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Selenium Accumulation in Sea Ducks Wintering at Lake Ontario

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Abstract Numbers of wintering sea ducks, including buffleheads (*Bucephala albeola*; BUFF), common goldeneyes (*Bucephala clangula*; COGO), and long-tailed ducks (*Clangula hyemalis*; LTDU), increased substantially at Lake Ontario after Dreissenid mussels (*Dreissena bugensis* and *D. polymorpha*) colonized the Great Lakes. Invertebrates, including Dreissenid mussels, are major diving duck prey items that can transfer some trace elements, such as selenium (Se) to higher trophic levels. Se can be problematic for waterfowl and it often has been detected at elevated levels in organisms using the Great Lakes. There are, however, few data on hepatic Se concentrations in sea ducks, particularly during the winter at Lake Ontario. In this study, we evaluated interspecific differences and temporal trends in hepatic Se concentrations among BUFF ($n = 77$), COGO ($n = 77$), and LTDU ($n = 79$) wintering at Lake Ontario. All three species accumulated Se throughout winter, but COGO did so at a higher rate than did BUFF and LTDU. Overall, Se concentrations were higher in LTDU [$\bar{x} = 22.7$; 95% CI = 20.8–24.8 µg/g dry weight (dw)] than in BUFF ($\bar{x} = 12.3$; 95% CI = 11.6–13.1 µg/g dw) and COGO ($\bar{x} = 12.0$; 95% CI = 10.7–3.5 µg/g dw) throughout the winter. Se concentrations were deemed elevated (>33 µg/g dw) in 0%, 5%, and 19% of BUFF, COGO, and LTDU, respectively. Presently there are no data on Se toxicity end points for these species, so it is unclear how acquiring concentrations of these magnitudes affect their short- and long-term health or reproduction.

The lower Great Lakes (LGL) and associated wetland complexes provide some of the most important habitat for waterfowl in eastern North America (Dennis et al. 1984; Prince et al. 1992). As a result of its geographical location within a highly industrialized, agricultural, and populated region of North America, aquatic ecosystems in the LGL basin are subject to numerous environmental stressors. The LGL also are an important trans-Atlantic and international shipping corridor, which periodically results in the introduction of invasive species (Environment Canada 2006). Two of the most prominent factors affecting the LGL ecosystem, and thus waterfowl, are non-native species introductions and environmental contaminants (Custer and Custer 1996; 2000; Wormington and Leech 1992).

The introduction of Dreissenid mussels (collectively zebra mussels, *Dreissena polymorpha*, and quagga mussels, *D. bugensis*) was one of the most biologically significant events to have occurred in recent times within the LGL and had major implications for the abundance, distribution, and food of waterfowl (Badzinski and Petrie 2006; Custer and Custer 1996; Hamilton and Ankney 1994; Wormington and Leech 1992). Dreissenid mussels were first detected in Lake St. Clair during the mid-1980s and

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became widespread and abundant throughout the LGL by the mid to late 1990s (Griffiths et al. 1991; Hebert et al. 1991). Dreissenid mussels are associated with concurrent declines in Gastropoda populations, but their shells also can increase available surface area for colonization by other invertebrates, including Amphipoda and Chironomidae (Stewart and Haynes 1994; Wisenden and Bailey 1995).

Following Dreissenid mussel introduction, there were not only large increases in numbers of spring- and fall-migrant lesser scaup (*Aythya affinis*) and greater scaup (*Aythya marila*) on the LGL but also in numbers of sea ducks, including scoters (*Melanitta* spp.), long-tailed ducks (*Clangula hyemalis*), bufflehead (*Bucephala albeola*), and common goldeneyes (*Bucephala clangula*) during the winter at Lake Ontario (Petrie and Knapton 1999; Schummer 2005). In some years, a combination of factors might enable large numbers of sea ducks to winter at Lake Ontario, including relatively mild temperatures, reduced ice cover, and locally abundant invertebrate forage (Assel 2003; Schummer et al. 2008b).

Invertebrates, such as Dreissenid mussels and Amphipoda, are major prey items of diving and sea ducks staging and wintering at the LGL (Custer and Custer 1996; Ross et al. 2005; Mitchell and Carlson 1993; Schummer et al. 2008a) and are known to bioaccumulate organic contaminants and trace elements present within aquatic environments (Custer et al. 2000; Mills et al. 1993; Secor et al. 1993; Weegman and Weegman 2007). Several studies have focused on selenium (Se) acquisition and possible Se-related effects on staging and winter body condition and health of lesser and greater scaup on the Great Lakes (Custer et al. 2000, 2003; Petrie et al. 2007; Ware 2008). Despite that sea ducks are also a major seasonal component of the LGL ecosystem, there are relatively few data on potential linkages among winter foods and Se acquisition for these species (Custer and Custer 2000; Schummer 2005; Sea Duck Joint Venture Management Board 2008).

In this study, we examined interspecific patterns and temporal dynamics of hepatic Se concentrations in buffleheads (BUFF), common goldeneyes (COGO), and long-tailed ducks (LTDU) collected during the winters of 2002–2003 and 2003–2004 on northeastern Lake Ontario. Dreissenid mussels and Amphipoda collected from the LGL and elsewhere contain detectable Se concentrations in their tissues (Custer et al. 2000; Mills et al. 1993; Ware 2008; Weegman and Weegman 2007). During winter, at the LGL, invertebrates are common prey of BUFF, COGO, and LTDU (Custer and Custer 1996; Ross et al. 2005), but these species had slightly different diets and/or foraging strategies at Lake Ontario (Schummer et al. 2008a). Thus, we expected that hepatic Se concentrations would increase throughout winter in all three species but also that concentrations might differ among species. We further compare hepatic Se concentrations of these species to (1) biological effect thresholds determined from captive mallards [*Anasplatyrhynchos*; ≥10 μg/g dry weight (dw) = reproductive impairment; ≥33 μg/g dw = health impairment; Heinz et al. 1990], (2) liver concentrations in other waterfowl, particularly those collected on the Great Lakes, and (3) those of conspecifics collected from other locations and periods during the annual cycle. These comparisons will determine whether any of these species of sea ducks wintering on Lake Ontario have potentially "elevated" (i.e., >33 μg/g dw; Heinz et al. 1990) Se concentrations, plus assess extent of temporal and geographic variation in hepatic Se concentrations within these species.

Materials and Methods

Study Area

This study was conducted at Lake Ontario, along the southeast shoreline of Prince Edward County, Ontario. Substrate and vegetation varied across the study area; mud substrate and abundant submerged aquatic macrophytes in the west (43°55′ N, 77°02′ W) and limestone substrate with little or no vegetation at the east end of Prince Edward Bay (43°56′ N, 76°51′ W) to Point Petre (43°50′ N, 77°09′ W; Barton 1986). Thus, once shallow bays at the west end of the bay froze, available food generally were benthic invertebrates, including Dreissenid mussels, Chronomidae, Amphipoda, and Gastropoda. Lake Ontario remains relatively ice-free most years (Assel 2003) and provides winter habitat for waterfowl, particularly sea ducks (Schummer 2005).

Liver Collections

We conducted this study under Canadian Wildlife Service Scientific-Capture Permit No. CA 0166. We collected adult ducks totaling 166 (2002–2003 = 102, 2003–2004 = 64) BUFF, 119 (2002–2003 = 59, 2003–2004 = 60) COGO, and 165 (2002–2003 = 77, 2003–2004 = 88) LTDU during 2002–2003 and 2003–2004 from December to March. All specimens were collected using shotguns (with steel shot). We attempted to collect birds each week throughout each winter (~50 individuals of each species per month) from 26 locations widely distributed across 60 km of shoreline. We ended collections when large changes in waterfowl abundance were observed during weekly surveys conducted in late winter; this minimized inclusion of migrants in analyses (Schummer 2005). At the end of daily collection sessions, birds were tagged, double-bagged, frozen, and transported to laboratory facilities at the University of Western Ontario, London, Ontario.

In the lab, birds were thawed at room temperature and dissected as described by Schummer (2005). During dissections, small samples of liver tissue (~5 g) were excised from each bird, placed separately in sample bags, and stored frozen until analyzed for Se. We did not analyze liver samples of all birds collected but rather a subset of individuals of each species. Livers heavily damaged during collection or those contaminated with visible amounts of bile were excluded from analyses. We randomly selected 40 livers from each species and sex for Se analyses. To distribute samples throughout winter, we divided total sample size (pooled for 2002–2003 and 2003–2004) of usable livers by 40 to produce a selection integer for each species and sex. Next, for each species and sex, we selected the bird collected earliest in December for Se analysis and used the selection integer to determine subsequent ducks to sample. For some species and sex combinations, a sample size of 40 was not available.

Contaminant Analyses

Frozen liver tissues were sent to Laurentian University, Sudbury, Ontario (Belzile et al. 2005). Liver samples were freeze-dried and ground to fine powder before digestion. After homogenization, a 0.2-g liver sample was weighed and digested with 2.0 mL of 30% (w/w) H_2O_2 and 8.0 mL of 15.0 M HNO_3 in a microwave digestion system. A procedure including a three-step preheating was applied and the microwave digestion was done at 210°C for 10 min. The digest was diluted to appropriate concentration before the determination of total Se by hydride generation–atomic fluorescence spectrometry (HG-AFS; PSA Millennium Excalibur 10.055). The instrument detection limit was 5 ng/L for Se and the method detection limit was 2.5 μg/kg dw. For quality control, the certified reference material DOLT-2 (dogfish liver) was used. For every eight samples digested, a reagent blank and a DOLT-2 sample were analyzed and 100% of DOLT-2 control analyses were within the certified variation range (6.06 ± 0.49 mg/kg dw). All reagent blanks were very low and therefore neglected.

Statistical Analyses

We used a General Linear Model using least squares (SAS Institute 2002) to evaluate several sources of variation in hepatic Se concentrations of sea ducks. The model we initially specified included main effects of year (2002–2003, 2003–2004), species (BUFF, COGO, LTDU), sex (female, male), and day (both years: 1 = 15 December; 100 = 22 March), plus interactive effects of Year × Day, Species × Day, and Sex × Day. Year and sex (plus two-way interactions with day) were included in models to test and control for possible variation due to these factors. Specification of remaining effects allowed us to test our hypotheses that hepatic Se concentrations would increase throughout winter in all three species and Se concentrations would differ among species. Type 3 sums of squares were evaluated and the initial model was reduced using backward elimination of interactions and appropriate main effects ($p > 0.10$). A Normal probability plot of model residuals was assessed and it was determined that a log (ln) transformation of hepatic Se concentrations was necessary to normalize error residuals; data conformed to all other assumptions of linear models. Throughout, we report geometric means and predicted values (back-transformed), and parameter estimates (ln-transformed) and 95% confidence intervals are reported.

Results

The final model describing variation in log-transformed hepatic Se concentrations of sea ducks included the main effects and interaction between species and day (Model: $R^2 = 0.55$, $F_{5,\ 227} = 55.87$, $p \leq 0.0001$; Effects: species, $F_{2,\ 227} = 25.24$, $p \leq 0.0001$; day, $F_{1,\ 227} = 83.94$, $p \leq 0.0001$; Species × Day, $F_{2,\ 227} = 4.45$, $p = 0.0127$). This model showed that hepatic Se concentrations increased throughout winter in all three species, but COGO accumulated Se at a faster rate than did BUFF and LTDU (Fig. 1; Tables 1, 2). Throughout the entire winter, BUFF had much lower hepatic Se concentrations than did LTDU. BUFF also had lower Se concentrations than did COGO late in winter, but both species had relatively similar concentrations throughout early- and mid-winter periods. In addition, COGO had lower hepatic Se concentrations than did LTDU throughout winter, but they began to approach concentrations accumulated by LTDU later in winter (Fig. 1).

Discussion

Se Acquisition and Interspecific Differences in Sea Ducks

Rates of acquisition and levels of trace elements or contaminants in birds are influenced by diet and trophic foraging level (Di Giulio and Scanlon 1984; Heinz 1996; Mazak et al. 1997). Major invertebrates eaten by BUFF, COGO, and LTDU at Lake Ontario have been shown to contain varying concentrations of Se (Mills et al. 1993;

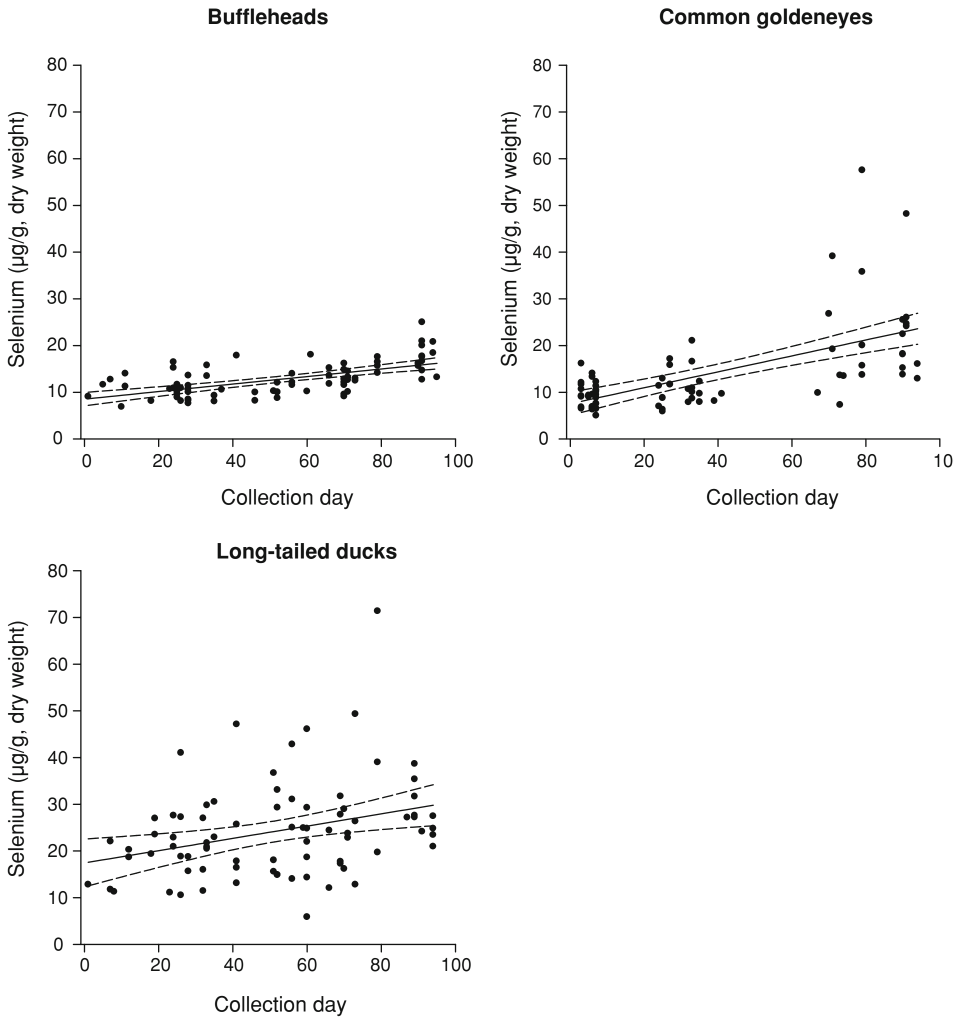

Fig. 1 Hepatic Se concentrations (µg/g dry weight) of BUFF, COGO, and LTDU collected from Lake Ontario along the southeast shoreline Prince Edward County, Ontario, Canada, during winters 2002–2003 and 2003–2004. *Solid line* linear regression fit line, *dotted lines* 95% CI. Day 0 on *x*-axis = 20 December

Table 1 Descriptive statistics of concentrations (µg/g dry weight) of hepatic Se of BUFF, COGO, and LTDU collected at northeastern Lake Ontario, December–March, 2002–2003 and 2003–2004

Statistic	BUFF	COGO	LTDU
N	77	77	79
Geometric mean	12.36	12.03	22.69
95% CI	11.62–13.12	10.74–13.47	20.80–24.75
Range	6.89–25.00	5.02–57.53	10.52–71.36
Median	12.30	11.10	23.42
% <10 µg/g dry weight[a]	22%	42%	1%
% 10–33 µg/g dry weight	78%	53%	85%
% ≥33 µg/g dry weight	0%	5%	14%

[a] ≥10 ppm dry weight = reproductive impairment in mallards; ≥33 ppm dry weight = health impairment in mallards

Source: Data from Heinz et al. (1990)

Table 2 Parameter estimates and 95% CI (confidence interval) from the model assessing sources of variation in hepatic selenium concentrations (µg/g dry weight) of BUFF, COGO, and LTDU collected at northeastern Lake Ontario, December–March, 2002–2003 and 2003–2004

Parameter	Estimate	95% CI
Intercept	2.82436	2.73773 to 2.91099
Species (BUFF)	−0.63679	−0.75788 to −0.51570
Species (COGO)	−0.72533	−0.82941 to −0.62125
Species (LTDU)	0.00000	–
Day	0.00540	0.00388 to 0.00691
Species × Day (BUFF)	0.00074	−0.00134 to 0.00282
Species × Day (COGO)	0.00501	0.00310 to 0.00692
Species × Day (LTDU)	0.00000	–

Secor et al. 1993; Ware 2008). As expected, we found that hepatic Se concentrations increased throughout winter within each of these sea duck species. Our results suggest that each of these three sea duck species, at least in part, obtain and accumulate Se throughout winter by eating benthic and pelagic invertebrates obtained from northeastern Lake Ontario.

Interspecific differences in diet and types of invertebrates consumed might account for differences observed in Se burdens (and rates of Se acquisition) by these three sea duck species during winter at northeastern Lake Ontario. In early winter, COGO at our study area consumed mostly plant matter, whereas LTDU fed nearly exclusively on aquatic macroinvertebrates (Amphipoda, Chironomidae, and Dreissenid mussels; Schummer et al. 2008a). Aquatic plants often have lower Se concentrations than do consumers, such as aquatic invertebrates (Hamilton and Buhl 2004; Sandholm et al. 1973). Thus, the lower hepatic Se concentrations in COGO relative to LTDU during early winter might have partly resulted from their consumption of an omnivorous, relatively low Se diet. Both BUFF and LTDU primarily ate aquatic macroinvertebrates throughout winter, but LTDU (and COGO during mid/late winter) ate more Dreissenid mussels than did BUFF at our study site (Schummer et al. 2008a). It is plausible that Dreissenid mussels, which are prolific filter feeders, might have had higher contaminant concentrations than did other major prey items (de Kock and Bowmer 1993). As a result, BUFF might have had lower hepatic Se concentrations because they consumed Dreissenid mussels much less frequently than did LTDU (and to some extent COGO). The above circumstantial evidence suggests that Dreissenid mussels influence hepatic Se concentrations to a greater degree relative to other prey for some species of ducks; this hypothesis could be tested in future studies.

Although hepatic Se concentrations increased throughout winter in all three species, there were differences in acquisition rates and in hepatic concentrations among species. Lower Se burdens in COGO and BUFF relative to LTDU during early winter might be due to lower exposure to Se prior to arrival at Lake Ontario and to a diet lower in Se early in winter (Schummer et al. 2008a). Relative to BUFF and COGO, LTDU use marine areas much more frequently during summer and fall migration (Robertson and Savard 2002), an environment typically enriched with respect to Se (Haygarth 1994; Ohlendorf 2003). Major differences in summer and fall habitat use among these species also could lead to interspecific differences in Se acquisition at those times and influence Se concentrations of ducks sampled during early winter in this study. It is also probable that some ducks collected in December had been feeding at Lake Ontario since arriving in November (Eadie et al. 1995; Gauthier 1993; Peterjohn 1989), so early winter Se concentrations might be the result of local acquisition.

Although it has been suggested that Se acquisition in diving ducks is related primarily to consumption of Dreissenid mussels (de Kock and Bowmer 1993; Petrie et al. 2007; Ross et al. 2005), sea ducks also might acquire Se by feeding on other invertebrates, such as Amphipoda and Chironomidae, during winter on the LGL (Schummer et al. 2008a). Amphipoda are omnivorous scavengers (MacNeil et al. 1997; Thorp and Covich 1991) and might bioaccumulate Se by consuming the soft tissues of dead and broken Dreissenid mussels that are abundant after winter storms (Schummer et al. 2008b). There are several other potential pathways for sea ducks to acquire Se, including intake of water, substrate (grit), plants, periphyton, and pseudo-feces from Dreissenid mussels (Bruner et al. 1994; Ohlendorf 2003). Future studies should evaluate alternative avenues for trophic transfer of Se to sea ducks, including piscivorous mergansers, molluscivorous scoters, omnivorous diving ducks, and other higher vertebrates using Lake Ontario.

Comparisons of Se Concentrations in Sea Ducks at Lake Ontario with Previous Studies

Review of available studies indicates that Se concentrations in BUFF, COGO, and LTDU at Lake Ontario are comparable to those recorded for other locations at different times of the year and especially during winter (see the Appendix). Exceptions include BUFF and COGO sampled in western Lake Erie that showed greater Se concentrations compared to most ducks we collected at Lake Ontario. Notably, BUFF and COGO collected at industrial sites of western Lake Erie had eaten primarily Dreissenid mussels (Custer and Custer 1996), whereas birds in our study ate primarily Chironomidae and Amphipoda (Schummer et al. 2008a). Overall, ducks collected from areas with little or no industrial development had lower Se concentrations, particularly during winter (see the Appendix). Further, hepatic Se concentrations in BUFF and COGO in our study differed little from those of lesser scaup (*Aythya affinis*) at other waterfowl staging and wintering locations in Illinois (($\bar{x} = 12.2\,\mu g/g$ dw), Louisiana ($\bar{x} = 11.8\,\mu g/g$ dw; Anteau et al. 2007), and Ontario (fall $\bar{x} = 5.98\,\mu g/g$ dw, spring $\bar{x} = 15.6\,\mu g/g$ dw; Petrie et al. 2007). Compared to BUFF and COGO, few data exist for Se concentrations in LTDU during winter. Review of those limited data showed that LTDU had relatively consistent Se levels throughout the year and concentrations in birds we collected at Lake Ontario were similar to or only slightly higher than those at Chesapeake Bay and at breeding grounds in Canada (see the Appendix). Similar to other studies of Se in waterfowl from the LGL (Custer and Custer 2000; Custer et al. 2000; Petrie et al. 2007), our results suggest that Lake Ontario is a source of Se for wintering sea duck species but less of a source than western Lake Erie (Custer and Custer 2000), and hepatic Se concentrations differ little from other wintering and staging areas for which data exist.

Potential Se-Related Impacts for Sea Ducks

Selenium is a trace element that is required for normal physiological processes in birds, but one for which there is a narrow threshold between background and harmful concentrations beyond which point reproductive impairment, acute health issues, and death can occur (Heinz et al. 1990; Hoffman 2002). Toxicity thresholds for Se have been only determined from studies using captive mallards; thus, data are not available for biological effect thresholds (e.g., reproductive impairment, health issues) for BUFF, COGO, or LTDU. Heinz et al. (1990) determined for mallards that Se concentrations ≥10 μg/g dw impaired reproduction, whereas concentrations ≥33 μg/g dw caused acute health problems. During winter at Lake Ontario, 99% of LTDU had Se concentrations ≥10 μg/g dw and 14% of individuals had concentrations >33 μg/g dw. Se concentrations >33 μg/g dw also were found in 14% (4 of 21) of COGO collected late in the winter, but no BUFF contained concentrations that high at any time throughout winter. Thus, health-related issues resulting from prolonged exposure and elevated concentrations of Se might be more probable in LTDU, compared to BUFF and COGO, wintering at Lake Ontario.

Relative to mallards, however, LTDU have a greater affinity for marine environments, which, compared to most freshwater environments, have naturally higher Se concentrations (Haygarth 1994; Ohlendorf 2003). Franson et al. (2007) suggested that common eiders (*Somateria mollissima*) and other sea ducks, are likely able to tolerate higher hepatic Se concentrations without negative health effects (see the Appendix; also see Franson et al. 2004). Se concentrations that greatly exceed 10 μg/g dw have been reported in white-winged scoter (*Melanitta* fusca; $\bar{x} = 32.6\,\mu g/g$ dw; DeVink et al. 2008a), king eider (*Somateria* spectabilis; $\bar{x} = 33.2\,\mu g/g$ dw; Braune and Malone 2006), and surf scoter (*Melanitta* perspicillata; $\bar{x} = 35.3\,\mu g/g$ dw; Braune and Malone 2006) without noticeable health effects. Although to a lesser extent than LTDU, BUFF and COGO also frequent tidal and marine systems (Eadie et al. 1995; Robertson and Savard 2002) and thus, like other sea ducks, also might be adapted to tolerate higher Se concentrations. It is thus currently unknown what effects, if any, Se concentrations accumulated by these three sea duck species wintering at Lake Ontario might have on immediate and/or future health and possibly reproduction.

Conclusion

We found that individuals of three sea duck species, particularly LTDU, at northeastern Lake Ontario accumulated Se throughout winter. The highly urbanized and industrialized northwestern section of Lake Ontario typically contains much larger concentrations of sea ducks, including BUFF, COGO, LTDU, and scoters (*Melanitta* spp), than does the northeastern part of the lake (Long Point Waterfowl, unpublished data). Sea ducks using that major wintering area might have higher Se concentrations and might thus be at higher risk to Se-related health issues than birds using northeastern Lake Ontario. Given the variety of functional foraging groups of invertebrates within the Great Lakes, a better understanding of Se concentrations in invertebrate communities and other possible transfer pathways is needed to adequately assess avenues of Se acquisition in sea ducks. The majority of birds in this study had hepatic concentrations ≥10 μg/g dw, a level that can cause reproductive problems in mallards. Sea ducks are long-distance migrants and typically nest months after departing from Lake Ontario (Eadie et al. 1995; Gauthier 1993; Robertson and Savard 2002), which allows considerable time for individuals to depurate Se prior to reproduction (see DeVink et al. 2008b; Grand et al. 2002; Heinz et al. 1990). Acute health problems occurred in mallards at hepatic Se concentrations >33 μg/g dw (Heinz et al. 1990), a level detected in 0% of BUFF, 5% of COGO, and 14% of LTDU. In this study we did not investigate acute health effects of various Se concentrations. Captive research should be conducted to document mobility and fate of Se, specific histological and physiological effects, and critical exposure rates for various species of sea ducks.

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Appendix

See Table 3

Table 3 Comparative concentrations (geometric mean; µg/g dry weight) of total hepatic) Se in livers of BUFF, COGO, and LTDU throughout North America

Species/location	Year/season	Sex	*N*	Se	Citation
Buffleheads					
Teslin Lake, Yukon	1988–1995	M	2	9.2	Braune and Malone (2006)
	April–August	F	4	11.5	
Watson Lake, Yukon	1988–1995	M	2	9.0	Braune and Malone (2006)
	April–August	F	3	7.5	
Yellowknife, Great Slave Lake, Northwest Territory	1988–1995	M	3	10.0	Braune and Malone (2006)
	April–August	F	2	10.0	
Apalachee Bay, Florida	1997	M&F	–	5.3	Michot et al. (1998)
	Winter				
Western Lake Erie, Michigan	1991–1993	M	10	32.1	Custer and Custer (2000)
	Fall–Spring				
Common goldeneyes					
Old Crow, Yukon	1988–1995	M	2	13.0	Braune and Malone (2006)
	April–August				
Teslin Lake, Yukon	1988–1995	F	1	7.3	Braune and Malone (2006)
	April–August				
Watson Lake, Yukon	1988–1995	M	4	9.0	Braune and Malone (2006)
	April–August				
Western Lake Erie, Michigan	1991–1993	M&F	8	36.2	Custer and Custer (2000)
	Fall–Spring				
Great Salt Lake, Utah	2004–2006	M	120	16.0	Vest et al. (2009)
	November–April	F	120	15.7	
Long-tailed ducks					
Kendall Island, Northwest Territory	1993–1994	M	4	27.0	Braune et al. (2005)
	May–July	F	5	21.0	
Inuvik, Northwest Territory	1993–1994	M	9	27.0	Braune et al. (2005)
	May–July	F	1	12.0	
Holman Island, Nunavut	1993–1994	M	8	12.0	Braune et al. (2005)
	May–July	F	2	17.0	
Coppermine, Nunavut	1993–1994	M	4	21.0	Braune et al. (2005)
	May–July	F	4	18.0	
Baker Lake, Nunavut	1993–1994	M	6	14.0	Braune et al. (2005)
	May–July	F	4	13.0	
Arviat, Nunavut	1993–1994	M	5	12.0	Braune et al. (2005)
	May–July	F	2	6.8	
Hall Beach, Nunavut	1993–1994	M	8	8.1	Braune et al. (2005)
	May–July	F	1	5.4	
Cape Dorset, Quebec	1993–1994	M	2	7.3	Braune et al. (2005)
	May–July	F	5	8.7	
Sanikiluaq, Quebec	1993–1994	M	4	13.0	Braune et al. (2005)
	May–July	F	4	11.0	
Chesapeake Bay, Maryland & Virginia	1985–1987	M	28	17.3	Mashima et al. (1998)
	January–April	F	39	18.2	
Chesapeake Bay, Maryland & Virginia	1994	M	16	12.3	Mashima et al. (1998)
	February–April	F	24	11.6	

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