

Diet, body condition and seasonal stress in American Black Duck *Anas rubripes* and Mallard *A. platyrhynchos* on Long Island, New York, during winter

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Abstract

Winter habitat for the American Black Duck *Anas rubripes* (hereon Black Duck) has decreased on the Atlantic coast of North America because of urbanisation and other factors. Human development makes restoration of coastal wetlands for wildlife difficult, but agriculture could increasingly provide food for Black Duck during winter. Diet, body condition and stress indices of Black Duck and Mallard *A. platyrhynchos* were compared between coastal wetlands and sites with Corn *Zea mays* fields on Long Island, New York, used by the birds from late-January to late-March. Black Duck and Mallard were captured at Corn sites, whilst only Black Duck were collected in coastal wetlands. Mallard were not available in coastal wetlands for collection during the study. Stable isotope analysis indicated that the Black Duck ate more animal matter (measured by a blood $\delta^{15}\text{N}$ index) at coastal than Corn sites, whereas Mallard and Black Duck at Corn sites had similar animal diets, although Mallard ate more Corn (determined by blood $\delta^{13}\text{C}$ levels) than Black Duck. Body mass decreased during the winter for Black Duck at both coastal and Corn sites but increased in Mallard at Corn sites. Stress indices, measured by packed red blood cell volume and heterophil/lymphocyte ratios, suggested less stress for Black Duck when using Corn than when at the coastal sites. Results suggest an endogenous mechanism for weight loss in the Black Duck during winter which differs from Mallards in our study area, although given that Black Duck generally appear to eat less Corn other factors not considered here may also contribute to the weight loss patterns. Overall, Black Ducks appeared to benefit less than Mallards from the availability of Corn. Where feasible, continued protection and restoration to increase quantity and quality of coastal wetlands should be the focus on Long Island and elsewhere where Black Duck and Mallard are sympatric.

Key words: body condition, coastal wetlands, Corn, isotope, stress, urbanisation.

Once the most common dabbling duck in portions of eastern North America (Eaton 1910), the American Black Duck *Anas rubripes* (hereafter Black Duck) population estimate (560,000) remains below the Black Duck Joint Venture goal of 640,000 (USFWS 2013, 2019). The 50% decline in numbers of American Black Duck since the 1950s has been attributed to loss of wintering habitat due to urbanisation, reductions in forested wetlands during the breeding period and winter, over-harvest from hunting, and competition and hybridisation with the Mallard *A. platyrhynchos* (Ankney *et al.* 1987; Longcore *et al.* 1998; Mank *et al.* 2004; Maisonneuve *et al.* 2006). Reduced quantity and quality of forested wetland breeding habitat may be limiting Black Duck abundance, recruitment and survival (Conroy *et al.* 2002; Fino *et al.* 2017). In addition, urbanisation, coastal wetland loss, sea level rise, and habitat fragmentation and degradation have increased and continue to threaten habitat availability for Black Duck (Conroy *et al.* 2002; Cramer *et al.* 2012).

The Mallard was once uncommon in eastern North America (Eaton 1910) but were able to expand their range into that region from the mid-1900s, as humans increasingly created a non-forested landscape similar to their traditional, mid-continent prairie-wetland region (Johnsgard & DiSilvestro 1976; Conroy *et al.* 1989; Johnson & Sorenson 1999; but see Merendino *et al.* 1995). Nowadays, the Mallard is the most common breeding and wintering duck in much of eastern North America and it is thought that they filled a portion of the niche previously the domain of the Black Duck as we cleared forests,

urbanised coastal areas, and initiated large-scale agriculture in the region (Crinigan 1960; Heusmann 1991; Harrigan 2006; USFWS 2019). In addition, millions of domestic Mallards of European genetic origin have been released directly into portions of the Black Duck's breeding and wintering ranges, from the 1900s to the present day (Heusmann 1991; Harrigan 2006; Lavretsky *et al.* 2014). Black Ducks commonly use coastal wetlands during winter but, where available, also make feeding flights to fields planted with Corn *Zea mays* where they eat this energy-rich waste grain (*i.e.* the kernels unintentionally left on the ground after harvest) (Delnicki & Reinecke 1986; Combs & Fredrickson 1996; Cramer *et al.* 2012). Mallard typically forage at inland freshwater sites, and similarly make foraging flights to feed on waste Corn (Baldassarre & Bolen 1984; Bleau 2018). This results in the Black Duck typically feeding without competition from Mallard at coastal wetlands, whereas they encounter and feed alongside Mallard at inland freshwater wetlands and in the Corn fields (Bleau 2018; Schummer *et al.* 2020; Flores & Schummer 2023).

Development on coastal wetland sites for nearly 400 years (Sanderson & Brown 2023) has resulted in less habitat and thus natural food resources being available for Black Duck in winter (Cramer *et al.* 2012). In New Jersey, animal and plant food resources in coastal wetlands are generally greater than at the inland freshwater wetlands where Mallard primarily foraged (Cramer *et al.* 2012). In contrast, on eastern Long Island, Plattner *et al.* (2010) determined that food resources were greater in freshwater than

coastal wetlands, but they did not include vertebrate animal foods. If food resources are lower in coastal than freshwater marshes on eastern Long Island, then the Black Duck may need to allocate a greater proportion of the day foraging than Mallards or would require more area of habitat per individual (Plattner *et al.* 2010). In Black Duck, and other waterfowl, the capacity to sustain nutrient reserves (*e.g.* lipids) affects survival within and among seasons and has cross-seasonal effects on reproduction (Sedinger & Alisauskas 2014; Alisauskas & DeVink 2015). The availability of wintering habitat and associated nutrients represented in foods therefore may be limiting the Black Duck population, with continued development and degradation of the Atlantic coastal wetlands potentially exacerbating habitat loss (Cramer *et al.* 2012; USFWS 2019).

Stable isotopes can be used as an index to differentiate and compare food ingested by waterfowl using coastal wetlands and Corn fields, with $\delta^{15}\text{N}$ levels detected in the blood indicating animal content and $\delta^{13}\text{C}$ levels determining plant content in the diet (Hobson & Clark 1992). While Corn may provide supplemental foraging opportunities for the Black Duck the extent to which they may benefit from these resources in comparison with Mallards is unknown. Understanding the contribution of Corn to Black Duck body condition and seasonal stress is important, especially for considering the consequences of the decline in quantity and quality of coastal wetlands. Waste Corn may increase Black Duck wintering carrying capacity, but concurrently understanding how Mallards may benefit

from this resource is also important because of the foraging niche overlap between these species and potential for inter-specific competition (Ankney *et al.* 1987; Schummer *et al.* 2020).

In addition to body mass, several indices of stress can be useful for understanding how food availability and predictability affects animals during winter (Gross & Siegel 1983, 1986; Vleck *et al.* 2000). Animals face a variety of potential stressors throughout their life-cycle including weather severity, food availability, predation, injury, disease, competition and other social interactions (Vleck *et al.* 2000). Hematocrit levels, or packed red blood cell volume (PCV), can be used as an index to measure stress, as it compares the quantity of whole red blood cell volume to total blood volume (Vleck *et al.* 2000). Similarly, heterophil to lymphocyte (H/L) ratios in blood is also a common stress indicator (Gross & Siegel 1983), with elevated H/L ratios potentially an advantageous response to injury and infection (Minias 2019). Food and water deprivation, extreme temperatures, light variability and social interactions can also elevate the number of heterophils, which has an inverse relationship with lymphocytes (Gross & Siegel 1986; Gross 1989; McFarlane & Curtis 1989). In wintering waterfowl, the PCV and H/L ratios can thus provide some insight into the relationships that habitat use, diet and body condition have with the birds' stress levels.

Mallard and Black Duck have a similar strategy of using a mix of endogenous and exogenous nutrient strategies in winter, migration and breeding (Reinecke *et al.* 1982; Hepp 1986; Heitmeyer 1988). Lipids are

used as energy for thermoregulation and daily activities in winter, but also as carry-over energy needed to fuel migration and during the breeding season, including energy for obtaining the protein (*i.e.* invertebrates) necessary for egg production (Rohwer 1986; Alisauskas & Ankney 1992; Esler & Grande 1994). Lipids remaining after migration (endogenous) are used in clutch formation (Ankney *et al.* 1991; Alisauskas & Ankney 1992). Body condition, as indexed by body mass adjusted for body size (Whyte & Bolen 1986; Hanson *et al.* 1990) and corresponding lipid reserves are influenced by food availability and predictability (Baldassarre *et al.* 1986; Whyte *et al.* 1986). When food is predictable, storing lipids is maladaptive because it necessitates greater exposure during foraging and feeding flights, and decreases flight mobility for predator avoidance (Batt *et al.* 1992). Overall, ducks foraging on energy dense food, predictably available during winter, tend to lose more weight (*i.e.* lipids) than those using sites with unpredictable food resources (Lima 1986; Barboza & Jorde 2002; Schummer *et al.* 2012).

This study aimed to compare the diet (measured as $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ levels in blood samples), body condition and stress indices recorded for Black Duck using Corn and coastal sites, and also to compare these same metrics for Black Duck and Mallard where the two species both occur in Corn fields and traps baited with Corn (hereafter Corn sites). It was hypothesised that Black Duck and Mallard would both lose body mass throughout winter despite foraging at Corn sites, because food resources were predictable and weight loss appears

advantageous when compared with exposure with constant feeding and carrying lipids not needed for migration or breeding (Perry *et al.* 1986; Loesch *et al.* 1992; Baldassarre & Bolen 2006). The prediction was that Black Duck using coastal wetlands would forage more on animal matter (*i.e.* have higher $\delta^{15}\text{N}$ levels) than plant matter (*i.e.* Corn; $\delta^{13}\text{C}$) compared to those using Corn sites, but these differences in foraging would not affect their body mass dynamics. Relative to Mallard, however, it was predicted that Black Duck would sustain less body mass throughout winter and have greater stress at Corn sites, because Mallard are known to exploit agricultural landscapes more than Black Duck and therefore may be better adapted to them (Ankney *et al.* 1987; Davis *et al.* 2014; English *et al.* 2017). Also, inter-specific competition and other social interactions with Mallard could increase Black Duck stress levels (Ankney *et al.* 1987; Schummer *et al.* 2020). Most Mallard in eastern North America are wild \times domestic, game-farm Mallard, with game-farm Mallard being of European origin which have been under artificial selection for decades, and thus more likely both to tolerate regular contact with people and to occur in high-densities with conspecifics (Lavretsky *et al.* 2020; Schummer *et al.* 2023). These game-farm Mallard are also fed commercial pellets and whole grains for greater survival and quick growth in captivity (Heusmann 1991; Lavretsky *et al.* 2014; Schummer *et al.* 2023). As such, the Black Duck and Mallard wintering on Long Island have had very different histories since the early 20th century, which were expected to lead to different strategies to survive the winter.

Methods

Study area

The study was conducted in Nassau and Suffolk counties on Long Island, New York, with data collected from 10 February–28 March 2018 and 26 January–30 March 2019. Nassau County contains coastal wetlands and freshwater ponds surrounded by residential homes while Suffolk County contains coastal wetlands, freshwater ponds and rural landscapes where Corn fields are available. Black Duck were lethally collected at Nassau County's coastal wetlands (at Toll Booth Pond 40.313°N, -73.547°W;

High Hill Pond 40.604°N, -73.497°W; and Meadow Island 40.602°N, -73.558°W; Fig. 1). Black Duck and Mallard were trapped in Suffolk County (New Suffolk 41.627°N, -72.774°W; Cutchogue 41.023°N, -72.511°W; Brookhaven 40.798°N, -72.891°W; Flanders 40.906°N, -72.583°W; and Aquebogue 40.933°N, -72.611°W; Fig. 1). Corn fields were readily available in Suffolk County and were visited regularly by Black Duck and Mallard (Flores & Schummer 2023; Stedman 2024). On average, Corn fields were 91 km away from the lethal collection area in the coastal wetlands of western Long Island in Nassau County. It

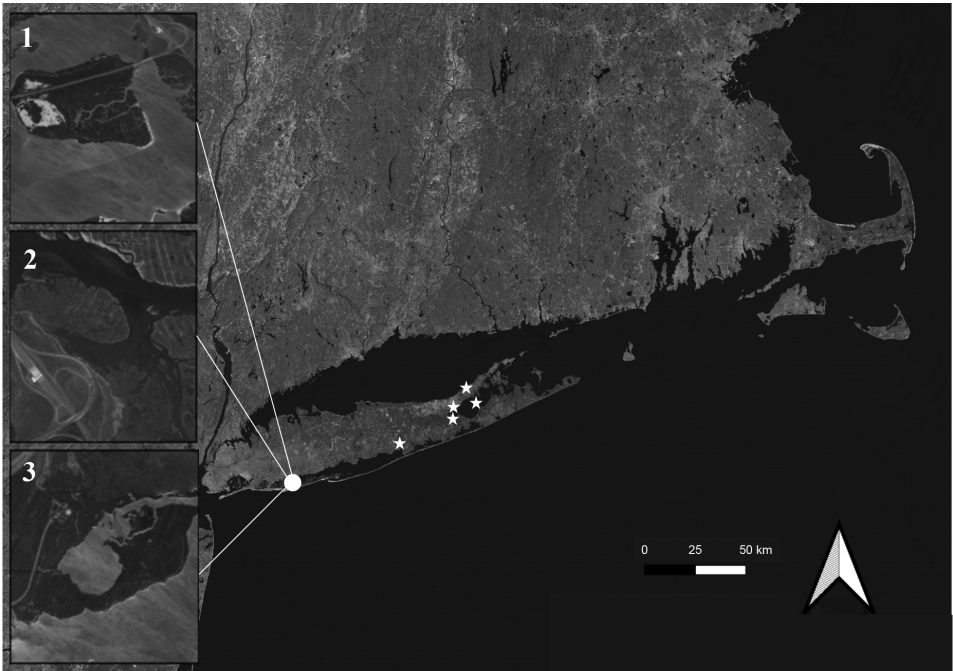


Figure 1. Map of Corn sites (white stars, left to right: Brookhaven, Flanders, Aquebogue, Cutchogue and New Suffolk) and lethal collection sites at coastal wetlands (white circle and insets: 1 = Meadow Island, 2 = Toll Booth Pond and 3 = High Hill Pond) in Suffolk and Nassau counties, Long Island, New York in 2018 and 2019.

was assumed that Corn fields were not readily accessible to Black Duck at coastal sites because their home ranges tend to be much smaller (*e.g.* mean = 1,082 ha; Ringelman *et al.* 2015) than the distance to the closest Corn field.

Lethal collection and trapping

Black Duck were collected by pass-shooting (*i.e.* shooting flying ducks without the aid of decoys to lure them into range) and shooting over decoys in coastal wetlands on daily tide changes as they moved between roost to feeding locations. Ducks were captured at Corn sites using rocket nets (in 2018), and at walk-in and swim-in cloverleaf funnel traps, baited with Corn (in 2018 and 2019; Bollinger *et al.* 1989; Evrard & Bacon 1998).

Ducks were aged using guidelines from Ashley *et al.* (2006) as second year (birds hatched the year prior to capture) or after second year (birds hatched > 2 years prior to capture) and sexed by cloacal examination and plumage (Carney 1992; Ashley *et al.* 2006). For each duck, body mass (scale accuracy of ± 1 g), tarsus length (calliper accuracy ± 0.02 mm), culmen length (± 0.02 mm), wing chord (measuring stick accuracy ± 1 mm), and head length (± 0.02 mm) were recorded. For ducks at Corn sites, an index of Corn present was recorded as 0 to 3 (0 = no Corn, 1 = 1/3 full, 2 = 1/2 full and 3 = full) by feeling the oesophagus and proventriculus (Conroy *et al.* 1989). This index was used to adjust body mass for Corn ingested by ducks sampled at Corn sites. Estimated mean (\pm s.e.) Corn wet weight for these indices, each derived from 30 samples, were: 1 = 60 ml (42.65 g \pm 0.29),

2 = 80 ml (57.06 g \pm 0.26) and 3 = 120 ml volumes (86.23 g \pm 0.51). This weight was subtracted from total body mass to calculate a total adjusted body mass. For Black Duck at coastal sites, Corn was never felt in their oesophagus and proventriculus.

For stable isotope ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ levels), PCV and H/L analysis, a 23-gauge needle and syringe were used to collect 2–3 ml of blood from the metatarsal vein for trapped ducks and by cardiac puncture from lethally collected ducks (Owen 2011). Blood (1 ml) was placed in a sterile Eppendorf tube for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis, filled a 70 μl capillary tube for PCV analysis, and a drop was allocated for a blood smear for H/L ratio analysis. Stable isotope samples were frozen within 6 h of collection and later shipped, frozen, to the Cornell Stable Isotope Laboratory for analysis. PCV values ($\pm 1\%$) were calculated after a centrifuge at 12,000 RPM for 10 min (Owen 2011). H/L analysis requires expertise in identification of cells in blood smears, so preserved blood smears from 2018 was sent to B. Grasperge (Doctor of Veterinary Medicine and Diplomate of the American College of Veterinary Pathologists) at Louisiana State University, USA for processing. Blood smears from 2019 could not be analysed because of logistical issues.

Diet analysis

Stable isotopes ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) were used to compare diet compositions between treatments (coastal or Corn) and species. At the Cornell Stable Isotope Laboratory, samples were combusted in an elemental analyser, and gases were sent to the isotope-ratio mass spectrometer using a continuous

flow interface. Data are reported as differences in isotopic ratios, for which the units are parts per thousand (or per mille; ‰), compared to Pee Dee Belemnite (PDB), for carbon, and atmospheric nitrogen (AIR), for nitrogen, according to the following equation: $\delta X = \left(\frac{R_{\text{sample}}}{R_{\text{std}}} - 1 \right) \times 1,000$, where δX is the isotope of interest (either $\delta^{15}\text{N}$ or $\delta^{13}\text{C}$, in ‰) and R is the ratio of the abundance of the heavy to the light isotope ($^{15}\text{N}/^{14}\text{N}$ or $^{13}\text{C}/^{12}\text{C}$), with R_{sample} being the ratio within the sample and R_{std} the ratio of heavy to light isotope within the international standard (Hobson *et al.* 1995).

Statistical analysis

Diet, body mass, PCV and H/L ratios were modelled as a function of an index of body size (mass model only), treatment (coastal or Corn), species (Black Duck or Mallard), date, year and their interactions using linear mixed models (PROC Mixed, SAS Institute 2009). To obtain the index of structural size, a Principal Components Analysis (PCA) of four morphological measurements (tarsus, culmen, head and wing chord) was conducted. An information theoretic approach was used to determine support for different models, based on Akaike's information criterion (AIC) (Burnham & Anderson 2002). The sex \times age interaction and year were controlled for by being included as covariates in all models and PC1 was also included to control for variation in structural size. Models ≤ 2.0 ΔAIC units from top models were considered to have some support (Burnham & Anderson 2002). When competing models were ≤ 2.0 ΔAIC units from the top models (Burnham

& Anderson 2002) model-averaging of predicted values was used because there was not overwhelming support for a single model. The most complex model used for analysis was treatment \times species \times date \times year, while controlling for sex \times age and PC1 as covariates.

Results

Sampling frame

Fifty-two Black Duck from coastal sites and 170 Black Duck and 61 Mallard from Corn sites were sampled during the study. As a result of logistical issues, however, both in collecting samples from the field and with processing them at the laboratory, the number of samples used for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis (Black Duck: $n = 217$ (88 in 2018, 129 in 2019); Mallard: $n = 61$ (14 in 2018, 47 in 2019)), differed from those used for body mass (Black Duck: $n = 222$ (92 in 2018, 130 in 2019); Mallard: $n = 61$ (14 in 2018, 47 in 2019)), PCV (Black Duck $n = 211$ (88 in 2018, 123 in 2019); Mallard $n = 61$ (14 in 2018, 47 in 2019)), and H/L ratio (Black Duck $n = 64$ (all in 2018)) analyses.

Dietary analysis

The best model for $\delta^{13}\text{C}$ was the interaction of species, treatment, date and year (Table 1 & Supporting Materials Table S1), with the score for next closest model being 2.5 AIC units from that of the best model. In 2018, Black Duck $\delta^{13}\text{C}$ measures were stable at Corn sites (0.1% decrease) and decreased by 27.9% at coastal sites, whereas $\delta^{13}\text{C}$ levels increased by 14.6% for Mallard at Corn sites over the same period (Fig. 2). In 2019, Black

Table 1. Mixed-effects models of $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, mass, PCV and H/L ratios for American Black Duck and Mallard sampled during winter on Long Island, New York, January–March 2018 and 2019. Only models with $\Delta\text{AIC} < 2$ and the null models are shown.

Response	Model ^a	K	ΔAIC^b	w_i
$\delta^{13}\text{C}$	SPECIES \times TREATMENT \times SEX \times AGE \times DATE \times YEAR	17	0.0	0.78
	Null	1	124.4	0.00
$\delta^{15}\text{N}$	SPECIES \times TREATMENT \times SEX \times AGE \times YEAR	15	0.0	0.76
	Null	1	160.0	0.00
Mass	SPECIES \times TREATMENT \times SEX \times AGE \times DATE \times YEAR \times PC1	19	0.0	0.92
	Null	1	350.0	0.00
PCV	SPECIES \times TREATMENT \times SEX \times AGE \times YEAR + DATE	16	0.0	0.67
	SPECIES \times TREATMENT \times SEX \times AGE \times YEAR	15	1.4	0.33
H/L	Null	1	232.6	0.00
	TREATMENT \times SEX \times AGE	8	0.0	0.52
	TREATMENT \times SEX \times AGE \times DATE	9	1.0	0.31
	Null	1	32.3	0.00

^aModels incorporated parameters of structural size (PC1), age, sex, American Black Duck or Mallard (SPECIES), study date (DATE), sampling year (YEAR) and coastal or agriculture site (TREATMENT).

^bModels are sorted by AIC, and models with $\Delta\text{AIC} \leq 2.0$ and null models are shown. The AIC values for the top models were 1260.0, 958.2, 3206.7, 1678.9 and 454.7 for $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, mass, PCV and H/L, respectively.

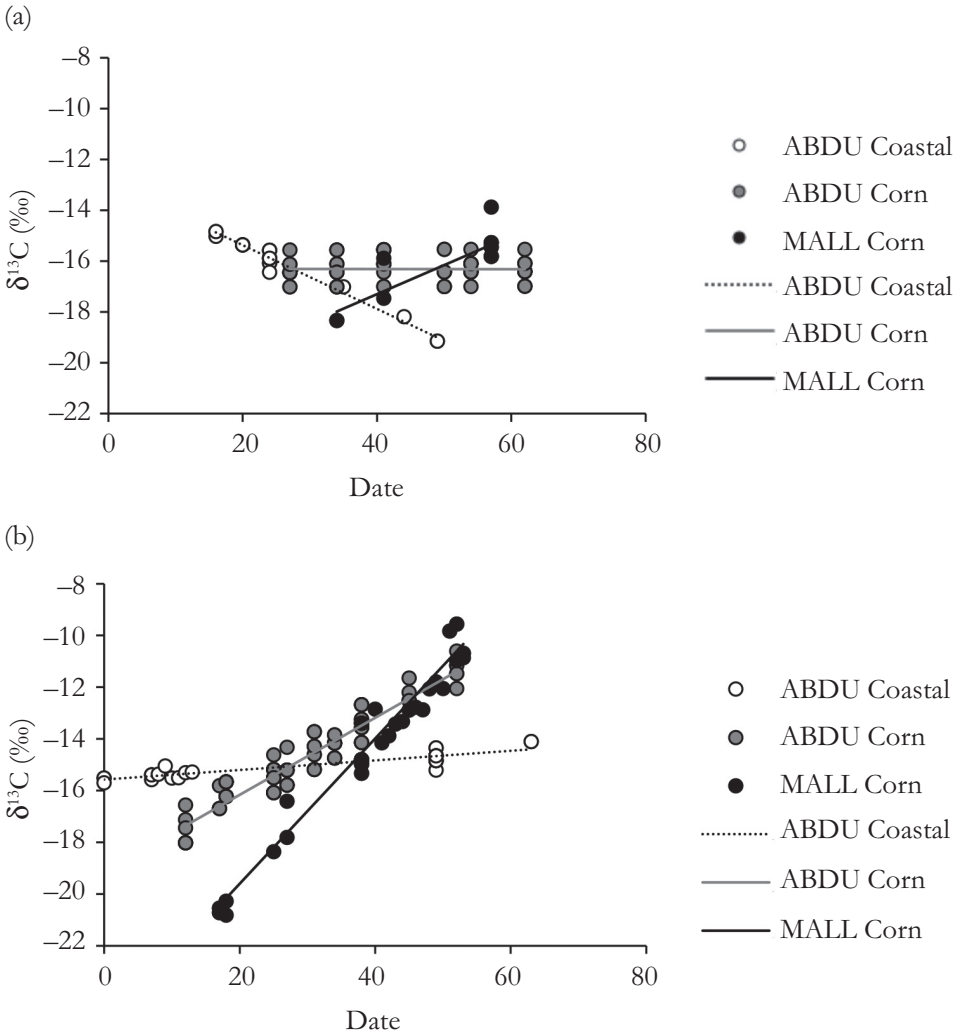


Figure 2. Mean $\delta^{13}\text{C}$ values in relation to date (0 = 26 January) during January–March in: (a) 2018 and (b) 2019, for Black Duck sampled at Corn sites ($n = 70$ in 2018; $n = 99$ in 2019) and coastal sites ($n = 18$ in 2018; $n = 30$ in 2019), and also for Mallard sampled at Corn sites ($n = 14$ and 47 for 2018 and 2019, respectively). Note: no Mallard were sampled on the coast. ABDU = American Black Duck, MALL = Mallard.

Duck $\delta^{13}\text{C}$ levels increased by 34.4% and 7.5% at Corn and coastal sites, respectively, whereas $\delta^{13}\text{C}$ increased by 48.8% for Mallard at Corn sites (Fig. 2).

The best model for $\delta^{15}\text{N}$ included the interaction of species, treatment and year (Table 1 & Supporting Materials Table S1). The score for the next closest model was 2.6

AIC units from that of the best model. Calculated model-predicted means (\pm s.e.) $\delta^{15}\text{N}$ for Black Duck using coastal sites (11.53 ± 0.45 in 2018; 11.35 ± 0.40 in 2019) were greater than for Black Duck (2018 = 8.58 ± 0.24 ; 2019 = 9.32 ± 0.23) and for Mallard at Corn sites (2018 = 7.70 ± 0.49 ; 2019 = 8.12 ± 0.35) in both years of the study (Fig. 3).

Body mass

Principal Component 1 explained 64% and 74% of the variation in body size in Black Duck and Mallard, respectively. The best model included the interaction of species, treatment, date and year (Table 1 & Supporting Materials Table S1). The score for the next closest model was 5.0 AIC units from that of the best model. The body mass of Black Duck at Corn sites decreased

during January–March by 4.8% (in 2018) and 2.0% (in 2019) and by 4.5% (2018) and 9.5% (2019) for those at coastal sites. In contrast, the body mass of Mallard utilising Corn sites increased over the same period, by 7.6% and 1.0% in 2018 and 2019, respectively (Fig. 4).

Stress indices

The best model for PCV included interactions among species, treatment, and year with an additive effect of date (Table 1 & Supporting Materials Table S1). Model averaging was used because the next closest model (interactions of species, treatment, sex, age and year) was 1.4 AIC units away from the best model. Black Duck and Mallard at Corn sites had greater mean (\pm s.e.) PCV than Black Duck at coastal sites (Fig. 5).

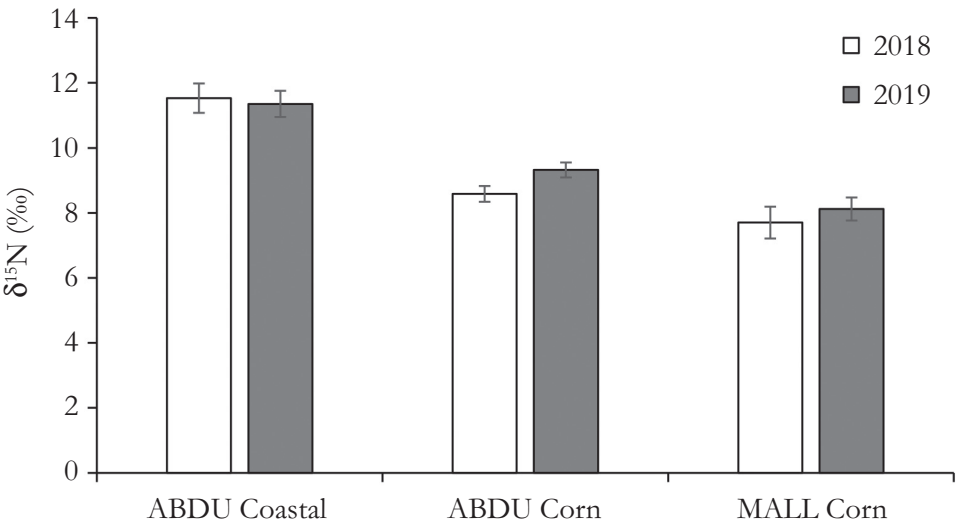


Figure 3. Mean $\delta^{15}\text{N}$ ratios for Black duck at Corn sites ($n = 70$ in 2018; $n = 99$ in 2019) and coastal sites ($n = 18$ in 2018; $n = 30$ in 2019), and also for Mallard at Corn sites ($n = 14$ and 47 for 2018 and 2019, respectively), for samples taken during January–March each year. Note: no Mallard were sampled on the coast. Standard error bars are shown. ABDU = American Black Duck, MALL = Mallard.

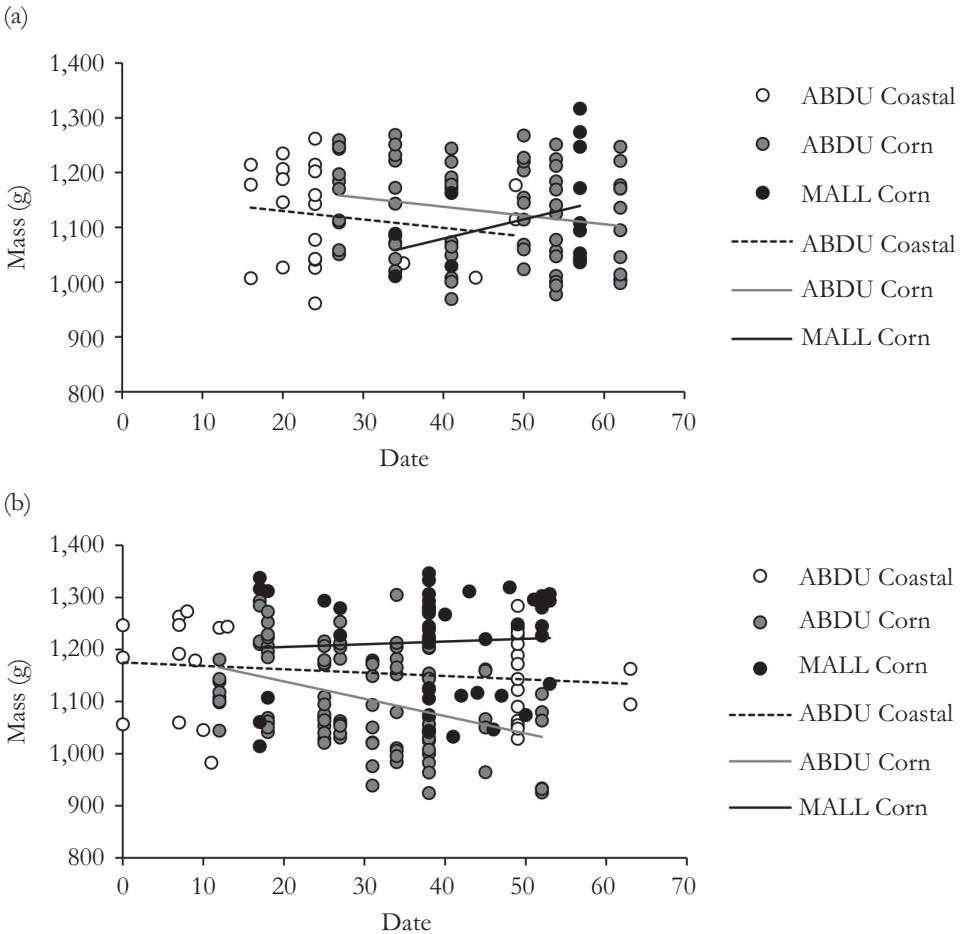


Figure 4. Model-predicted relationship between body mass (g) and date (0 = 26 January) during January–March in: (a) 2018 and (b) 2019, for Black Duck at Corn sites ($n = 70$ in 2018; $n = 100$ in 2019) and coastal sites ($n = 22$ in 2018; $n = 30$ in 2019), and also for Mallard at Corn sites ($n = 14$ and 47 in 2018 and 2019, respectively). Note: no Mallard were sampled on the coast. ABDU = American Black Duck, MALL = Mallard.

The best model for H/L ratios included treatment (Table 1 & Supporting Materials Table S1). Model averaging was used because the next closest model (interactions of treatment, sex, age and date) was 1.0 AIC units away from the best model. In 2018, the H/L ratio in Black Duck using Corn sites

increased by 132.4% while for Black Duck at coastal sites it increased by 1,868.1% from February to March in 2018 (Fig. 6).

Discussion

In accordance with prior research (English *et al.* 2017; Barboza & Jorde 2018), Black Duck

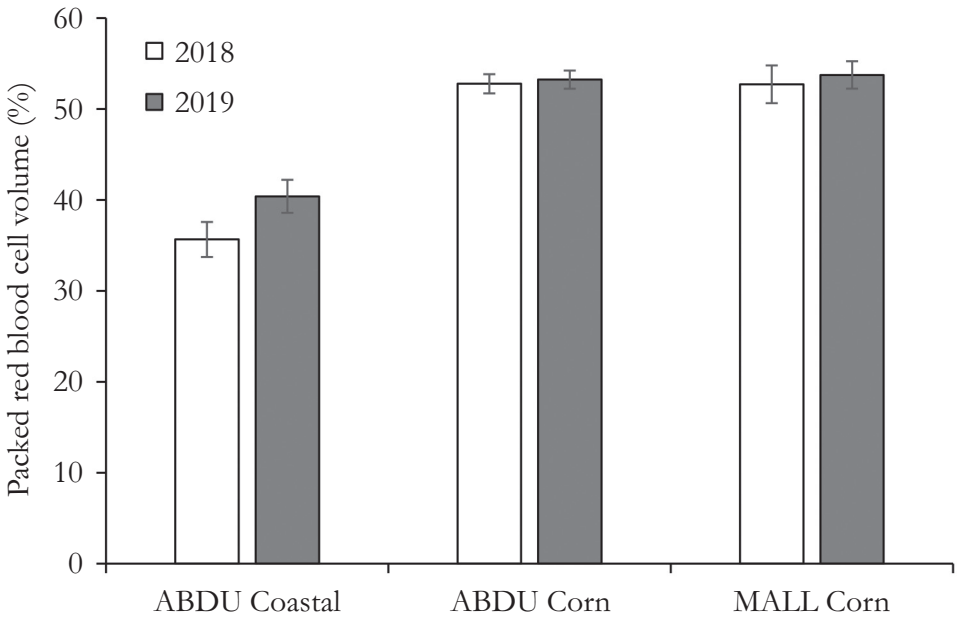


Figure 5. Model predicted mean packed red blood cell volume (PCV) for Black Duck at Corn sites ($n = 70$ in 2018; $n = 96$ in 2019) and at coastal sites ($n = 18$ in 2018; $n = 27$ in 2019), and also for Mallard at Corn sites ($n = 27$ in 2018; $n = 47$ in 2019), for samples taken during January–March each year. The additive effect of date is not shown; PCV increased by 3.20% in all species and sites during our study. No Mallard were sampled on the coast. Standard error bars are shown. ABDU = American Black Duck, MALL = Mallard.

at the coastal wetland sites had greater $\delta^{15}\text{N}$ signatures in their blood than Black Duck or Mallard using Corn sites, suggesting that the Black Duck likely consume more animal food during winter in areas where Corn fields do not occur. Mallards were absent during the lethal collection of Black Duck on coastal wetlands, also indicative of differences in habitat use by these closely related species. Black Duck and Mallard foraging on Corn may meet their daily energy demands in a shorter period than those foraging in coastal wetlands on Long Island (Brodsky & Weatherhead 1984; Kross *et al.* 2008; Plattner *et al.* 2010).

However, the greater increases in $\delta^{13}\text{C}$ levels during winter for Mallard at Corn sites suggested that they ate more Corn than Black Duck. In a complementary study, densities of Mallard feeding in Corn fields were found, on average, to be 50% greater than those for Black Duck at these sites (Flores & Schummer 2023), and Mallard also tend to use freshwater wetlands along with the Corn fields, whereas Black Duck regularly use Long Island's coastal wetlands (Plattner *et al.* 2010; English *et al.* 2017; Stedman 2024). Coastal wetlands remain relatively free of Mallard, enabling Black Duck to feed with little potential inter-

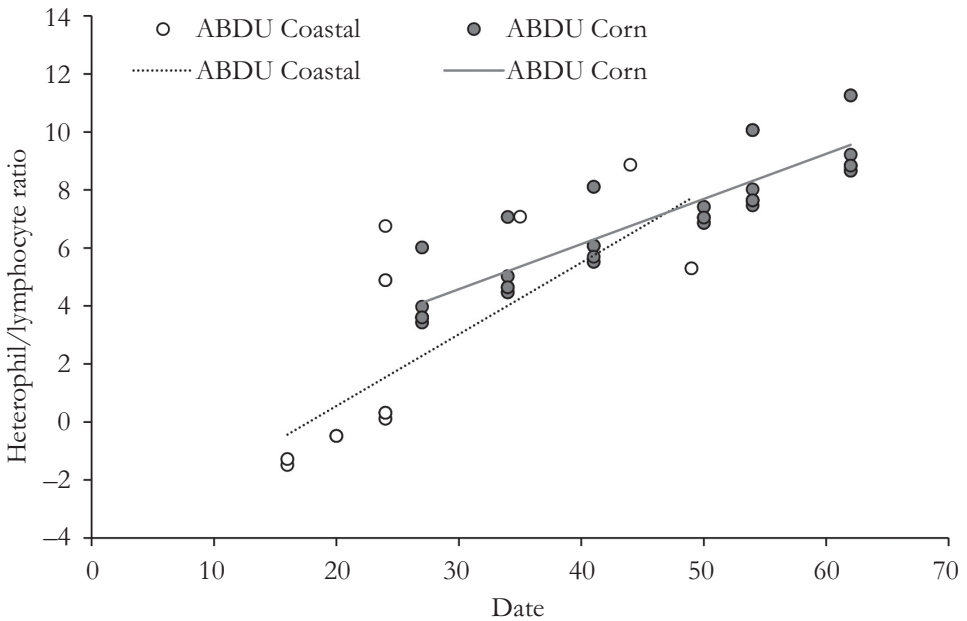


Figure 6. Heterophil to lymphocyte ratios (H/L) in relation to date (0 = 26 January), for Black Duck at Corn sites ($n = 54$) and coastal sites ($n = 10$) during January–March 2018. ABDU = American Black Duck.

specific competition (Baldassarre 2014). Corn fields provide additional feeding opportunities for Black Duck, but here they also encounter and interact with Mallard. Whilst our study was observational, inferences were strengthened by concurrent studies of both species in the region. Additional research is however required, to include concurrent tracking of individual Black Duck and Mallard, to determine the portion of time spent in different habitats and diurnal patterns of site use during the winter season. Moreover, lethal collection of decoyed birds can introduce bias, such as lower body condition (Dufour *et al.* 1993; Pace & Afton 1999), but the Black Duck taken during our study were mostly paired and did not decoy well, and the majority of

our sample was collected by pass-shooting from hidden positions (A. Flores, pers. obs.), which reduces the level of bias especially in late-winter (Schummer *et al.* 2012).

Consistent with the differences in diet, and similar to findings from previous studies (Barboza & Jorde 2018), Mallard in our study area gained or sustained mass throughout winter, whereas Black Duck body mass declined or was stable during the same period, even when both species were frequenting Corn sites. Although an endogenous mechanism has been shown to control the waterfowl lipid reserves during winter (Perry *et al.* 1986; Loesch *et al.* 1992; Baldassarre & Bolen 2006), results suggest subtle differences in nutrient strategies during winter between these closely-related

species. Trends in body mass were different between years, but Mallard were heavier at the end of winter in both years of the study at a time when Straub *et al.* (2012) and others (Stafford *et al.* 2014) consider food resources to be most limiting. Sustaining greater lipid reserves during winter into spring may give Mallard a competitive advantage over Black Duck by allowing them to initiate spring migration sooner, and consequently to select and occupy higher quality breeding territories (Petrie *et al.* 2012). The Mallard breeding range has increasingly overlapped with that of Black Duck and in many cases Black Duck were replaced by Mallard breeding pairs (Ankney *et al.* 1987; Petrie *et al.* 2012; Messmer *et al.* 2015; Macy 2020). Greater lipid reserves in Mallard than Black Duck would be hypothesised to result in greater productivity because clutch size is related to lipid reserves in the Mallard (Krapu 1981) and those initiating nests earlier typically have greater reproductive success (Dzus & Clark 1998). GPS-tagging Mallard and Black Duck at our study site during winter, to track their winter habitat use, timing of migration, breeding location and onset of nesting would provide further information about the utility of Corn fields to these species (Stedman 2024). It is cautioned that marking ducks, including GPS-tagging has limitations that need to be addressed and each study objective should align with the technologies applied (Ward & Flint 1995; Garrettsen & Rohwer 1998; Lameris *et al.* 2018).

Differences in body mass dynamics during winter between Black Duck and Mallard may result from differences in predictability and energy density of food

resources among landscapes. Food availability is more consistent in coastal than freshwater wetlands (Plattner *et al.* 2010) and coastal wetlands are less likely to be affected by ice and snow events that can make foods less predictable in freshwater wetlands and Corn fields (Schummer *et al.* 2010). Food and energy density are typically less in coastal wetlands than freshwater wetlands and Corn fields, but coastal wetlands food resources are also more consistently available because daily tides can refresh animal foods (Albright *et al.* 1983; Jorde 1986; Lewis *et al.* 2019). When food is predictable, but at relatively low density (*e.g.* at coastal wetlands), storing lipid reserves early in the non-breeding period and then mobilising those reserves throughout winter is considered adaptive (Baldassarre & Bolen 2006). However, when food resources are unpredictable, but abundant (*i.e.* at freshwater wetlands and Corn fields), the strategy may change towards storing lipid reserves throughout winter when possible (Lima 1986). Body mass of Black Duck declined at Corn sites even though isotopic analysis suggested they increased Corn consumption throughout winter, and animal matter intake by Black Duck (as indexed by $\delta^{15}\text{N}$) was also less at Corn than at coastal sites. This pattern further suggests an underlying endogenous mechanism of lipid mobilisation in Black Duck, even when energy-dense, Corn food resources were available and used. However, this pattern was not evident in Mallard, which maintained or increased body mass during winter. Overall, subtle differences in habitat use and forage strategies between Black Duck and Mallard during winter may explain

the differences detected in their body mass dynamics.

Black Duck have a strategy of strong winter philopatry, whereby they do not leave wintering areas during severe cold and ice events and are subject to starvation (Albright *et al.* 1983; Morton *et al.* 1989; Ringelman *et al.* 2015). This behaviour may have evolved because Black Duck use coastal wetlands that rarely freeze for extended periods and food resources were historically abundant and predictable (Stephens *et al.* 2007; Plattner *et al.* 2010). In contrast, Mallard tend to move south when cold temperatures persist (Schummer *et al.* 2010) and may use a risk-aversion strategy of storing lipids as fuel for migration, in case of unpredictable weather (but see Mastro *et al.* 2022). Mallard tend to be flexible in resource use during winter, migrating farther south during wetter and colder winters (Nichols *et al.* 1983) and individual Mallard that survive winter at one location may not return the following year (Krementz *et al.* 2012). It also should be noted that Mallard along the north Atlantic coast have substantial introgression of game-farm genes (*i.e.* $\geq 10\%$), which may influence how they store lipids for winter survival and migration compared to wild North America Mallard and Black Duck (Lavretsky & Sedinger 2023; Schummer *et al.* 2023; Lavretsky *et al.* 2023). Declines in the quantity and quality of coastal wetlands and differences in body mass between Black Duck and Mallard using Corn sites could provide a survival advantage to Mallard over Black Duck wintering at Long Island because of the differences in feeding and body mass strategies which we observed,

but further study that tracks individual movements of these ducks and nesting success are needed to confirm the situation.

In our study, PCV was similar for the Black Duck and Mallard using Corn sites, but substantially less for Black Duck using coastal sites, indicating that the Black Duck at coastal sites may experience relatively higher stress than those at Corn sites (Vleck *et al.* 2000). For Black Duck, we also detected that H/L ratios increased throughout winter, but with greater increases at Corn than at coastal sites. Corn sites provide a greater density of energy-rich food than coastal wetlands, which may result in less stress for ducks eating Corn. Although body mass declined at Corn sites in Black Duck, the relative predictability and abundance of Corn was likely greater than food sources in coastal wetlands. Consistent access to food resources at Corn sites may have decreased winter stress in Black Duck, despite the recorded declines in body mass. Alternatively, lower lymphocytes (white-blood cells) at Corn sites may make ducks more susceptible to disease because their immune system is less prepared, or it may indicate they are not actively fighting infection or disease (Minias 2019).

Results do not suggest that supplemental Corn provided throughout winter at our study site was beneficial to Black Duck, especially when compared to Mallard at the same locale. However, during prolonged freeze events when coastal food resources are functionally unavailable for extended periods (*e.g.* > 7 days) supplemental Corn to the landscape may reduce risk of starvation. For Black Duck, that may have stronger winter philopatry compared to Mallard,

supplemental foods may be even more important. Black Duck using Corn sites had greater PCV and H/L ratios than Black Duck using coastal wetlands. However, Black Duck sampled at Corn sites appeared to benefit less from this supplemental food than Mallard at the same sites. When possible, the focus should be on continued protection and restoration of coastal wetlands with the aim of increasing winter carrying capacity of Black Duck. However, continued threats to coastal wetlands from urbanisation, sea level rise, and habitat fragmentation and degradation may necessitate that Corn supply a greater portion of the daily energy requirements of Black Duck in the future. Understanding daily movements of individual Black Duck and Mallard to determine relative levels of niche overlap (*i.e.* habitat use and selection) and resulting survival and reproductive effort is needed to better inform management of Corn fields for these ducks wintering in a relatively suburban/urban environment (Flores 2020; Flores & Schummer 2023).

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