Wetland drawdown and the nutritional value of *Lemna minor* to a wild Trumpeter Swan brood

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Introduction

In wetlands, drought followed by flooding stimulates primary productivity and rapid population growth of invertebrates (Neckles *et al.* 1990). Kadlec (1962) found that drawdown released nutrients that also enhanced the population growth of fast-growing common duckweed (*Lemna minor*) (hereafter *Lemna* or duckweed) which is an important habitat for macroinvertebrates (Harper and Bolen 1996). Lumsden *et al.* (2015) reported that drawdown of a managed pond in Ontario in 2009 produced an abundance of gastropods in 2010 on which a brood of Trumpeter Swans (*Cygnus buccinator*) fed. This surge in abundance was followed by a snail population collapse (Lumsden *et al.* 2015). A similar release of nutrients in these managed ponds from drawdowns in 2010 and 2011 stimulated a strong productive pulse of duckweed that was colonized by snails. In each year, a brood of Trumpeter Swans fed on duckweed and associated invertebrates throughout the summer months, but it is not clear if the swans were attracted by the nutritional value of the duckweed alone or to the combined/enhanced nutritional value (e.g., calcium) added by the snails which colonized it. This paper reports on the nutritional value of the *Lemna* with and without snails and the foraging behaviour of a brood of Trumpeter Swans which shifted in response to changes in pond conditions related to *Lemna* growth following drawdown.

Methods

Three ponds in Aurora, Ontario (44° 00' N 079 ° 28' W), were used in this study (Figure 1). The House pond (0.4 ha, 0.6 m deep) and its use by Trumpeter Swans is described in Lumsden *et al.* (2015). The Garden pond (0.14 ha, 0.6 m deep) was drawn down to dryness in early August 2010 and re-flooded in late September 2010. The North pond (0.2 ha, 1.0 m deep) was drawn down in mid-August 2011 and re-flooded in late September 2011.Water levels were kept stable in the Garden and North ponds in the

Parents feeding and stirring up food items for small cygnets. *Photo by Harry Lumsden.*

autumn of 2012. Various natural foods used by the swans were collected from the ponds and shorelines, stored frozen and then freeze-dried and analysed for their percentage content of protein, calcium, phosphorus and magnesium by Laboratory Services at the University of Guelph. The Garden pond supported a vigorous stand of bur-reed (*Sparganium americanum*), cattail (*Typha* spp.), rice cutgrass (*Leersia oryzoides*) and arrowhead (*Sagittaria latifolia*) among which the *Lemna minor* was present on the water surface. A bottomless bucket (537.3 cm^3) (Lumsden *et al.* 2015) was used to take standardized samples of *Lemna* from each pond in 2011 and 2012. Samples were collected by placing the bottomless bucket over the *Lemna* and scooping it from the water surface within the bucket using a 1.2 mm screen mesh sieve. No benthic samples were collected from the Garden pond. The North pond had no emergent vegetation and its surface was not sampled. However, in 2012, one set of benthic samples was taken at 10 points spaced

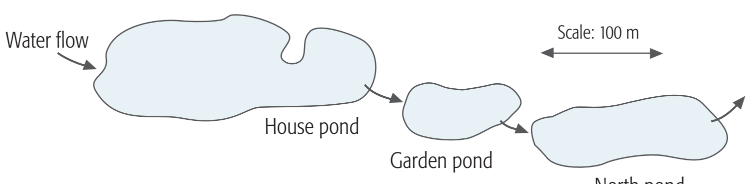

Figure 1. The relative position of the three ponds at the Aurora, Ontario, study site.

8 m apart, 0.5 m from shore, along the east shore; a second set of benthic samples was taken at 10 points similarly spaced 8 m apart, about 3 m from the east shore. Benthic samples were collected by pushing the above mentioned bottomless bucket into the benthos, then excavating the loose mud into a container (Lumsden *et al.* 2015). All invertebrates in each *Lemna* and benthic sample were counted, preserved and identified by Dr. G. Mackie (Department of Integrative Biology, University of Guelph).

Results

Lemna and snail abundance and nutrient levels, 2011

In 2011, *Lemna* covered close to 100% of the water surface of the Garden pond among the macrophytes and was colonized abundantly by snails (*Physella gyrina*). Two samples of *Lemna* (combined wet mass 227 g) taken on 1 July 2011 contained 33 live snails (0.12 snails/g *Lemna*). Four samples of *Lemna* taken on 24 and 26 July 2011 (combined wet mass 472 g) contained 531 live snails (1.13 snails/g *Lemna*). On 11 August 2011, one sample of 113 g of *Lemna* contained 256 live snails (2.27 snails/g *Lemna*).

Nutritional analysis of the dried *Lemna* (including colonizing small snails) sampled on 1 July 2011 showed that the protein content was 21.0%, calcium 1.90%, phosphorus 0.41% and magnesium 0.45% (Table 1). In samples from 24 July-11 August combined (including large snails), the values were protein 29.1%, calcium 5.95%, phosphorus 0.47% and magnesium 0.40% (Table 1).

Lemna and snail abundance and nutrient levels, 2012

In 2012, two years after the drawdown of the Garden pond, a second year of abundant *Lemna* production occurred. During this period, there was no water flowing through the ponds from an adjacent creek because a drain pipe was blocked, allowing nutrient rich water to remain in the ponds. Samples collected on 12 July 2012 in the Garden pond produced an average of 982 g *Lemna*/m^2 and 203 live snails/m^2 (0.2 snails/g *Lemna*). Samples from the North pond taken on 12 July 2012 produced an average of 447 g *Lemna* /m^2, but no live snails and only one dead snail.

In the Garden pond, the analysis of the *Lemna* sample with snails on 12 July showed: protein 27.8%, calcium 4.02%, phosphorus 0.52% and magnesium 0.36%. The nutrient value of the *Lemna* alone in the North (snail-free) pond on 12 July 2012 was: protein 24.4%, calcium 1.90%, phosphorus 0.43% and magnesium 0.34%. Live snails, alone, collected from the House and Garden ponds contained: protein 10.3%, calcium 18.15%, phosphorus 0.21% and magnesium 0.09% (Table 1).

Lemna and snail abundance and nutrient levels, 2013

In 2012, the ponds were not drawn down and in 2013, water flow through the ponds from an adjacent creek was resumed and there was no pulse of *Lemna* production. In the Garden pond, the adults swans fed on cattail (protein 9.1%, calcium 1.84%, phosphorus 0.69% and magnesium 0.17%) and burreed (protein 12.9%, calcium 1.93%,

Table 1. Nutrient analysis of *Lemna minor* plus snails, *Lemna* alone and snails alone at the Aurora, Ontario, study site in 2011 and 2012.

	Lemna + Snails			*Lemna* alone	Snails alone
	%	%	%	%	%
Protein	21.0	29.1	27.8	24.4	10.3
Calcium	1.90	5.95	4.02	1.90	18.15
Phosphorous	0.41	0.47	0.52	0.43	0.21
Magnesium	0.45	0.40	0.36	0.34	0.09
Sample site	Garden Pond	Garden Pond	Garden Pond	North Pond	House Pond and Garden Pond (combined)
Sample period	1 July 2011	24 July 2011 11 August 2011 (combined)	12 July 2012	12 July 2012	12 July 2012
Notes	Small snails	Large snails	Small and large snails	(no snails)	(no *Lemna*)

phosphorus 0.67%, magnesium 0.6%) (Table 2) for two days only. They sometimes ate *Spirogyra* (protein 23.30%, calcium 2.09%, phosporus 0.35%, and magnesium 0.30%) in the House pond. However, in 2013 they subsisted largely on whole corn provided in a hopper. The cygnets followed their parents and ate *Sagittaria* leaves and chewed on the ends of the stems of cattail and bur-reed uprooted by their parents. On 16 June 2013, the cygnets accepted a meal of commercial poultry ration (PuriNature Growena, Cargill Ltd.) which contained: protein 15%, calcium 0.85%, and phosphorus 0.70%. These values for protein are higher, for calcium much lower and for phosphorus about the same as in the cattail and bur-reed samples.

On 7 August 2013, samples collected from one transect in the North pond showed 3 live snails and 44 dead snails (82 dead snails/m^2) and samples from the other transect had 2 live snails and 107 dead snails (199 dead snails/m^2). The live snails on both transects were confined to the northern-most four sampling sites of the two transects, which thus contained 14 live snails/m^2 and 9 live snails/m^2, respectively. Cygnets were seen to grub briefly only in this circumscribed area. A grass sample was collected on 15 September 2013 from the lawn near the House pond because both cygnets and adults were observed grazing on lawn grass (cygnets more so); the sample had: protein (29.9%), calcium (1.22%), phosphorus (0.40%) and magnesium (0.22%) (Table 2).

Table 2. Nutrient analysis of local algae and macrophytes in the House and Garden ponds, and lawn grasses and commercial poultry ration at the Aurora, Ontario, study site in 2013.

	Spirogyra	Cattail	Bur-reed Stems	Lawn Grasses	Poultry ration
	%	%	%	%	%
Protein	23.3	9.1	13.1	29.9	15.0
Calcium	2.09	1.84	1.93	1.22	0.85
Phosphorus	0.35	0.69	0.67	0.40	0.70
Magnesium	0.30	0.17	0.26	0.22	–
Sample period	2 July 2013	2 to 12 July 2013	15 September 2013	15 September 2013	

Discussion

A pulse in *Lemna* production in two ponds in 2011 and 2012 after drawdowns in 2010 and 2011, respectively, demonstrates that this plant can rapidly respond to nutrients released from the organic sediments after they were exposed to the air. The *Lemna* response was ephemeral and did not re-occur in 2013 when flow-through of creek water resumed, presumably lowering the nutrient concentrations. The Trumpeter Swans responded to the superabundance of *Lemna* in both 2011 and 2012 by feeding almost exclusively in *Lemna*-rich ponds. When the ponds were not dominated by *Lemna* in 2013, the brood consumed other natural foods plus grain and commercial chow. The rapid colonization of snails onto *Lemna* indicates that the snails can use the plant as a substrate for feeding. Their presence suggests that any foraging on *Lemna* by swans would potentially involve the ingestion of significant quantities of snails. This raises the question of whether *Lemna* alone can be of any nutritional value to swans (especially the rapidly growing cygnets) or only when in combination with significant abundances of snails? The chemical analysis results indicate that *Lemna* is a rich source of nutrients, especially protein, even in the absence of adhering snails. In this regard, it compares well with the protein content of domestic poultry rations. The high nutritional value of the protein and its component amino acids in duckweeds (*Lemnaceae*) has been reported by Rusoff *et al.* (1980). The levels of the protein in the *Lemna* samples available to the cygnets in this study correspond well with those given in Rusoff *et al.* (1980) and Men *et al.* (2001), who suggested using duckweed as a protein additive to domestic duck grower rations.

While live snails alone offered relatively little protein (10.3%) to the diet of cygnets compared to that of *Lemna* alone (range 21%-29%), the higher nutritional quality of the animal protein with its essential amino acids may be important to developing cygnets (Sedinger 1984). Moreover, the potential contribution of calcium by snails (range 4.02%-5.95%) would also be considerable, and was much higher than in any other food item assayed in this study, making snails an attractive calcium source and offering an enhanced diet in combination with *Lemna.* The number of snails living among the *Lemna* increased between 1 July 2011 (370/m^2) and 24 July-11 August (2470/m^2). Dead snail shells presumably could also supply dietary calcium but the cygnets apparently did not consume them as they did not grub in areas where benthic sampling revealed abundant snail shells but few live snails.

Young cygnets do not independently choose feeding locations that satisfy their nutritional needs because they are physically unable to do extended searches on their own. They depend upon the guidance of their parents to lead them into nutrient-rich areas. Parents do this, but not necessarily solely for the cygnet's benefit, as the breeding female must also replenish protein and calcium reserves depleted during egg laying and incubation periods (Thomas 1983). Later, both parents need calcium and protein following their moult, hence, they must feed in nutrient-rich areas at the same time as developing cygnets. Thus, the nutritional needs and appetitive behaviour of parents aligns with the nutritional needs of the cygnets.

The Aurora Trumpeter Swans had access to the ponds at all times, and the adults were able to assess the collapse of the snail population in the House pond in 2011 (Lumsden *et al.* 2015) and the abundance of *Lemna* and snails in the Garden pond. They led their brood to the Garden pond as soon as the cygnets could travel (within 1-2 days), where they found a highly nutritious diet of *Lemna* colonized by snails. The cygnets development through the summer corresponded with a steady increase in the quantity and quality of food available provided by the high abundance of *Lemna* and increasing abundance and size of snails. The *Lemna* lacking snails in the North pond was still higher in its protein and calcium content than the poultry ration (which the cygnets only briefly accepted in 2011). As in 2010 (Lumsden *et al.* 2015), these broods demonstrated a strong appetite for the most nutritious food available. We hypothesize that they sought calcium.

Selection of foraging habitat based on nutrition alone is unlikely in most animals because they often face a tradeoff between finding nutritious food and avoiding predators (Lima and Dill 1990). The Aurora swans exhibited habitat choices consistent with assessing predation risk against nutritional benefit. In 2012, the brood moved to the North pond after only one day in the *Lemna*-rich Garden pond (despite the high nutritional value available there) following the loss of a cygnet, probably due to predation by a Snapping Turtle (Lumsden 2013). The protein level of *Lemna* was slightly lower in the North pond compared to the Garden pond (24.4% vs. 27.8%), but the potential dietary calcium level in the North pond was much lower (1.9% vs. 4.02%) presumably because of the absence of snails in the *Lemna.* Thus, predation risk apparently over-rode a nutritionally-based feeding choice in the choices made by the swans. Nevertheless, our analysis of nutritional value and foraging habitat use indicates that swans have the capacity to evaluate and consume abundant resources, such as *Lemna* or *Lemna* plus snails, based on their greater nutritional value compared with other foods locally available.

Summary

Sequential drawdowns of two ponds in 2010 and 2011 released nutrients from the substrate which stimulated a strong summer pulse of *Lemna minor* production in the refilled pond in the first year after drawdown. This production was ephemeral and did not reoccur in 2013. The *Lemna* and associated invertebrates, primarily snails, were fed on all summer each year by a brood of wild Trumpeter Swans. The colonization of *Lemna* by snails significantly increased the calcium content of the food, and may in part explain its attractiveness to the swan family with its rapidly growing cygnets.

Acknowledgements

We thank Diana Lumsden for typing drafts of this paper and Dr. Gerry Mackie (Department of Integrative Biology, University of Guelph) for identifying the pond invertebrates. This paper was much improved by constructive comments from the referees and editors.

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