Temporal trends (2001 – 2021) of stable isotopes in the muscle and liver of beluga whales (*Delphinapterus leucas*) from the Eastern Beaufort Sea population in support of the Tarium Niryutait Marine Protected Area indicator evaluation

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by

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ABSTRACT

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The Eastern Beaufort Sea (EBS) beluga population, one of the largest beluga populations in Canada, is under increasing anthropogenic pressures including climate-related ecosystem changes and exposure to contaminants. The Tarium Niryutait Marine Protected Area (TN MPA), located in the Mackenzie Estuary, Northwest Territories, was designated in 2010 with the objective to "conserve and protect beluga whales and other marine species, their habitats and their supporting ecosystem". Carbon and nitrogen stable isotope ratios are used as ecological tracers that can provide insights into the structure of marine food webs and the diet of marine mammals that were selected as ecological indicators to monitor the effectiveness of the MPA. In this report, we present muscle and liver $\delta^{15}N$ and $\delta^{13}C$ (n = 482 and n = 469, respectively) samples collected from EBS belugas between 2001 and 2021. As $\delta^{15}N$ values in muscle and liver were correlated with each other in small ($R = 0.37$; $p < 0.01$), medium ($R = 0.37$; $p < 0.01$) and large whales ($R = 0.41$; $p < 0.01$), $\delta^{15}N$ trends observed in liver were overall similar to those reported in muscle. Due to the small sample size for small whales, no significant trends were observed over the study period except for $\delta^{15}N$ in liver ($R = 0.39$; $p < 0.01$) with values decreasing between 2001 and 2016 before slightly increasing. $\delta^{15}N$ and $\delta^{13}C$ values in the muscle of medium and large whales revealed similar non-linear trends between 2001 and 2021. In medium whales, $\delta^{15}N$ values in muscle declined until 2007/2008 before increasing non-linearly until 2021, while in large whales, $\delta^{15}N$ values remained fairly stable until 2008 before increasing until. $\delta^{13}C$ values increased between 2001 and 2006 and then declined until 2016/2017 before stabilizing in recent years in both medium and large whales. Taken together, these temporal variations resulted in minimal overlaps between the niches of whales sampled between 2013 and 2017 and those sampled between 2003 and 2007 suggesting that there was a shift in feeding areas between these two time periods led by lower $\delta^{13}C$ during the period 2013-2017. This $\delta^{13}C$ shift could be reflecting feeding occurring more predominantly within the Beaufort Sea food web as well as in more pelagic environments during 2013-2017. Results in trends support the use of $\delta^{15}N$ and $\delta^{13}C$ in muscle as an indicator for the TN MPA that can provide insights into food web shifts, yet we also recommend the evaluation of stable isotopes in lower trophic levels given the known geographical variations of $\delta^{15}N$ and $\delta^{13}C$ across the Bering Sea and Beaufort Sea along with the migratory path of the belugas.

RÉSUMÉ

Noël, M., Rosenberg, B., Wardekker, M., Neumann, D., Brewster, J., MacPhee, S., Loseto, L.L. 2026. Temporal trends (2001 – 2021) of stable isotopes in the muscle and liver of beluga whales (*Delphinapterus leucas*) from the Eastern Beaufort Sea population in support of the Tarium Niryutait Marine Protected Area indicator evaluation. Can. Tech. Rep. Fish. Aquat. Sci. 3825: vii + 35 p. https://doi.org/10.60825/8cmq-kj62

La population de bélugas de l'est de la mer de Beaufort (EMB), l'une des plus grandes populations de bélugas au Canada, est soumise à des pressions anthropiques croissantes, notamment des changements écosystémiques liés au climat et une exposition aux contaminants. La zone de protection marine Tarium Niryutait (ZPM TN), située dans l'estuaire du Mackenzie où les bélugas se rassemblent chaque été, a été désignée en 2010 dans le but de « conserver et protéger les bélugas et autres espèces marines, leurs habitats et leur écosystème associé». Les ratios d'isotopes stables du carbone et de l'azote sont utilisés comme traceurs écologiques et peuvent fournir des informations sur la structure des réseaux trophiques marins et le régime alimentaire des mammifères marins. Ils ont été sélectionnés comme indicateurs écologiques clés pour surveiller l'efficacité de l'AMP. Dans ce rapport, nous présentons les niveaux de δ^{15}N et de δ^{13}C dans des échantillons de muscle (n = 482) et de foie (n = 469) prélevés sur des bélugas de L'EMB entre 2001 et 2021. Comme les niveaux de δ^{15}N dans le muscle et le foie étaient corrélés entre eux chez les petites (R = 0.37; p < 0.01), moyennes (R = 0.37; p < 0.01) et les grandes baleines (R = 0.41; p < 0.01), les tendances δ^{15}N observées dans le foie étaient globalement similaires à celles trouvées dans les muscles. En raison de la petite taille de l'échantillon pour les petites baleines, aucune tendance significative n'a été observée au cours de la période d'étude, à l'exception de δ15N dans le foie (R = 0,39; p < 0,01), dont les niveaux ont diminué entre 2001 et 2016 avant d'augmenter légèrement. Les niveaux de δ^{15}N et δ^{13}C dans les muscles des moyennes et grandes baleines ont révélé des tendances non-linéaires similaires entre 2001 et 2021. Alors que les niveaux de δ15N dans les muscles ont diminué jusqu'en 2007/2008 avant d'augmenter de manière non linéaire jusqu'en 2021 chez les baleines de taille moyenne, les niveaux de δ^{15}N sont restés assez stable jusqu'en 2008 avant d'augmenter jusqu'en 2021 chez les grandes baleines. Les niveaux de δ13C ont augmenté entre 2001 et 2006 puis ont diminué jusqu'en 2016/2017 avant de se stabiliser ces dernières années chez les baleines de taille moyenne, semblable à ce qui a été observé chez les grandes baleines. Prises ensemble, ces variations temporelles ont entraîné des chevauchements minimes entre les niches alimentaires des baleines échantillonnées entre 2013 et 2017 et celles échantillonnées entre 2003 et 2007, ce qui suggère qu'il y a eu un changement dans les zones d'alimentation utilisées entre ces deux périodes, entraîné par une baisse de δ^{13}C au cours de la période 2013-2017. Ce changement de δ^{13}C pourrait refléter une alimentation qui se produirait plus principalement dans le réseau trophique de la mer de Beaufort ainsi que dans des environnements plus pélagiques durant 2013-2017.Nos résultats soutiennent l'utilisation de δ^{15}N et δ^{13}C dans le muscle comme indicateur du TN MPA qui peut fournir des informations sur les changements dans le réseau trophique, mais nous recommandons également l'évaluation de ces niveaux dans le contexte des valeurs d'isotopes stables pour les organismes situés plus

bas dans le réseau trophique étant donné les variations géographiques connues de $\delta^{15}N$ et $\delta^{13}C$ à travers la mer de Béring et la mer de Beaufort ainsi que le chemin migratoire des béluga

INTRODUCTION

The Eastern Beaufort Sea (EBS) beluga whale (*Delphinapterus leucas*) population is recognized as one of the largest in Canada, estimated at approximately 32,500 individuals (Harwood et al., 1996; Mayette et al., 2023). Every spring, the EBS beluga migrate from the Bering Sea to the Beaufort Sea where they spend their summer with high site fidelity to the Mackenzie Estuary where large aggregations of nearly 2,000 individuals have been recorded (Harwood et al., 1996, Harwood et al., 2014). It is in these waters where the Inuvialuit have harvested beluga for subsistence for hundreds of years (Alunik et al., 2003; McGhee 1988). Beluga continue to be part of a traditional way of life and provide food and cultural well-being to the Inuvialuit (Usher 2002; Waugh et al., 2018). As part of Inuvialuit being stewards of their resources, they, together with Fisheries and Oceans Canada (DFO) used a Marine Protected Areas (MPAs) area-based management tool to conserve and manage beluga as an important resource. The Tarium Niryutait Marine Protected Area (TN MPA), located in the Mackenzie Estuary was designated in 2010 with the objective to "conserve and protect beluga whales and other marine species, their habitats and their supporting ecosystem" (Gazette, 2010). It is made up of three separate and distinct sub-areas within the Mackenzie River Estuary where belugas aggregate each summer and subsistence harvesting occurs: Niaqunnaq (Shallow Bay), Okeevik (in Beluga Bay, east Mackenzie Bay near Kendall and Pelly Islands) and Kittigaryuit (Kugmallit Bay). To assess the effectiveness of regulations and other management activities in meeting the TN MPA conservation objectives, there is need to assess the ecological monitoring plan (DFO & FJMC, 2013) and indicators proposed and monitored (Brewster et al., 2021; DFO 2010).

Indicators are variables that are measured and/or observed repeatedly and consistently over time from which to draw conclusions on existing conditions and measure changes or trends over time (DFO & FJMC, 2013; FJMC, 2013). They can be used to describe the impacts of various stressors to the state of the ecosystem or to compare actual conditions within the TN MPA with targets for desired ecological conditions. A total of 28 ecological indicators have been selected to meet monitoring and management goals of the TN MPA, some of which focus on ecosystem structure and function, with the investigation of beluga diet using stable isotopes in muscle (Loseto et al., 2010).

Carbon and nitrogen stable isotope ratios (i.e. $\delta^{13}C$, $\delta^{15}N$) are used as ecological tracers that can provide insights into the structure of marine food webs (Boecklen et al., 2011) and the diet of marine mammals (Tucker et al., 2007; Newsome et al., 2010). While carbon stable isotopes can provide information on the dietary origins of carbon sources (i.e nearshore *vs* offshore or benthic/littoral *vs* pelagic (France, 1995)), nitrogen stable isotopes provide information on trophic position in a food web (DeNiro and Epstein, 1978, 1981). In addition, the different isotopic turnover rates between the two tissues can provide diet information on different time scales: 2-3 months for muscle and a few days to weeks for liver (Tieszen et al., 1983; Hilderbrand et al., 1996, Vander Zanden et al., 2015). While stable isotopes in muscle were selected as ecological indicator for the TN MPA, values in liver are also evaluated in order to evaluate diet over different time periods. Beluga whales consume a variety of both pelagic and benthic prey species but Arctic cod (*Boreogadus saida*), one of the most energy-dense prey in the Arctic, has been identified as their primary prey (Loseto et al., 2008; 2009). Habitat selection of beluga whales is driven by sex, size and reproductive status and likely leads to different habitat-specific food webs according to their spatial segregation (Richard et al., 2001; Loseto et al., 2006). While females with calves and small belugas select open-water habitats near the mainland likely feeding within the estuarine-shelf food web, large males select close sea-ice cover in and near the Arctic Archipelago likely feeding benthically and medium males tend to

select habitats near the ice edge likely feeding on the sea-ice associated Arctic cod and/or in pelagic food webs (Loseto et al., 2006; 2008).

With the Arctic warming at an alarming rate and the Beaufort Sea experiencing some of the fastest rates of sea ice cover change in the entire Arctic (Environment and Climate Change Canada (ECCC), 2021), the associated ecosystem changes have a significant impact on Arctic marine species such as beluga whales. For example, loss of sea ice along with warming ocean temperatures have been predicted to decrease the abundance of Arctic cod due to northward expansion of subarctic competitors such as Pacific sand lance (*Ammodytes hexapterus*) (Michel et al., 2012; Falardeau et al., 2014; McNicholl et al., 2016). Indeed, Choy et al. (2020) reported an increase in the diversity of prey in EBS beluga diets using stable isotopes and fatty acids between 2011 and 2014 with a decrease in the proportion of Arctic cod in the diet and an increase in capelin (*Mallotus villosus*) (Choy et al., 2020). This low Arctic cod contribution to the diet was associated with some of the lowest body condition indices reported for this population which was shown to impact oxygen storage capacity and therefore potentially hinder whales to reach preferred prey sources, evade predators or escape ice entrapments (Choy et al., 2017). Climate-change related changes in the Beaufort Sea ecosystem are therefore impacting the EBS beluga food web and ultimately their health.

Here, we report on stable isotopes measured in beluga whale muscle and liver collected between 2001 and 2021 in collaboration with Inuvialuit hunters at four whaling camps (Hendrickson Island, East Whitefish, Kendall Island and Shingle Point) within the TN MPA. The specific objectives of this report were to 1) expand on the previous temporal assessment (1981 - 2012) conducted by Loseto et al. (2015) and 2) evaluate potential changes in beluga diet and/or their food web over the 20-year period.

MATERIALS AND METHODS

SAMPLE COLLECTION

Beluga liver and muscle samples were collected by Inuvialuit hunters during subsistence harvests at Hendrickson Island (n = 557), East Whitefish (n = 116), Kendall Island (n = 130) and Shingle Point (n = 12) from 2001 to 2021 (Figure 1, Appendix 1). Sampling efforts were part of a larger beluga health monitoring program and collaboration between Inuvialuit hunters from Shingle Point, Inuvik and Tuktoyaktuk, the Fisheries Joint Management Committee (FJMC), local Hunters and Trappers Committees (HTCs) and DFO (Lockhart et al., 2005; Stern et al., 2005; Noël et al., 2018; Loseto et al., 2015). Samples were collected by monitors, local hunters trained in scientific collection of the samples, on site and stored in a portable -20°C freezer in the field before shipment to the Freshwater Institute (DFO) in Winnipeg where they were stored at -20°C until analysis. Length and sex were recorded on site for each individual. Ages of whales were determined by counting individual growth layer groups in the dentine (Stewart et al., 2006) up to 2015, then, from 2016 onwards, aspartic acid racemization measured in the nucleus of the eye-balls were used for aging following methods from Pleskach et al., (2016).

For the purpose of this report, we focused on samples collected at Hendrickson Island between 2001 and 2021. However, samples were also collected at nearby camps, namely East Whitefish, Kendall Island and Shingle Point (whales collected within the shallow bay subregion) since 2010 (and in 2005 at Kendall Island) and were included in this report as these sites were just different locations where hunters bring the belugas for processing and did not imply different beluga populations (Fig. 1).

Few females were collected as hunters generally select medium to larger sized males. For these reasons, and to avoid additional confounding factors associated with sex, we focused the current data set on male beluga whales.

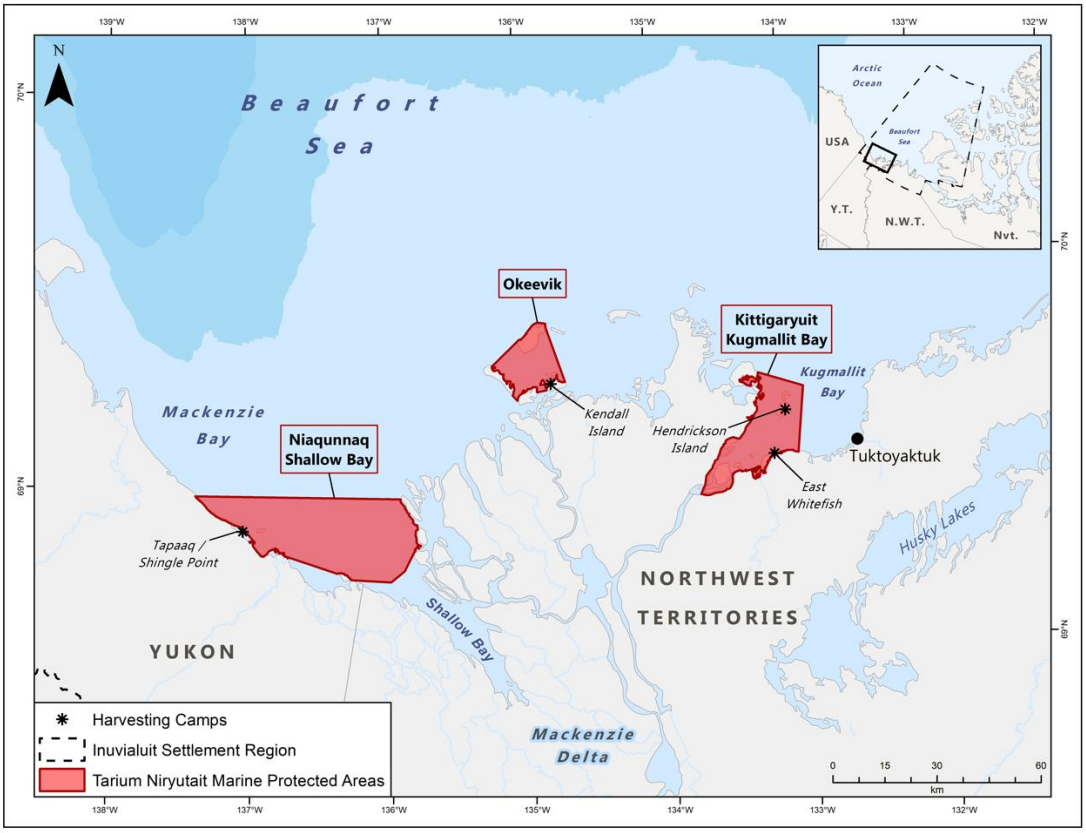


Figure 1: Beluga samples were collected during the annual beluga harvest between 2001 and 2021 at four sampling camps (*) within the TN MPA.

STABLE ISOTOPE ANALYSIS

Liver and muscle samples were analyzed for carbon and nitrogen stable isotopes at the Freshwater Institute (FWI) Biotracers Laboratory as described in Rosenberg et al. (2015). Briefly, subsamples were freeze dried and one mg of sample was loaded into tin capsules and analyzed using a Thermo Advantage V Plus continuous flow Isotope Ratio Mass Spectrometer coupled with a Costech 4010 Elemental Analyzer. Internal repeatability of in house fish standard is +/-0.08 ‰ for $\delta^{13}C$ and +/-0.16‰ for $\delta^{15}N$.

Carbon and nitrogen results were expressed using standard delta (δ) notation in units of *per mil* (‰). The delta values of carbon and nitrogen represent deviations from a standard such as

$$\delta_{sample} = [(R_{sample} / R_{standard}) - 1] \times 1000$$

where R is the ^{13}C /^{12}C or $^{15}N/^{14}N$ ratio in the sample and the standard. The standards used for carbon was Vienna PeeDee Belemnite (VPDB) and IAEA-N-1 (IAEA, Vienna) for nitrogen.

Since lipids are depleted in ^{13}C, they usually have ^{13}C values more negative than those reported in proteins (Post et al., 2007). As described in Choy et al. (2016), lipids significantly affect $\delta^{13}C$ values in beluga liver and a lipid correction model was used ($\delta^{13}C_{corrected}$ = -1.868 + 0.839 x $\delta^{13}C_{raw}$).

DATA ANALYSIS

Accounting for size as a confounding factor in temporal stable isotope assessment

Previous studies on the EBS beluga population showed that the size of a beluga defines the habitat it selects and the prey it feeds on (Loseto et al., 2006; 2009). Size (length) was therefore a key confounding factor to take into account when investigating stable isotopes in muscle and liver. Beluga size groups have been defined and used previously and the same groupings were applied here: small (under 380 cm), medium (380 – 420 cm) and large (over 420 cm) (Loseto et al., 2006; 2008a, b; 2009; 2015). The final datasets comprised a total of 554 muscle and 537 liver samples analyzed for nitrogen and carbon stable isotopes in male beluga whales sampled at the four camps between 2001 and 2021 (Appendix 1 and 2).

Statistical analyses

Stable isotope outliers were determined in both tissues and within each size group using the interquartile range method and have been removed from the data set.

All statistical analyses were performed in R 4.3.2 (R Core Team, 2020). Normality and homogeneity of variances were tested for biological variables and stable isotope data using the Kolmogorov-Smirnov and Levene's test, respectively. If the assumptions of normality and homogeneity of variances were not met, data were log transformed before further statistical analyses (using x + 40 for $\delta^{13}C$ to make all values non-negative, Choy et al., 2017). Analysis of variance were used to evaluate differences amongst sampling camps and amongst years, followed by a Tukey's post-hoc test. Results were considered significant with p-values below 0.05.

Temporal trends in stable isotopes in muscle and liver were assessed using a method used by AMAP (AMAP, 2020) for contaminants and recently by Morris et al., 2022. Briefly, temporal trends of stable isotopes were modeled using individual concentration data rather than annual medians. Linear and non-linear models were explored, and best-fit models were selected using the Akaike Information Criterion corrected for small sample size (AIC_c) (Burnham and Anderson, 2002).

NicheROVER was used to generate two-dimensional ($\delta^{15}N$ and $\delta^{13}C$) probabilistic (95%) regions for each sampling year using a Bayesian framework (Swanson et al., 2015). NicheROVER was also used to estimate the probability of isotopic niche overlap between years, where a mean overlap >= 50% was considered high (Brewster et al., 2016). PERMANOVAs were used to evaluate differences in niche centroids (defined by mean $\delta^{15}N$ and mean ^{13}C) amongst years.

RESULTS AND DISCUSSION

CONFOUNDING FACTORS

Sampling location

Samples were collected at four different locations where hunters bring the belugas for processing. While all samples were collected from belugas from the same population, whales located at the different sampling sites may imply that they are from different groups and may have been using different areas to feed therefore resulting in different stable isotope signatures.

Depending on sampling years, there were some isotopic differences amongst sampling locations in the muscle of medium whales (Figure 2). Specifically, in 2011 whales sampled at Kendall Island had significantly higher values of δ^{15}N values (17.7 $\pm$ 0.2 ‰) compared to those sampled at Hendrickson Island (17.2 $\pm$ 0.1 ‰; $p < 0.05$) even though remaining in the same trophic level. In 2017 whales sampled at East Whitefish had significantly lower δ^{13}C (-19.7 $\pm$ 0.1 ‰) compared to those sampled at Hendrickson Island (-19.1 $\pm$ 0.1 ‰; $p < 0.05$) even though remaining in the same trophic level. In 2018 whales sampled at East Whitefish had significantly higher values of δ^{15}N in muscle (17.9 $\pm$ 0.1 ‰) compared to those sampled at Hendrickson Island (17.2 $\pm$ 0.3 ‰; $p < 0.05$). Last in 2021 whales sampled at Kendall Island had significantly lower values of δ^{15}N in muscle (17.1 $\pm$ 0.2 ‰) compared to those sampled at Hendrickson Island (17.8 $\pm$ 0.1 ‰; $p < 0.05$). These differences could not be explained by size since there were no significant differences length between these locations for those years.

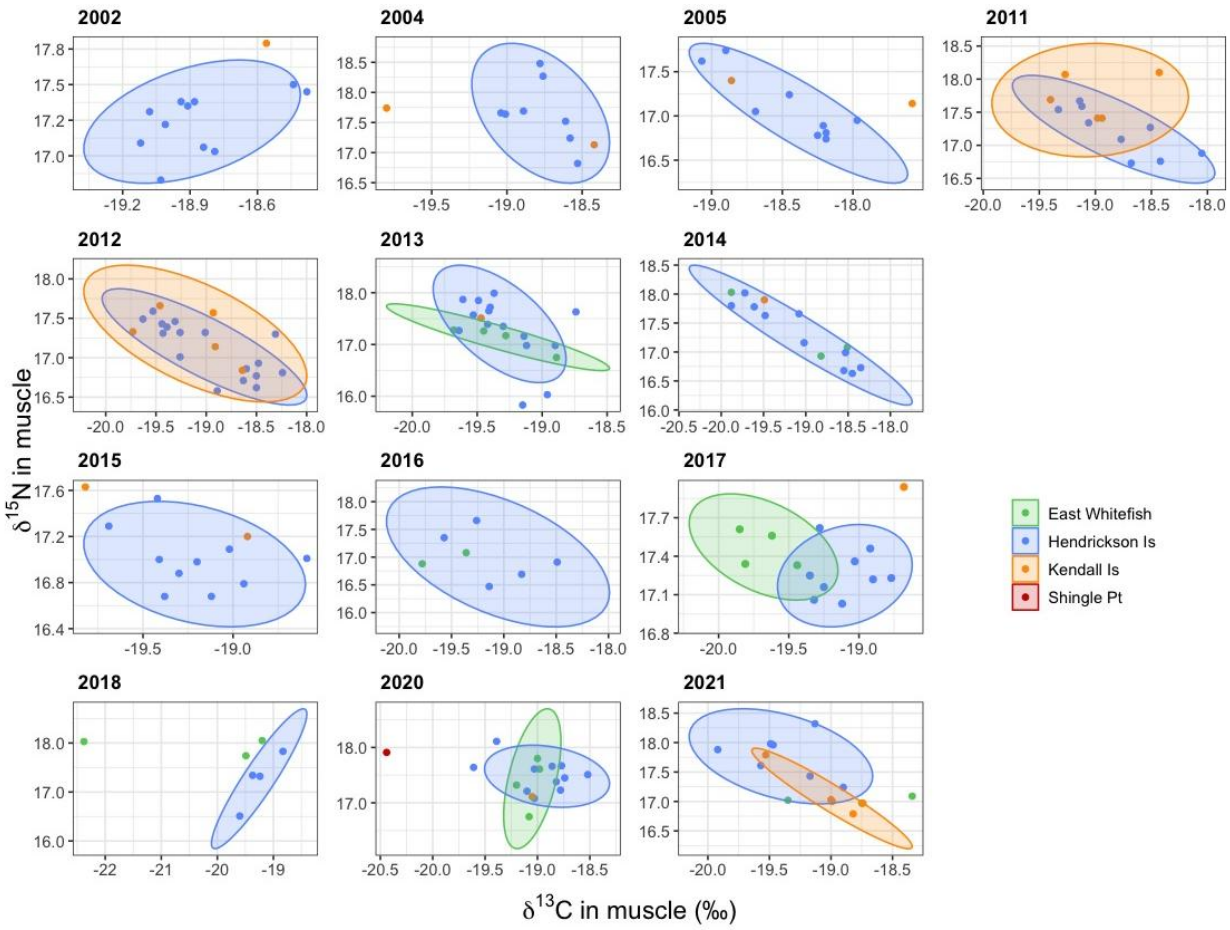


Figure 2: Biplot of $\delta^{15}N$ and $\delta^{13}C$ values in the muscle of individual EBS medium male beluga whales sampled between 2001 and 2021 at four sampling locations (Plots only presented for years where data was available for more than one location).

Similarly, large whales also showed spatial differences in muscle $\delta^{15}N$ and $\delta^{13}C$ (Figure 3). In 2011, whales sampled at Kendall Island had significantly higher muscle $\delta^{15}N$ (18.3 ± 0.2 ‰) compared to those sampled at Hendrickson Island (17.4 ± 0.1 ‰; $p < 0.05$). In 2018, whales sampled at Kendall Island and Shingle Point had significantly lower muscle $\delta^{15}N$ (17.5 ± 0.1 and 17.2 ± 0.1 ‰, respectively) compared to those sampled at Hendrickson Island (17.8 ± 0.1 ‰; $p < 0.05$). In 2021, whales sampled at Kendall Island had significantly higher values of $\delta^{13}C$ (-19.2 ± 0.1 ‰) compared to those sampled at Hendrickson Island (-19.5 ± 0.1 ‰; $p < 0.05$). These differences could not be explained by size since there were no significant differences in length between these locations for those years.

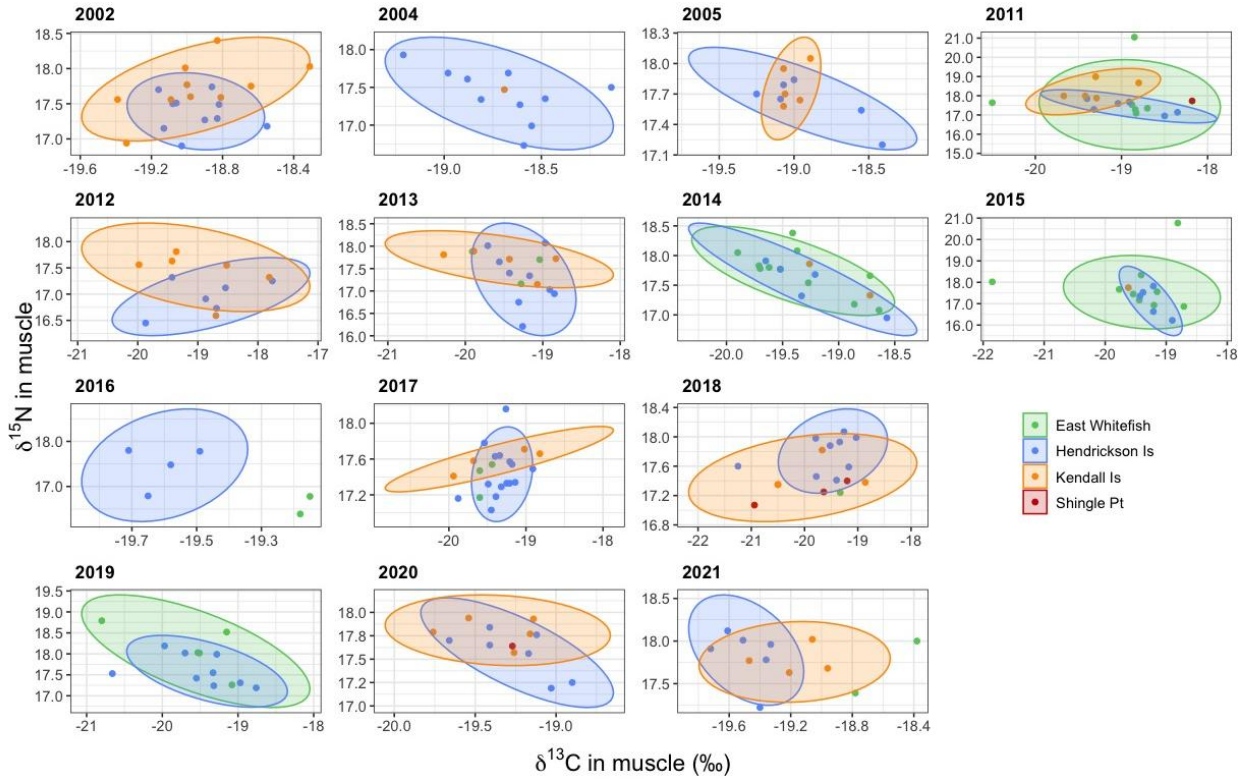


Figure 3: Biplot of $\delta^{15}N$ and $\delta^{13}C$ values in the muscle of individual EBS large male beluga whales sampled between 2001 and 2021 at four sampling locations (Plots only presented for years where data was available for more than one location).

As with muscle, liver $\delta^{15}N$ and $\delta^{13}C$ in medium whales also showed spatial and temporal variability (Figure 4). In 2011, whales sampled at Kendall Island had significantly higher liver $\delta^{15}N$ (18.6 $\pm$ 0.1 ‰) compared to those sampled at Hendrickson Island (18.1 $\pm$ 0.1 ‰; $p < 0.05$). These differences could not be explained by size since there were no significant differences in length between these locations for those years.

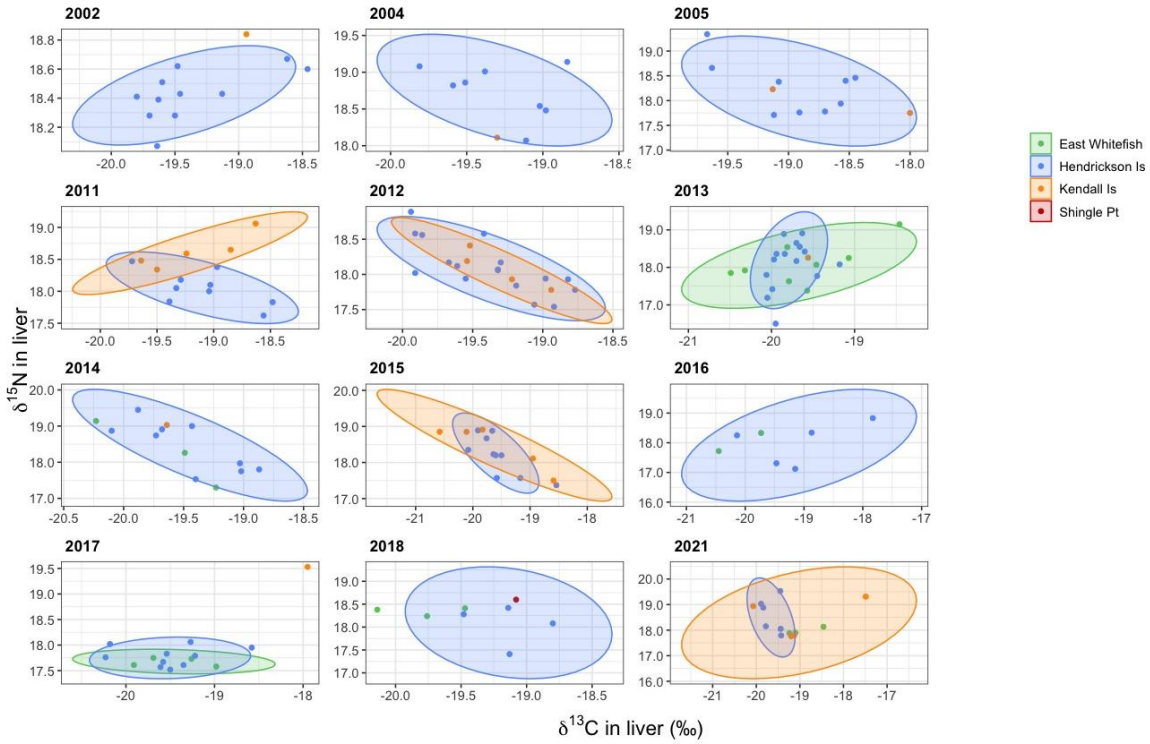


Figure 4: Biplot of $\delta^{15}N$ and $\delta^{13}C$ values in the liver of individual EBS medium male beluga whales sampled between 2001 and 2021 at four sampling locations (Plots only presented for years where data was available for more than one location).

For the large whales, the isotopic differences in liver were observed in several years (Figure 5). In 2016, whales sampled at East Whitefish had significantly lower values liver $\delta^{15}N$ (17.5 ± 0.1 ‰) compared to those sampled at Hendrickson Island (18.5 ± 0.03 ‰; $p < 0.05$), yet remained within the same trophic level. In 2018, whales sampled at Kendall Island and Shingle Point had significantly lower liver $\delta^{15}N$ (18.1 ± 0.1 and 18.0 ± 0.3 ‰, respectively) compared to those sampled at Hendrickson Island (18.7 ± 0.2 ‰; $p < 0.05$). In 2021, whales sampled at East Whitefish had significantly higher values of $\delta^{13}C$ (-19.0 ± 0.1 ‰) compared to those sampled at Hendrickson Island (-20.0 ± 0.1 ‰; $p < 0.05$). These differences could not be explained by size since there were no significant differences (see below) in length between these locations for those years.

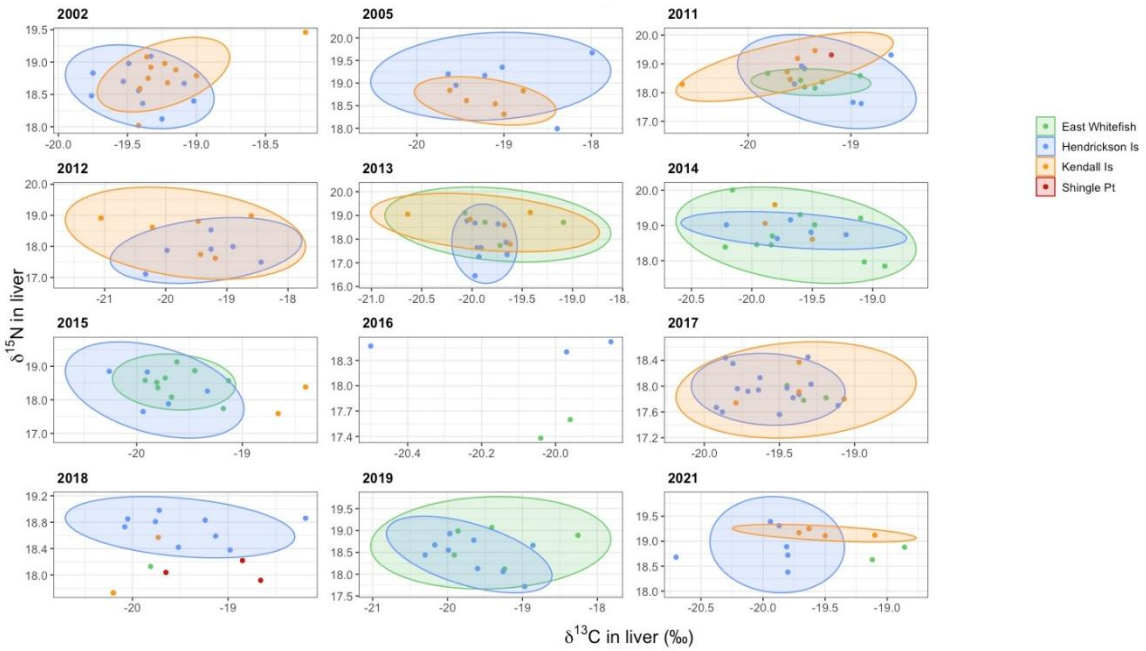


Figure 5: Biplot of $\delta^{15}N$ and $\delta^{13}C$ values in the liver of individual EBS large male beluga whales sampled between 2001 and 2021 at four sampling locations (Plots only presented for years where data was available for more than one location).

Hendrickson Island has been established as a long-term monitoring station where a wide variety of samples are collected every year in collaboration with local hunters as opposed to other locations where usually a limited number of samples are collected. Our results suggested that there were some differences in the isotopic signatures amongst whales sampled at different locations warranting additional analyses to better understand the variations in the diets of whales sampled at those four sampling locations. For the purpose of this report, we will therefore focus on analyses of temporal trends on samples collected at Hendrickson Island and East Whitefish given their close geographical proximity in Kugmallit Bay as opposed to Kendall Island and Shingle Point locations.

Size

For the rest of the assessment, whales sampled at Hendrickson Island and East Whitefish were grouped into the Kugmallit Bay grouping to increase sample size and focus on stable isotope analysis of belugas taken from geographically the same location. Outliers were removed within each size group.

For stable isotopes in muscle, two and five outliers were removed for $\delta^{13}C$ and $\delta^{15}N$, respectively, in small whales, one outlier was removed for $\delta^{13}C$ and $\delta^{15}N$ in medium whales and five and seven outliers were removed for $\delta^{13}C$ and $\delta^{15}N$, respectively, in large whales. For the final muscle dataset, there were no inter-annual differences in length in small ($p = 0.367$ and $p = 0.540$ for $\delta^{15}N$ and $\delta^{13}C$, respectively), medium ($p = 0.341$ and $p = 0.388$ for $\delta^{15}N$ and $\delta^{13}C$, respectively) and large whales ($p = 0.269$ and $p = 0.314$ for $\delta^{15}N$ and $\delta^{13}C$, respectively) suggesting that length was not a confounding factor in the temporal trend analyses of stable isotopes in muscle.

For stable isotopes in liver, two outliers were removed for $\delta^{13}C$ in small whales, three and two outliers were removed for $\delta^{13}C$ and $\delta^{15}N$, respectively, in medium whales and two and three

outliers were removed for $\delta^{13}C$ and $\delta^{15}N$, respectively, in large whales. For the final liver dataset, there were no inter-annual differences in length in small ($p = 0.180$ and $p = 0.435$ for $\delta^{15}N$ and $\delta^{13}C$, respectively), medium ($p = 0.321$ and $p = 0.304$ for $\delta^{15}N$ and $\delta^{13}C$, respectively) and large whales ($p = 0.320$ and $p = 0.242$ for $\delta^{15}N$ and $\delta^{13}C$, respectively) suggesting that length was not a confounding factor in the temporal trend analyses of stable isotopes in liver.

TEMPORAL TRENDS

Stable isotopes in muscle

$\delta^{15}N$

Over the entire study period, muscle $\delta^{15}N$ values were significantly different between the three size groups ($p < 0.01$) with small whales having the lowest $\delta^{15}N$ (17.1 ± 0.08 ‰) followed by medium size whales (17.3 ± 0.03 ‰) and larger whales (17.5 ± 0.03 ‰, $p < 0.05$). Of note, these results suggest that all three groups were feeding within the same trophic level or combination of trophic levels (within 3 ‰, Cabana and Rasmussen, 1994). Loseto et al. (2008a) also reported differences amongst the three size groups in $\delta^{15}N$ values in the muscle of beluga whales sampled from Hendrickson Island in 2004 with the small whales having the lowest $\delta^{15}N$ followed by large whales and medium whales.

For small whales, there was no significant trend between 2001 and 2021 (Figure 6) and no significant differences in muscle $\delta^{15}N$ amongst years ($p = 0.059$) likely due to the small sample size. $\delta^{15}N$ values in 2001 (17.1 ‰; $n = 1$) appeared similar to those reported in 2021 (17.2 ± 0.12 ‰).

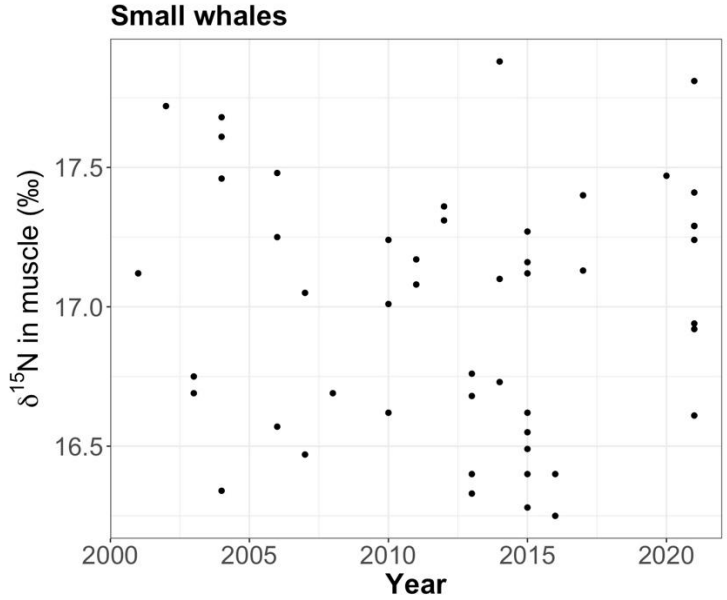


Figure 6: Total $\delta^{15}N$ values in the muscle of individual EBS small male beluga whales sampled between 2001 and 2021.

In both medium and large whales, there were significant non-linear trends in muscle $\delta^{15}N$ between 2001 and 2021 ($r = 0.16$ and $r = 0.10$ for medium and large whales, respectively, $p < 0.05$; Figure 7). In medium whales, muscle $\delta^{15}N$ declined until 2007/2008 before increasing non-linearly until 2021 with values in 2021 (17.6 ± 0.15 ‰), being similar to those reported in 2001

(17.4 ± 0.09 ‰; p = 0.252) but significantly higher than those reported in 2008 (17.1 ± 0.15 ‰; p < 0.5). In large whales, muscle δ^{15}N remained fairly stable from 2001 to 2008 before increasing until 2021 though values in 2021 (17.8 ± 0.11 ‰) were similar to those reported in 2001 (17.7 ± 0.08 ‰; p = 0.876).

Using data only for whales harvested at Hendrickson Island between 1981 and 2012, Similarly, Loseto et al. (2015) reported an increase in muscle δ^{15}N from 2010 to 2012 in medium size belugas sampled from Hendrickson Island, while they did not find significant trends for large whales. Loseto et al. (2015) evaluated trends using yearly averages of muscle δ^{15}N from whales sampled only at Hendrickson Island which may explain the differences in trends especially for large whales between their study and the present report. Given the large home range of beluga whales and the known variations of δ^{15}N across the Beaufort Sea, Chukchi and Bering Seas (Loseto et al., 2015; Schell et al., 1998), it is challenging to accurately assess the factors driving the variations in δ^{15}N in the muscle of belugas. With the range observed in the present data, medium and large beluga whales were feeding within the same trophic level (within 3 ‰, Cabana and Rasmussen, 1994) and the variations observed may have been driven by a combination of a shift of δ^{15}N signals lower in the food web along with spatial variability in prey signals along their migratory path.

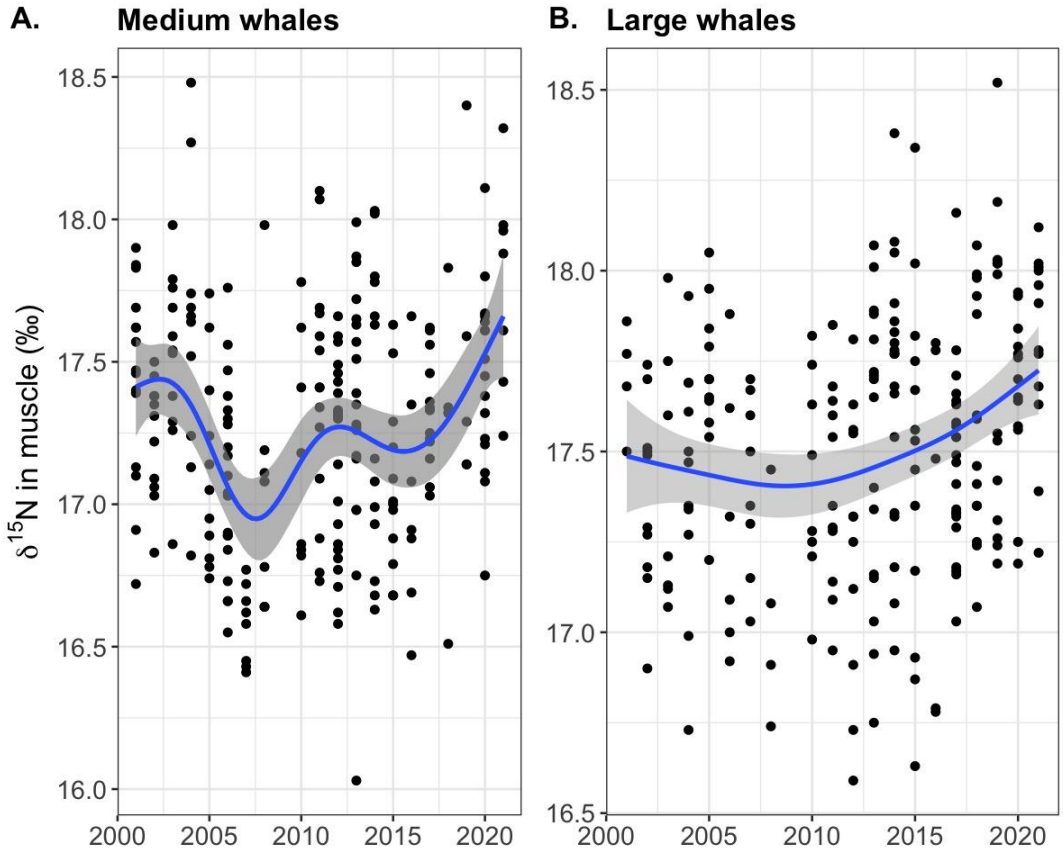


Figure 7: Total δ^{15}N values in the muscle of individual EBS male beluga whales sampled between 2001 and 2021. Whales were grouped by size into medium and large whales.

$\delta^{13}C$

Muscle $\delta^{13}C$ were significantly higher in medium whales (-18.9 $\pm$ 0.04 ‰) compared to small and large whales (-19.2 $\pm$ 0.08 and -19.1 $\pm$ 0.04‰, respectively, $p < 0.01$). Differences in $\delta^{13}C$ indicates differences in feeding locations with the lower $\delta^{13}C$ signal in small and large whales suggesting more offshore/pelagic feeding compared to medium whales. Interestingly, Loseto et al. (2008) did not find a significant difference in $\delta^{13}C$ values between the three size groups of beluga whales sampled at Hendrickson Island in 2004 but the sample size was limited (n = 26) and also included females. Our results also differed from previous reports suggesting feeding within the estuarine/shelf food web for smaller beluga whales (Loseto et al., 2008a).

In small whales, there was no significant trend in muscle $\delta^{13}C$ between 2001 and 2021 (Figure 8) and no significant differences in $\delta^{13}C$ amongst years ($p = 0.499$).

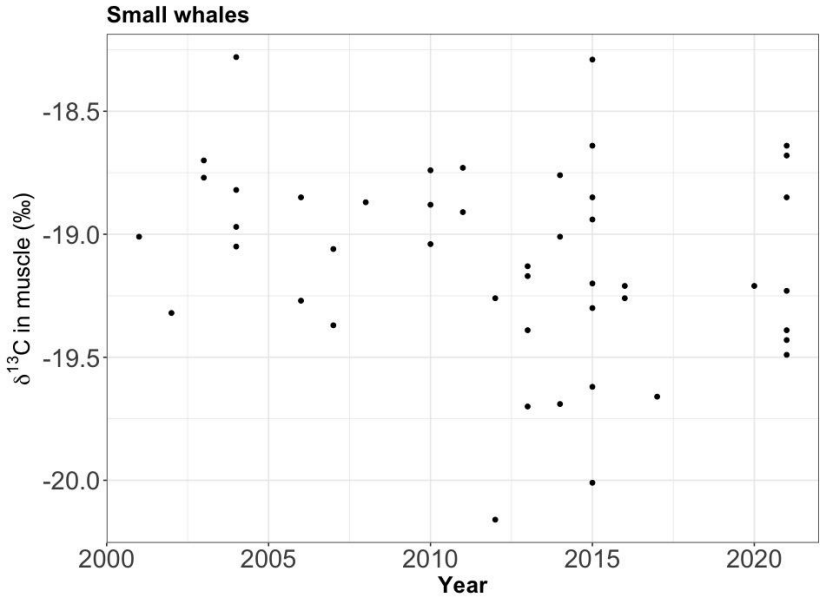


Figure 8: Total $\delta^{13}C$ values in the muscle of individual EBS small male beluga whales sampled between 2001 and 2021.

In both medium and large whales, there were significant non-linear trends in muscle $\delta^{13}C$ between 2001 and 2021 ($r = 0.36$ and $r = 0.35$ for medium and large whales, respectively, $p < 0.01$; Figure 9). In medium whales, muscle $\delta^{13}C$ increased between 2001 and 2006 and then declined until 2016/2017 before stabilizing in recent years. $\delta^{13}C$ reported in medium whales in 2006 (-18.3 $\pm$ 0.10 ‰) was significantly higher than that reported in 2001 (-19.0 $\pm$ 0.08 ‰; $p < 0.01$) and all years beyond 2012 ($p < 0.01$). Over the entire study period, muscle $\delta^{13}C$ values in 2001 were similar to those reported in 2021 (-19.2 $\pm$ 0.14 ‰; $p = 0.979$). A similar pattern was observed for large whales with decreasing $\delta^{13}C$ values from 2006 (-18.6 $\pm$ 0.16 ‰) to 2016 (-19.5 $\pm$ 0.09 ‰; $p < 0.01$) after which values remained fairly stable. However, $\delta^{13}C$ values were stable in the early 2000's as opposed to the increase observed in medium whales. Over the entire study period, $\delta^{13}C$ values in large whales sampled in 2001 (-18.7 $\pm$ 0.24 ‰) were similar to those reported in 2021 (-19.3 $\pm$ 0.16 ‰; $p = 0.484$).

Using only whales sampled at Hendrickson Island, Loseto et al. (2015) found no significant trends in $\delta^{13}C$ in the muscle of medium and large whales between 2002 and 2012. Just like for $\delta^{15}N$ in muscle, assessing the drivers of $\delta^{13}C$ variations over time in the muscle is challenging

due to the geographical variation in $\delta^{13}C$ whereby concentrations become depleted moving eastward from the Bering Sea, Chukchi Sea and Beaufort Sea (Schell et al., 1998; Stern and Macdonald, 2005). The decline in $\delta^{13}C$ observed here in the muscle of medium and large whales for a period of 10 years between 2006 and 2016/2017 may be attributed to feeding more predominantly within the Beaufort Sea food web as well as in more pelagic environments.

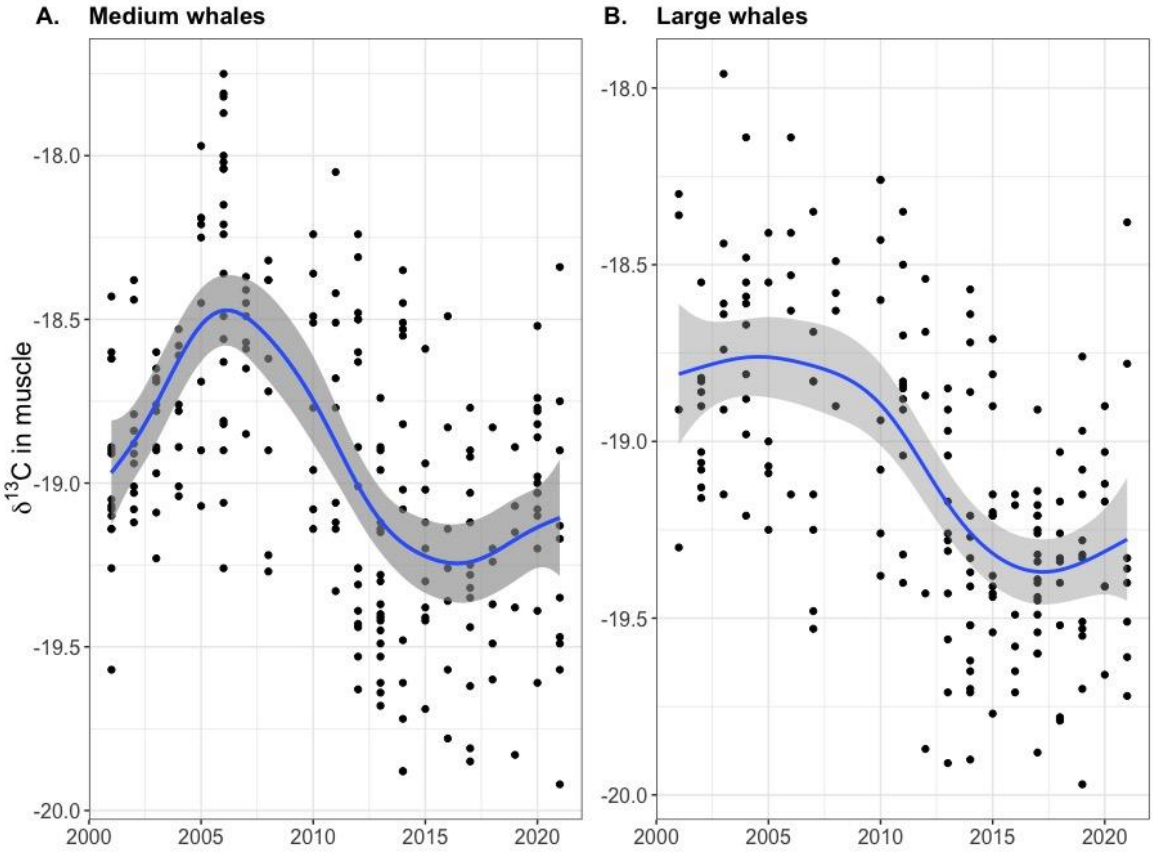


Figure 9: Total $\delta^{13}C$ values in the muscle of individual EBS male beluga whales sampled between 2001 and 2021. Whales were grouped by size into medium and large whales.

Stable isotopes in liver

$\delta^{15}N$

Over the entire study period, values of liver $\delta^{15}N$ were significantly different between the three size groups ($p < 0.01$) with small whales having the lowest values (17.9 ± 0.08 ‰) followed by medium size whales (18.2 ± 0.04 ‰) and larger whales (18.4 ± 0.04 ‰, $p < 0.05$).

As muscle and liver $\delta^{15}N$ values were correlated with each other in small ($R = 0.37$; $p < 0.01$), medium ($R = 0.37$; $p < 0.01$) and large whales ($R = 0.41$; $p < 0.01$; Appendix 3), $\delta^{15}N$ trends observed in liver were overall similar to those reported in muscle.

In small whales, there was a significant non-linear trend in $\delta^{15}N$ in liver ($R = 0.39$; $p < 0.01$) with values decreasing between 2001 and 2016 before slightly increasing (Figure 10). $\delta^{15}N$ values in 2001 (18.8 ‰; $n = 1$) were higher than those reported in 2016 (17.3 ± 0.02 ‰) and 2021 (17.8 ± 0.07 ‰). While no statistical analysis was possible with the year 2001 when data was only

available for one small whale, there was no significant difference in $\delta^{15}N$ values between small whales sampled in 2016 and 2021.

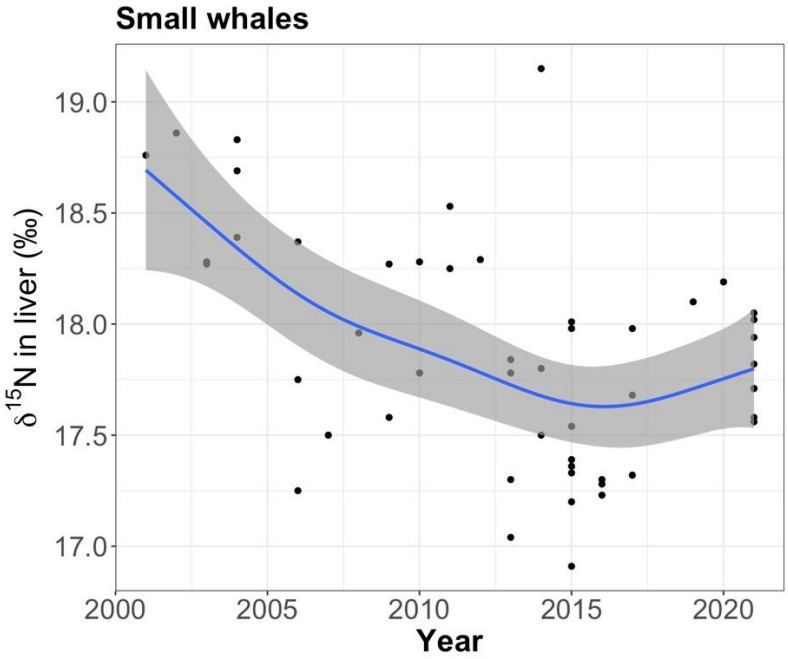


Figure 10: Total $\delta^{15}N$ values in the liver of individual EBS small male beluga whales sampled between 2001 and 2021.

In both medium and large whales, there were significant non-linear trends in $\delta^{15}N$ in liver between 2001 and 2021 ($r = 0.25$ and $r = 0.18$ for medium and large whales, respectively, $p < 0.01$; Figure 11) that were, overall, similar to those reported in muscle. In medium whales, $\delta^{15}N$ in liver were highly variable with an increase between 2001 and 2003 followed by a decrease until 2008 as observed in muscle and then a non-linear increase until 2014 before declining again until 2017 and finally increasing until 2021 (Figure 11). However, $\delta^{15}N$ values in liver were only significantly different between 2003 (18.9 ± 0.12 ‰) and 2008 (17.8 ± 0.18 ‰; $p < 0.01$). Over the entire study period, $\delta^{15}N$ values in liver in 2001 (18.6 ± 0.10 ‰) were similar to those reported in 2021 (18.4 ± 0.21 ‰; $p = 0.999$). A similar trend was observed for large whales where $\delta^{15}N$ values in liver were stable in the early 2000's before declining between 2004 (18.7 ± 0.14 ‰) and 2008 (17.9 ± 0.14 ‰; $p = 0.088$) followed by stable values until 2017 (17.9 ± 0.06 ‰) when they increased until 2021 (18.9 ± 0.12 ‰; $p < 0.01$). Over the entire study period, $\delta^{15}N$ values in liver in 2001 (18.7 ‰, $n = 1$) were similar to those reported in 2021 (18.9 ± 0.12 ‰).

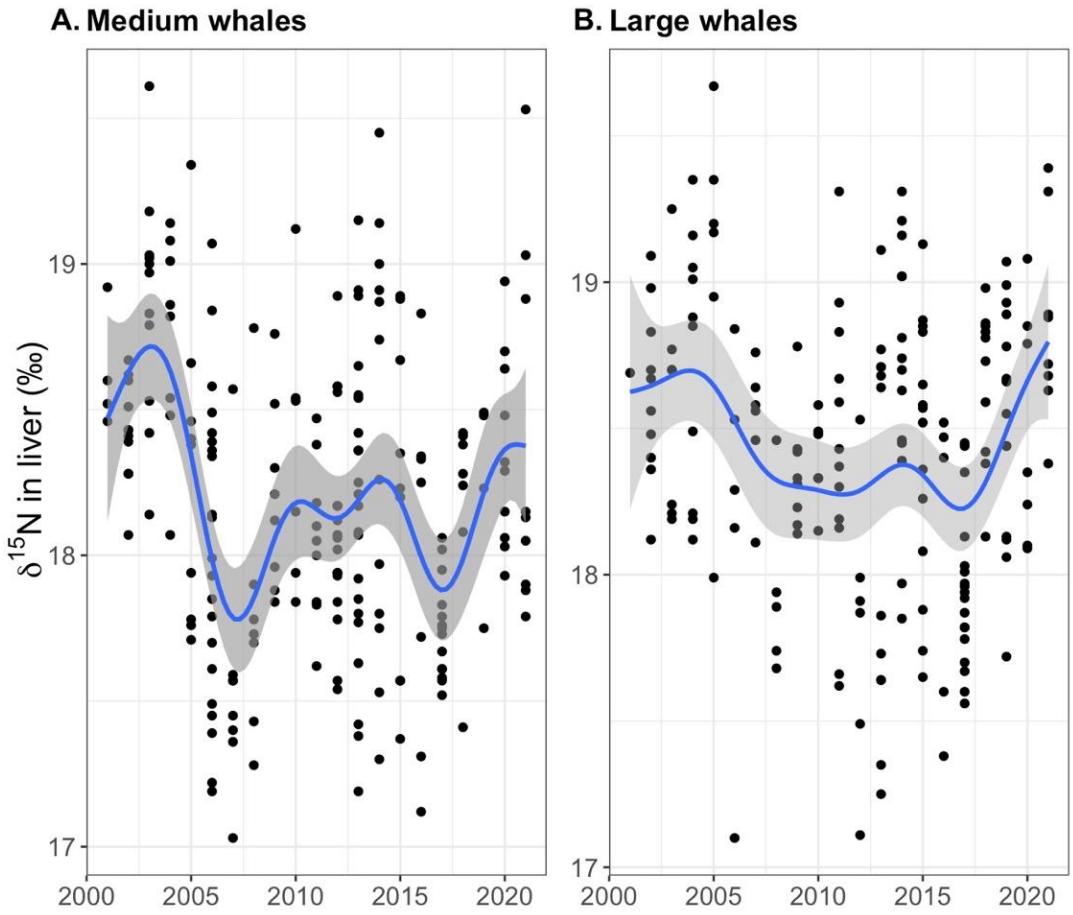


Figure 11: Total $\delta^{15}N$ values in the liver of individual EBS male beluga whales sampled between 2001 and 2021. Whales were grouped by size into medium and large whales.

$\delta^{13}C$

Over the entire study period, values of $\delta^{13}C$ in liver were significantly different between the three size groups ($p < 0.01$). While small and medium whales had similar $\delta^{13}C$ values in muscle (-19.3 $\pm$ 0.06 and -19.3 $\pm$ 0.03‰), these values were significantly lower than those reported in large whales (-19.5 $\pm$ 0.03 ‰). These results are different than those reported in muscle where small and large whales had similar $\delta^{13}C$ signals.

As $\delta^{13}C$ values in muscle and liver were correlated with each other in small ($r = 0.23$; $p < 0.01$), medium ($r = 0.39$; $p < 0.01$) and large whales ($r = 0.34$; $p < 0.01$; Appendix 4), $\delta^{13}C$ trends observed in liver were overall similar to those reported in muscle.

In small whales, there was no significant trend between 2001 and 2021 (Figure 12). There were also no significant differences in $\delta^{13}C$ in liver amongst years ($p = 0.181$).

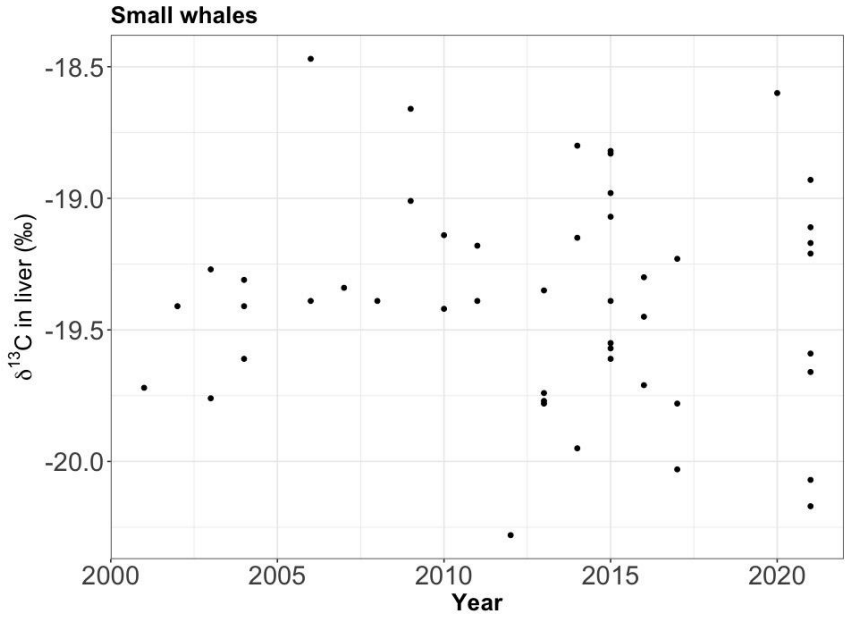


Figure 12: Total $\delta^{13}C$ values in the liver of individual EBS small male beluga whales sampled between 2001 and 2021.

In both medium and large whales, there were significant non-linear trends in $\delta^{13}C$ in liver between 2001 and 2021 (R = 0.14 and R = 0.16 for medium and large whales, respectively, $p < 0.01$) similar to those reported in muscle (Figure 13). In medium whales, $\delta^{13}C$ increased between 2001 (-19.5 $\pm$ 0.12 ‰) and 2006 (-19.0 $\pm$ 0.13 ‰) but the difference was not significant between the two years ($p = 0.979$). Values then declined until 2015 (-19.5 $\pm$ 0.14 ‰) before increasing slightly in recent years. Over the entire study period, $\delta^{13}C$ values in 2001 were similar to those reported in 2021 (-19.4 $\pm$ 0.14 ‰; $p = 0.989$).

A similar pattern was observed for large males with decreasing $\delta^{13}C$ values from 2006 (-19.3 $\pm$ 0.24 ‰) to 2016 (-20.1 $\pm$ 0.11 ‰; $p = 0.120$) after which values remained fairly stable. However, $\delta^{13}C$ values in liver were stable in the early 2000's as opposed to the increase observed in medium whales. Over the entire study period, $\delta^{13}C$ values in large whales sampled in 2001 (-20.1; n = 1) were similar to those reported in 2021 (-19.7 $\pm$ 0.19 ‰).

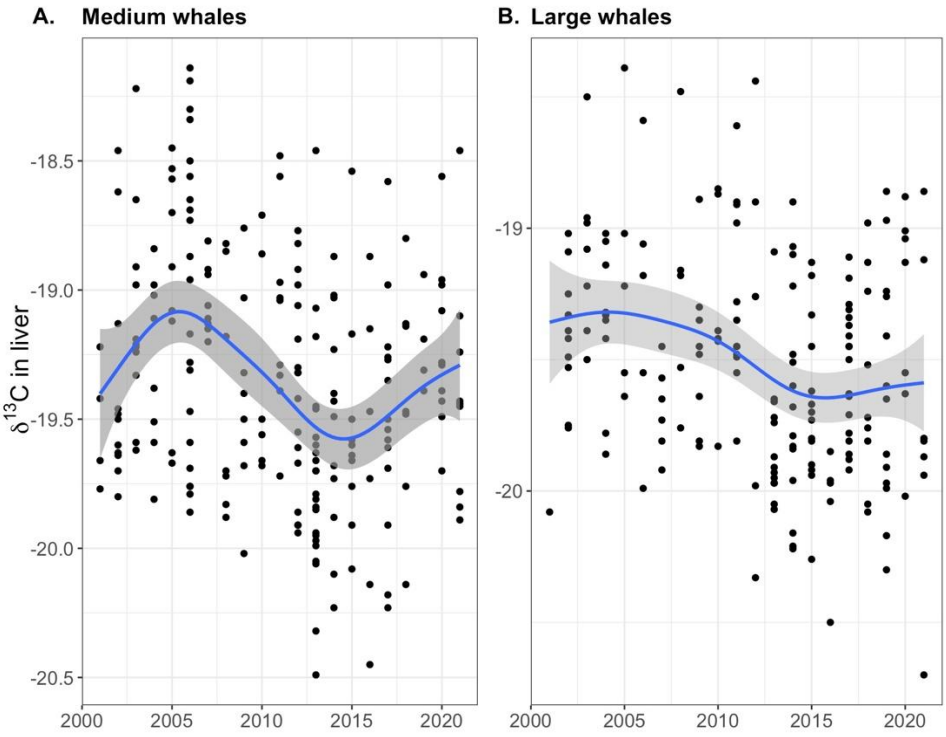


Figure 13: Total $\delta^{13}C$ values in the liver of individual EBS male beluga whales sampled between 2001 and 2021. Whales were grouped by size into medium and large whales.

NICHE

Muscle

Biplots of $\delta^{15}N$ and $\delta^{13}C$ values in muscle revealed that there were differences in isotopic niche size amongst years for both medium and large whales ($p < 0.01$; Figure 14).

For medium whales, niche sizes ranged from 0.35 ± 0.13 ‰^{2} in 2007 to 2.88 ± 0.89 ‰^{2} in 2021. Whales sampled in 2002 (0.73 ± 0.24 ‰^{2}), 2003 (0.78 ± 0.26 ‰^{2}) and 2019 (0.63 ± 0.33 ‰^{2}) also had some of the smallest niche sizes and whales sampled in 2006 (2.18 ± 0.48 ‰^{2}), 2008 (2.20 ± 0.86), 2010 (2.22 ± 0.86 ‰^{2}) and 2016 (2.66 ± 1.04 ‰^{2}) had some of the largest niche sizes (Figure 14).

For the smallest niches reported, the 2007 niche overlapped significantly with six of the 20 years sampled with the most overlap being with 2008 (92.5%; credible interval (CI): 54.9 – 100%) and 2010 (87.3%; CI: 36.3 – 100%) while the 2019 niche overlapped with 13 of the 20 years sampled with the most overlap being with 2021 (89.5%; CI: 58.1 – 100%) and 2013 (86.3%; CI: 50.6 – 99.8%). The largest niche reported for the whales sampled in 2021 overlapped significantly with 10 of the 20 years sampled with the most overlap being with 2013 (72.7 %; CI: 44.5 – 92.7%), 2020 (64.9 %; CI: 38.7 – 89.1%) and 2001 (64.9%; CI: 38.0 – 89.4%). There were minimal overlaps between the niches of whales sampled between 2013 and 2017 and those sampled between 2003 and 2007 suggesting a shift in baseline during those two time periods or that medium whales were feeding from different areas during these two time periods characterized with lower $\delta^{13}C$ during the period 2013-2017(Appendix 5, Figures 13A and 14).

Niche sizes were larger for large whales compared to medium whales similar to what was found by Choy et al. (2017) in the same population of belugas and supported the fact that large males tend to have larger habitat range and have the ability to exploit a higher diversity of habitats (Richard et al., 2001). For the large whales, niche sizes ranged from 0.34 ± 0.18 ‰^{2} in 2008 to 10.20 ± 3.02 ‰^{2} in 2011. Large whales sampled in 2002 (0.81 ± 0.28 ‰^{2}), 2005 (0.69 ± 0.30 ‰^{2}) and 2020 (0.77 ± 0.32 ‰^{2}) had some of the lowest niche sizes reported over the study period while large whales sampled in 2012 (3.23 ± 1.44 ‰^{2}), 2013 (2.89 ± 0.87 ‰^{2}), 2018 (2.99 ± 0.98 ‰^{2}), 2019 (4.44 ± 1.20 ‰^{2}) and 2021 (2.37 ± 0.85 ‰^{2}) had some of the highest niche sizes (Figure 14). This may suggest a broader range of resources were exploited in search for prey.

The smallest 2008 niche was overlapping significantly with 10 of the 20 years sampled with the greatest overlap being with 2011 (98.3 %; CI: 87.6 – 100%) and 2004 (88.2%; CI: 51.4 – 100%) while the largest 2011 niche was only significantly overlapping with the 2015 (89.4%; CI: 68.0 – 99.5%) and 2019 (50.6%; CI: 28.1 – 77.8%) niches (Appendix 6). Similar to what was observed for medium whales, there were minimal overlaps between the niches of whales sampled between 2011 and 2019 and those sampled between 2001 and 2007 with the largest segregations being between 2016 - 2017 and the early 2000s suggesting that large whales were also feeding from different areas during these two time periods characterized with lower δ^{13}C during the period 2011 – 2019 (Appendix 6, Figures 13B and 14).

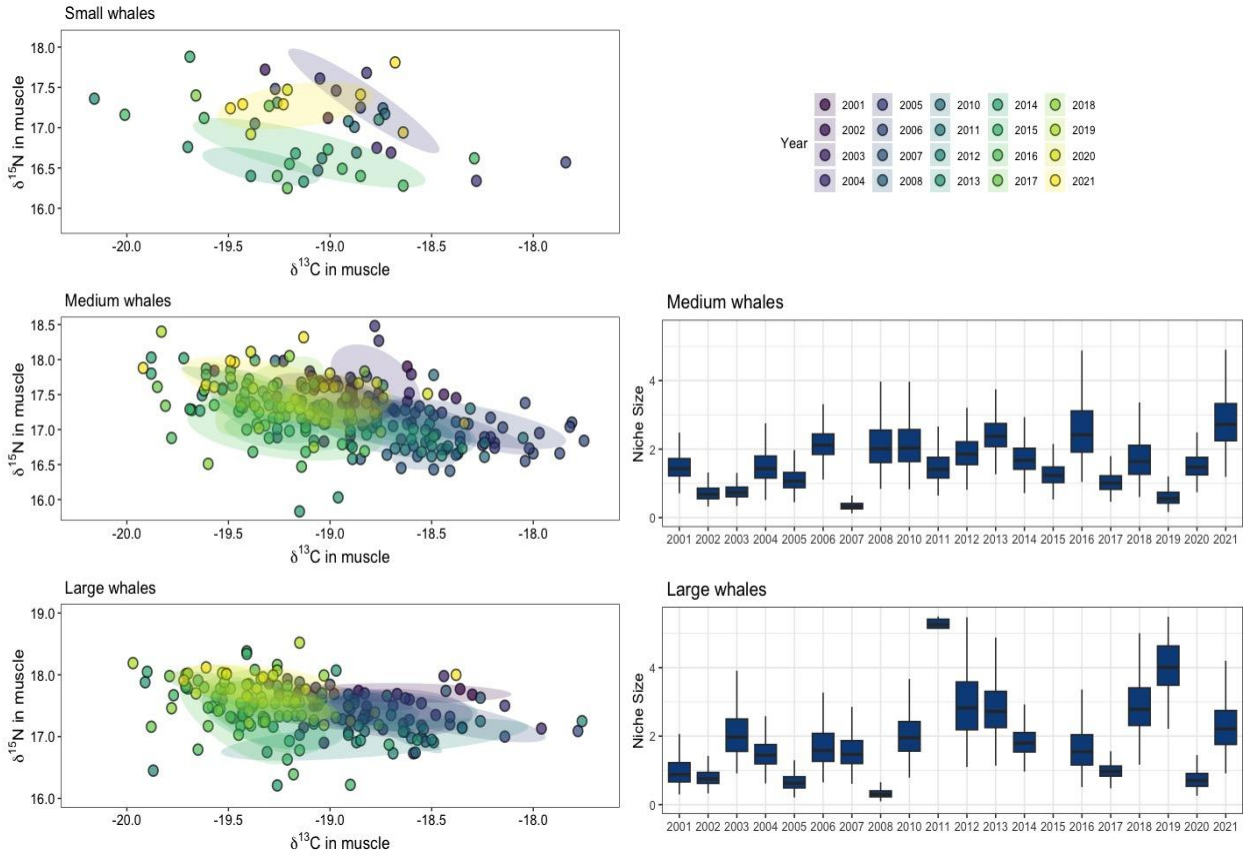


Figure 14: Biplot of $\delta^{15}N$ and $\delta^{13}C$ values in the muscle of individual male beluga whales sampled between 2001 and 2021 at Hendrickson Island and East Whitefish (results are presented separately for small, medium and large whales). Niche sizes are presented for each year for medium and large whales (Due to the limited sample size for small whales, niche sizes could not be generated).

Liver

Biplots of $\delta^{15}N$ and $\delta^{13}C$ values in liver revealed that there were differences in isotopic niches amongst years for both medium and large whales ($p < 0.01$; Figure 15) but the differences were not as marked as with the muscle data.

Overall, niche sizes obtained with the liver data were larger than those obtained using the muscle data (2.8 ± 2.2 and 1.6 ± 0.90 ‰^{2}, respectively). For medium whales, niche sizes ranged from 0.48 ± 0.26 ‰^{2} in 2001 to 8.05 ± 3.33 ‰^{2} in 2016 with liver data. Whales sampled in 2007 (0.94 ± 0.36 ‰^{2}) and 2019 (0.93 ± 0.50 ‰^{2}) had some of the lowest niche sizes reported and whales sampled in 2006 (4.16 ± 0.96 ‰^{2}), 2013 (4.30 ± 0.91 ‰^{2}), 2020 (4.32 ± 1.40 ‰^{2}) and 2021 (4.15 ± 1.57 ‰^{2}) had some of the largest niche sizes reported (Figure 15). Overall, there were more overlaps amongst years compared to muscle and the segregation between 2003-2007 and 2013-2017, even though present to some degree, was not as strong.

As opposed to what was observed for medium whales, niche sizes obtained with the liver data were similar to those obtained using the muscle data (2.6 ± 1.7 and 2.9 ± 3.6 ‰^{2}, respectively) For the large whales, niche sizes ranged from 0.59 ± 0.25 ‰^{2} in 2007 to 5.73 ± 2.43 ‰^{2} in 2005. Large whales sampled in 2002 (1.21 ± 0.43 ‰^{2}), 2009 (1.00 ± 0.37 ‰^{2}), 2010 (0.85 ± 0.38 ‰^{2}) and 2017 (1.16 ± 0.27 ‰^{2}) also had some of the lowest niche sizes reported over the study period while large whales sampled in 2012 (5.05 ± 2.21 ‰^{2}), 2013 (3.55 ± 1.03 ‰^{2}), 2014 (3.75 ± 1.05 ‰^{2}), 2019 (3.97 ± 1.08 ‰^{2}) and 2021 (3.14 ± 1.26 ‰^{2}) had some of the highest niche sizes (Figure 15). Similar to medium whales, there were more overlaps amongst years compared to muscle with even the smallest niches of 2007 and 2010 overlapping with most years. In addition, the strong segregation observed between 2016 - 2017 and the early 2000s was not as present with the liver data (Appendix 8).

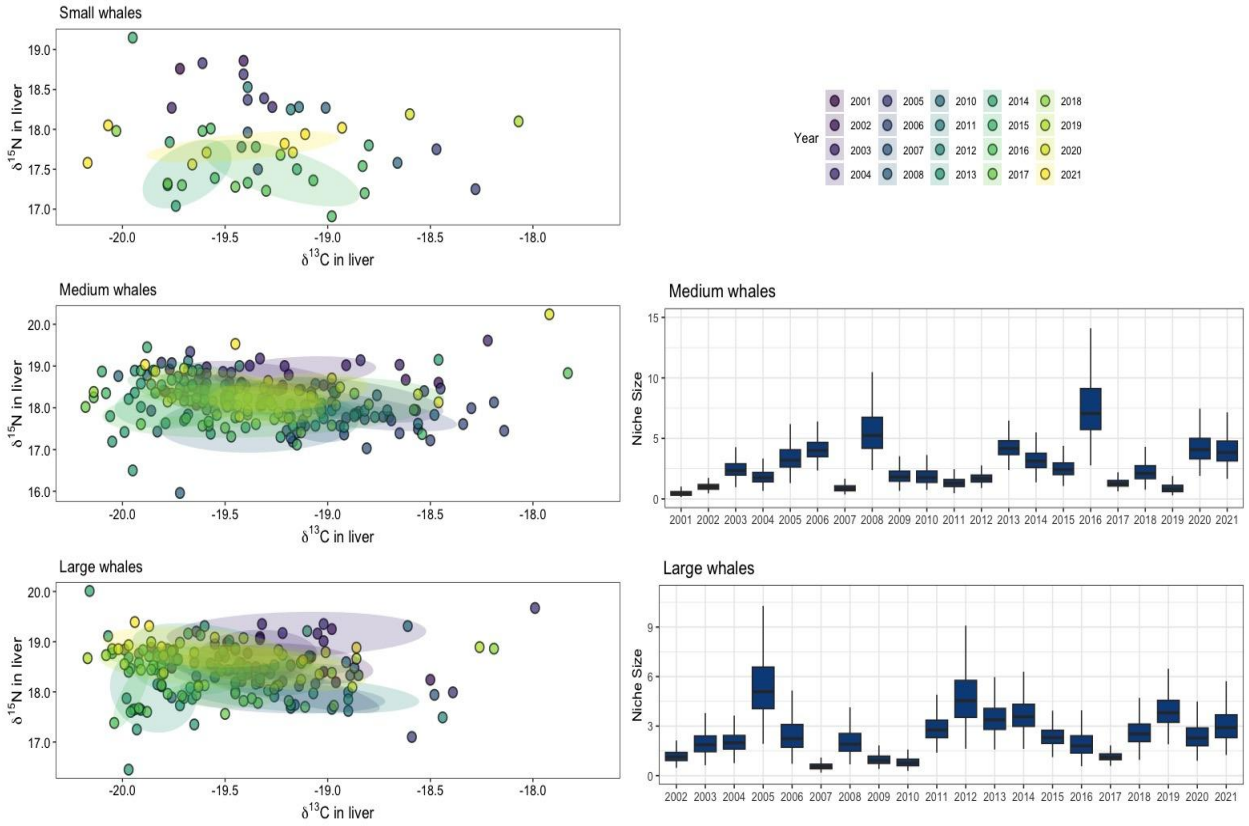


Figure 15: Biplot of $\delta^{15}N$ and $\delta^{13}C$ values in the liver of individual male beluga whales sampled between 2001 and 2021 at Hendrickson Island and East Whitefish (results are presented separately for small, medium and large whales). Niche sizes are presented for each year for medium and large whales (Due to the limited sample size for small whales, niche sizes could not be generated).

CONCLUSION

The values of $\delta^{15}N$ and $\delta^{13}C$ in the muscle of medium and large whales revealed similar non-linear trends between 2001 and 2021. While $\delta^{15}N$ values in muscle declined until 2007/2008 before increasing non-linearly until 2021 in medium whales, $\delta^{15}N$ values remained fairly stable until 2008 before increasing until 2021 in large whales. $\delta^{13}C$ values increased between 2001 and 2006 and then declined until 2016/2017 before stabilizing in recent years in medium whales similar to what was observed in large whales. Taken together, these temporal variations resulted in minimal overlaps between the niches of whales sampled between 2013 and 2017 and those sampled between 2003 and 2007 suggesting that there was either a shift in baseline stable isotope signature or a shift in feeding areas between these two time periods led by lower $\delta^{13}C$ during the period 2013-2017 potentially characteristic of feeding more predominantly within the Beaufort Sea food web as well as in more pelagic environments.

Observed temporal trends in $\delta^{15}N$ did not exceed a trophic level (within 3 ‰, Cabana and Rasmussen, 1994), suggesting variability within the same trophic level which may reflect mixing diet and/or diet signals within the same trophic level. These results support the use of $\delta^{15}N$ and $\delta^{13}C$ values in beluga muscle as a key ecological indicator for the TN MPA that can provide

insights into food web shifts due to climate change and/or other stressors. Given that muscle and liver were providing similar information on stable isotope trend, we recommend prioritizing investigation of stable isotope in the muscle tissue given that it is likely to reflect a more recent signature compared to liver given the difference in turnover rates between the two tissues. In order to accurately interpret changes, this indicator needs to be evaluated together with other food web markers such as fatty acids. In addition, given the known geographical variations of $\delta^{15}N$ and $\delta^{13}C$ across the Bering Sea and Beaufort Sea along with the migratory path of the belugas, the stable isotope results need to be put into context with stable isotope value reported lower in the food web, including in their prey.

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APPENDICES

Appendix 1: Average (mean ± standard deviation) length for male beluga whales sampled at each whaling camp between 2001 and 2021 and analyzed for carbon and nitrogen stable isotopes in muscle. Belugas were grouped based on their length into small (< 380 cm), medium (≥ 380 cm and ≤ 420 cm) and large (> 420 cm).

		Small		Medium		Large	
Year	**Location**	**n**	**Length (cm)**	**n**	**Length (cm)**	**n**	**Length (cm)**
2001	Hendrickson Is	1	375.9	15	403.1 ± 3.2	4	435.6 ± 5.6
2002	Hendrickson Is	1	373.4	11	399.5 ± 3.8	10	435.6 ± 2.9
	Kendall Is			1	411.1	10	441.1 ± 3.0
2003	Hendrickson Is	2	356.9 ± 21.6	11	406.2 ± 3.0	7	431.2 ± 4.3
2004	Hendrickson Is	4	354.5 ± 2.5	8	411.2 ± 2.2	10	433.1 ± 3.8
	Kendall Is	1	340.4	2	398.8 ± 10.2	1	434.3
2005	Hendrickson Is			9	397.3 ± 4.1	6	438.6 ± 5.4
	Kendall Is	1	355.6	2	398.8 ± 2.6	5	461.3 ± 10.7
2006	Hendrickson Is	3	376.8 ± 0.87	20	400.9 ± 2.1	6	430.1 ± 2.4
2007	Hendrickson Is	2	360.7 ± 12.7	8	404.1 ± 3.7	8	443.2 ± 8.4
2008	Hendrickson Is	1	373.4	8	405.8 ± 3.9	4	436.2 ± 5.5
2010	Hendrickson Is	3	374.3 ± 4.2	8	401.0 ± 3.3	8	446.7 ± 10.3
2011	Hendrickson Is	2	369.6 ± 3.8	9	394.6 ± 2.7	6	427.1 ± 1.8
	East Whitefish					6	436.2 ± 5.1
	Kendall Is	4	358.8 ± 4.1	5	399.8 ± 3.7	5	428.7 ± 2.9
	Shingle Point					1	431.8
2012	Hendrickson Is	2	372.1 ± 3.8	17	400.8 ± 2.6	6	430.3 ± 4.4
	Kendall Is			5	398.3 ± 6.0	6	439.0 ± 5.7
2013	Hendrickson Is	1	352.1	15	402.9 ± 3.1	9	430.9 ± 2.8
	East Whitefish	3	323.4 ± 15.7	4	406.4 ± 4.0	3	436.9 ± 8.2
	Kendall Is			1	401.3	5	431.8 ± 3.0
2014	Hendrickson Is	2	352.4 ± 17.2	10	404.9 ± 3.3	5	433.3 ± 4.4
	East Whitefish	1	363.2	3	411.5 ± 5.3	11	446.8 ± 6.9
	Kendall Is			1	403.9	2	436.9 ± 5.1
2015	Hendrickson Is	6	362.6 ± 6.1	10	401.1 ± 3.8	5	432.3 ± 4.2
	East Whitefish	2	365.8 ± 5.1			9	441.7 ± 5.8
	Kendall Is			2	402.6 ± 6.3	1	459.7
2016	Hendrickson Is			5	404.9 ± 3.5	4	428.6 ± 2.8
	East Whitefish	2	348.0 ± 7.6	2	411.5 ± 7.6	2	431.8 ± 5.1
2017	Hendrickson Is	1	370.8	9	410.9 ± 2.2	15	435.0 ± 2.4
	East Whitefish	2	368.3 ± 7.6	4	394.4 ± 4.9	3	448.7 ± 4.7

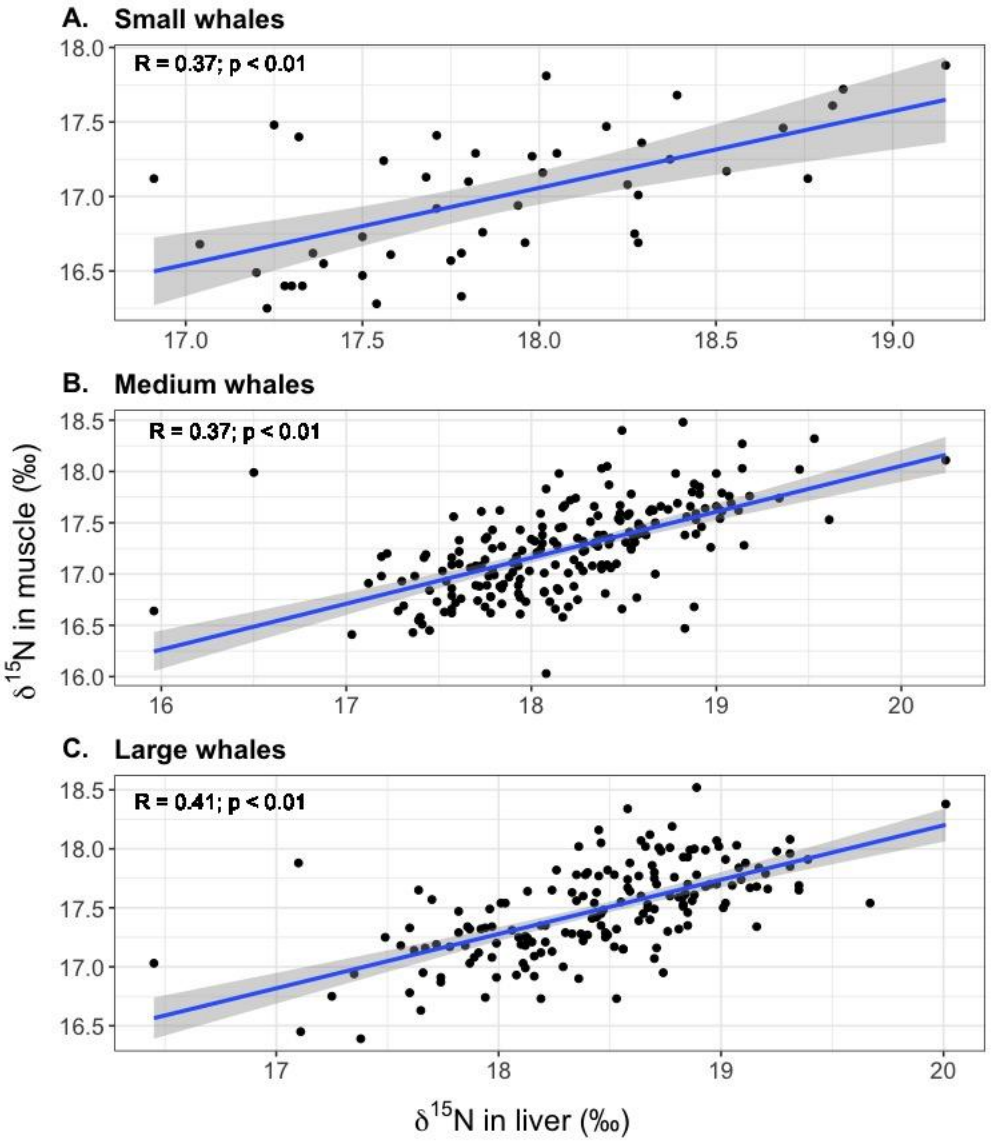
	Kendall Is			1	391.2	4	433.1 ± 3.0
2018	Hendrickson Is			4	406.1 ± 5.8	9	438.0 ± 3.3
	East Whitefish			3	414.0 ± 3.9	1	429.3
	Kendall Is					4	450.2 ± 6.7
	Shingle Point					3	457.2 ± 8.8
2019	Hendrickson Is	1	165.1	5	413.0 ± 1.5	9	431.8 ± 3.7
	East Whitefish					5	451.6 ± 7.3
2020	Hendrickson Is	1	370.8	11	402.5 ± 3.8	7	434.0 ± 4.4
	East Whitefish			4	406.4 ± 4.3		
	Kendall Is	1	365.8	1	408.9	5	437.4 ± 4.4
	Shingle Point			1	414.0	1	467.4
2021	Hendrickson Is	7	355.9 ± 10.1	7	400.2 ± 4.4	6	439.4 ± 4.3
	East Whitefish	1	373.4	3	401.3 ± 8.9	2	449.6 ± 10.2
	Kendall Is			5	407.4 ± 4.5	4	440.7 ± 3.0

Appendix 2: Average (mean ± standard deviation) length for male beluga whales sampled at each whaling camp between 2001 and 2021 and analyzed for carbon and nitrogen stable isotopes in liver. Belugas were grouped based on their length into small (< 380 cm), medium (≥ 380 cm and ≤ 420 cm) and large (> 420 cm).

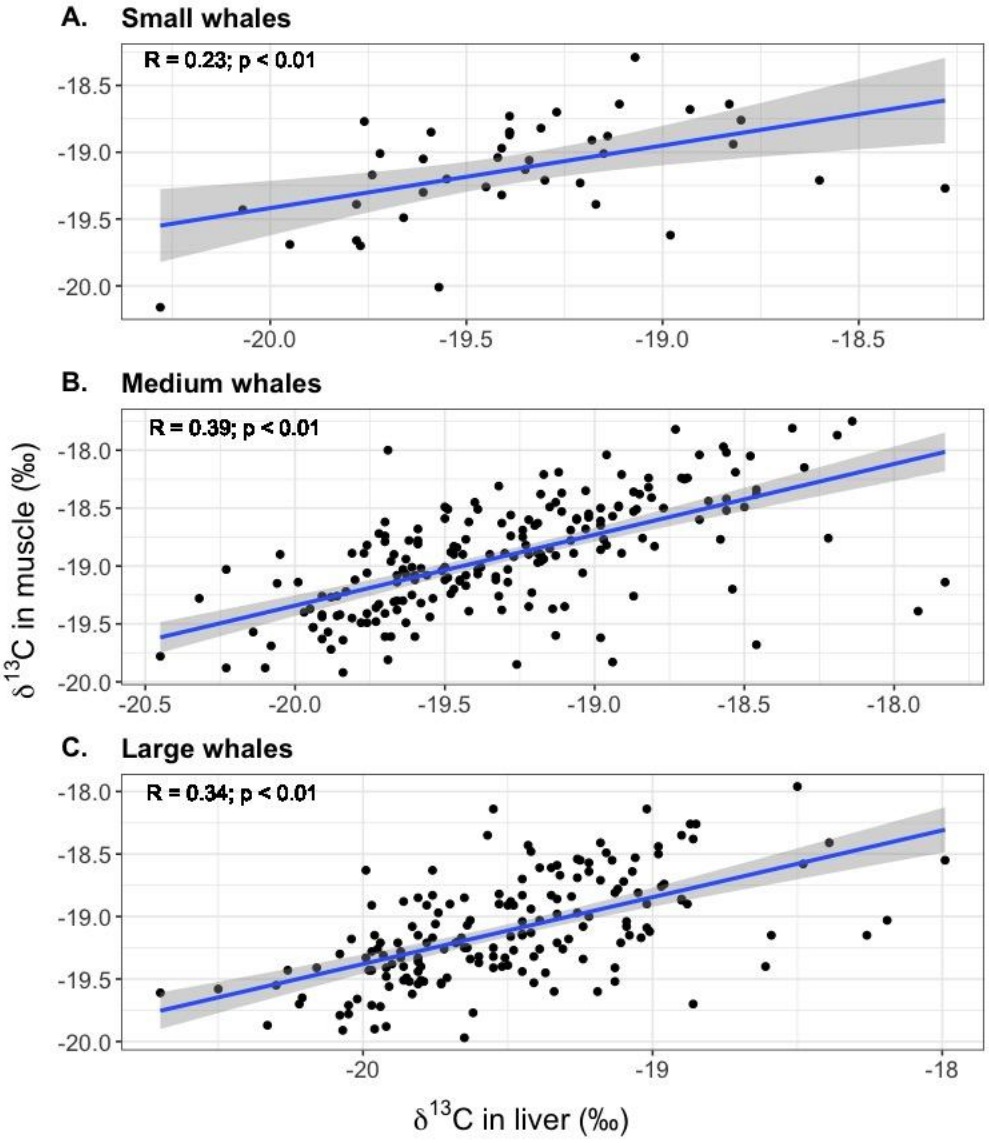
Year	Location	Small		Medium		Large	
		n	Length (cm)	n	Length (cm)	n	Length (cm)
2001	Hendrickson Is	1	375.9	4	404.2 ± 6.1	1	442.0
2002	Hendrickson Is	1	373.4	11	399.5 ± 3.8	10	435.6 ± 2.9
	Kendall Is			1	411.1	10	441.1 ± 3.0
2003	Hendrickson Is	2	356.9 ± 21.6	11	406.2 ± 3.0	7	431.2 ± 4.3
2004	Hendrickson Is	3	352.4 ± 1.6	8	411.2 ± 2.2	10	433.1 ± 3.8
	Kendall Is			1	388.6		
2005	Hendrickson Is			9	397.4 ± 4.1	6	438.6 ± 5.4
	Kendall Is	1	355.6 ± 0.9	2	398.8 ± 2.6	5	461.3 ± 10.7
2006	Hendrickson Is	3	376.8 ±0.9	355.6	401.6 ± 2.1	5	430.8 ± 2.9
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	East Whitefish	1	363.2	3	411.5 ± 5.3	10	447.8 ± 7.5
	Kendall Is			1	403.9	3	435.2 ± 3.4
2015	Hendrickson Is	6	362.6 ± 6.1	10	401.1 ± 3.8	5	432.2 ± 4.2
	East Whitefish	2	365.8 ± 5.1			9	441.7 ± 5.8
	Kendall Is			5	406.1 ± 4.8	2	440.7 ± 19.1
2016	Hendrickson Is	1	378.5	5	404.9 ± 3.5	3	429.2 ± 3.9
	East Whitefish	2	348.0 ± 7.6	2	411.5 ± 7.6	2	431.8 ± 5.1
2017	Hendrickson Is	1	370.8	10	410.5 ± 2.0	15	435.0 ± 2.4
	East Whitefish	2	368.3 ± 7.6	4	394.4 ± 4.9	3	4487 ± 4.7
	Kendall Is			1	391.2	4	433.1 ± 3.0

2018	Hendrickson Is			4	406.1 ± 5.8	9	438.0 ± 3.3
	East Whitefish			3	414.0 ± 3.9	1	429.3
	Kendall Is					3	446.2 ± 7.5
	Shingle Point			1	401.3	3	457.2 ± 8.8
2019	Hendrickson Is	1	165.1	4	412.1 ± 1.6	9	431.8 ± 3.7
	East Whitefish					5	451.6 ± 7.3
2020	Hendrickson Is	1	370.8	11	402.5 ± 3.8	7	434.0 ± 4.4
2021	Hendrickson Is	7	355.9 ± 10.1	6	402.2 ± 4.7	6	439.4 ± 4.3
	East Whitefish	1	373.4	3	401.3 ± 8.9	2	449.6 ± 10.2
	Kendall Is			4	407.0 ± 5.8	4	440.7 ± 3.0

Appendix 3: There were significant relationships between $\delta^{15}N$ values measured in the muscle and liver of EBS male beluga whales. Whales were grouped by size into small (A), medium (B) and large whales (C).



Appendix 4: There were significant relationships between $\delta^{13}C$ values measured in the muscle and liver of EBS male beluga whales. Whales were grouped by size into small (A), medium (B) and large whales (C).



Appendix 5: Results of the probabilities of niche overlap among years using muscle data for medium beluga whales. The mean probability indicates the probability of Year A niche being found within the niche of Year B. The probability of overlap is indicated by mean. The niche overlaps were calculated using $\alpha = 0.95$.

	YEAR A 2001	2002	2003	2004	2005	2006	2007	2008	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
YEAR B																				
2001	NA	**86.63**	**92.61**	**65.19**	**61.94**	48.63	29.48	**67.02**	**68.09**	**79.11**	**66.27**	49.56	**67.47**	44.84	41.49	**67.46**	**55.92**	**73.75**	**85.65**	**64.91**
2002	49.87	NA	**55.12**	38.04	36.29	31.04	2.05	42.34	44.58	47.82	43.59	27.09	33.66	44.38	33.09	42.22	17.52	29.99	49.25	28.47
2003	**61.89**	**60.77**	NA	**58.63**	47.75	32.44	9.6	41.95	46.23	**52.25**	28.23	12.8	29.48	10.33	14.54	23.64	24.72	13.82	**57.72**	32.93
2004	**63.99**	**70.97**	**89.09**	NA	53.34	41.01	42.36	**55.56**	**59.56**	**58.07**	39.91	15.5	36.18	20.12	22.63	26.56	27.34	22.36	**61.59**	35.49
2005	**54.88**	**55.56**	**72.82**	44.48	NA	**62.65**	16.59	48.4	**52.85**	**61.68**	32.49	10.96	33.67	8.38	13.98	21.23	16.98	13.24	47.62	30.04
2006	**75.32**	**87.07**	**80.73**	**57.57**	**92.04**	NA	**54.58**	**75.58**	**77.67**	**83.89**	**67.29**	31.37	**62.45**	37.71	36.98	54	32.18	**50.11**	**70.84**	47.78
2007	3.49	1.02	2.31	4.72	6.19	7.03	NA	17.89	14.23	9.08	12.94	2.91	10.3	6.66	7.88	0.65	0.11	7.15	1.7	3.3
2008	**83.47**	**90.48**	**85.2**	**62.03**	**81.93**	**68.29**	**92.46**	NA	82.2	**86.81**	**78.98**	**52.38**	**71.31**	**62.95**	**55.53**	**67.51**	48.95	**67.27**	**80.17**	**59.83**
2010	**83.44**	**92.14**	**89.36**	**70.22**	**83.1**	**72.13**	**87.32**	**83.21**	NA	**84.91**	**75.01**	47.1	**66.41**	**57.81**	**52.4**	**61.18**	45.62	**60.34**	**80.76**	**57.07**
2011	**79.65**	**80.41**	**76.09**	47.34	**79.26**	**61.84**	**47.05**	**71.56**	**69.56**	NA	**69.65**	42.24	**73.88**	38.86	38.49	**64.35**	43.7	**70.08**	**73.26**	**57.76**
2012	**71.3**	**82.48**	**57.16**	37.07	**70**	**56.48**	**81.32**	**77.16**	**70.95**	**83.93**	NA	**64.35**	**79.63**	**79.06**	**66.49**	**91.43**	**54.19**	**71.21**	**68.33**	**60.89**
2013	**71.31**	**66.3**	**53.9**	30.06	20.31	20.11	30.94	49.87	44.51	**55.52**	**69.2**	NA	**66.83**	**90.15**	**76.72**	**88.37**	**78.09**	**86.28**	**73.6**	**72.66**
2014	**67.04**	**67.59**	47.44	29.16	**51.16**	40.85	**60.08**	**65.58**	**58.33**	**78.15**	**74.1**	48.63	NA	42.23	40.8	**71.75**	42.77	**82.07**	**61.62**	**60.21**
2015	40.51	**60.04**	23.19	17.63	15.92	19.75	39.6	45.44	39.39	42.7	**64.04**	**60.58**	46.44	NA	**66.89**	**73.57**	47.65	49.81	44.03	37.29
2016	**69.52**	**81.11**	**58.82**	41.07	47.68	42.64	**72.91**	**69.78**	**64.8**	**71.37**	**82.37**	**77.29**	**69.28**	**94.53**	NA	**89.8**	**66.22**	**69.42**	**69.87**	**60.57**
2017	**57.53**	**71.68**	**45.62**	25.77	29.45	25.53	2.7	41.82	39.36	**55.23**	**60.73**	**50.82**	**54.69**	**56.62**	46.62	NA	49.06	**55.39**	**59.18**	47.7
2018	**55.3**	35.53	**47.97**	37.71	14.08	11.76	0.95	25.48	24.23	34.89	41.97	**62.13**	41.21	59.75	49.76	**71.53**	NA	**56.1**	**62.27**	**52.91**
2019	26.69	26.4	5.78	5.63	3.18	7.26	25.11	21.93	17.4	24.52	30.9	27.31	38.59	22.16	19.41	34.01	22.55	NA	27.26	28.95
2020	**87.14**	**90.23**	**91.73**	**70.36**	**50.11**	**40.7**	14.03	**60.79**	**62.57**	**71.57**	**65.72**	**57.49**	**62.19**	**59.2**	49.54	**76.72**	**64.81**	**69.08**	NA	**64.97**
2021	**94.05**	**92.2**	**94.3**	**71.01**	**67.03**	**55.52**	48.88	**76.04**	**75.78**	**85.25**	**83.73**	**76.75**	**84.06**	**75.58**	**66.42**	**92.43**	**75.2**	**89.51**	**92.48**	NA

Appendix 6: Results of the probabilities of niche overlap among years using muscle data for large beluga whales. The mean probability indicates the probability of Year A niche being found within the niche of Year B. The probability of overlap is indicated by mean. The niche overlaps were calculated using α = 0.95. (Bold are values considered significant (> 50%).

	YEAR A 2001	2002	2003	2004	2005	2006	2007	2008	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
YEAR B																				
2001	NA	36.83	38.72	41.16	**66.31**	31.29	35.2	11.44	38.97	15.91	6.22	20.22	34.69	11.28	10.41	31.6	29.54	21.72	42.69	39.82
2002	39.65	NA	45.03	**55**	**64.81**	30.95	**60.69**	**58.19**	**51.72**	18.79	25.07	33.93	42.3	12.21	10.84	39.39	18.59	21.41	**58.58**	31.48
2003	**78.47**	**91**	NA	**88.33**	**85.44**	**75.4**	**76.74**	**84.54**	**80.53**	33.38	48.81	43.53	**53.45**	21.71	21.98	**50.82**	32.28	32.68	**66.89**	49.98
2004	**67.31**	**84.58**	74.68	NA	**85.7**	**68.68**	**66.24**	**86.23**	**70.39**	27.9	37.37	30.86	46.59	17.02	6.72	33.41	26.53	26.81	**56.68**	45.21
2005	45.99	43.79	39.87	49.91	NA	41.36	37.27	21.71	39.92	13.82	9.15	17.55	35.24	9.33	4.41	22.07	21.88	19.71	36.99	36.37
2006	**65.53**	**66.61**	**70.46**	**78.75**	**85.28**	NA	**57.63**	**64.65**	**65.87**	24.2	33.72	25.5	43.52	15.81	7.75	29.31	26.78	26.82	49.22	43.62
2007	**60.98**	**90.47**	**67.19**	**74.03**	**82.83**	56.76	NA	**66.6**	**74.46**	28.57	37.05	**55.83**	**66.17**	22.82	44.67	**82.18**	44.56	42.04	**85.59**	**54.1**
2008	6.77	29.83	18.68	25.41	18.23	12.11	18.6	NA	17.91	6.11	12.92	5.6	11.5	3.56	0.24	3.33	3.3	5.38	11.63	6.59
2010	**79.58**	**93.66**	**81.06**	**85.18**	**88.29**	**72.02**	**86.13**	**75.53**	NA	33.75	47.36	**55.94**	**65.15**	24.87	40.72	**76.75**	43.17	41.64	**82.9**	**57.64**
2011	**92.64**	**99.97**	**95.93**	**98.5**	**98.87**	**86.18**	**98.14**	**98.31**	**96.37**	NA	83.4	**97.53**	**96.51**	**74.41**	**96.65**	**99.41**	**81.44**	**84.52**	**99.43**	**95.55**
2012	27.65	**67.62**	**63.4**	**62.97**	39.01	**63.51**	**58.04**	**85.44**	**61.08**	29.42	NA	49	31.09	26.36	**52.45**	41.43	14.45	22.88	36.67	18.66
2013	48.62	**91.05**	49.79	**57.07**	**74.58**	34.15	**80.03**	**63.23**	**62.27**	44.76	**52.2**	NA	**86.22**	41.63	**87.13**	**97.16**	**62.45**	**65.15**	**96.1**	**75.99**
2014	47.82	**89.37**	**52.97**	**64.21**	**82.5**	41.72	**78.66**	**73.44**	**63.15**	30.48	29.99	**60.97**	NA	27.99	44.12	**78.58**	**56.19**	**61.56**	**96.88**	**71.32**
2015	**93.57**	**99.97**	**95.52**	**98.23**	**99.16**	**86.81**	**98.83**	98.06	**96.68**	**89.38**	**89.18**	**99.38**	**99.58**	NA	**99.05**	**100**	**96.79**	**97.38**	**99.9**	**99.05**
2016	10.67	17.5	8.69	5.15	10.98	4.13	32.83	1.52	18.87	19.88	26.81	**55.36**	45.01	23.88	NA	**71.71**	36.95	38.33	50.14	34.75
2017	30.51	49.76	19.64	21.36	45.84	13.31	**53.53**	9.36	34.01	19.08	14.39	**53.12**	**55.69**	18.47	**54.24**	NA	39	35.12	**77.58**	47.44
2018	**76.73**	**67.51**	**50.84**	**56.1**	**82.33**	39.48	71	25.52	**59.76**	35.84	15.1	**59.38**	**80.4**	37.15	**51.04**	**85.57**	NA	**68.51**	**88.44**	**84.43**
2019	**73.99**	**96.27**	**73.84**	**82.32**	**93.58**	**62.47**	**91.67**	76.85	**81.26**	**50.79**	51.35	**82.9**	**96.73**	51.5	**74.97**	**96.75**	**84.86**	NA	**98.76**	**91.43**
2020	24.34	**62.21**	25.36	29.24	42.07	16.91	**52.7**	33.92	36.58	15.25	11.9	37.9	**59.46**	13.01	22.92	**57.94**	32.02	31.28	NA	41.21
2021	**75.45**	**76.28**	**56.89**	**64.33**	**87.38**	45.67	**74.79**	36.84	**64.78**	37.97	18.42	**59.59**	**83.04**	33.54	46.76	81.1	**70.25**	**64.72**	**90.97**	NA

Appendix 7: Results of the probabilities of niche overlap among years using liver data for medium beluga whales. The mean probability indicates the probability of Year A niche being found within the niche of Year B. The probability of overlap is indicated by mean. The niche overlaps were calculated using α = 0.95. (Bold are values considered significant (> 50%).

	YEAR A 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
YEAR B 2001	NA	33.8	18.21	28.25	16.62	14.56	4.75	6.86	22	34.65	15.82	15.83	14.4	24.61	17.89	7.16	1.1	18.16	27.51	13.51	21.73
2002	57.35	NA	33.64	41.22	31.62	25.32	7.68	14.64	48.94	41.18	31.01	37.75	31.08	29.66	33.42	19.88	3.73	42.43	51.75	34.82	33.08
2003	**89.24**	**82.73**	NA	**83.62**	**50.88**	36.35	15.24	23.55	**59.09**	**60.88**	43.82	48.01	43.22	48.53	44.92	28.6	13.95	51.3	**69.58**	**64.48**	**53.89**
2004	**90.23**	**70.7**	**68.63**	NA	**55.13**	38.5	20.17	20.57	51.63	**63.4**	47.92	40.46	33.98	48.07	37.07	25.06	10.5	44.69	**69.45**	**50.83**	**51.76**
2005	**89.24**	**79.04**	**69.97**	**85.26**	NA	**76.1**	**66.03**	39	**75.91**	**84.52**	**91.28**	**76.74**	42.91	**66.19**	**60.73**	45.69	46.1	71.11	**91.03**	**62.85**	**68.81**
2006	**97.5**	**89.33**	56.3	**78.47**	**85.99**	NA	**84.31**	53.44	**93.32**	**93.11**	**98.73**	**96.82**	61.9	**82.03**	**87.74**	**56.36**	**74.61**	**91.22**	**94.44**	**61.22**	**80.41**
2007	11.84	15.23	8.79	14	24.54	27.79	NA	23.31	27.18	29.8	43.92	35.39	8.73	24.31	24.11	16.28	29.36	26.6	45.94	16.64	21.91
2008	**85.4**	**84.99**	**61.53**	**73.14**	**71.14**	**72.75**	**96.36**	NA	**90.14**	**82.53**	**88.8**	**90.85**	**79.01**	**75.72**	**82.07**	**63.9**	**92.35**	**86.38**	**94.48**	**68.38**	**76.77**
2009	**79.78**	**79.23**	36.14	49.79	**53.34**	**56.48**	**50**	37.9	NA	**73.19**	**81.23**	**82.7**	53.44	**59.72**	**69.07**	40.37	**61.69**	**78.39**	**84.35**	46.93	**59.54**
2010	**94.19**	**66.28**	37.56	**58.27**	**56.19**	**58.04**	**50.34**	29.3	**70.68**	NA	**80.93**	**73.4**	37.5	**63.97**	**59.73**	30.86	34.71	**65.99**	**79.54**	39.5	**58.64**
2011	47.43	**55.8**	18.96	27.61	49.16	**54.6**	**46.03**	26.18	**68.09**	**62.39**	NA	**72.13**	29.88	44.62	**50.51**	29.89	38.85	**63.63**	**71.67**	32.4	43.65
2012	**71.08**	**61.62**	21.86	29.4	42.07	**57.08**	**65.73**	36.18	**78.85**	**70.89**	**81.41**	NA	44.35	**61.27**	**73.86**	34.71	**59.13**	**75.64**	**72.55**	34.63	**54.46**
2013	**96.64**	**90.1**	**73.64**	**85.42**	**58.31**	**56.84**	**50.24**	**63.47**	**90.09**	**80.02**	**71.37**	**84.45**	NA	**75.12**	**81.35**	61.1	**86.82**	**84.83**	**92.83**	**69.85**	**77.45**
2014	**97.71**	**74.48**	45.65	**69.21**	**58.82**	**66.49**	**86.7**	51.2	**86.11**	**88.47**	**82.36**	**92.14**	**57.25**	NA	**87.27**	42.99	**67.68**	**82.06**	**88.09**	48.49	**76.48**
2015	**89.49**	**67.48**	31.02	44.49	44.26	**59.05**	**79.39**	48.28	**82.88**	**78.25**	**75.3**	**91.12**	**57.11**	**76.89**	NA	41.07	**72.23**	**80.08**	**76.5**	40.74	**66.19**
2016	**88.09**	**97.42**	**74.77**	**80.35**	**86.72**	**84.54**	**87.57**	**76.72**	**96.26**	**86.83**	**96.96**	**94.55**	**88.82**	**76.78**	**85.48**	NA	**98.96**	**93.69**	**96.96**	**82.38**	**81.68**
2017	2.1	5.43	3.51	4.5	21.38	32.03	**51.59**	33.24	37	24.57	47.77	47.41	35.1	26.43	36.32	31.7	NA	38.39	34.16	20.97	25.11
2018	**81.65**	**79.07**	36.25	49.85	**57.1**	**63.25**	**58.88**	41.99	**86.57**	**77.13**	**86.22**	**87.72**	**56.61**	**64.42**	**74.57**	44.37	**69.01**	NA	**84.28**	47.81	**62.96**
2019	41.72	49.62	29.93	39.7	36.32	32.66	36.15	22.89	**50.03**	47.24	**53.58**	47.34	23.19	33.42	33.41	21.76	31.59	43.64	NA	34.89	35.09
2020	**84.18**	**90.44**	**89.58**	**84.15**	**71.46**	**61.44**	**57**	**56.44**	**87.16**	**76.29**	**81.7**	**81.07**	**71.79**	**64.04**	**69.63**	**58.72**	**82.14**	**80.54**	**95.89**	NA	**71.49**
2021	**98.48**	**89.02**	**70.5**	**89.03**	**78.43**	**76.66**	**80.91**	**58.23**	**93.12**	92	**91.8**	**94.43**	**69.7**	**86.32**	**88.11**	**55.5**	**79.11**	**89.49**	**95.78**	**67.65**	NA

Appendix 8: Results of the probabilities of niche overlap among years using liver data for large beluga whales. The mean probability indicates the probability of Year A niche being found within the niche of Year B. The probability of overlap is indicated by mean. The niche overlaps were calculated using $\alpha = 0.95$. (Bold are values considered significant (> 50%).

	YEAR A 2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
YEAR B																				
2002	NA	**57.48**	**68.5**	23.34	45.69	**76.29**	27.8	**75.37**	**72.72**	**57.03**	16.47	24.31	48.82	**52.92**	8.7	31.27	**56.13**	49.22	**63.92**	45.65
2003	**82.54**	NA	**73.83**	42.3	49.86	**51.43**	42.95	**67.74**	**77.5**	**67.91**	28.2	18.71	**47.81**	43.69	6.57	30.61	**61.45**	**52.98**	**71.51**	45.2
2004	**93.31**	**74.14**	NA	42.17	**55.24**	**85.13**	45.17	**84.72**	**81.59**	**73.01**	28.96	36.99	**62.56**	**67.3**	17.3	**57.77**	**66.48**	**60.92**	**74.7**	**57.75**
2005	**90.41**	**89.21**	**88.25**	NA	**56.33**	**76.51**	44.62	**75.19**	**82.76**	**75.22**	34.13	38.57	**72.88**	**63.91**	26.44	40.04	**80.68**	**70.03**	**80.66**	**73.83**
2006	**77.55**	48.58	**57.52**	19.65	NA	**84.72**	**65.08**	**83.25**	**70.93**	**62.32**	39.25	33.31	**56.9**	**64.86**	17.49	**57.02**	51.67	**54.85**	**67.8**	49.3
2007	42.97	13.14	28.83	7.45	25.3	NA	13.68	**52.14**	36.83	23.46	8.27	25.83	29.32	44.86	15.53	24.98	32.18	30.09	29.14	27.12
2008	41.51	38.74	34.32	13.02	**58.85**	49.55	NA	**70.97**	**62.99**	**53.69**	**54.58**	39.93	30.69	**51.96**	37.16	**86.10**	28.89	41.37	48.55	18.3
2009	**62.16**	39.31	43.51	11.98	43.68	**78.55**	37.62	NA	**77.13**	48.24	21.56	28.3	34.93	**53.96**	20.63	46.78	41.86	44.18	**52.26**	26.18
2010	48.33	41.66	34.48	12.94	28.73	**52.29**	21.84	**70.07**	NA	39.42	14.85	18.59	24.08	36.63	14.83	28.04	34.53	34.63	42.91	16.77
2011	**95.78**	**87.08**	**88.42**	47.03	**71.85**	**91.59**	**76.4**	**93.39**	**91.98**	NA	**54.11**	**50.59**	**67.06**	**78.71**	31.89	**86.37**	**74.44**	**71.83**	**86.06**	**60.18**
2012	**60.53**	62.9	**51.59**	27.8	**68.85**	**63.11**	**90.67**	**83.91**	**84.93**	**71.18**	NA	**66.74**	42.71	65.84	**67.63**	**96.83**	49.73	**58.34**	**66.46**	31.11
2013	**71.21**	30.97	**59.17**	22.58	47.97	**97.29**	47.4	**76.2**	**56.61**	**51.94**	49.35	NA	**66.75**	**85.72**	**83.02**	**86.17**	**55.76**	**59.92**	**54.02**	**62.18**
2014	**98.15**	**81.94**	**91.7**	48.73	**74.22**	**98.7**	**68.08**	**96.41**	**90.56**	**84.53**	46.02	**60.92**	NA	**90.68**	52.5	**81.48**	**82.27**	**81.89**	**87.92**	**84.55**
2015	**89.11**	**52.61**	**73.12**	26.06	**62.2**	**98.48**	**60.03**	**91.34**	**77.62**	**68.83**	44.05	**65.74**	**70.79**	NA	**61.06**	**89.64**	**67.32**	**69.5**	**71.51**	**66.76**
2016	17.04	6.07	14.83	7	17.04	**52.52**	23.49	33.05	22.71	16.86	28.69	**57.59**	28.32	47.24	NA	45.49	28.05	32.96	18.07	31.67
2017	31.61	16.98	26.18	5.73	39.51	**50.46**	**57.48**	**65.33**	**50.77**	39.54	40.88	42.16	23.62	49.85	34.24	NA	17.89	30.18	31.41	10.85
2018	**91.31**	**78.3**	**77.52**	45.59	48.47	**92.96**	30.79	**85.19**	**90.37**	**67.2**	23.13	39.53	**64.83**	**70.83**	39.03	33.9	NA	**73.43**	**76.23**	**73.29**
2019	**98.05**	**89.54**	**88.97**	**51.42**	**73.07**	**98.88**	**74.29**	**98.62**	**97.32**	**87.05**	**52.3**	**61.31**	**81.05**	**90.96**	**65.2**	**82.82**	**90.83**	NA	**91.42**	**84.14**
2020	**93.86**	**80.2**	**79.6**	37.36	**67.79**	**90.07**	**60.12**	**90.5**	**88.86**	**77.27**	38.28	39.06	**66.13**	**72.1**	24.56	**57.51**	**73.38**	**69.5**	NA	**62.82**
2021	**88.93**	**70.05**	**80.59**	47.72	**47.92**	**90.49**	25.95	**74.84**	**75.24**	**62.15**	19.01	42.27	**74.73**	**70.91**	40.4	30.15	**81.54**	**70.93**	**71.46**	NA