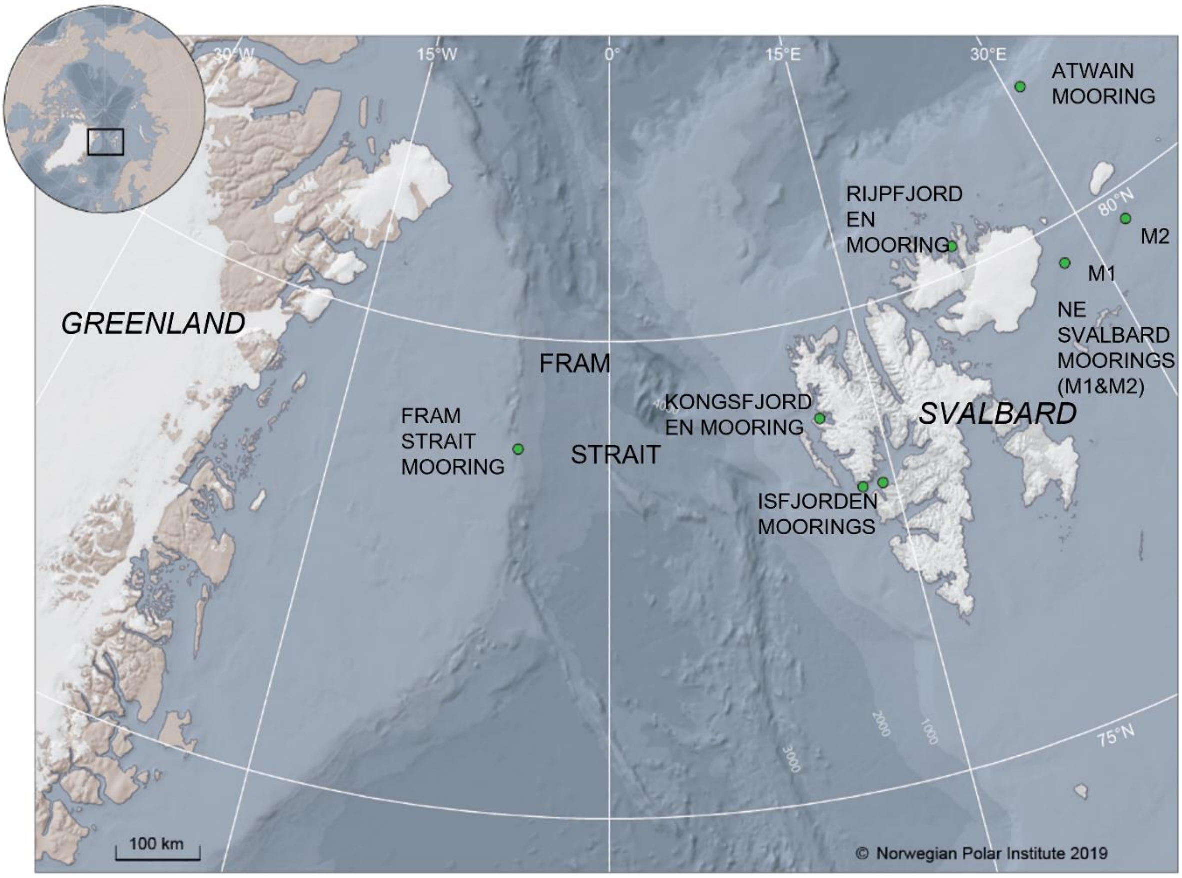

Figure 2. Location of the Passive Acoustic Monitoring (PAM) sites mentioned in the study (source: Heidi Ahonen).

Discussion:

The Workshop welcomed the results obtained from the acoustic monitoring of bearded seals in Svalbard, but due to time limitations, comments were made under the general discussion item 4.6.

4.5 INDIGENOUS KNOWLEDGE AND LOCAL KNOWLEDGE

Lori Quakenbush presented "The value of Indigenous and Local Knowledge to studies of marine mammals in Alaska".

Author's summary:

Marine mammals are important species for subsistence harvests in western and northern Alaska. Indigenous marine mammal hunters are experts in marine mammal natural history, behaviour, and local habitat use. Combining technological tools like satellite telemetry and indigenous and local knowledge (IK) provides valuable complementary contemporaneous and historical information about each species. The Alaska Department of Fish and Game's Arctic Marine Mammal Program includes an IK component to its studies whenever possible. Benefits include knowing 1) where to go to find animals to capture and instrument, 2) if behaviour documented by satellite telemetry is new or different, or if it is a known behaviour observed by indigenous hunters, 3) if the condition of harvested animals are normal and if abnormal conditions have been seen before and how often. By conducting group interviews in coastal communities, using general topics regarding marine mammals, extensive information about movements relative to season and sea ice for multiple species can be detailed on maps and in writing. In addition to valuable general information about migration timing, local movements, and habitat use, specific information is provided that would not have been accessible otherwise. For example, bearded seals were rarely seen on land by biologists, therefore, it was thought to be an uncommon behaviour. IK, however, tells us that it is not uncommon for bearded seals to haul out on land. Learning that young bearded seals travel up rivers in the summer and haul out on riverbanks, greatly increased our ability to capture and tag bearded seals. When several bearded seals with yellow blubber were harvested, but otherwise appeared healthy, it was important to know if this was something new and of concern. During an IK interview a hunter shared that old bearded seals have yellow blubber that makes seal oil yellow and this has not changed with time.

Discussion:

The presence of yellow blubber in bearded seals from Alaska intrigued the Workshop participants, since this trait had never been observed in animals from Svalbard. Despite the reasons for having yellow blubber remaining unknown, Quakenbush indicated it did not seem to be associated with any disease and seals were usually healthy.

Relevant citations:

Huntington HP, Quakenbush LT, Nelson M. 2016 Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska from traditional knowledge interviews. Biol. Lett. 12: 20160198.http://dx.doi.org/10.1098/rsbl.2016.0198. Electronic supplementary material includes reports by village and is available at http://dx.doi.org/10.1098/rsbl.2016.0198 or via http://rsbl.royalsocietypublishing.org.

Huntington HP, Quakenbush LT, and Nelson M. Evaluating the Effects of Climate Change on Indigenous Marine Mammal Hunting in Northern and Western Alaska Using Traditional Knowledge. Front. Mar.4:319. doi: 10.3389/fmars.2017.00319.

4.6 GENERAL DISCUSSION: MANAGEMENT ZONES AS A WAY FORWARD FOR ASSESSMENTS?

The Workshop co-Chairs invited the participants to discuss potential management zones for bearded seals in the Arctic, with an emphasis on the delimitation of management units in the North Atlantic.

Within the Atlantic, preliminary results pointed to the following genetic units:

1) Svalbard-East Greenland-South Greenland
2) Hudson-Davis Strait
3) Northwest Greenland (Melville Bay)

Additional structure was considered possible between Hudson and Davis Strait seals (2), and samples from Melville Bay (3) were expected to cluster with those from the Canadian High Arctic (Grise Fjord and Resolute), but additional data and analyses were needed to determine that.

Currently, there is no evidence supporting different genetic units in the Pacific; all of Alaska is managed as one stock, and the whole Beringia area (Alaska and Chukotka) is considered a single population. With more genetic sampling and analysis, it is possible that more structure will be revealed, helping to identify distinct management units in the Pacific bearded seal population.

The Workshop participants agreed to delineate management units on a map, using both genetics and other evidence, including information on catches within their boundaries. Although little non-genetic evidence for discrete management units was presented at the Workshop, it was recommended that information from tracking and from vocalisation studies, such as the one indicating a possible connection between Svalbard and the White Sea, be combined with the results of genetic analyses to better delineate population structure. It was also noted that demographically independent populations, not supported by immigration/emigration could be identified, but that it was also important to focus on ecologically significant populations for conservation purposes. The Workshop participants agreed that both elements should be included in the management zone delimitation, also emphasising the need to indicate to Greenland the priority areas from where abundance estimates should be obtained.

The fact that Svalbard and East Greenland populations clustered together in the genetic analyses despite no evidence of movement of seals across the Fram Strait could possibly be linked to a problem of small sample size limiting genetic resolution and masking separated localities. The Workshop **recommended** more efforts in sampling to increase coverage of the circumpolar genetic analyses. This led to a second **recommendation** to prepare a proposal for an in-depth genetic analysis in the North Atlantic area, specifying number of samples needed and where they should be collected, and apply for funding to the Norwegian Arctic program.

5. BEARDED SEAL ABUNDANCE, HEALTH, CONDITION AND POPULATION STATUS

5.1 ABUNDANCE

5.1.1 Bering and Chukchi Seas

Boveng presented "Abundance of bearded seals in the Pacific Arctic".

Author's summary:

A joint U.S. and Russian Federation program completed aerial surveys for bearded, ringed, spotted, and ribbon seals in the ice-covered regions of the Bering Sea during spring of 2012 and 2013, followed by a similar survey of the Chukchi Sea in 2016. To complete the first comprehensive survey for ice seals in the seas surrounding Alaska and Chukotka, the U.S. team also surveyed the sea ice of the Beaufort Sea within the U.S. Exclusive Economic Zone (EEZ) and a western portion of the Canadian EEZ during spring of 2021 (figure 3). Seals were surveyed using an instrument-based system for detection with infrared cameras, and classification to species with high-resolution colour cameras. Together, the four surveys comprised approximately 120,000 km of 'on effort' track line, supporting the estimation of seal densities over an area of 2.3 million km^2. A spatial-temporal, model-based approach was used to estimate seal densities and their relationship to environmental covariates, while accounting for detection rates, variation in availability due to portions of seals in the water during surveys, species mis-classification rates, and rates of disturbance by the aircraft. Abundance estimates for bearded seals have been completed for the Bering and Chukchi Seas, which together comprise over 500,000 individuals. With a coefficient of variation of 13% that reflects the precision of our Chukchi Sea bearded seal estimate, a 25% decline in the population would have a 33% chance of being detected in a subsequent survey; a 50% decline would be detected 97% of the time.

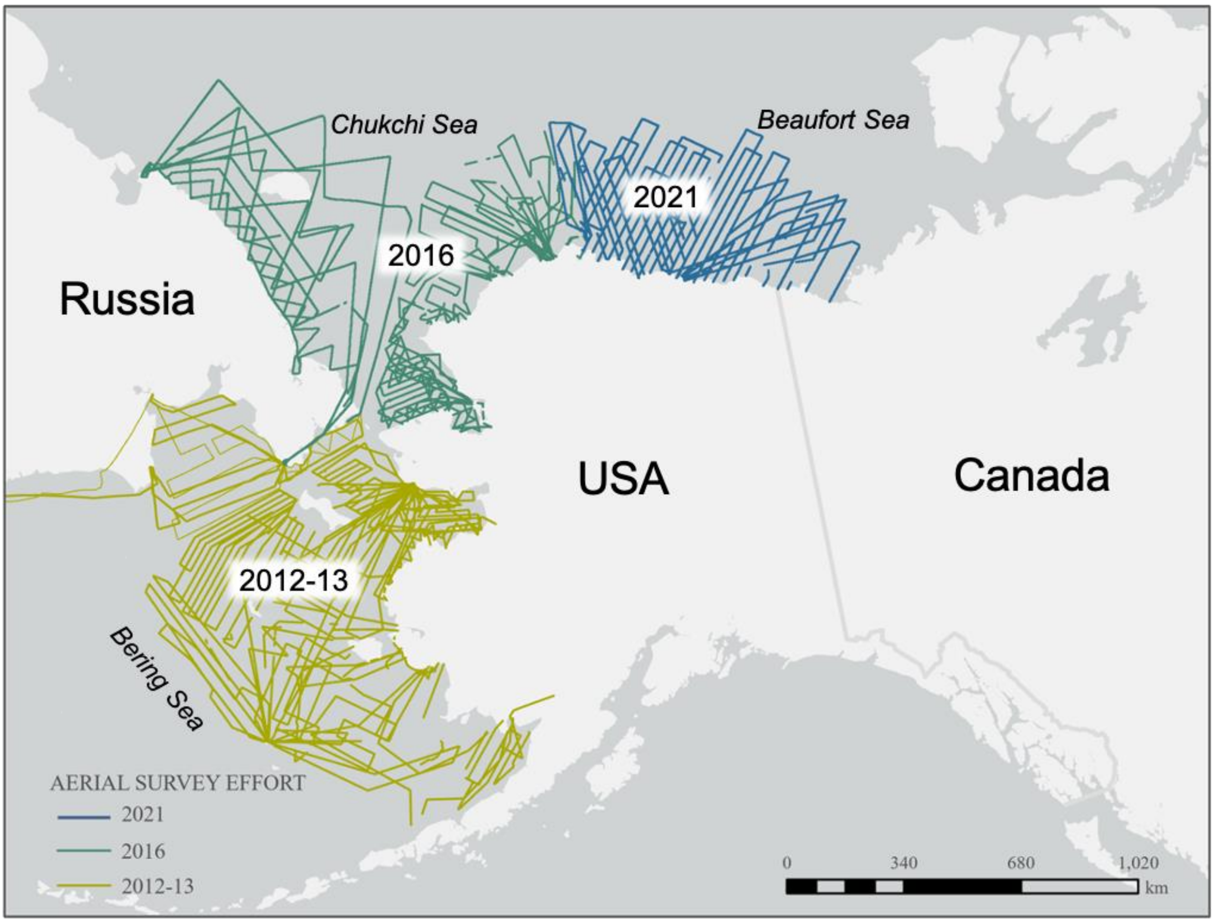

Figure 3. Location of transects and timing of the aerial ice seal surveys in the Bering, Beaufort and Chukchi seas (source: Peter Boveng).

Discussion:

A question was posed about the raw numbers of seals sighted during the surveys in order to give an idea of the data on which the estimates are based. Boveng indicated that in the eastern Chukchi Sea alone, surveyed by the U.S. team, there were 5,166 ringed and 1,157 bearded seal sightings. Despite covering only about 2% of the total sea ice area with the survey cameras' footprints, and incorporating more sources of variability than previously possible, the broad distributions of the survey tracks and the large numbers of sightings provide reasonable confidence intervals around the final abundance estimates.

Relevant citations:

Chernook, V. I., I. S. Trukhanova, A. N. Vasiliev, A. I. Grachev, D. I. Litovka, V. N. Burkanov, and S. V. Zagrebelny. 2018. Abundance and distribution of phocid seals on ice in the western Bering Sea in spring, 2012–2013. Izvestiya TINRO 192:74-88.

Chernook, V. I., I. S. Trukhanova, A. N. Vasiliev, D. I. Litovka, D. M. Glazov, and V. N. Burkanov. 2019. First instrumental aerial survey of ringed seals (*Pusa hispida*) and bearded seals (*Erignathus barbatus*) in the Russian zone of the Chukchi and East-Siberian Seas in spring 2016 TINRO 199:152-162.

Conn, P. B., J. M. Ver Hoef, B. T. McClintock, E. E. Moreland, J. M. London, M. F. Cameron, S. P. Dahle, and P. L. Boveng. 2014. Estimating multispecies abundance using automated detection systems: ice-associated seals in the Bering Sea. Methods in Ecology and Evolution 5:1280-1293.

Conn, P. B., D. S. Johnson, J. M. V. Hoef, M. B. Hooten, J. M. London, and P. L. Boveng. 2015. Using spatiotemporal statistical models to estimate animal abundance and infer ecological dynamics from survey counts. Ecological Monographs 85:235-252.

Conn, P. B., E. E. Moreland, E. V. Regehr, E. L. Richmond, M. F. Cameron, and P. L. Boveng. 2016. Using simulation to evaluate wildlife survey designs: polar bears and seals in the Chukchi Sea. Royal Society Open Science 3:150561.

London, J. M., P. B. Conn, S. K. Hardy, E. L. Richmond, J. M. Ver Hoef, M. F. Cameron, J. A. Crawford, A. L. von Duyke, L. T. Quakenbush, and P. L. Boveng. 2022. Haul out behavior and aerial survey detectability of seals in the Bering and Chukchi seas. bioRxiv https://doi.org/10.1101/2022.04.07.487572

McClintock, B. T., E. E. Moreland, J. M. London, S. P. Dahle, G. M. Brady, E. L. Richmond, K. M. Yano, and P. L. Boveng. 2015. Quantitative assessment of species identification in aerial transect surveys for ice-associated seals. Marine Mammal Science 21:1057-1076.

Sigler, M., D. DeMaster, P. Boveng, M. Cameron, E. Moreland, K. Williams, and R. Towler. 2015. Advances in methods for marine mammal and fish stock assessments: thermal imagery and CamTrawl. Marine Technology Society Journal 49:99-106.

5.1.2 Estimates based on close-kin mark-recapture

Quakenbush presented “Close-kin mark-recapture used to estimate bearded seal population abundance and demographics”.

Author’s summary:

Bearded seals (*Erignathus barbatus*) use sea ice for pupping, nursing, and moulting, and are a vital subsistence resource to coastal Alaska Natives. In 2012, bearded seals were listed as threatened under the U.S. Endangered Species Act, resulting in higher scrutiny for management assessments. To provide better estimates of abundance, survival and vital rates, the Alaska Department of Fish and Game (ADFG) and the National Marine Fisheries Service are using close-kin mark-recapture (CKMR) methods with genetic samples of bearded seals harvested by 13 Alaskan communities spanning the Bering, Chukchi, and Beaufort seas. This first application of CKMR in Alaska seeks to estimate the size of the bearded seal population needed for management. ADFG’s ice seal biomonitoring program archived 1,759 samples with tooth ages, harvested from 1998 to 2020. A subset (282) was used to generate a ~3,000 single nucleotide polymorphism (SNP) panel; all samples were genotyped and sexed. After rigorous quality control, kin relationships were established for 1,484 seals (~1 million pairwise comparisons) at 2,569 loci. Kin relationships included two parent offspring pairs (POPs) and ~22 half sibling pairs (HSPs), four of which were potentially confounded with grandparent-grandoffspring pairs (GGPs). Mitochondrial DNA analysis identified 15 of the 22 HSPs (68%) as paternally related, providing substantial evidence of heterogeneity in adult male reproductive success consistent with the observed proportion of territorial vs. roaming behaviour of males during breeding. In addition, the lack of full sibling pairs suggests a lack of female to male fidelity. Underpinning the CKMR analysis is an age-structured population dynamics model composed of annual survival probabilities and fecundity parameters. The model incorporates probabilities associated with POPs, HSPs, and GGPs. The preliminary models assume that age is known, and abundance is constant over time. Models that did not accommodate heterogeneity in adult male breeding success resulted in a population abundance estimate of ~232,000 (CV = 0.21), however when included, the proportion of adult males breeding is estimated at 0.34 (SE = 0.15) leading to a 76% increase in abundance to ~409,000 (CV = 0.35). Our next steps are to refine the model (e.g., by including aging error) and to increase sampling to improve precision going forward.

Discussion:

The Workshop welcomed the preliminary results obtained by applying close-kin mark-recapture methods to the study of Alaskan bearded seals, but due to time limitations, questions and comments were postponed to the general discussion item 5.3.

Relevant citations:

Taras, B.D., P.B. Conn, M.V. Bravington, L. Quakenbush, A. Kilian, A.R. Lang, and A. Bryan. 2023. Close-kin mark-recapture used to estimate bearded seal population abundance and demographics. (poster). Alaska Marine Science Symposium, January 2023, Anchorage, Alaska, USA.

5.1.3 Greenland surveys

Rosing-Asvid presented "Abundance of bearded seal in Greenland waters", a working paper NAMMCO SC/29/BS-RSWG/XX, by Rikke Guldborg Hansen.

Author's summary:

This presentation gave an overview of available surveys from Greenland where bearded seals also have been counted (figure 4).

West Greenland: Central west Greenland has been surveyed many times (2006, 2012, 2022), and data on bearded seals are available and can possibly also be extracted from surveys conducted in: 1981, 1982, 1990, 1991, 1993, 1994, 1998, 1999. The surveys were conducted in March-April and show high abundance in an area which also has high catches at that time of the year. Melville Bay has also been surveyed twice in the summer (2014, 2022) and there are indications of a small pocket of local seals living in that area. The North Water polynya has been surveyed a number of times (2009, 2010, 2014, 2018, 2020), and from this area abundance estimates have been published for the 2010 and 2014 surveys, both producing estimates of about 6,000 bearded seals. No surveys are available from Southwest Greenland.

East Greenland: Two surveys from Northeast Greenland (2017, summer and winter) had too few sightings for an abundance estimate. Some surveys are available from the central part of East Greenland (but they only cover the fjords and a narrow strip off the coast, not the entire distribution of bearded seals in the area). No surveys are available from the southeastern part of Greenland.

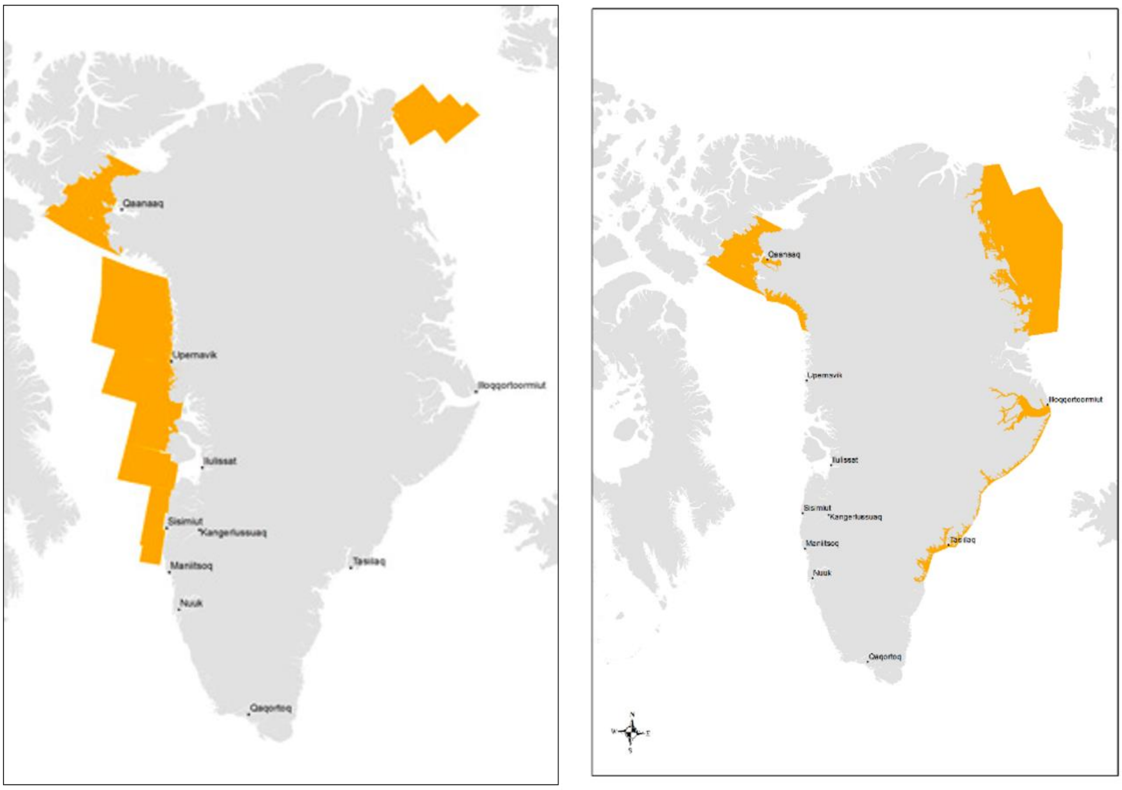

Figure 4. Survey areas carried out where bearded seals have been observed in winter (left) and summer (right) in Greenland.

Discussion:

The Workshop welcomed the availability of survey data for abundance estimation in Greenland, noting the good situation in West Greenland, where several surveys had been conducted from 1981 to 2022, and from which the data had been validated and used for estimating abundance of other species. The data from the later surveys were digitalised. Rosing-Asvid, however, indicated that although it is the plan to estimate the abundance of bearded seal from these surveys, there was currently no scheduled timeframe to do so.

It was also noted that zero or a few sightings during a survey also brought information on abundance, especially if considered within a trend.

The Workshop **recommended** that estimates of bearded seals be generated from the existing surveys. Under point 6.2, General Discussion, the Workshop provided recommendations on how to prioritise the work, as requested by the Scientific Committee of NAMMCO.

5.1.4 Canada surveys

David Yurkowski presented "Synthesising bearded seal estimates for Canadian High Arctic".

Author's summary:

A synthesis was presented of bearded seal abundance and density estimates from aerial surveys (1958 to 2022) across the Canadian Arctic that included Amundsen Gulf/Beaufort Sea, the Canadian Arctic Archipelago, the Hudson Bay Complex, Lancaster Sound/Baffin Bay/Davis Strait and Ellesmere Island (figure 5). A total of 24 publications and reports were compiled with survey effort ranging between 2,000 km^2 – 145,000km^2 and with bearded seal densities ranging between 0.02 bearded seals per km^2 to 0.24 bearded seals per km^2. Higher seal densities occurred in the Beaufort Sea area and the Baffin bay-Davis Strait area compared to the other geographic areas (Hudson Bay Complex and High-Arctic Archipelago and Ellesmere Island). This bearded seal review paper will be submitted for publication.

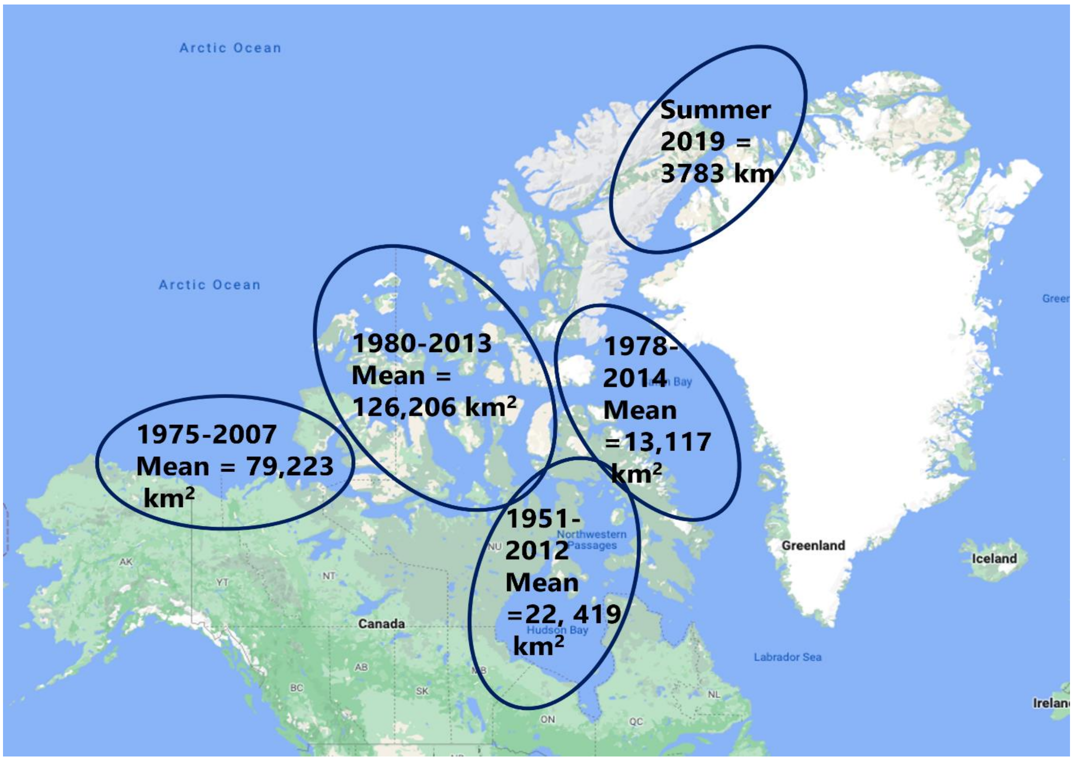

Figure 5. Location of the surveyed areas in the Canadian Arctic, showing approximate area surface and timing (years) of the aerial surveys (source: David Yurkowski).

Discussion:

The Workshop welcomed the effort made by the authors in compiling all Canadian surveys in a review paper.

5.2 GROWTH, CONDITION, POPULATION PARAMETERS, VITAL RATES AND ENERGETICS

5.2.1 Nunavut

Steve Ferguson presented "Nunavut bearded seals".

Author's summary:

The Canadian Arctic has a smaller population of bearded seals compared to ringed seals, leading to fewer archived tissue samples, hunt statistics, and body growth measurements. However, data from hunts between 1976 and 2003 suggest that bearded seal stocks in Canada are stable. Most bearded seals are hunted in Nunavut, particularly in the Baffin Region. Bearded seals are also harvested further west in the Canadian Arctic in coastal waters of the Northwest Territories and Yukon, but in much smaller numbers. Despite hunters taking fewer seals than they did 30 years ago, this is not believed to reflect changes in bearded seal abundance. Fisheries and Oceans Canada has over 300 bearded seal tissue samples stored in freezer archives, mostly collected from Sanikiluaq and Arviat in Hudson Bay during the 2000s. The bearded seal harvest is mainly composed of pups, with fewer juveniles than expected. Reproductive metrics suggest that bearded seals are more fecund than ringed seals. Compared to other seal species, bearded seals are the largest, averaging around 210 cm in length. Ringed and bearded seals grow faster than subarctic harp and harbour seals, which have more indeterminate growth.

Discussion:

Ferguson informed that differences in growth and vital rates between sexes had not been investigated for Nunavut bearded seals due to the few data available, but it was noted, however, that the species did not show much dimorphism. To the question of why pregnancy rates were so low, compared for example to Svalbard, it was clarified that the samples used to generate such rates also included immature individuals (pups and juveniles), and that the numbers would be refined later.

5.2.2 Labrador

Charmain Hamilton presented "Bearded seals in Labrador, Canada".

Author's summary:

Bearded seals were taken by commercial sealers as part of a sampling program run by Fisheries and Oceans Canada, Newfoundland and Labrador Region. Between 1979 and 2021, 485 bearded seals were sampled by this program, with the lower jaw, stomach and reproductive organs taken from each seal and morphometric measurements, muscle and blubber samples taken from a subset of seals. The majority of seals were young of the years (YOYs) and were killed in January and February in north-eastern Newfoundland. Bearded seal YOYs (9-10 months of age) had a mean body length and weight of 160 ± 10 cm and 97 ± 22 kg. Sternum blubber depth and maximum girth increased with age and leveled off when seals were approximately seven years old. Bearded seals had an asymptotic standard length of 241 ± 6 cm and female seals had a higher body weight than males. YOY body length and weight decreased from 1988-2018. Sternum blubber depth and maximum girth also decreased after 1990. The Newfoundland and Labrador region likely had an ecosystem shift in the early 1990's. Concurrent with this shift, large declines occurred in the biomass of groundfish and capelin stocks. Sea-ice declines are also ongoing in the region. These ecological shifts appear to have negatively affected the growth and condition of bearded seals in the north-western Atlantic Ocean.

Discussion:

The Workshop welcomed the information presented on temporal changes in growth and condition of seals in Labrador. To the question of whether the diet of seals had changed during the study period, Hamilton indicated that answering this question was a work in progress, but preliminary results indicated changes in the case of some crustaceans and fish species. In presence-absence analyses, an increased frequency of cod (*Gadus* spp.), increased frequency of sculpin (grouping of *Triglops* spp., *Myoxocephalus* spp., *Gymnocanthus tricuspis*, *Artediellus* spp. and *Icelus spp.*) and a decreased frequency of snow crab (*Chionoecetes opilio*) were found between 1984 and 2018.

Relevant citations:

Bengtson, J. L., Boveng, P. L., & Jansen, J. K. (2010). Status review of the bearded seal (*Erignathus barbatus*). https://repository.library.noaa.gov/view/noaa/3761/noaa_3761_DS1.pdf

Davis, C. Stirling, I., Strobeck, C., & Coltman, D. W. (2008). Population structure of ice-breeding seals. Molecular Ecology, 17(13), 3078–3094.

Kosygin, G. M., & Potelov, V. A. (1971). Age, sex and population variability of the craniological characters of bearded seals. Marine Mammals (Fur Seals and Seals), 80, 266–288.

Manning, T. H. (1974). Variations in the Skull of the Bearded Seal. Biological Papers of the University of Alaska, 16, 1–21.

Risch, D., Clark, C. Corkeron, P. J., Elepfandt, A., Kovacs, K. M., Lydersen, C., Stirling, I., & Van Parijs, S. M. (2007). Vocalizations of male bearded seals, *Erignathus barbatus*: classification and geographical variation. Animal Behaviour, 73(5), 747–762.

5.2.3 Alaska

Quakenbush presented "Growth, body condition, and vital rates of bearded seals in Alaska, 1960s, 1970s, 2000s, and 2010s".

Author's summary:

Declines in sea ice are predicted to negatively affect ice-associated seals including bearded seals (*Erignathus barbatus*), a species important to Alaska Natives for food. A decline in the length of the ice-covered season reduces their time to rest, rear pups, and moult on sea ice. There are no abundance estimates that can detect population trends; however, data from the subsistence harvest can be used as indices of population status. We compare bearded seal length at age (growth), blubber thickness (body condition), pregnancy rate (productivity), age at maturity, and proportion of pups harvested (pup survival to weaning) during the 2000s and 2010s (years of sea ice decline) to the 1960s and 1970s (before sea ice decline). Seal length standardised by birth year indicated growth was below average for bearded seal females born in the late 1970s, rose to above average in the early 1990s, dipped again in the early 2000s, but has been above average during 2016–2018. Changes in male length were less extreme and more variable, with no sustained periods above or below average. Blubber thickness for adults was average or above for most years. Below average exceptions for adults included 2003, 2011, and 2017. Below average years for both indices were often followed by average or above average years. Pregnancy rate during the 2010s was significantly higher for bearded (97%) seals than during the earlier periods. The average age of maturity (i.e., age at first ovulation) for female bearded seals decreased over time to 2.6 years in the 2010s indicating favourable conditions for early growth and maturity. Finally, a higher proportion of pups were harvested in the 2010s indicating that pups were being produced, weaned, and surviving to be harvested. Overall, these indices have not shown sustained decreases in bearded seal growth, body condition, productivity, or pup survival that would be indicative of a population decline as has been predicted to occur with declining sea ice.

Discussion:

The appropriateness of using the proportion of pups in the harvest as an index of pup production was questioned. It was noted that proportions in the harvest were disproportionately high compared to the population proportion of pups, and doubts were expressed on the reliability of that index given that absolute references are biased by hunter selection. Quakenbush clarified that the proportion of pups in the harvest was used only as a relative year-to-year indicator of the presence of pups post weaning, with large numbers of pups in the harvest considered indicative of large numbers in the population. Low numbers of pups in the harvest would be considered an indicator of a poor year for pup survival if the pregnancy rate for that year was average. The annual pregnancy rate indicates females are becoming pregnant, the proportion of pups in the harvest is a relative indication that pups are being born and surviving to be harvested.

Given that results indicated high productivity of bearded seals in recent years, despite declining sea ice, comparisons were made with other species in terms of ovulation and pregnancy rates. In the case of grey seals, it was noted that pregnancy rates also remained very high despite environmental changes, whereas in the case of harp seals, pregnancy rates could decline despite high ovulation rates due to late term abortions.

Relevant citations:

Crawford, J.A., L.T. Quakenbush, and J.J. Citta. A comparison of ringed and bearded seal diet, condition and productivity between historical (1975–1984) and recent (2003–2012) periods in the Alaskan Bering and Chukchi seas. Progress in Oceanography. 2015. http://dx.doi.org/10.1016/j.pocean.2015.05.011

Quakenbush, LBiological monitoring of ice seals in Alaska to determine health and status of populations—diet, disease, contaminants, reproduction, body condition, growth, and age at maturity. Final report to the National Marine Fisheries Service for award #NA16NMF4390029.

Rode, K.D., E.V. Regehr, J.F. Bromaghin, E.V. Regehr, R.R. Wilson,St. Martin, J.A. Crawford, and L.T. Quakenbush. 2021. Seal body condition and atmospheric circulation patterns influence polar bear body condition, recruitment, and feeding ecology in the Chukchi Sea. Global Change Biology. 2021;00:1‑18.

5.2.4 Svalbard

Lydersen presented “Growth and population parameters for bearded seals from Svalbard, Norway”.

Author’s summary:

Peak pupping period in Svalbard is in the first week of May. Pups are born on an ice floe or at the edge of the fast ice. They moult in utero and have an average birth mass of 37.1 ±3.8 (SD) kg (range 33–47 kg, n = 25). They swim and dive from day 1. Pup growth rate is 3.0 ±0.7 kg/day (1.8–4.8 kg/day, n = 64) during the nursing period, and this period lasts for about 24 days. 18 pups reached body masses over 100 kg (max recorded 124 kg). Average maternal parturition mass was 369 kg, and even if they feed during lactation, they experience a daily mass loss of 4.4 kg. Growth curves for males and females show an asymptotic body length of 231.1 ± 11.4 cm and 233.1 ± 7.5 cm for males and females, respectively. Corresponding values for body mass was 269.9 ± 26.2 kg for males and 275.3 ± 47.8 for females; several females with body masses above 400 kg has been live captured during the start of the lactation period with max recording of 421 kg. Body condition drops from May to August in males (breeding and moulting) and in females from May to June (lactation period). All males over 6 years of age were sexually mature and corresponding number for females were 5 years.

5.2.5 Energetics and metabolism

Colleen Reichmuth presented "Bearded seals: physiology and energetics of cooperating individuals".

Author's summary:

Bearded seals have a unique physiology that is consistent with their evolutionary isolation from other phocid seals. Because extrapolating information from related species is difficult, direct physiological data are especially important. Measurements of energy intake throughout development are now available for captive bearded seals (Rosen et al. 2021), with additional data being archived at the University of California Santa Cruz (C. Reichmuth, unpublished data). Energetic measurements from the same bearded seals trained to cooperate in metabolic sampling procedures provide insight into species-typical and comparative physiology. Highlights of this work include the first species measurements of resting metabolism showing low mass-specific energy demands and little seasonal variation in metabolic costs associated with moult (Thometz et al. 2021). Similar data for ringed and spotted seals show significantly higher mass-specific energetic costs and strong seasonal increases in metabolic demand. The unusual seasonal energetic patterns of bearded seals are consistent with their prolonged moulting strategy. While total metabolic demand increases with increasing body size, mass-specific metabolism declines during development. Resting metabolic costs declined by 35% from age 2 to 7 in a male bearded seal (Pardini et al., 2022 preliminary data). The metabolism of an adult bearded seal was compared while he rested calmly in or out of water, both during and outside of moult. Metabolic costs were not higher in water, even during moulting periods. Rather, metabolic costs remained low for the bearded seal year-round, whether in water or during haul out, during both moulting and non-moulting periods (Thometz et al. 2023). Ongoing work with trained bearded seals is focused on measuring the differential metabolic costs associated with resting, swimming, and diving (Thometz et al., 2022 preliminary data; Meranda et al., 2023 preliminary data). These activity-specific costs can be used to inform bioenergetic modelling efforts for the species. Data available indicates that despite their polar distribution, bearded seal metabolism is the lowest measured thus far for phocid seals, which are already at the low-end of the distribution for marine mammals.

Discussion for 5.2.4 and 5.2.5

The Workshop welcomed the information on growth and population parameters of seals in Svalbard and on energetics and metabolism obtained from the study of captive bearded seals in California, but due to time limitations, questions and comments were postponed to the general discussion item 6.3.

Relevant citations:

Meranda Ruscher B., Thometz N.Rosen DAS, and Reichmuth C. (2023) Stationary diving metabolic costs in Alaskan ice seals. Alaska Marine Science Symposium, Anchorage, Alaska, 23-27 January.

Pardini M., Meranda M., Thometz N.M., Rosen D.A.S., and Reichmuth C. (2022) Physiological and energetic measurements of bearded seals (Erignathus barbatus) during early development. Alaska Marine Science Symposium, Anchorage, Alaska, 24-27 January.

Rosen D.A.S., Thometz N.M., Reichmuth C. (2021) Seasonal and Developmental Patterns of Energy Intake and Growth in Alaskan Ice Seals. Aquat Mamm 47:559–573.

Thometz N.M., Hermann-Sorensen H., Russell B., Rosen, D.A.S., and Reichmuth, C. (2021) Molting strategies of Arctic seals drive annual patterns in metabolism. Conserv Physiol. doi: 10.1093/conphys/coaa112

Thometz N.M., Rosen D.A.S., Hermann-Sorensen H., Meranda M., Pardini M., and Reichmuth C. (2023) Maintaining control: metabolism of molting Arctic seals in water and when hauled out. J Exp Biol. doi: 10.1242/jeb.244862

Thometz, N.M., Pardini, M., Meranda, M., Ruscher, B., Rosen, D.A.S, and Reichmuth, C. 2022. Metabolic costs of stationary diving and submerged swimming in bearded seals (Erignathus barbatus). Alaska Marine Science Symposium, Anchorage, Alaska, 24-27 January.

5.2.1 Publicly available information on bearded seals in Russia

Jana Djukarić presented the information on bearded seals which is publicly available in Russia, summarising newest publications of sightings, seasonal distribution and migration movements as well as harvest numbers from all Russian management zones.

Author's summary:

Opportunistic sighting data of bearded seals was available from 1987 to 2022 along the whole Russian coast from the rusmam.ru database, and sightings from a 2016 survey in the Eastern Kara Sea (Semenov & Evfratova, 2019). Bearded seals were observed along the whole Russian coast from east to west. A study by Solovyeva et al. (2021) showed the seasonal distribution and migrations of five tagged animals in the Sea of Okhotsk from mid-September 2013 to April 2017. Movement patterns were closely related to ice formation and condition. During migrations, bearded seals avoided open water, set up haul out sites on ice whose concentration was over 75% and reached winter habitats by mid-January (Solovyeva et al., 2021).

An overview of catch data was taken from Zagrebelny et al. (2023), which summarised harvest numbers for major pinniped species in Russian waters from 2014-2019. Sealing in the Russian Federation is almost exclusively done by indigenous settlements in the north and far east. The status of bearded seal stocks in Russia can be characterised as stable, and the effect of the harvest is minimal on the populations. Most regions experience no commercial harvesting or minimal activity. Large-scale commercial harvesting of marine mammals in Far Eastern and north-western seas has significantly decreased since the mid-1990s (from 250,000 to 5,000–6,000 animals a year). Out of 11 regions with allocated quotas for bearded seals, nine regional catches stayed below 50% of the annual quota.

Discussion:

The Workshop welcomed this compilation of recent research on bearded seals conducted in Russian waters and the valuable information provided in the presentation and thanked Djukarić to have prepared it in the short time imparted.

Relevant citations:

Semenov A.R., & Evfratova S.S. (2019). Marine mammal sightings in the coastal area of the eastern Kara Sea. Marine Mammals of the Holarctic, Collection of Scientific papers, 2019, 1, 297-303. https://doi.org/10.35267/978-5-9904294-0-6-2019-1-297-303

Solovyeva, M. A., Kuznetsova, D. M., Glazov, D. M., & Rozhnov, V. V. (2021). The Seasonal Distribution and Migrations of Bearded Seals, *Erignathus barbatus*, in the Sea of Okhotsk According to Satellite Telemetry Data. Russian Journal of Ecology, 52 (6), 504–513. https://doi.org/10.1134/S1067413621040093

Zagrebelny S.V., Kuzin A.E., Gushcherov P.S., Chakilev M.V., Kornev S.I., Boltnev A.I. (2023) Resources of major commercial pinniped species and their harvest in the Russian Federation in 2014–2019. Marine Mammals of the Holarctic. XI International Conference Online, 1-5 March 2021. 111-119. https://doi.org/10.35267/978-5-9904294-8-2-2023-111-119

5.3 GENERAL DISCUSSION AND GAP ANALYSIS

The Workshop co-Chairs invited the participants to a more general discussion on today's presentations.

A comment was made on Reichmuth's presentation, noting that bearded seals did not increase metabolic rate during moulting and hence the process took longer than in other sympagic Arctic seal species. The reasons for that are not completely known and it was agreed that further research was needed. Reichmuth noted that moulting was not just about hair and that seals were replacing their epidermis, necessary for protecting the body throughout the year. Because captive animals live in a sheltered environment, it was suggested to recreate, if possible, air and water regimes when measuring metabolic rates in captivity. Despite differences in captive conditions, seasonal trends in metabolic rates are likely to reflect underlying physiological changes.

The Workshop agreed that access to Russian samples was key to increase coverage in genetic analyses for population structure. However, given that direct communication with Russia was now impossible, alternative approaches were needed, for example, through obtaining DNA from seal bones or other material in museum collections. Old material from past expeditions to Russia might be available in museums in the USA and Norway, and participants from these countries agreed to communicate with Tange Olsen and McCarthy to see which specific samples (locations) were needed and to investigate the possible existence of such samples in the collections of their respective museums. The possibility to infer population structure in Alaska from CKMR models was also noted and was considered a good opportunity for collaboration between Workshop participants.

Clarification was requested on how the disturbance rate used in the estimation of abundance from aerial surveys in the Bering and Chukchi seas was determined. Boveng informed that such disturbance rate referred to disturbance from the aircraft doing the surveys (e.g, number of seals going to the water when the plane approached, prior to counting), and not to natural disturbance, which was assumed to be captured by the haul out data. The Workshop was informed that resolution from satellite imagery was poor to detect and classify Arctic seals at this time, with pessimistic prospects to improve satellite images for ice seals in the short term given typical atmospheric obstruction. However, new technological improvements to estimate sea ice thickness and snow on top of the ice were now allowing snow depth indexes to become available and be used in research on Arctic seal population dynamics.

It was noted that the Beringia area, with a high density of bearded seals, was also very shallow and so provided easy access to benthic prey for seals. Therefore, depth or other external covariates could be used in modelling exercises to determine seal density-habitat relationships, and such relationships could be extrapolated to other areas with missing population data to get estimates. The Workshop agreed that more research was however needed, for example on ecological differences between Pacific and Atlantic bearded seals, before extrapolating habitat modelling results across the species range.

Due to the predation risk posed by walrus and the trophic overlap between walrus and bearded seals, it was suggested that negative correlations between both species might occur at small scales. Apparent displacement of bearded seals had been observed in Svalbard, where walruses are making a comeback, but overlap between both species was still routinely observed in Alaska. The Workshop **agreed** that further research on this topic was needed and that bearded seal-walrus interactions should be investigated across the bearded seal range.

In terms of gap analysis, the Workshop highlighted the need to obtain abundance estimates for most areas in the panarctic, to be used as a baseline for the precautionary management of bearded seal stocks. Given that the lack of such information was particularly acute in the Atlantic Arctic, it was **recommended** to identify un-surveyed areas where surveys should be conducted, and to prioritise: 1) those areas with substantial catches or sources of mortality, and 2) the timely analysis of existing survey data from Greenland.

The co-Chairs welcomed the prospects for future collaborations, new ideas, and advice coming out from this Workshop.

6. OTHER ISSUES

6.1 THREATS TO BEARDED SEALS (INCLUDING CLIMATE CHANGE)

6.1.1 Health issues, harmful algae, and parasites in Alaska

Quakenbush presented "Health issues: harmful algae, parasites, and contaminants in bearded seals in Alaska".

Author's summary:

Declines in sea ice are predicted to negatively affect ice-associated seals including bearded seals (*Erignathus barbatus*), a species important to Alaska Natives for food. A longer open-water season has the potential for greater exposure of Arctic marine mammals to pathogens, parasites, and contaminants. Indeed neurotoxins (domoic acid (DA) and saxitoxin (SXT)) produced by harmful algae blooms (HABs) are being detected in Arctic pinnipeds and are increasing. Bearded seals have the highest prevalence of DA and SXT of ice seal species in Alaska, although no signs of acute toxicity have been reported. On the other hand, a review of helminth parasites in ice seals, collected between 2006 and 2015, did not show any new species or greater prevalence of endemic species. Bearded seal tissues have been tested for contaminants during two periods (2003–2007 and 2011–2016) so that temporal changes, if any, can be determined. Concentrations of trace elements of concern (e.g., Hg, Cd, Pb), organochlorines (OCs: PCB, HCH, DDT, CHL), as well as PBDEs and PFCs have been determined, although these data have not been fully analysed or published. In general, bearded seals in Alaska have lower contaminant concentrations than seals in other regions of the panarctic. Of these potential health issues, exposure to HABs is increasing and appears to be the greatest potential health concern to bearded seals in Alaska.

Discussion:

The Workshop welcomed the information on bearded seal health issues in Alaska, noting the low levels of contaminants there compared to other populations in Canada or Europe. The Workshop was also informed that seal lice was rare in Alaska (only one observation), a fact consistent with a healthy bearded seal population.

Relevant citations:

Correa, L., M. Castellini, L.T. Quakenbush, and T.M. O'Hara. 2015. Selenium concentrations in skeletal muscle, liver, and regions of the heart and kidney in bearded seals from Alaska, USA. Environmental Toxicology and Chemistry 34(10):2403–2408

Lefebvre K.A., L Quakenbush, E. Frame, K. Burek Huntington, G. Sheffield, R. Stimmelmayr, A.Bryan, et al. 2016. Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment. Harmful Algae 55:13–24. http://dx.doi.org/10.1016/j.hal.2016.01.007

Leidenberger S, Harding K, Härkönen T (2007) Phocid seals, seal lice and heartworms: a terrestrial host–parasite system conveyed to the marine environment. Dis Aquat Org 77:235-253. https://doi.org/10.3354/dao01823

Quakenbush, L., A. Bryan, M. Nelson, and J. Snyder. 2016. Pacific Walrus (*Odobenus rosmarus divergens*) Saint Lawrence Island harvest sample analyses, 2012–2014 and 2016. Final report to
Alaska Department of Fish and Game, State Wildlife Grant and U.S. Fish and Wildlife Service. 61 pp.

Foster, G., I.H. Nymo, K.M. Kovacs, K.B. Beckmen, A.C. Brownlow, J.L. Baily, M.P. Dagleish, J. Muchowski, L.L. Perrett, M. Tryland, C. Lydersen, J. Godfroid, B. McGovern, A.M. Whatmore. First isolation of *Brucella pinnipedialis* and detection of *Brucella* antibodies from bearded seals *Erignathus barbatus.* Diseases of Aquatic Organisms 128: 3–20. https://doi.org/10.3354/dao03211

VanWormer, E., J. A. K. Mazet, A. Hall, V. A. Gill4, P. L. Boveng, J. M. London , T. Gelatt, B. S. Fadely, M. E. Lande, J. Sterling, V. N. Burkanov, R. R. Ream, P. M. Brock, L. D. Rea, B. R. Smith, A. Jeffers, M. Henstock, M. J. Rehberg, K. A. Burek-Huntington, S. L. Cosby, J. A. Hammond, and T. Goldstein Viral emergence in marine mammals in the North Pacific may be linked to Arctic sea ice reduction. Scientific Reports 9:15569. https://doi.org/10.1038/s41598-019-51699-4

2020. Biological monitoring of ice seals in Alaska to determine health and status of populations—diet, disease, contaminants, reproduction, body condition, growth, and age at maturity. Final report to the National Marine Fisheries Service for award #NA16NMF4390029.

Walden, H.S., A.L. Bryan, A. McIntosh, P. Tuomi, A. Hoover-Miller, R. Stimmelmayr, and L. Quakenbush. 2020. Helminth fauna of ice seals in the Alaskan Bering and Chukchi seas, 2006-2015. Journal of Wildlife Diseases 56(4):863–872. https:/doi.org/10.7589/2019-09-228

Hendrix A.M., K.A. Lefebvre L. Quakenbush, A. Bryan, R. Stimmelmayr, G. Sheffield, G. Wisswaesser, M.L. Willis, E.K. Bowers, P. Kendrick, E. Frame, T. Burbacher, and D.J. Marcinek. 2021.Marine Mammal Science. https:/doi.org/10.1111/mms.12822

6.1.2 Health assessment of harvested and found dead seals

Raphaela Stimmelmayr presented “Diseases and Parasites of the Bearded seal (*Erignathus barbatus*): Pacific Arctic”.

Author’s summary:

The bearded seal (*Erignathus barbatus*), a robust northern seal with circumpolar distribution, is an important subsistence resource for indigenous people of the Pacific Arctic. The major parts of bearded seals used are meat, organs, and blubber for human and dog food. Seal oil rendered from blubber remains an essential condiment for many native foods. Additional traditional uses for seal oil/blubber included use as a heating fuel and waterproofing compound. Other by-products include skin derived by-products such as foot gear, boat covers (skin boats), lines, and harnesses. Traditionally implements were also made from their bones, rain gear and translucent windows from their intestines, and dyes from their blood. Though an important northern subsistence species, few studies have been directed specifically toward assessing bearded seal health. Baseline animal health data is critical to detect and interpret trends in health in a changing environment. The North Slope Borough Department of Wildlife Management (NSB DWM) maintains community-based harvest monitoring and veterinary medicine-based health assessment programs for key Arctic subsistence species including the bearded seal. Briefly, we collect life history information and tissue samples from both harvested and found dead bearded seals that support both standard life history analysis (e.g., age, genetics, diet, contaminants, body condition, reproduction) and veterinary health assessment (e.g., pathology, harmful algal toxins, pathogens, parasites). We reviewed our existing pathology data of bearded seals to provide a baseline perspective about the health and common disease conditions of bearded seals. Much of the information presented here on pathologic conditions of bearded seals besides published data comes from observations by indigenous marine mammal hunters, field biologists, individual case studies from stranded/harvest animals, and from our long term systematic health assessment program of harvested bearded seals on the North Slope, Alaska (e.g., single case reports of incidental gross pathology and/or histopathological findings detected during systematic studies of organ tissues collected during post-mortem examination of healthy, hunter concern (2011-2022, n=203; < 2011, n=62) and found dead bearded seals (2011-2022, n=43). Diseases are broadly categorised by etiology as infectious and non-infectious. Lesions are described by organ systems. Tumours, trauma, and toxins are summarised

separately under the non-infectious disease section. The information provided is a co-production of knowledge reflecting perspectives of Inuit indigenous and local hunter knowledge, veterinary medicine, and biology. A manuscript on the "Health and Disease Conditions of the Bearded Seal (*Erignathus barbatus*) Synthesis and Future Direction" with a Pacific Arctic focus is anticipated to be submitted for peer review later this year.

Discussion:

The Workshop welcomed the results presented, further confirming bearded seals as a healthy and robust species. However, it was noted that bearded seals were among the affected Arctic pinniped species in two unusual mortality events in Alaska over the last decade, which remain unresolved.

The Workshop was informed that cataracts occurred in all age classes in ringed, spotted, and bearded seals. Compared to other Arctic mammals, seals seemed to stand out as having higher cataract rates, a possible indicator of other health issues.

Relevant citations:

Hendrix AM, Lefebvre KA, Quakenbush L, Bryan A, Stimmelmayr R, Sheffield G, Wisswaesser G, Willis ML, Bowers EK, Kendrick P, Frame E, Burbacher T, Marcinek DJ. Ice seals as sentinels for algal toxin presence in the Pacific Arctic and subarctic marine ecosystems. Mar Mamm Sci. 2021 Oct;37(4):1292-1308.

NOAA 2018-2022 Ice Seal Unusual Mortality Event in Alaska https://www.fisheries.noaa.gov/alaska/marine-life-distress/2018-2022-ice-seal-unusual-mortality-event-alaska

NOAA 2011–2016 Unusual Mortality Event https://www.fisheries.noaa.gov/alaska/marine-life-distress/diseased-ice-seals-and-unusual-mortality-events#2011%E2%80%932016-unusual-mortality-event

Stimmelmayr, R. Update on a "New" Disease Syndrome in Ice Seals and Pacific Walrus in the Arctic , in: Kovacs, K. (ed.). (2013). Circumpolar ringed seal (Pusa hispida) monitoring. Norwegian Polar Institute, Report Series 143. 45pp. Tromsø: Norwegian Polar Institute, 2013.

Walden HS, Bryan AL, McIntosh A, Tuomi P, Hoover-Miller A, Stimmelmayr R, Quakenbush L. HELMINTH FAUNA OF ICE SEALS IN THE ALASKAN BERING AND CHUKCHI SEAS, 2006-15. J Wildl Dis. 2020 Oct 1;56(4):863-872.

6.1.3 Shipping threats to bearded seals

Olnes presented "Shipping threats to bearded seals in Alaska".

Author's summary:

Throughout the Arctic, diminishing sea ice extent and an increase in the open-water period is allowing for increased shipping activity. In waters surrounding Alaska, an increase in shipping may be due to increased use of global shipping routes (i.e., the Northwest Passage and the Northern Sea Route), but may also be due to increased regional shipping of goods to coastal communities. Bearded seals use many areas with higher levels of vessel traffic, with the greatest observed overlap occurring in the summer months and within the Bering Strait and Norton Sound regions. However, the threat posed by shipping traffic to bearded seals is poorly understood. The risk of collisions or displacement by ships to bearded seals is considered low. Another concern is an increase in noise disturbance that could negatively affect bearded seals. Male bearded seals are known to vocalise throughout the year, but this behaviour is particularly important during the spring mating season and strongly associated with sea ice presence. Currently, shipping traffic is low during this time, but noise from shipping could become a greater threat if vessel traffic increases throughout the year.

Discussion:

The Workshop welcomed the information provided, noting that shipping in the Arctic was increasing not only during summer but also in winter, although less in Alaska than in other areas, such as in Norway. There were not enough data to answer whether bearded seals were avoiding high ship traffic areas. So far, mainly juveniles have been tracked in Alaskan waters, typically using coastal areas where vessel traffic is low. It was also mentioned that ongoing work on walrus and harbour seals could provide some insights into how to best study shipping threats to bearded seals.

Relevant citations:

Quakenbush, L.T., J.A. Crawford, M.A. Nelson, and J.R. Olnes. 2019. Pinniped movements and foraging: village-based satellite tracking and collection of traditional ecological knowledge regarding ringed and bearded seals. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Alaska Outer Continental Shelf Region, Anchorage, AK. OCS Study BOEM 2019-079. 131 pp + appendices.

Berkman, P.A., Fiske, G.J., Lorenzini, D., Young, O.R., Pletnikoff, K., Grebmeier, J.M., Fernandez, L.M., Divine, L.M., Causey, D., Kapsar, K.E., and L.L. Jørgensen. 2022. Satellite Record of Pan-Arctic Maritime Ship Traffic. NOAA technical report OAR ARC 22-10. https://doi.org/10.25923/mhrv-gr76

Fournet, M.E.H., Silvestri, M., Clark, C.W., Klinck, H., and A.N. Rice. 2021. Limited vocal compensation for elevated ambient noise in bearded seals: implications for an industrializing Arctic Ocean. Proceedings of the Royal Society B 288: 20202712. https://doi.org/10.1098/rspb.2020.2712

6.1.4 Climate change issues

Lydersen presented "Threats to bearded seals - including climate change Svalbard, Norway".

Author's summary:

Svalbard and the northern Barents Sea region have had the greatest decrease in the seasonal duration of sea-ice cover in the Arctic. Land-fast sea ice extent has declined dramatically, especially in west coast fjords. This is partly due to the increased temperature of the West Spitsbergen Current and more frequent intrusion of this current across the polar front and into the fiord-systems on the west coast of Svalbard. In addition to creating poorer ice conditions, the Atlantic Water masses also transport Atlantic fish and invertebrate species up to high latitudes. Loss of sea ice habitats will likely be the factor that has the most impact on bearded seals in this area. Bearded seals use sea ice for pupping, nursing, moulting and general resting. However, bearded seals have replaced sea ice with glacier ice to some extent, for some of these needs, and growth rates of nursing pups have remained the same before and after the major collapse in sea ice in 2006. However, most tide-water glaciers in Svalbard are in a negative mass balance so these alternative platforms will gradually disappear as the glacier fronts retreat onto shore. In a future without spring sea ice or glacier ice, one could suggest that bearded seals might shift to land as a substrate for all of these biological events for which they normally use sea ice. More and more bearded seals are observed hauling out on shore in Svalbard, but so far, no pupping or nursing havebeen observed on land.

There is concern that a warmer Arctic will result in increased disease risks for, and increased anthropogenic impacts on, marine mammals. Antibodies for both Brucella and Toxoplasma gondii have been found in bearded seals in Svalbard, and Brucella has been increasing with time; trends in T. gondii are unknown as we have only a single base-line measurement. Fisheries and oil exploration is likely of minor concern since these industries normally do not take place in shallow, coastal areas occupied by bearded seals in Svalbard. However, some seismic exploration for scientific purposes does take place in bearded seal habitat, with unknown impacts. Hunting takes place in a restricted area at low levels. Since 2002 harvesting levels have varied between 2-34 animals per year. Tourism is increasing exponentially, but there are quite restrictive rules regarding disturbance to animals.

In Arctic coastal marine ecosystems, reduced sea ice cover will result in less sympagic production, with less "rain" of sympagic production to the benthos, which is likely to result in less benthic production. This, in addition to competition from an increasing walrus population in Svalbard, is likely to lead to less food availability for the bearded seals. More walruses will also lead to more predation by them on bearded seals (which has been documented many times in the area) and as walrus reoccupy formerly used areas, they might displace bearded seals. In the fjords on the west side of Svalbard, the more boreal harbour seals are extending their distributional area, taking over areas occupied previously by ringed and bearded seals. This is almost certainly a consequence of warmer water and a new prey base that is not ideal for the two Arctic endemic seal species.

We have little information on contaminant levels in bearded seals in Svalbard, but there is a risk that increased outflow of pollutants from glaciers and previously frozen ground and rivers in northern Russia may increase pollution levels. Assessing the cumulative effects of all these factors combined on bearded seal demographics is an important future undertaking. However, there are too many unknowns currently to accurately evaluate synergies and total risk levels. Bearded seal might adapt to changing conditions more easily than some other Arctic endemic seals. The primary predator of bearded seals in Svalbard is polar bears (regardless of how much sea ice there is). Thus, pupping on shore may be viable for this species in this location given that pups can swim at a very young age if necessary. Also tracking studies show that individuals exhibit a high degree of specialization in their habitat use and diving behaviour, which may help these seals adapt in a rapidly changing Arctic ecosystem. Further, they also have highly varied diet with respect to benthic vs pelagic and fish vs invertebrates. However, there is a lot of uncertainty with regards to issues such as diseases, effects of pollutants (and toxicity), effects of lack of sea ice on their breeding system and other issues that may affect this population in negative ways.

Discussion:

Asked about other bearded seal predators than polar bears in Svalbard, Lydersen informed that, the analysis of Greenland sharks' stomach content had found 40-50% of seal remains in them, mostly belonging to ringed seals but also some to bearded seals. Greenland sharks probably take the seals when they sleep at the surface or in the water column, but there is currently no indication of high mortality caused by Greenland sharks, nor an increase in population of this predator in the Arctic. A fatty acid study identified bearded seals as prey for killer whales in Greenland, but this was not considered a cause of concern for bearded seals in Svalbard, due to the rarity of killer whales there.

6.2 SUMMARY – GAP ANALYSIS AND UNRESOLVED DISCUSSION POINTS

The co-Chairs invited participants to the final discussion, highlighting that management zone delimitation and recommendations to Greenland were expected results from this Workshop.

6.2.1 Management zones as a way forward for assessments? - continued

Following a previous recommendation from the Workshop, two maps with potential management zones were shown: a first one (Figure 6) with proposed management units based on available genetic information and a second one (Figure 7) with management units based on other lines of evidence (i.e., from tracking studies, type of vocalisations and known geographical barriers).

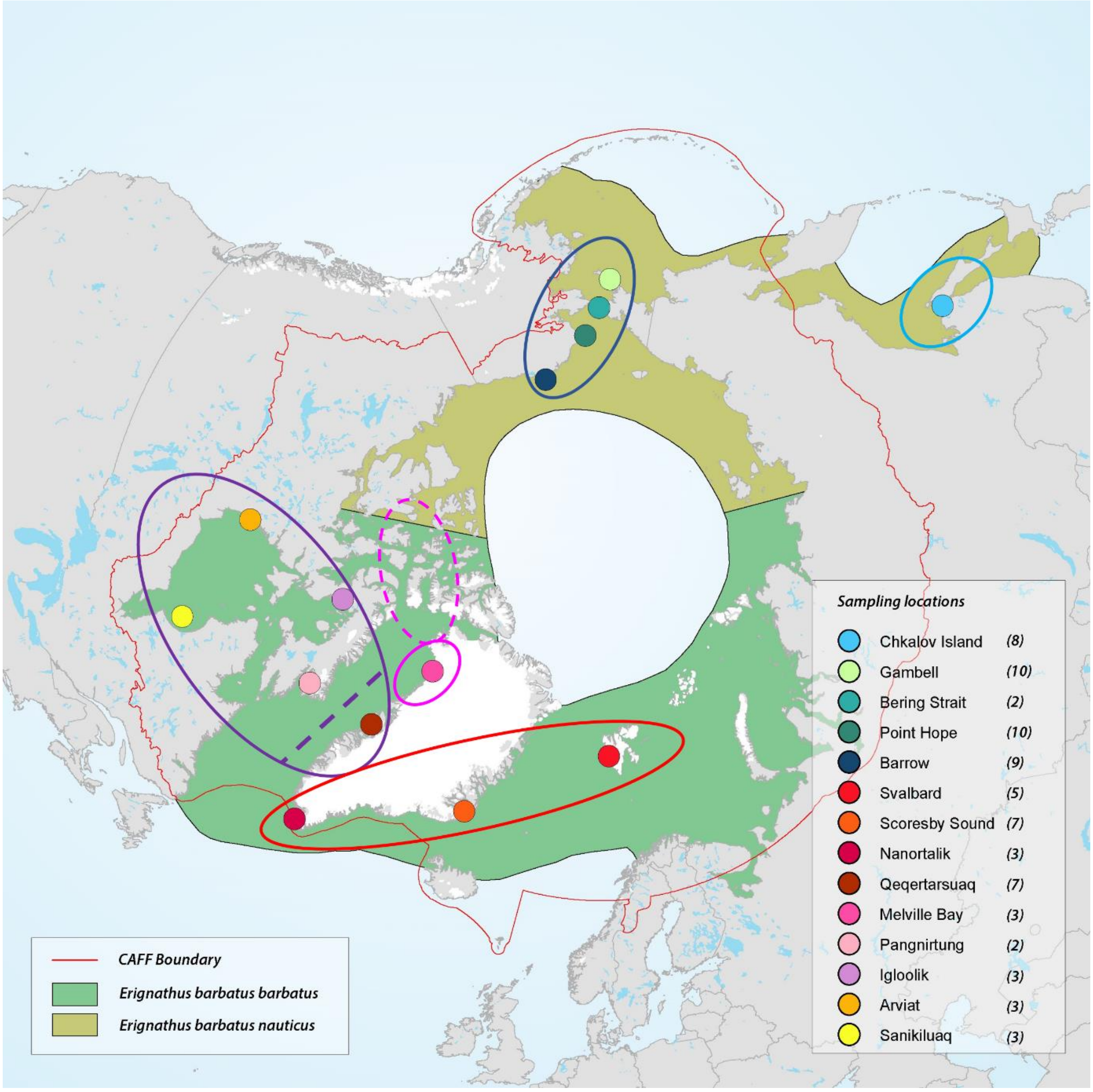

Figure 6. Management zone delimitation for bearded seal in the Panarctic based on preliminary results from the circumpolar genetic analyses. Dashed lines indicate potential boundaries not confirmed by preliminary results but expected with additional sampling.

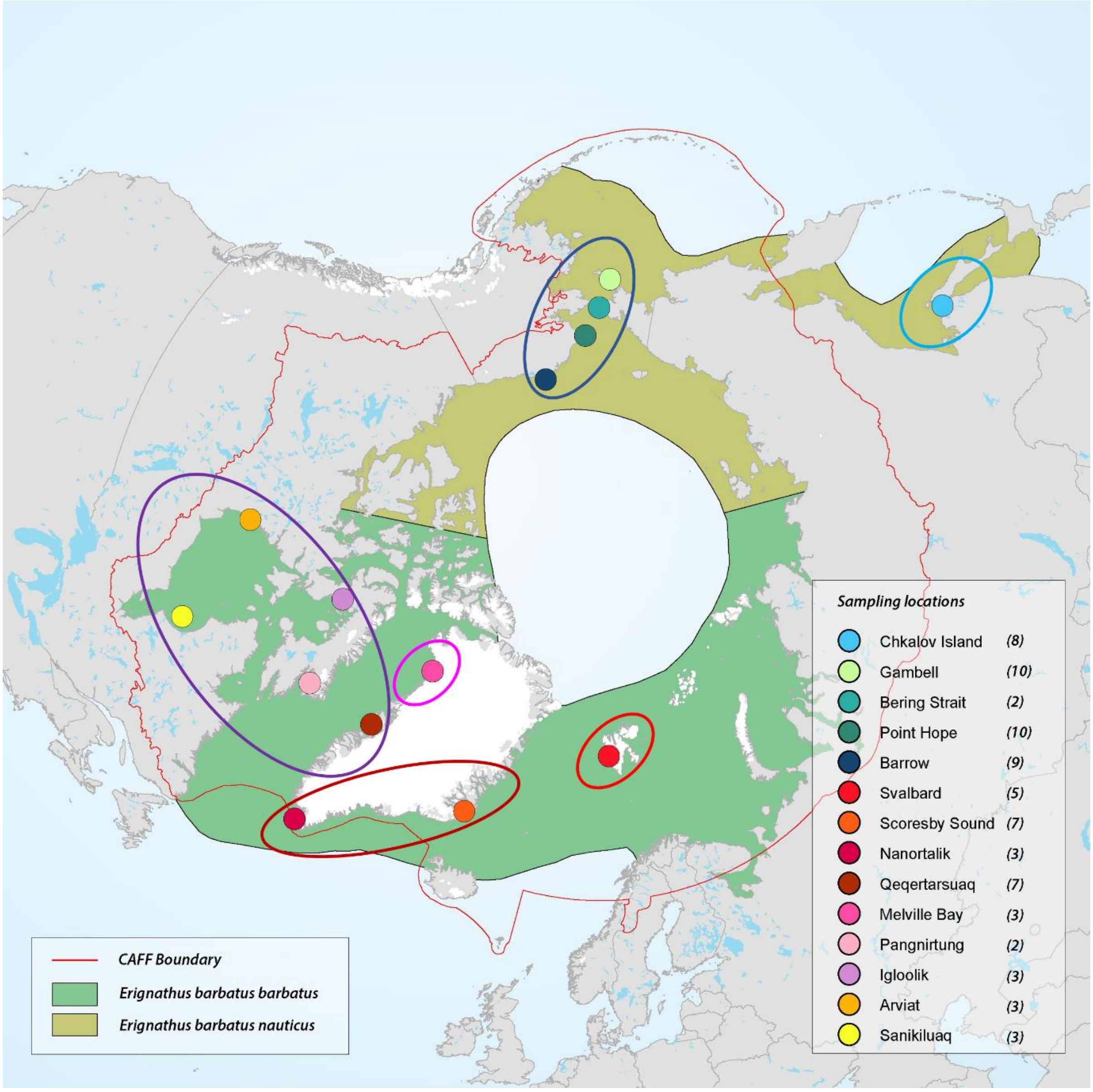

Figure 7. Management zone delimitation for bearded seal in the Panarctic based on available results from tracking, acoustics and other non-genetic studies.

The Workshop agreed that the structure found by the genetic analyses was a good launching point to draw boundaries, but that balancing it with other lines of evidence was important, such as the lack of documented movement between Svalbard and Greenland.

From experience in Alaska, it was noted that data from satellite tagging of mature animals was very difficult to interpret, due to the obtained data being always under a year of duration and not spanning the breeding season, when interesting movements, such as breeding dispersal, could be captured. The possibility that an animal from one site ended up breeding in a different place was a critical piece of information currently lacking that could provide additional knowledge on population structure in the Pacific and elsewhere. It was noted that, for units to be demographically linked, it only took a small percentage of migration between populations, and that such dispersal events could be detected with other techniques, such as mitochondrial genome sequencing.

To the question of whether genetic similarity was evidence of movement between areas, despite no movement observed, the Workshop was informed that genetics reflect demographic history as well as contemporary connectivity. Genetic studies may not always reflect the fine structure needed for a precautionary management approach and so other lines of evidence, such as the one provided by tagging studies, should factor into management zone delimitations. The Workshop agreed that greater sample size was needed to increase the resolution of the presently available genetic results and determine whether some areas that currently cluster together could be eventually separated.

The Workshop recommended that a group of participants work together towards an improved genetic dataset, with extra samples from the North Atlantic, and continue looking at management zones based on updated population structure results. It was estimated that updated population structure results for the North Atlantic could be ready in 6 months and it was agreed that a provisional group would coordinate the samples required/received for the analyses, with regular meetings, so the task would be completed within the estimated time frame. Tange Olsen and McCarthy also agreed to provide a text with protocols for keeping samples and shipping them, as well as with recommendations of what could be done with different existing type of samples.

The Norwegian participants informed the Workshop of the possibility to apply for financial support in May, during the next grant round in Norway for Arctic Council work, to try to advance the genetic analyses.

6.2.1 Recommendation for prioritisation of abundance estimate work in Greenland

The Workshop had been requested by the Scientific Committee of NAMMCO to provide recommendations on how to prioritise the analysis of the existing survey data for generating abundance estimate of bearded seals in the NAMMCO management areas. The general recommendation was to start by analysing the existing data from West Greenland (and Melville Bay), as key hunting areas were seen of major priority, and there was the opportunity to provide a trend in abundance. The Workshop recommended to start with the latest surveys first and then move backwards, especially as the most recent data were digitalised and would require less groundwork.

The Workshop discussed the possibility to use models that could analyse all surveys together, but this was considered not possible at the moment.

6.2.2 Other issues

A collaboration between participants from Alaska, Canada and Greenland was suggested, with the aim to build models using covariates to inform population estimates in areas with data gaps. It was noted that testing habitat-density relationships in East Svalbard would be also interesting, but that obtaining funding for this type of effort was difficult.

The Workshop was informed that wind was increasing in the Pacific Arctic and that the wind chill-haul out interaction during moulting could be affecting the energetics of bearded seals. In addition, the reduction of sea ice to haul out on might also impact energetics. Therefore, it was agreed that studies comparing moulting on ice vs. moulting on shore were needed, to anticipate any changes in energetics due to seals hauling out more on shore in the future. It was also noted that there was a lot of information on bearded seal diet and that the foraging versatility of the species could also help assessing the resilience of bearded seals in a changing Arctic.

Regarding the predation risk posed by walrus and the possible displacement of bearded seals by this species, the Workshop agreed it was more important to focus on the dynamics of bearded seal predators in general as well as the changes in the ecosystem affecting predator-prey interactions, in a multispecies sense. Also, in the light of possible interactions with climate change, the Workshop recommended to continue expanding the screening and study of bearded seal pathogens.

Finally, the Workshop agreed that it should follow the progress made by ongoing studies using CKMR methods (bearded seals, walruses and moose in Alaska), for future applications in the demographic study of bearded seals. The Workshop also supported a transboundary Canada-Greenland tagging project: given that bearded seals disappear (no catches) from the Canadian side of Baffin Bay in the winter, it is possible that they move to Greenland and are included in the Greenland winter/spring surveys. Therefore, it is important to improve such knowledge, for management purposes. The Workshop did not recommend prioritising satellite tagging projects for investigating population structure, as they do not provide such information. However, such studies are good at providing results on seal habitat use (i.e., home range, foraging areas) and should continue for those purposes.

7. RECOMMENDATIONS FOR PRIORITY ACTIONS

Theme	Recommendations
Management zone delimitation	• Use available genetic information and other lines of evidence (e.g., movement patterns) to produce a map with potential management zones, indicating information on catch data within their boundaries. • Make efforts to collect more samples and increase coverage for the circumpolar genetic analyses.
Circumpolar genetic analyses (sampling)	• Prepare a proposal for an in-depth genetic analysis in the North Atlantic area (specifying number of samples needed and where they should be collected) and apply for funding through NAMMCO (Norwegian Funding). • Try to obtain DNA from Russian seal bones or other material in museum collections elsewhere, to provide samples from Russian waters. Old material from past Russian expeditions might be available in museums in the USA and Norway. • Establish a provisional group to coordinate samples for genetic analyses.
Fill population data gaps	• Conduct modelling with external covariates to determine seal density-habitat relationships. Extrapolate such relationships to other areas with missing population data to make abundance estimates. However, more research on ecological differences between Pacific and Atlantic bearded seals should be done before extrapolating habitat modelling results. • Collaboration between groups in the USA, Canada (DFO) and Greenland (GINR) to combine survey data. • Transboundary Canada-Greenland seal tagging project. • Identify unsurveyed areas where surveys should be conducted, prioritising those with substantial catches or sources of mortality. • Timely analysis of Greenland existing survey data
Metabolism and moulting	• Investigate wind chill - haul out interaction during moulting season. • Consider information on metabolism and moulting process and their consequences for bearded seals in a changing Arctic.
Impact of predation/pathogens on bearded seal populations	• Investigate effects of predation on bearded seals across their range, to assess vulnerability of Arctic predator-prey systems under climate change. • Continue and expand screening for pathogens in bearded seals.
Abundance estimation in Greenland	• West Greenland and Melville Bay as high priority (key hunting areas) as major priority, to get abundance estimates. • Start with most recent surveys, then work backwards in time.
Close-Kin mark recapture models	• Investigate possibilities to obtain population structure/geographic patterns using this genetic method. • Follow developments of current CKMR projects.

8. MEETING CLOSE AND ADOPTION OF REPORT

The co-Chairs thanked everyone for their contributions, also thanking NAMMCO for taking over the organisation of the Workshop despite the geopolitical situation and for providing the assistance and support to make it possible. All participants thanked the co-Chairs for their able chairing.

The meeting was closed at 19:13 on March 23, 2023. A first draft report was circulated on April 20 and finalised on June 14, 2023.

9. APPENDIX 1: LIST OF PARTICIPANTS

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- Anna Bryan, (Alaska Department of Fish and Game), Anna.bryan@alaska.gov

10. APPENDIX 2: AGENDA

Day 1

1. **Welcome from the Co-Chairs and Opening Remarks**
2. **Adoption of agenda**
3. **Appointment of rapporteurs**
4. **Bearded seal populations/stocks on a circumpolar scale**
    - **4.1. Genetics**
        - 4.1.1.Circumpolar genetic data
        - 4.1.2.Population structure in the North Pacific
    - **4.2. Movement data**
        - 4.2.1.Satellite tracking in Alaska
        - 4.2.2.Distribution, diving and feeding behaviour in bearded seals
        - 4.2.3.Satellite tracking in Greenland
    - **4.3. Hunting statistics**
        - 4.3.1.Greenland
        - 4.3.2.Alaska
    - **4.4. Acoustics**
        - 4.4.1.Chukchi Sea
        - 4.4.2.Svalbard
    - **4.5. Indigenous Knowledge and Local Knowledge**
    - **4.6. General Discussion: management zones as a way forward for assessments?**

Day 2

5. **Bearded seal abundance, health, condition and population status**
    - **5.1. Abundance**
        - 5.1.1.Bering and Chukchi Seas
        - 5.1.2.Estimates based on close-kin mark-recapture
        - 5.1.3.Greenland surveys
        - 5.1.4.Canada surveys
    - **5.2. Growth, condition, population parameters, vital rates and energetics**
        - 5.2.1.Nunavut
        - 5.2.2.Labrador
        - 5.2.3.Alaska
        - 5.2.4.Svalbard
        - 5.2.5.Energetics and metabolism
        - 5.2.6.Publicly available information on bearded seals in Russia
    - **5.3. General Discussion and Gap analysis**

Day 3

6. **Other issues**
    - **6.1. Threats to bearded seals (including climate change)**
        - 6.1.1.Health issues, harmful algae, and parasites in Alaska
        - 6.1.2.Health assessment of harvested and found dead seals
        - 6.1.3.Shipping threats to bearded seals
        - 6.1.4.Climate change issues

11. APPENDIX 3: LIST OF BACKGROUND DOCUMENTS

Title/reference	Document type
Ahonen, H., Stafford, K. M., de Steur, L., Lydersen, C., Wiig, Ø., & Kovacs, K. M. (2017). The underwater soundscape in western Fram Strait: Breeding ground of Spitsbergen's endangered bowhead whales. *Marine Pollution Bulletin*, *123*(1–2), 97–112. https://doi.org/10.1016/j.marpolbul.2017.09.019	Research article
Bengtsson, O., Hamilton, C. D., Lydersen, C., Andersen, M., & Kovacs, K. M. (2021). Distribution and habitat characteristics of pinnipeds and polar bears in the Svalbard Archipelago, 2005–2018. *Polar Research*, *40*. https://doi.org/10.33265/polar.v40.5326	Research article
Breed, G., Cameron, M., Ver Hoef, J., Boveng, P., Whiting, A., & Frost, K. (2018). Seasonal sea ice dynamics drive movement and migration of juvenile bearded seals Erignathus barbatus. *Marine Ecology Progress Series*, *600*, 223–237. https://doi.org/10.3354/meps12659	Research article
Carroll, S. S., Horstmann-Dehn, L., & Norcross, B. L. (2013). Diet history of ice seals using stable isotope ratios in claw growth bands. *Canadian Journal of Zoology*, *91*(4), 191–202. https://doi.org/10.1139/cjz-2012-0137	Research article
Citta, J. J., Lowry, L. F., Quakenbush, L. T., Kelly, B. P., Fischbach, A. S., London, J. M., Jay, C. V., Frost, K. J., Crowe, G. O., Crawford, J. A., Boveng, P. L., Cameron, M., Von Duyke, A. L., Nelson, M., Harwood, L. A., Richard, P., Suydam, R., Heide-Jørgensen, M. P., Hobbs, R. C., … Gray, T. (2018). A multi-species synthesis of satellite telemetry data in the Pacific Arctic (1987–2015): Overlap of marine mammal distributions and core use areas. *Deep Sea Research Part II: Topical Studies in Oceanography*, *152*, 132–153. https://doi.org/10.1016/j.dsr2.2018.02.006	Research article
Correa, L., Castellini, J. M., Quakenbush, L. T., & O'Hara, T. M. (2015). Mercury and selenium concentrations in skeletal muscle, liver, and regions of the heart and kidney in bearded seals from Alaska, USA: Hg and Se by region in bearded seal heart and kidney. *Environmental Toxicology and Chemistry*, *34*(10), 2403–2408. https://doi.org/10.1002/etc.3079	Research article
Crance, J. L., Berchok, C. L., Kimber, B. M., Harlacher, J. M., Braen, E. K., & Ferguson, M. C. (2022). Year-round distribution of bearded seals, Erignathus barbatus, throughout the Alaskan Chukchi and northern Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, *206*, 105215. https://doi.org/10.1016/j.dsr2.2022.105215	Research article
Crawford, J. A., Quakenbush, L. T., & Citta, J. J. (2015a). A comparison of ringed and bearded seal diet, condition and productivity between historical (1975–1984) and recent (2003–2012) periods in the Alaskan Bering and Chukchi seas. *Progress in Oceanography*, *136*, 133–150. https://doi.org/10.1016/j.pocean.2015.05.011	Research article
Descamps, S., Aars, J., Fuglei, E., Kovacs, K. M., Lydersen, C., Pavlova, O., Pedersen, Å. Ø., Ravolainen, V., & Strøm, H. (2017). Climate change impacts on wildlife in a High Arctic archipelago—Svalbard, Norway. *Global Change Biology*, *23*(2), 490–502. https://doi.org/10.1111/gcb.13381	Research article
Foster, G., Nymo, I., Kovacs, K., Beckmen, K., Brownlow, A., Baily, J., Dagleish, M., Muchowski, J., Perrett, L., Tryland, M., Lydersen, C., Godfroid, J., McGovern, B., & Whatmore, A. (2018a). First isolation of Brucella pinnipedialis and detection of Brucella antibodies from bearded seals Erignathus barbatus. *Diseases of Aquatic Organisms*, *128*(1), 13–20. https://doi.org/10.3354/dao03211	Research article
Hamilton, C. D., Kovacs, K. M., & Lydersen, C. (2018). Individual variability in diving, movement and activity patterns of adult bearded seals in Svalbard, Norway. *Scientific Reports*, *8*(1), 16988. https://doi.org/10.1038/s41598-018-35306-6	Research article

Hamilton, C. D., Lydersen, C., Aars, J., Acquarone, M., Atwood, T., Baylis, A., Biuw, M., Boltunov, A. N., Born, E. W., Boveng, P., Brown, T. M., Cameron, M., Citta, J., Crawford, J., Dietz, R., Elias, J., Ferguson, S. H., Fisk, A., Folkow, L. P., … Kovacs, K. M. (2022a). Marine mammal hotspots across the circumpolar Arctic. *Diversity and Distributions*, *28*(12), 2729–2753. https://doi.org/10.1111/ddi.13543	Research article
Hamilton, C., Kovacs, K., & Lydersen, C. (2019). Sympatric seals use different habitats in an Arctic glacial fjord. *Marine Ecology Progress Series*, *615*, 205–220. https://doi.org/10.3354/meps12917	Research article
Hamilton, C., Lydersen, C., Aars, J., Biuw, M., Boltunov, A., Born, E., Dietz, R., Folkow, L., Glazov, D., Haug, T., Heide-Jørgensen, M., Kettemer, L., Laidre, K., Øien, N., Nordøy, E., Rikardsen, A., Rosing-Asvid, A., Semenova, V., Shpak, O., … Kovacs, K. (2021). Marine mammal hotspots in the Greenland and Barents Seas. *Marine Ecology Progress Series*, *659*, 3–28. https://doi.org/10.3354/meps13584	Research article
Hamilton, C., Lydersen, C., Fedak, M., Freitas, C., Hindell, M., & Kovacs, K. (2019). Behavioural ontogeny of bearded seals Erignathus barbatus through the first year of life. *Marine Ecology Progress Series*, *627*, 179–194. https://doi.org/10.3354/meps13072	Research article
Hindell, M. A., Lydersen, C., Hop, H., & Kovacs, K. M. (2012). Pre-Partum Diet of Adult Female Bearded Seals in Years of Contrasting Ice Conditions. *PLoS ONE*, *7*(5), e38307. https://doi.org/10.1371/journal.pone.0038307	Research article
Huntington, H. P., Quakenbush, L. T., & Nelson, M. (2016). Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska from traditional knowledge interviews. *Biology Letters*, *12*(8), 20160198. https://doi.org/10.1098/rsbl.2016.0198	Research article
Huntington, H. P., Quakenbush, L. T., & Nelson, M. (2017). Evaluating the Effects of Climate Change on Indigenous Marine Mammal Hunting in Northern and Western Alaska Using Traditional Knowledge. *Frontiers in Marine Science*, *4*, 319. https://doi.org/10.3389/fmars.2017.00319	Research article
Jensen, S. K., Aars, J., Lydersen, C., Kovacs, K. M., & Åsbakk, K. (2010). The prevalence of Toxoplasma gondii in polar bears and their marine mammal prey: Evidence for a marine transmission pathway? *Polar Biology*, *33*(5), 599–606. https://doi.org/10.1007/s00300-009-0735-x	Research article
Kovacs, K. M., Krafft, B. A., & Lydersen, C. (2020). Bearded seal (*Erignathus barbatus*) birth mass and pup growth in periods with contrasting ice conditions in Svalbard, Norway. *Marine Mammal Science*, *36*(1), 276–284. https://doi.org/10.1111/mms.12647	Research article
Kovacs, K. M., Lydersen, C., Overland, J. E., & Moore, S. E. (2011). Impacts of changing sea-ice conditions on Arctic marine mammals. *Marine Biodiversity*, *41*(1), 181–194. https://doi.org/10.1007/s12526-010-0061-0	Research article
Laidre, K. L., Stern, H., Kovacs, K. M., Lowry, L., Moore, S. E., Regehr, E. V., Ferguson, S. H., Wiig, Ø., Boveng, P., Angliss, R. P., Born, E. W., Litovka, D., Quakenbush, L., Lydersen, C., Vongraven, D., & Ugarte, F. (2015). Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century: Arctic Marine Mammal Conservation. *Conservation Biology*, *29*(3), 724–737. https://doi.org/10.1111/cobi.12474	Research article
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