The influence of temperature on the prevalence of skin lesions in beluga whales

by

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Abstract

Increasing temperatures create a source of stress and increased risk of disease in Arctic species. Many cetaceans have been reported to have skin infections with characteristic lesions. The prevalence of some of these infections has been linked to changes in salinity, temperature, and group size. Although skin lesions have been reported in beluga whales (*Delphinapterus leucas*), no studies have examined the factors influencing lesion prevalence in this species. The objective of this study was to determine if there is a relationship between these lesions and sea surface temperature. Underwater cameras and citizen science were used to observe and classify lesions as pigmentation, ulcers, or pock marks. Lesion prevalence was then compared to sea surface temperatures from the day, week, and month the photo was taken, along with that of the previous day, week, and month using logistic regression. Lesion prevalence decreased with increasing water temperature. Pigmentation lesions decreased as daily and previous day's temperatures increased, while ulcer and pock mark prevalence decreased as monthly temperatures increased. There is a relationship between temperature and lesions, but there are likely other factors at play, such as moulting, salinity, age class, grouping size, or sex. While no signs of stress related to warmer water temperatures in the summer habitat were found, emerging patterns indicate directions for future research into the threats that beluga whales face.

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Contents

Abstract i

Acknowledgments ii

List of Tables iv

List of Figures v

Introduction 1

Methods and Materials 6

Results 12

Discussion 16

Citations 22

List of Tables

Table 1. The number of photos examined by year, the number of excellent quality photos used for lesion assessment, and the proportion of individuals where a condition was present. One image could be marked as having more than one condition. Proportion of any lesion was calculated from the excellent quality photos, while proportion of each lesion type was calculated just from the number of images marked that any lesion type was present..... 12
Table 2. Generalised linear mixed models results for the correlation between sea surface temperature and skin lesion presence. Each model included one lesion type and one water temperature variable, with year included as a random effect. Significant results are highlighted in green..... 14

List of Figures

Figure 1. A. Beluga whale (*Delphinapterus leucas*) skin lesion suspected to be caused by an alphaherpes virus. – Reprinted from "Alphaherpesvirus: isolation, identification, partial characterisation, associated pathologic findings, and epidemiology in beluga whales (*Delphinapterus leucas*) in Alaska and Arctic Canada" by O. Nielsen, K. Burek-Huntington, L. Loseto, M. Morell, and C. Romero, 2018, Arctic Science, 4:338-357. Licensed under CC BY 4.0. B. Tattoo skin disease on a dusky dolphin (*Lagenorhynchus* obscurus) – Reprinted from "Tattoo skin disease in Cetacea: A review, with new cases for the northeast Pacific" by M. Van Bressem, K. Van Waerebeek, and P. Duignan, 2022, Animals, 12:3581. Licensed under CC BY 4.0. C. Clustered lesions on a bottlenose dolphin (*Tursiops truncatus*). – Reprinted from "Seasonal prevalence of skin lesions on dolphins across a natural salinity gradient" by M. Guinn, C. Toms, C. Sinclaire, and D. Orbach, 2024, Sustainability, 16: 4260. Licensed under CC BY 4.0. D. Grey patches on a southern resident killer whale (*Orcinus orca*). – Reprinted from "Epidemiology of skin changes in endangered southern resident killer whales (*Orcinus orca*)" by J. Gaydos, J. Leger, S. Raverty, H. Nollens, M, Haulena, E. Ward, C. Emmons, M. Hanson, K. Balcomb, D. Ellifrit, M. Weiss, and D. Giles, 2023, PLos ONE, 18: e0286551. Licensed under CCO 1.0..... 2

Figure 2. Map of the Churchill River estuary and surrounding area. A red dot has been placed at the coordinates used to gather sea surface temperature data (58.76346°, -94.204889°). Adapted from "Beluga (*Delphinapterus leucas*) response to personal watercraft and motorized whale watching vessels in the Churchill River estuary" by E. Ausen, M. Marcoux, W. Chan, and D. Barber, 2022, Frontiers in Marine Science, 9: 837425. Licensed under CC BY 4.0..... 7

Figure 3. Example image and tasks from Beluga Bits "Spots, Specks, and Streaks" workflow on Zooniverse..... 9

Figure 4. Beluga whales with pigmentation (A), ulcers (B), pock marks (C), fetal folds (D), rake marks (E), and scarring (F)..... 10

Figure 5. The proportion of individual beluga whale (Delphinapterus leucas) classified as having any skin condition, pigmentation, ulcers, and pock marks from 2016-2024 (excluding 2020) by month..... 13

Figure 6. Relationships between (A,B) the daily water surface temperature (°C) of the Churchill River estuary and (C,D) that of the previous day and the probability of beluga whales having (A,C) any lesions and having (B,D) pigmentation lesions from 2016-2024 (excluding 2020)..... 15

Figure 4. Relationship between the (A) average weekly surface temperature (°C) of the Churchill River estuary and (B) that of the previous week and the probability of beluga whales having a skin lesion from 2016-2024 (excluding 2020)..... 15
Figure 5. Relationship between the (A,B,C) average monthly surface temperature (°C) of the Churchill River estuary and that of the (D) previous month and the probability of beluga whales having (A,D) any lesions and having (B) pock marks or (C) ulcer lesions from 2016-2024 (excluding 2020).. 16
Figure 6. Adult Burrunan dolphin (*Turnisops australis*) found dead in Lake King North in Australia in 2007 (A,B). Adapted from "Fresh water skin disease in dolphins: a case definition based on pathology and environmental factors in Australia" by P. Duignan, N. Stephens, and K. Robb, 2020, Scientific Reports, 10:21979. Licensed under CC BY 4.0. Adult beluga whales (*Delphinapterus leucas*) photographed in the Churchill River estuary between 2016 and 2024 (C,D)..... 19

Introduction

Increasing temperatures due to human activities are causing environmental changes on a global scale (Cohen et al. 2020). This change is especially apparent in the Arctic, where temperatures are increasing four times more rapidly than the global average (Chylek et al. 2022). This means that Arctic species are at a higher risk of climate-induced stress and exposure to novel pathogens when climate warming allows new species to survive in the Arctic (Cohen et al. 2020). While infectious diseases are a part of natural population dynamics, an increase in infection could cause population decline (Verborgh et al. 2019).

Many cetaceans have been reported to show evidence of infectious skin diseases, such as herpes or pox viruses (Van Bressem et al. 2009; Nielsen et al. 2018; Gaydos et al. 2023). These diseases often cause characteristic skin lesions (Figure 1) (Mikaelian et al. 2001; Krasnova et al. 2015; Nielsen et al. 2018; Croft et al. 2020). However, these lesions are often poorly understood as they cannot be easily sampled, assessed, or diagnosed in cetaceans due to their primarily marine habitat, which makes them difficult to sample. Some skin lesion samples have been analyzed, mostly from live animals, typically those living in human care or from deceased wild individuals, making culturing difficult (Nielsen et al. 2018; Croft et al. 2020). This leaves most information regarding infectious agents relying on assumptions from comparing lesion appearance to identified diseases in other animals (Hamilton and Marx 2005; Guinn et al. 2024).

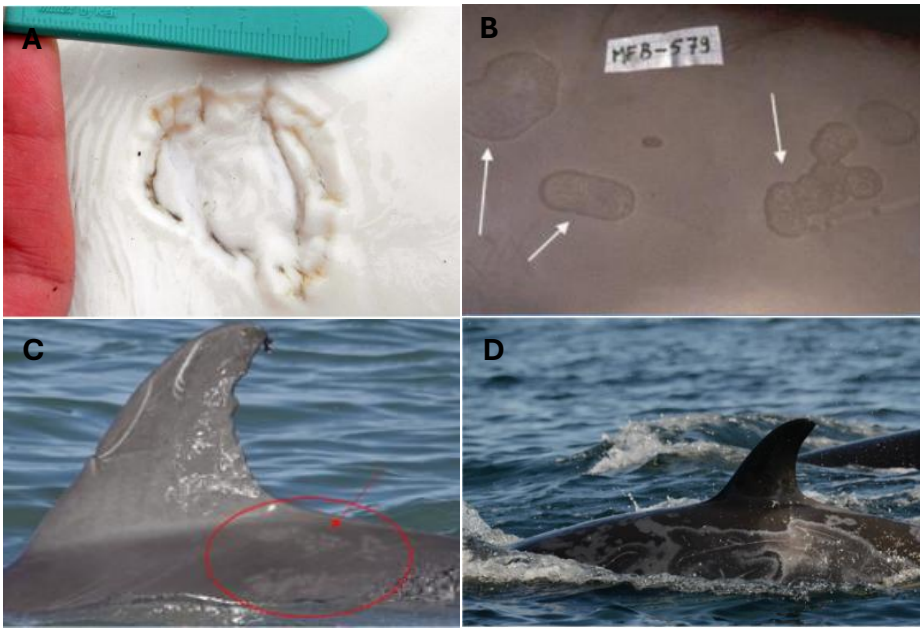

Figure 7. A. Beluga whale (*Delphinapterus leucas*) skin lesion suspected to be caused by an alphaherpes virus. – Reprinted from "Alphaherpesvirus: isolation, identification, partial characterisation, associated pathologic findings, and epidemiology in beluga whales (*Delphinapterus leucas*) in Alaska and Arctic Canada" by O. Nielsen, K. Burek-Huntington, L. Loseto, M. Morell, and C. Romero, 2018, Arctic Science, 4:338-357. Licensed under CC BY 4.0. B. Tattoo skin disease on a dusky dolphin (*Lagenorhynchus obscurus*) – Reprinted from "Tattoo skin disease in Cetacea: A review, with new cases for the northeast Pacific" by M. Van Bressem, K. Van Waerebeek, and P. Duignan, 2022, Animals, 12:3581. Licensed under CC BY 4.0. C. Clustered lesions on a bottlenose dolphin (*Tursiops truncatus*). – Reprinted from "Seasonal prevalence of skin lesions on dolphins across a natural salinity gradient" by M. Guinn, C. Toms, C. Sinclaire, and D. Orbach, 2024, Sustainability, 16: 4260. Licensed under CC BY 4.0. D. Grey patches on a southern resident killer whale (*Orcinus orca*). – Reprinted from "Epidemiology of skin changes in endangered southern resident killer whales (*Orcinus orca*)" by J. Gaydos, J. Leger, S. Raverty, H. Nollens, M, Haulena, E. Ward, C. Emmons, M. Hanson, K. Balcomb, D. Ellifrit, M. Weiss, and D. Giles, 2023, PLos ONE, 18: e0286551. Licensed under CCO 1.0.

The presence of certain viral infections can be inferred from the modifications they cause on the skin. Pox viruses are known to infect cetaceans and create characteristic lesions. One presentation, known as tattoo skin disease, creates large, discoloured spots on several odontocete species, such as bottlenose dolphins (*Tursiops truncatus*; Van Bressem et al. 2009; Croft et al. 2020) and

bowhead whales (*Balaena mysticetus*; Van Bressem et al. 2022) (Figure 1). Lesions caused by herpes viruses have been confirmed in beluga whales (*Delphinapterus leucas*) originating from Hudson Bay, and evidence of similar lesions has been observed in other beluga populations (Krasnova et al. 2015; Nielsen et al. 2018). Other infectious agents, such as bacteria and fungi, are also suspected to cause skin diseases in cetaceans; however, cultures are often unsuccessful in determining the exact agent responsible (Mikaelian et al. 2001; Russo et al. 2018).

In bottlenose and Burrunan dolphins (*T. australis*), the prevalence of skin lesions is negatively correlated with salinity and temperature, while in North Atlantic right whale and killer whale populations, prevalence has shown links with grouping and age (Wilson et al. 1999; Hamilton and Marx 2005; Van Bressem et al. 2009; Croft et al. 2020; Duignan et al. 2020; Guinn et al. 2024; Nicholls et al. 2026). The negative correlation between age and disease is likely due to younger individuals having a less-developed immune system (Banuet-Martinez et al. 2017).

A lack of infectious vectors in the Arctic contributes to relatively low levels of infectious disease in Arctic species; however, due to warming climates, there is likely to be an increase in infectious disease in Arctic populations (Barratclough et al. 2023). In marine mammals, the increase in viral infections has been linked to close contact in winter due to the lack of sea ice, while bacterial and parasitic infections may be increasing due to the range expansion of infectious agents when northern temperatures increase (VanWormer et al. 2019; Barratclough et al. 2023). Changes in lesion prevalence under different environmental conditions may be due

to stress or optimal temperatures for the infectious agent; bacteria often have an optimum temperature at which the rate of growth increases (Adams et al. 2010; Cohen et al. 2020).

Beluga whales are a species of toothed whale native to the Arctic and subarctic placed in the family Monodontidae, along with the narwhal (*Monodon monoceros*) (Stewart and Stewart 1989; Hobbs et al. 2019). Beluga whales have no dorsal fin and are white as adults; newborns are grey to brown and become lighter with age (Stewart and Stewart 1989). Beluga whales go through an annual moult, shedding cellular debris and stratum externum in the summer after it builds up over winter (St. Aubin et al. 1990). At birth, they average 1.5 metres long and grow to approximately 2.6-4.5 metres at maturity, depending on sex and population (COSEWIC 2020). Beluga whales have a circumpolar distribution and can be found off the coast of Russia, the United States, Canada, Greenland, and Norway (Hobbs et al. 2019).

The Eastern Hudson Bay, Ungava Bay, and Cumberland Sound populations of beluga whales are considered Threatened or Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and the Western Hudson Bay population is assessed as stable and not at risk (COSEWIC 2020). In 2015, the Western Hudson Bay population was estimated to have over 50,000 individuals (Matthews et al. 2017). Western Hudson Bay beluga whales spend the winter in the Hudson and Davis straits and migrate to estuaries in Ontario and Manitoba in spring, primarily the Seal River, Churchill River, and Nelson River (Hobbs et al. 2019).

Estuaries have a mix of freshwater and marine water, in the Arctic they undergo a complete annual freeze-thaw cycle. Beluga whales migrate into the estuary after ice breakup in late spring/early summer and migrate out of the estuaries before the surface freezes in the fall (Kuzyk et al. 2008). Despite research on skin lesions in other cetacean species, there has been little research on the environmental or demographic factors that impact the prevalence of skin lesions in beluga whales.

Marine mammals are often difficult to sample directly in the wild due to their marine habitat and behaviour. Photography offers a non-invasive method to monitor difficult-to-sample populations (McGuire et al. 2020). This data collection method is frequently used to monitor marine mammals, especially whales, and gain insight into social structure, reproduction, behaviour, population structure and dynamics, and to monitor health (McGuire et al. 2020; Moore et al. 2021; Ryan et al. 2022; Gaydos et al. 2023). Collecting data from an above-water platform is effective for counts and identification, while underwater cameras allow a larger portion of the individual's body to be viewed and may provide advantages to assess a greater portion of the focal individual (Westphal et al. 2022).

The purpose of this study is to determine the prevalence of skin lesions in beluga whales from the Churchill River estuary and compare them to a sea surface temperature dataset to determine the potential influence of water temperature on disease transmission and prevalence. I hypothesised that the prevalence of skin lesions would change with changes in sea surface temperature. I predicted that at higher water temperatures, there would be a higher prevalence of lesions. This is

because beluga whales are a cold-adapted species and may be more susceptible to infection when stressed by warm water temperatures (Wilson et al. 1999; Harvell et al. 2002). I also hypothesise that different skin lesion types arise from different infectious agents and therefore may respond differently to changes in water temperature. Additionally, I predicted that no relationships would be found with the water surface temperature from the day the photo was taken, or the day before, since infections need time to take effect. This will help us understand the possible impacts of climate change and warming Arctic waters on the health of beluga whales.

Methods and Materials

Data collection took place in the Churchill River estuary (Figure 2). This estuary is approximately 13 kilometres long and 3 kilometres wide at high tide (Kuzyk et al. 2008). During summer, 2,000-3,000 beluga whales are estimated to reside in this area (Matthews et al. 2017).

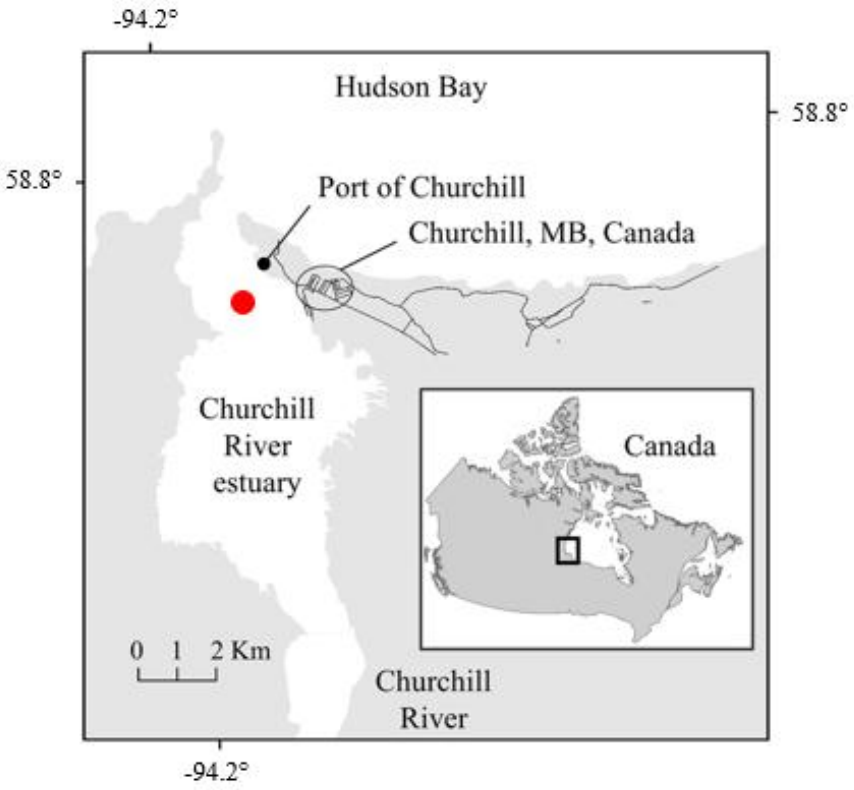

Figure 8. Map of the Churchill River estuary and surrounding area. A red dot has been placed at the coordinates used to gather sea surface temperature data (58.76346°, -94.204889°). Adapted from "Beluga (*Delphinapterus leucas*) response to personal watercraft and motorized whale watching vessels in the Churchill River estuary" by E. Ausen, M. Marcoux, W. Chan, and D. Barber, 2022, Frontiers in Marine Science, 9: 837425. Licensed under CC BY 4.0.

Photos were collected from 2016 to 2024, in collaboration with Polar Bears International and Explore.org, using the equipment and protocols outlined in Westphal et al. (2022). Depending on the year, a video camera was mounted on the stern of an aluminium hull boat or on the side of an inflatable hull boat. The boats were operated for approximately four hours each day, two hours before and after high tide, from approximately July 15th to September 1st, though exact dates varied between years. The boat operators piloted the boat into the vicinity of the whales

while not actively pursuing them, then would either drift or move under an idle to maintain position in the current. Whales could choose to approach and follow the boat. Slow moving motorboats have been shown to have negligible negative effect on beluga behaviour in Churchill, so researchers have been able to mount cameras on boats to get an underwater view of the whales with minimal disturbance (Ausen et al. 2022). This method is considered non-invasive and allows the whales to be viewed from multiple angles, often providing images of markings over the whole body (Westphal et al. 2022).

Extracted frames of the raw footage were uploaded to the citizen science website Zooniverse.org in the Beluga Bits project (https://www.zooniverse.org/projects/stephenresearch/beluga-bits). Zooniverse is a site that allows volunteers to participate in scientific research by classifying photos and videos for various projects. Classifying is done through workflows, where researchers set up questions about each image. Beluga Bits is a Zooniverse project run by the Assiniboine Park Conservancy and is used to study beluga in the Churchill River Estuary. For this project, photos were initially uploaded to the General Photo Classification and Beluga Bodies workflows, where volunteers were asked to assess the photo quality and if a whale was present. Volunteers were also asked to draw boxes around each beluga, allowing images to be divided into individual subject photos. Workflows began with a tutorial, guiding volunteers on how to classify photos. For this project, I used photos of individual beluga marked as excellent quality by at least 7 participants out of 10 total raters.

These excellent quality photos were then uploaded to the 'Spots, Specs, and Streaks' workflow designed for this research project. In this workflow, participants were first asked if the focal beluga had any kind of skin condition. If they answered no, they were presented with a new image of a different beluga. If they answered yes, they were asked to classify the type of lesion present as pigmentation, ulcers, pock marks, or other (Figure 3). These lesions are of unknown origin and were categorised based on appearance.

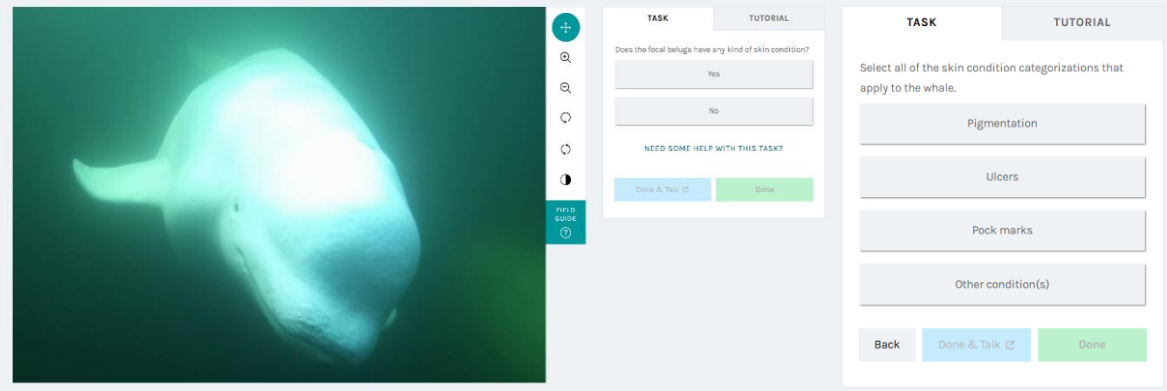

Figure 9. Example image and tasks from Beluga Bits "Spots, Specks, and Streaks" workflow on Zooniverse.

Pigmentation refers to areas that are lighter or darker than the surrounding skin and can be any shape, ulcers are defined as circular lesions that look rough in the center and pock marks are clusters of small indentations in the skin (Figure 4). An 'other' category was also included for skin abnormalities that may not fit in any of the three categories, but this category was not included in analysis. Other skin anomalies seen on beluga whales include rake marks, fetal folds, moulting skin, and scarring (Figure 4). Different lesion types are thought to be caused by different pathogens or may represent different stages of infection and healing due to the same pathogen. If they represent stages of the same infection, the prevalence might

shift from one type to another over time or prevalence might be correlated, representing a base level of infection in the population. Participants were provided with examples of each lesion type in the tutorial, along with images of characteristics that may be mistaken for skin conditions, such as rake marks, fetal folds, or moulting skin. Each image was classified by 10 participants before it considered complete and was "retired" and not assessed further. I considered a skin condition present on a beluga when it was identified by five or more people. For the specific lesion types, I considered it present if at least two participants selected the type. The workflow did allow for more than one lesion type to be indicated on the same beluga.

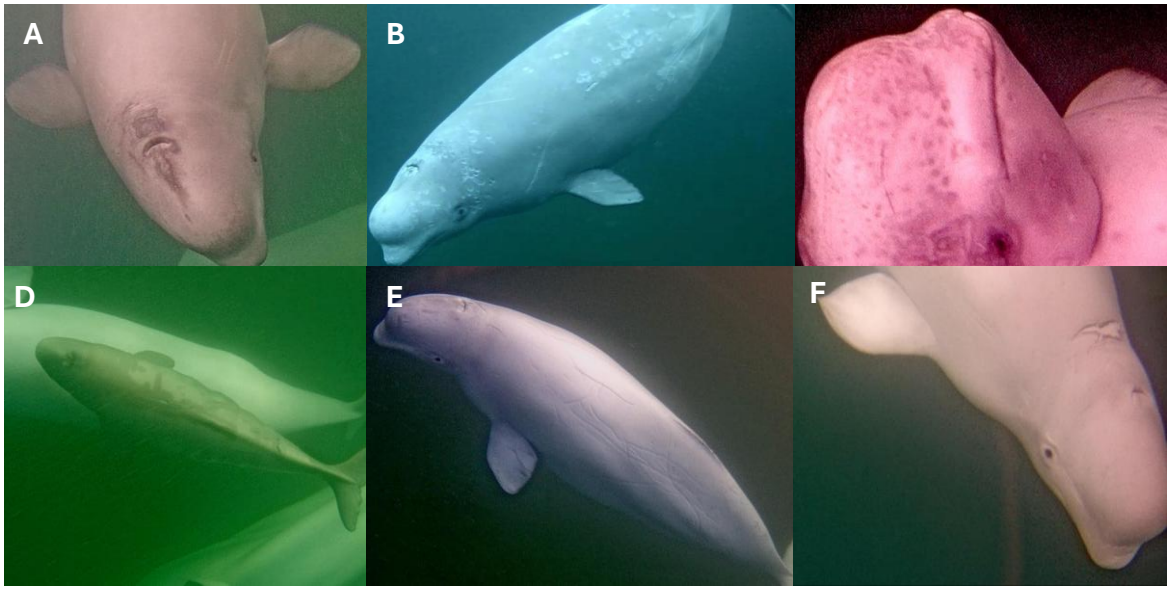

Figure 4. Beluga whales with pigmentation (A), ulcers (B), pock marks (C), fetal folds (D), rake marks (E), and scarring (F).

The sea surface temperature data were extracted from the NOAA 1/4° Daily Optimum Interpolation Sea Surface Temperature (OISST) dataset (Huang et al. 2020). These data were collected using satellites to measure sea surface

temperatures on a 2° × 2° basis and interpolated to 0.25° × 0.25° (Huang et al. 2020). I used an arbitrary point (lat. 58.768346°, long. -94.204889°) in the center of the Churchill River estuary to determine the sea surface temperature (Figure 2). Temperature data was downloaded and weekly and monthly temperatures were calculated by taking the average of daily temperatures for that period at this location during the study period. A generalised linear mixed model with a logit function was used to examine the relationship between water temperature and lesion presence. Models included the temperature variable for the time the photo was taken, daily, weekly, and monthly averages, along with those from previous time steps, previous day, previous week, and previous month, to account for potential differences in the incubation times of infections. The model was run separately for each temporal scale to avoid multicollinearity. Year was included as a random effect. Each temperature model was also run separately for each lesion type.

Statistical analyses were conducted using R Studio (Posit team 2025). R packages used for analysis were car, tidyverse, and lme4, and plotting was done with sjplot and ggplot2 (Bates et al. 2015; Wickham 2016; Fox and Weisberg 2019; Wickham et al. 2019; Lüdecke 2025). Statistical significance was assessed using an alpha value of 0.05. Variables with *p*-values below this threshold were considered to have significant relationships, and corresponding model coefficients were examined to determine the strength and direction of those relationships.

Results

Data was collected during July of every year except 2018, August of every year, and September of 2017 and 2021. The total number of images classified was 10,090. No data was included from 2020 due to poor water clarity and thus low image quality that year resulting in no photos being classified as excellent. The year with the highest number of excellent-quality photos was 2019 and the year with the least was 2022 (Table 1). July showed the highest proportion of individuals with lesions in all years and lesion types, except pigmentation in 2017, where a higher proportion of individuals had pigmentation lesions in August (Figure 5).

Table 3. The number of photos examined by year, the number of excellent quality photos used for lesion assessment, and the proportion of individuals where a condition was present. One image could be marked as having more than one condition. Proportion of any lesion was calculated from the excellent quality photos, while proportion of each lesion type was calculated just from the number of images marked that any lesion type was present.

Year	Total photos assessed	Excellent quality photos	Proportion with any lesion	Proportion with pigmentation	Proportion with ulcers	Proportion with pock marks
2016	20,106	2522	0.23	0.49	0.66	0.79
2017	14,896	1362	0.44	0.60	0.61	0.79
2018	7183	413	0.41	0.60	0.54	0.75
2019	30,766	2988	0.32	0.72	0.56	0.68
2021	26,237	1618	0.12	0.65	0.43	0.60
2022	18,286	102	0.50	0.47	0.55	0.80
2023	11 126	155	0.36	0.47	0.47	0.70
2024	20 185	920	0.23	0.31	0.49	0.86

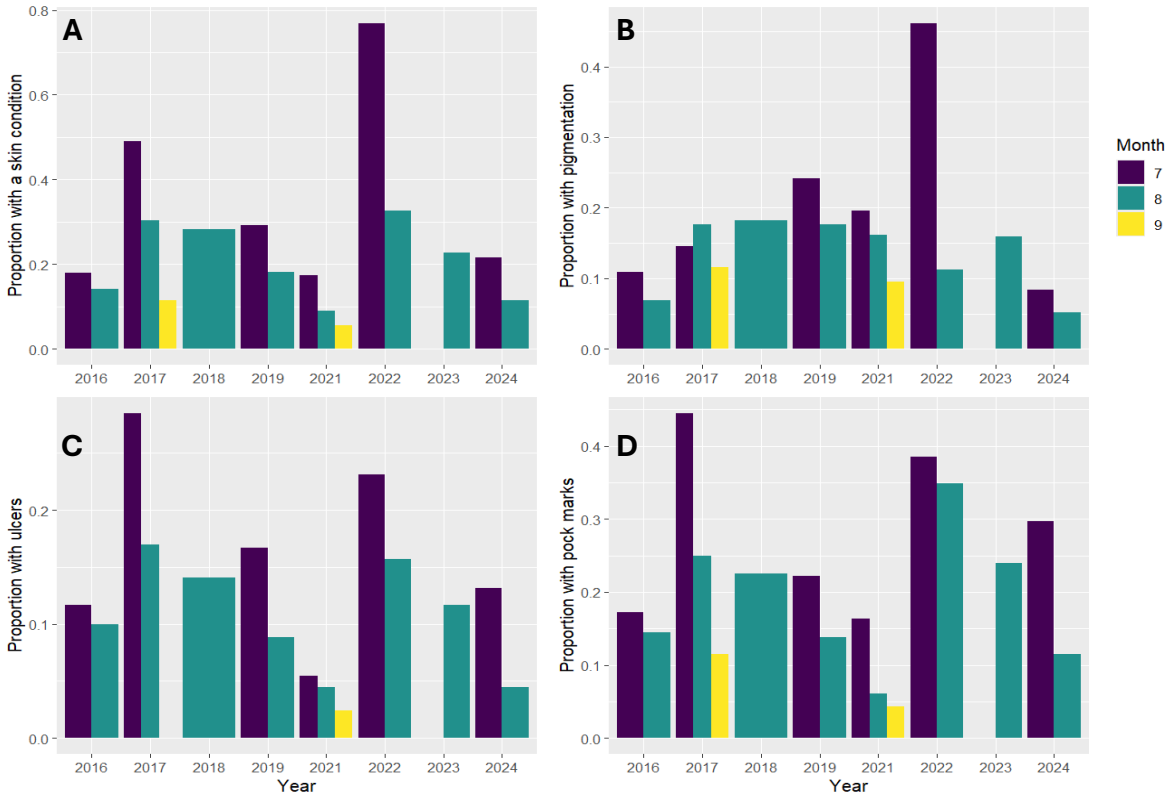

Figure 5. The proportion of individual beluga whale (*Delphinapterus leucas*) classified as having any skin condition, pigmentation, ulcers, and pock marks from 2016-2024 (excluding 2020) by month.

In all cases, the prevalence of skin lesions was found to either be negatively correlated or show no correlation with water temperature. The probability of a whale having a skin lesion decreased by 8% with each 1°C increase in daily water temperature and 10% with each 1°C increase of the previous day's temperature (Figure 6). A 7% decrease in probability of pigmentation lesions was observed with each 1°C increase in daily temperature and a 6% decrease with each 1° C increase in previous day's temperature (Figure 6). With each 1°C increase in the weekly temperature and that of the previous week, the probability of a whale having a skin lesion decreased by 11% and 10%, respectively (Figure 7). The average monthly

temperature showed significant relationships with the presence of any lesion, ulcers, and pock marks, with each 1°C increase in temperature showing a reduced probability of lesion presence by 11%, 3%, and 4%, respectively (Figure 8). The probability of a lesion being present decreased by 10% with each 1°C increase in the previous month's average temperature (Figure 8). No other relationships were significant (Table 2).

Table 4. Generalised linear mixed models results for the correlation between sea surface temperature and skin lesion presence. Each model included one lesion type and one water temperature variable, with year included as a random effect. Significant results are highlighted in green.

Lesion type	Temperature variable	Log-odds	Standard error	z	p
Any condition	Daily	-0.083	0.017	-4.77	<0.0001
	Previous day	-0.010	0.017	-5.97	<0.0001
	Weekly	-0.112	0.019	-6.03	<0.0001
	Previous week	-0.101	0.017	-5.92	<0.0001
	Monthly	-0.120	0.010	-11.68	<0.0001
	Previous Month	-0.096	0.010	-9.54	<0.0001
Pigmentation	Daily	-0.068	0.030	-2.23	0.026
	Previous day	-0.065	0.029	-2.25	0.025
	Weekly	-0.033	0.031	-1.08	0.279
	Previous week	-0.031	0.027	-1.14	0.255
	Monthly	0.027	0.016	1.61	0.108
	Previous Month	0.024	0.016	1.44	0.149
Ulcers	Daily	0.004	0.029	0.14	0.890
	Previous day	-0.001	0.027	-0.05	0.961
	Weekly	-0.016	0.030	-0.52	0.604
	Previous week	-0.014	0.026	-0.55	0.585
	Monthly	-0.032	0.016	-2.04	0.041
	Previous Month	-0.022	0.015	-1.43	0.153
Pock marks	Daily	-0.034	0.035	-0.99	0.324
	Previous day	-0.061	0.034	-1.83	0.067
	Weekly	-0.048	0.036	-1.32	0.188
	Previous week	-0.041	0.032	-1.27	0.206
	Monthly	-0.043	0.018	-2.36	0.018
	Previous Month	-0.031	0.018	-1.73	0.083

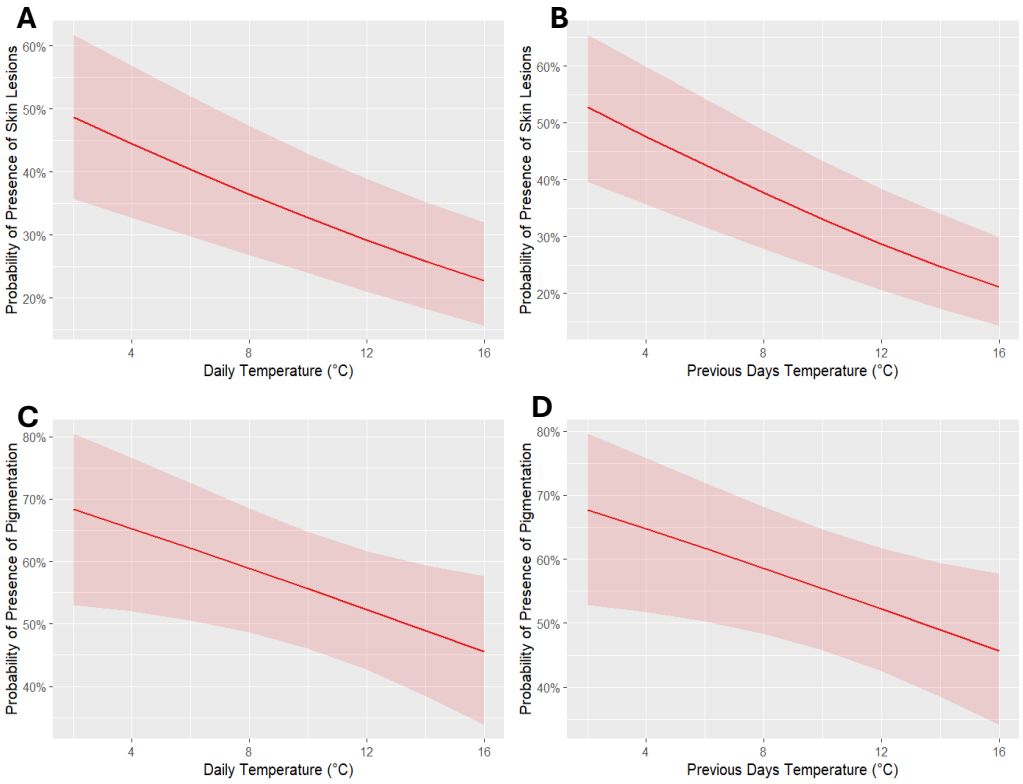

Figure 6. Relationships between (A,B) the daily water surface temperature (°C) of the Churchill River estuary and (C,D) that of the previous day and the probability of beluga whales having (A,C) any lesions and having (B,D) pigmentation lesions from 2016-2024 (excluding 2020).

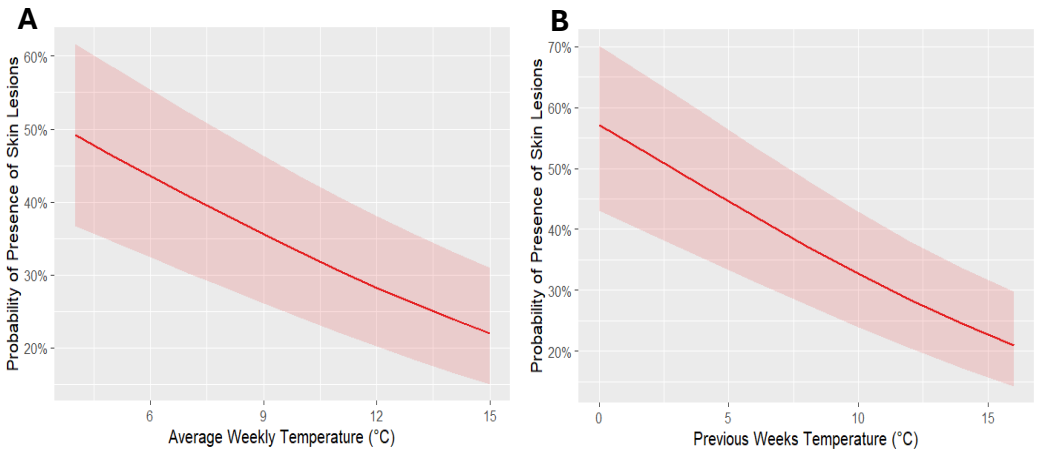

Figure 13. Relationship between the (A) average weekly surface temperature (°C) of the Churchill River estuary and (B) that of the previous week and the probability of beluga whales having a skin lesion from 2016-2024 (excluding 2020).

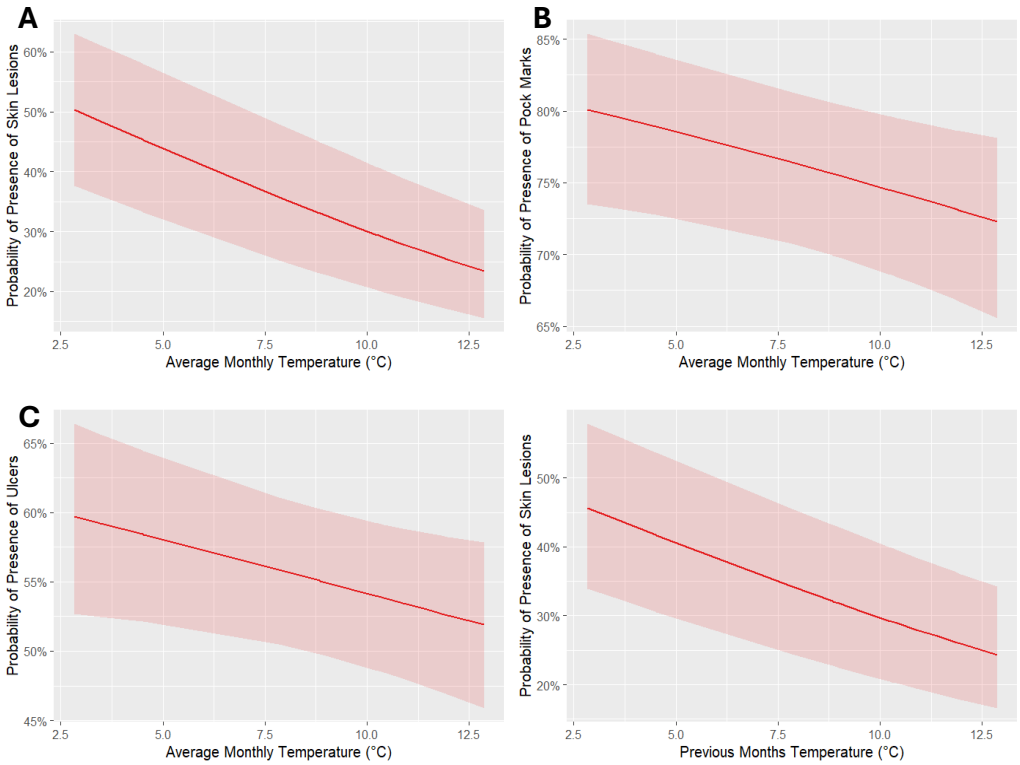

Figure 14. Relationship between the (A,B,C) average monthly surface temperature (°C) of the Churchill River estuary and that of the (D) previous month and the probability of beluga whales having (A,D) any lesions and having (B) pock marks or (C) ulcer lesions from 2016-2024 (excluding 2020).

Discussion

My results show that there is a relationship between sea surface temperature and the prevalence of skin lesions in beluga whales. Contrary to my predictions, as the temperature increased, there was a decrease in the probability of lesions being present. However, lesion types did differ in their relationships with temperature; pigmentation showed significant relationships with both daily and the previous day's temperature, while ulcers and pock marks only showed significant relationships with monthly temperature. These results suggest that while there is some

relationship between temperature and prevalence in my study area, there are likely other factors driving the presence of conditions.

Pigmentation lesions exhibited a pattern of increasing prevalence with decreasing temperatures on a daily basis, so the visual appearance of these marks may be influenced by temperature, rather than indicating infection. Beluga whales are known to move into warmer estuary environments which is thought to aid in moulting during the summer (St. Aubin et al. 1990). Colder temperatures interfering with the moulting process may be creating the pigmented patches seen on the beluga whales.

Defining pigmentation as areas lighter or darker than the surrounding skin makes it difficult to use these results to determine a potential cause. Lighter patches and darker patches could be the results of different processes. Using only images also prevents an understanding of what physiological process is causing the lesions, such as cellular changes taking place. This is also true for ulcers and pock marks, without tissue samples there is no way to tell what is causing the lesions to appear, only what may be influencing their presence.

The prevalence of ulcers and pock marks did not show a strong relationship with water temperature apart from monthly temperatures, so it is possible these markings are scars from a previous infection or were caused by a condition that is not strongly influenced by temperature. Both ulcers and pock marks showed a

similar relationship with monthly temperature, this could indicate that they are caused by the same pathogen, representing different stages of infection.

The lesions that were classified as ulcers also appear to be superficially similar to lesions caused by freshwater exposure in Burrunan and Pacific bottlenose dolphins (Figure 9) (Duignan et al. 2020). These dolphins are thought to have acquired the lesions in mixed salt and fresh water after a heavy rainfall decreased the salinity below a tolerable level (Duignan et al. 2020). While beluga whales are known to be more common in lower salinity water (Scharffenberg et al. 2019), it is possible they are impacted by lower salinity levels in similar ways. Duignan et al. (2020) reported dolphins being seen with lesions for months prior to finding the deceased individuals, the beluga whales could be reacting to the change in salinity as they move into the estuary, showing signs of some cellular changes.

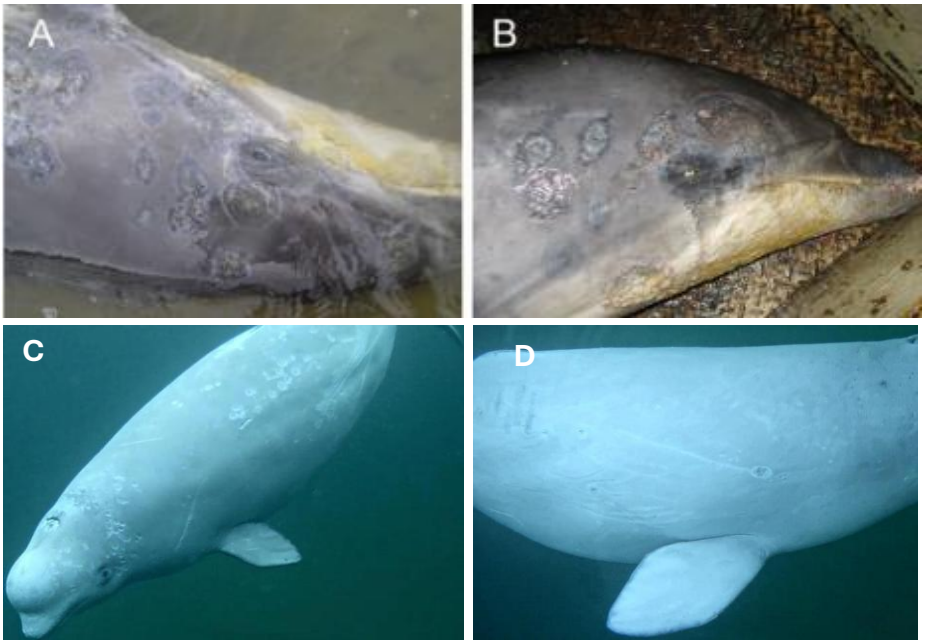

Figure 15. Adult Burrunan dolphin (*Turnisops australis*) found dead in Lake King North in Australia in 2007 (A,B). Adapted from "Fresh water skin disease in dolphins: a case definition based on pathology and environmental factors in Australia" by P. Duignan, N. Stephens, and K. Robb, 2020, Scientific Reports, 10:21979. Licensed under CC BY 4.0. Adult beluga whales (*Delphinapterus leucas*) photographed in the Churchill River estuary between 2016 and 2024 (C,D).

One major assumption of the analyses performed on this dataset is the independence of samples. Individual beluga whales are difficult to identify, so I did not attempt to determine if the same beluga whale is present in multiple photos in the dataset. Because the dataset was large and there are 2000-3000 whales in the estuary during the sampling months, it was assumed that this did not impact the results, but this is still something that may have affected my results. Future research should attempt to track disease progression on known individuals or remove repeated samples of the same individual within the same year.

Previous studies on other cetaceans have found a link between skin lesion prevalence and both age class and grouping size with younger individuals showing higher rates of infection and larger groups having higher prevalence (Wilson et al. 1999; Hamilton and Marx 2005; Van Bressem et al. 2009). These trends are likely due to younger individuals having less developed immune systems and larger groups having more contact and therefore more disease transmission (Banuet-Martinez et al. 2017). The age class of individuals was not assessed for the images included in this project, preventing any assessment of a relationship between age and prevalence. The relationship with grouping size is also difficult to assess with this dataset because whales can block the view of other individuals from the camera, water quality can prevent seeing whales further away, and individuals could simply be out of view. Additionally, during the first stages of classification photos, are split to create images of individuals so they can be more easily assessed. Due to these reasons, there was no attempt to determine the grouping sizes.

Studies on disease in other mammals have found relationships between disease prevalence and sex, generally with males having more incidence of disease than females (Folstad and Karter 1992). The immunocompetence handicap hypothesis suggests that testosterone acts as an immunosuppressant creating a negative feedback loop between secondary sex characteristics and infection (Folstad and Karter 1992). There is conflicting evidence of this relationship in cetaceans; Gaydos et al. (2023) found that older female killer whales were less likely to be seen with certain lesion types than males or younger females, while Guinn et

al. (2024) found no evidence that lesion prevalence in bottlenose dolphins differs between sexes. In harbour porpoises (*Phocoena spinipinnis*), males show a 2 times higher rate of tattoo skin disease compared to females (Van Bressem et al. 2022). No attempt was made to sex the beluga whales in this project as the orientation of individuals within the photos often doesn't allow for sex to be determined. Assessing the relationships between lesions and sex, age, and grouping size may be a good next step.

Another hypothesis is that the prevalence of skin conditions is linked to winter conditions. This study incorporated the surface water temperatures in the whales' summer habitat, but beluga spend the winter in the Hudson and Davis Straits. The sea surface temperature in these areas over the winter, or the freeze-up and break-up dates of ice, may have a greater influence on skin condition prevalence than temperature in the summer. The proportion of individuals classified as having skin lesions was shown to decrease throughout the summer in every year except 2017. This could indicate that lesions are being acquired in the winter or spring and are healing throughout the summer.

There is little information on the progression of diseases and non-disease skin lesions in whales. Most research focuses on identifying disease, transmission factors, and mortality. The lesions studied in this project are of unknown origin, there was no attempt to track lesion progression over time. To understand the impact of these lesions, learn more about the causes, and understanding transmission and influential environmental factors, it would be beneficial to understand the

progression from initial appearance to healing. This could be done by tracking individuals, taking repeated samples or images to learn about the changes in the lesions over time.

The findings that skin lesion prevalence in beluga whales decreases with an increase in sea surface temperature contradicts the initial hypothesis that beluga whales are experiencing high temperature stress in the summers but still indicates there is a relationship between environment and skin lesions. This indicates the need for future research into the pathology of lesions, relationships to other environmental variables such as salinity and winter temperatures, and lesion progression or healing over time. Arctic ecosystems are rapidly changing; it is important to understand the factors that could influence the health of Arctic species.

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