# Ecological factors differentially affect mercury levels in two species of sympatric marine birds of the North Paci c

J.M. Hipfner [a,], K.A. Hobson [b], J.E. Elliott [a]

[a] Environment Canada, Paci c Wildlife Research Centre, RR#1 5421 Robertson Road, Delta, BC, Canada, V4K 3N2
[b] Environment Canada, 11 Innovation Blvd., Saskatoon, SK, Canada, S7N 3H5

a r t i c l e i n f o

Article history:
Received 22 September 2010
Received in revised form 10 December 2010
Accepted 15 December 2010
Available online 26 January 2011

Keywords:
Auklets
Breeding stage
Mercury
Seabirds
Stable isotopes
Triangle Island

a b s t r a c t

In 2003 and 2004, we measured mercury concentrations and $^{15}N$ and $^{13}C$ values in the whole blood of adults of two species of seabirds, Cassin's auklet (Ptychoramphus aleuticus) and rhinoceros auklet (Cerorhinca monocerata), during their prelaying, incubation, and provisioning periods. We also collected whole blood from the offspring of both seabirds. Among prey items, $^{15}N$ values were higher in sh than in crustaceans, while $^{13}C$ did not vary systematically between prey types. Mercury concentrations in prey showed little relationship with either stable isotope. In the zooplanktivorous Cassin's auklet, year, reproductive stage, and $^{15}N$ and $^{13}C$ stable isotope values explained only 14% of the variation in mercury concentrations in adult blood, and none of these variables had a statistically signi cant effect. In contrast, these same variables explained 41% of the variation in mercury levels in the more piscivorous rhinoceros auklet, and all but $^{15}N$ values had statistically signi

nitrogen ( $^{15}N$) in tissues sampled from a wide range of food web components ( Jarman et al., 1996; Braune et al., 2005). A positive correlation between tissue $^{15}N$ values and mercury concentrations is often found within seabird communities ( Campbell et al., 2005; Elliott, 2005; Anderson et al., 2009 ), although some studies report no such relationship in both intraspeci c (Jaeger et al., 2009) and interspeci c (Lavoie et al., 2010) comparisons. Others nd that the strength of the correlation depends on the tissue sampled ( Bond and Diamond, 2009 ).

In addition, because stable-carbon isotope measurements ( $^{13}C$) are typically higher in benthically linked rather than pelagic biota in marine foodwebs ( Hobson and Welch 1992 ), and because benthic habitats are reducing environments where the contaminant accumulates in sediments ( Fitzgerald et al., 2007 ), positive correlations between mercury load and $^{13}$

2.2. Laboratory analyses

All blood and prey samples were shipped frozen to the Environment Canada laboratory at the National Wildlife Research Centre (NWRC) in Ottawa.

For each prey item, copepod, euphausiid, saury, rock sh and sandlance, the samples were prepared as three equal subpools for analysis. Those subpools were weighed, and then homogenized using a Retsch ball mill. Blood samples were thawed, weighed to determine their moisture content, and then freeze-dried and homogenized. The freeze-dried samples were divided in half, with one half remaining at NWRC for measurement of total mercury concentrations, the other sent to the Environment Canada lab of KAH for measurement of stable isotope ratios of carbon and nitrogen (see below).

Concentrations of mercury in freeze-dried blood and prey samples were determined using an AMA-254 advancer mercury analyser. Results are reported in g g $^{1}$ dry weight. Quality assurance procedures included use of certi ed reference materials (CRM „ Daily Calibration Check Standards from Institute for Reference Materials and Measurements: ERM®-CE278 Mussel Tissue and BCR®-463 Tuna Fish). The accuracy of the method was con rmed by analyzing the concentration of certi ed reference materials Dolt-3 and Tort-2 from NRC and Oyster Tissue 1566b from NIST. To check for the homogeneity of mercury in the samples, 16 samples were analyzed in duplicate. Replicates of the certi ed reference materials were also analyzed to check the calibration of the instrument, the within-run precision, and the reproducibility of the method. The practical detection limit of the instrument is 0.12 ng Hg, which corresponds to 0.006 g g $^{1}$ in the average 0.020 g dry mass sample.

Recoveries of total mercury for the daily calibration check standards ranged from 98.7 to 105.3% „ within acceptable limits. Based on 16 replicate measurements, measurement precision for mercury was estimated to be 1.84%±2.60 SE for blood samples. For two prey samples, one sh and one crustacean, the measurement precision was estimated to be 1.1% and 0.3%, respectively.

Stable-carbon and nitrogen isotope assays of whole dried blood and homogenized prey items were performed on 1 mg subsamples of powdered material at the stable isotope facility of the Department of Soil Science, University of Saskatchewan. Lipids were not removed from blood samples due to expected low lipid levels. However, we used a 2:1 chloroform:methanol soak and rinse to remove lipids from prey samples to avoid effects of differential concentrations of isotopically ( $^{13}$C) light lipids. Samples were rst loaded into tin cups and combusted in a Robo-Prep elemental analyzer at 1200 °C. The resultant $CO_2$ and $N_2$ gases were separated and analyzed using an interfaced Europa 20:20 continuous- ow isotope ratio mass spectrometer, with every fth sample separated by two (albumin) laboratory standards. Results were reported in delta notation in parts per thousand ( ‹ ) relative to Air ( $^{15}$N) and VPDB ( $^{13}$

### 3.2. Stable isotopes in seabird blood

In the full MANOVA model, each of year, species and reproductive stage (all three adult phases plus nestlings) had highly statistically signi cant effects on $^{15}N$ and $^{13}C$ values (all $p < 0.001$). Therefore,

F 1.19, all pN0.28). Further, standard errors around parameter estimates overlapped zero. Thus, there was no indication that any of our suite of ecological predictor variables appreciably in uenced mercury concentrations in Cassin's auklets ( Fig. 4).

For rhinoceros auklets, in contrast, the full model including year, stage, $^{15}N$ and $^{13}C$ values had good explanatory power ( $R^2 = 0.41$, $F_{5,65} = 9.10$, $p < 0.001$), and all variables had statistically signi cant effects ($p < 0.02$) with the exception of $^{15}N$ ($p = 0.998$). Based on parameter estimates and their standard errors ( Table 5), mercury concentrations in adult rhinoceros auklets were higher in 2003 than in 2004, peaked prior to laying ( Fig. 4), and increased with $^{13}C$ values. It is clear from Fig. 5 however that there was a positive relationship between mercury concentrations and $^{13}C$ values only in 2003, but as we had no a priori reason to expect this yearly difference we did not include the year × $^{13}C$ term in our model. When we added that interaction term, it markedly improved the explanatory power of the model ($R^2 = 0.56$) and the interaction term was highly statistically signi cant ($p < 0.001$).

### 3.4. Mercury in seabird blood in relation to age

rhinoceros auklet provisioners (1.754 g g $^{1}$ ±0.113 SE) and theirs (0.406 g g $^{1}$ ±0.123 SE). However, the relative difference was similar, in that adult values were approximately 3 ..4 times higher

Wang Q, Kim D, Dionysiou DD, Sorial GA, Timberl ake D. Sources and remediation for mercury contamination in aquatic systems: a liter ature review. Environ Poll 2004;131:323 ..36.
Wanless S, Harris MP. Time spent at the colony by male and female guillemots Uria aalge and razorbills Alca torda. Bird Study 1988;33:168 ..76.
Wayland M, Hoffman DJ, Mallory ML, Alisauskas RT, Stebbins KR. Evidence of weak contaminant-related oxidative stress in Glaucous Gulls ( Larus hyperboreus) from the Canadian Arctic. J Toxicol Environ Health A 2010;73:1058 ..73.
Wayland M, Gilchrist HG, Neugebauer E. Concentrations of cadmium, mercury and selenium in common eider ducks in the eastern Canadian Arctic: in uence of reproductive stage. Sci Total Environ 2005;351:323 ..32.
Wolf SG, Sydeman WJ, Hipfner JM, Abraham CL, Tershy B, Croll DA. Range-wide reproductive consequences of ocean climate variability for the seabird Cassin's Auklet. Ecology 2009;90:742 ..53.