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Authors: Cong, Peihao, Wang, Xin, Cao, Lei, and Fox, Anthony D.

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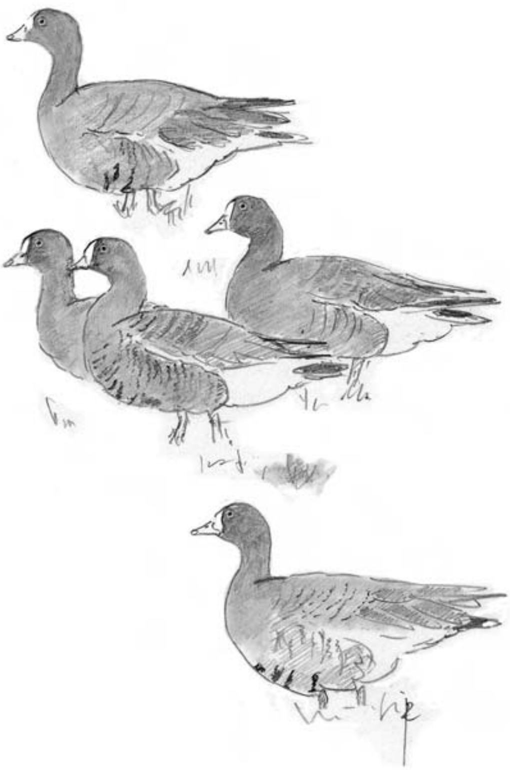
Within-winter shifts in Lesser White-fronted Goose *Anser erythropus* distribution at East Dongting Lake, China

Peihao Cong[1], Xin Wang[1], Lei Cao[1,*] & Anthony D. Fox[2]



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At the important wintering site, East Dongting Lake in the Yangtze River floodplain, Lesser White-fronted Geese *Anser erythropus* showed within-season shifts in distribution and abundance between local areas. On arrival in November, over 4,000 geese grazed high-biomass stands of new growth spikerush *Eleocharis migoana* on exposed mud flats at Caisang Lake. High feeding densities depleted *Eleocharis* by early December, when the geese departed to feed on old-growth above-ground *Carex heterolepis* at nearby lakes. Cool, arid conditions inhibited plant growth until January, when the grass *Alopecurus aequalis* and *C. heterolepis* restarted growing, attracting geese back to Caisang Lake. Greater numbers returned in late February when *E. migoana* began to grow, rapidly building to peak at 4,500 in late March when geese began spring migration. Habitat management that maintains these patterns of plant growth and availability may be critical to keeping present Lesser White-fronted Goose numbers at this site.

Key words: goose foraging, *Eleocharis migoana*, *Carex heterolepis*, *Alopecurus aequalis*

[1]School of Life Sciences, University of Science and Technology of China, Hefei, Anhui 230026, China; [2]Dept. of Bioscience, Aarhus University, Kalø, Grenåvej 14, DK-8410, Rønde, Denmark;
*corresponding author (caolei@ustc.edu.cn)

Grazing avian herbivores, notably geese, face nutritional challenges during the course of a winter: changes in forage quality and food depletion profoundly affect their distributions within and between habitats (van Eerden 1984, Prins & Ydenberg 1985, Drent & Prins 1987, Vickery *et al.* 1995, Percival *et al.* 1998). The onset of spring is a critical period in the annual cycle of pre-migratory geese as energy demands are highest at that time while food quality tends to drop below acceptable values by rapid ageing of food plants (Prop & Deerenberg 1991, Bos *et al.* 2004). By timely migration and selection of staging areas within narrow climatic zones, western Palearctic goose species are able to benefit of a temperature gradient across Europe, thus obtaining food of high quality throughout winter and spring (Black *et al.* 2007). Goose species wintering in eastern Asia, in particular those in the subtropical monsoon area of China, face a different climate regime throughout the winter season. The temperatures in this region are generally higher and precipitation in winter is twice as high as in north-western Europe. Plant production is therefore higher, as is the chance that food plants become unpalatable to geese (Van Soest 1982). One of the goose species in the region is the globally threatened Lesser White-fronted Goose *Anser erythropus*. This species is confined to three wintering areas: small numbers (<500) at a few European wintering localities, 10,000–21,000 in mostly unknown wintering areas in the Caspian and Black Sea regions, and 20,000 at East Dongting Lake (EDTL) in the Yangtze River floodplain of China (Cao *et al.* 2008, Tolvanen *et al.* 2009, Wang *et al.* 2011, T. Aarvak in litt.). At EDTL, the species switches between ephemeral wetland inundation plant communities (Fox *et al.* 2008). Such high concentrations of a vulnerable goose species at a single site, reliant upon natural inland vegetation, are unusual. We aimed to explore in which way the geese might benefit from environmental gradients in the foraging area caused by cyclic patterns in water level of the floodplain. This paper presents data on plant biomass, diet, and feeding behaviour of the Lesser White-fronted Goose at EDTL to describe shifts between habitats and better understand the species' food requirements at this important site.

STUDY AREA AND METHODS

Study area

East Dongting Lake National Nature Reserve (NNR) and Ramsar Site (29.32°N, 112.98°E) in Hunan Province, China, comprises 190,000 ha of shallow freshwater lakes, marshes and seasonally inundated sedge meadows, which receive water from the Yangtze River (Taylor *et al.* 2005). The Reserve is part of 500,000 ha of extensive wetlands, which includes two more Ramsar sites, listed as Important Bird Areas partly because of their importance for Swan Geese *Anser cygnoides* and Lesser White-fronted Geese (Chan *et al.* 2004). Water levels rise and fall with those in the Yangtze River, fluctuating 16–18 m each year (Research Institute for Yangtze Water Resources Protection 1999), reduced in recent years to 10–12 m (Y. Jiang pers. comm.). The subtropical monsoon climate experiences 1200–1330 mm annual rainfall and a mean temperature of 17°C, with frequent sub-zero temperatures in winter (Taylor *et al.* 2005). Large annual water level fluctuations create vegetation types dominated by relatively few species amongst the extensive submerged, floating and emergent aquatic vegetation (Research Institute for Yangtze Water Resources Protection 1999; Fox *et al.* 2008). Away from main water channels, higher and less frequently inundated extensive mud flats are dominated by sedge meadows of *Carex heterolepis* and lesser amounts of *C. unisexualis*. Lower down, extensive areas of bare mud flats are progressively exposed in winter by water level recession, colonised by ephemeral stands of short, fine graminoid species, principally dominated by the grass *Alopecurus aequalis* or the spikerush *Eleocharis migoana*. Outside the lake-retaining dyke there are extensive areas of intensively cultivated rice, winter wheat and vegetables, and some planted woodland, but no natural goose grazing habitat. The wetlands and surrounding areas are state owned and were designated as a NNR in December 1984. Fishing, reed harvesting and grazing (mostly goats and buffalo) occur throughout the wetlands, but hunting is illegal and strictly controlled. This study was confined to three major areas used by the Lesser White-fronted Geese throughout the 2008/2009 winter in the northwest corner of EDTL (Figure 1).

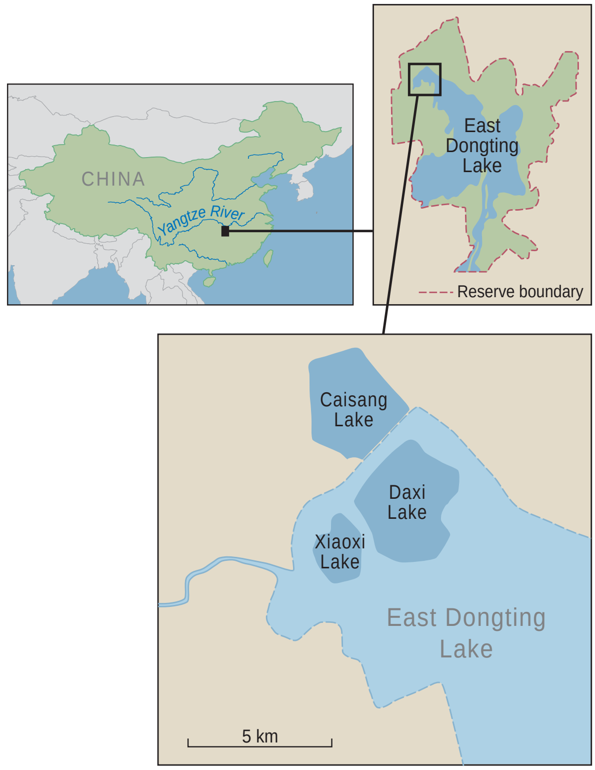

Figure 1. Map of study area showing the location of East Dongting Lake in China and the relative geographical relationships of Caisang, Daxi and Xiaoxi Lakes within the East Dongting Lake complex of wetlands. Daxi, Xiaoxi and Caisang Lakes are basins within East Dongting Lake that retain water in the areas indicated through the winter, all of the East Dongting Lake area shown is fully inundated in summer.

Goose counts

Lesser White-fronted Goose counts at Caisang, Daxi and Xiaoxi Lakes in the northwest corner of EDTL (Figure 1) were undertaken by day on feeding grounds by two observerson 15 October 2008 and then on the eighth of each month until April. Extra counts were undertaken on six dates in November at Caisang Lake (and the maximum taken for this month) and weekly counts undertaken there from 8 November 2008 – 22 March 2009.

Diet analysis

Lesser White-fronted Goose faeces were collected at regular intervals from Caisang Lake between 18 October 2008 and 24 March 2009 to track diet changes. Fresh single droppings were selected at intervals greater than 2 m (never from roost piles), to maximise the probability that they originated from different individuals. Ten droppings were combined for each sample.

Samples of substrate and associated vegetation were cut from the study area, brought back and raised to florescence in a greenhouse to identify the range of species present. After identification, slides of plant epidermal surfaces were prepared for identification of epidermal fragments in droppings. Faecal material was mixed and diluted in water, fixed (but not stained) on a microscope slide and microscopically examined under 100× magnification. Most fragments were identifiable to species level based on cell structures, and 200 of these were identified along a transect across each slide.

Dietary plant biomass

Twenty 100×100 m plots were marked out contiguously with coloured bamboo poles in Caisang Lake in areas most used by geese and 10×10 cm samples of the sward were dug from near the centre of each. Turves were brought to the laboratory to determine above-ground biomass of the important species on 13 dates approximately evenly distributed between 5 November 2008 and 9 April 2009. Above-ground plant parts were clipped from the turf, identified and sorted into live and dead biomass for each species and oven dried at 50–60°C for 24–48 hours; dry weight determinations were then converted to biomass per unit area (g/m^2).

Goose grazing pressure on vegetation types

Geese produce droppings at a reasonably constant rate, so dropping densities provide an index of local grazing pressure (Owen 1971). To establish the relationship between the amount of food and grazing pressure, representative areas covered by *Alopecurus*, *Carex* and *Eleocharis* were selected in Caisang Lake. All three species showed similar patterns in above-ground biomass (essentially elongation of leaf and stem lengths), with increasing biomass with distance from the waterline. Therefore, three transects perpendicular to the shoreline were defined covered by a single plant species, and numbers of fresh goose droppings (0–5 days old) were counted within a 1×1 m bamboo frame every 10 m. Twenty of these quadrats were defined in each of the three transects, and in each a randomly placed sample (*Alopecurus* 10×20 cm on 2 February 2009; *Carex* 20×20 cm on 21 February 2009; *Eleocharis* 10×10 cm on 20 March 2009) of the substrate and sward was dug out, brought to the laboratory, sorted and dried using the above methods.

Meteorological data

Minimum daily temperatures (as an indication of frequency of sub-zero temperatures and ground frost prevalence) and daily precipitation (as source of moisture recharge to the mudflats) were obtained from the meteorological station at Yueyang City (29.37°N, 113.12°E), on the shores of EDTL.

RESULTS

Seasonal local abundance of geese

Lesser White-fronted Geese appeared in large numbers in November (Table 1), but dispersed from the study area, and especially from Caisang Lake, in December and January. More frequent counts at Caisang Lake show the pattern of rapid decline after a mid November peak; few geese were present during early December to late January, followed by a rapid rise from late-January to a peak in late March (Figure 2A).

Seasonal changes in plant biomass and diet

When geese arrived in October, Caisang Lake mud flats exposed by autumn water table recession were dominated by single species stands of *Eleocharis* and little else (Figure 2C). This food was attractive to Lesser White-fronted Geese, dominating the diet during October until early December (Fig. 2B). *Eleocharis* was rapidly depleted, all above-ground biomass was removed during November (there being no other grazers present in this area). Little to no biomass remained in early December (Figure 2C) when geese abandoned Caisang Lake to feed on dense beds of old tall-growth *Carex heterolepis* accumulated in autumn in nearby Daxi Lake (Table 1 and Figure 1). From January, *Alopecurus* and low growth *Carex* (which does not form

Table 1. Numbers of Lesser White-fronted Geese counted at Caisang, Daxi and Xiaoxi Lakes from October 2008 to March 2009.

Lake	October	November	December	January	February	March
Caisang	14	4024 *	257	944	1477	3000
Daxi	149	0	2337	255	6150	3354
Xiaoxi	296	1650	0	65	790	2100

*Count represents the maximum of 19 counts in that month at this site. More frequent counts from Caisang Lake are presented in Figure 2A.

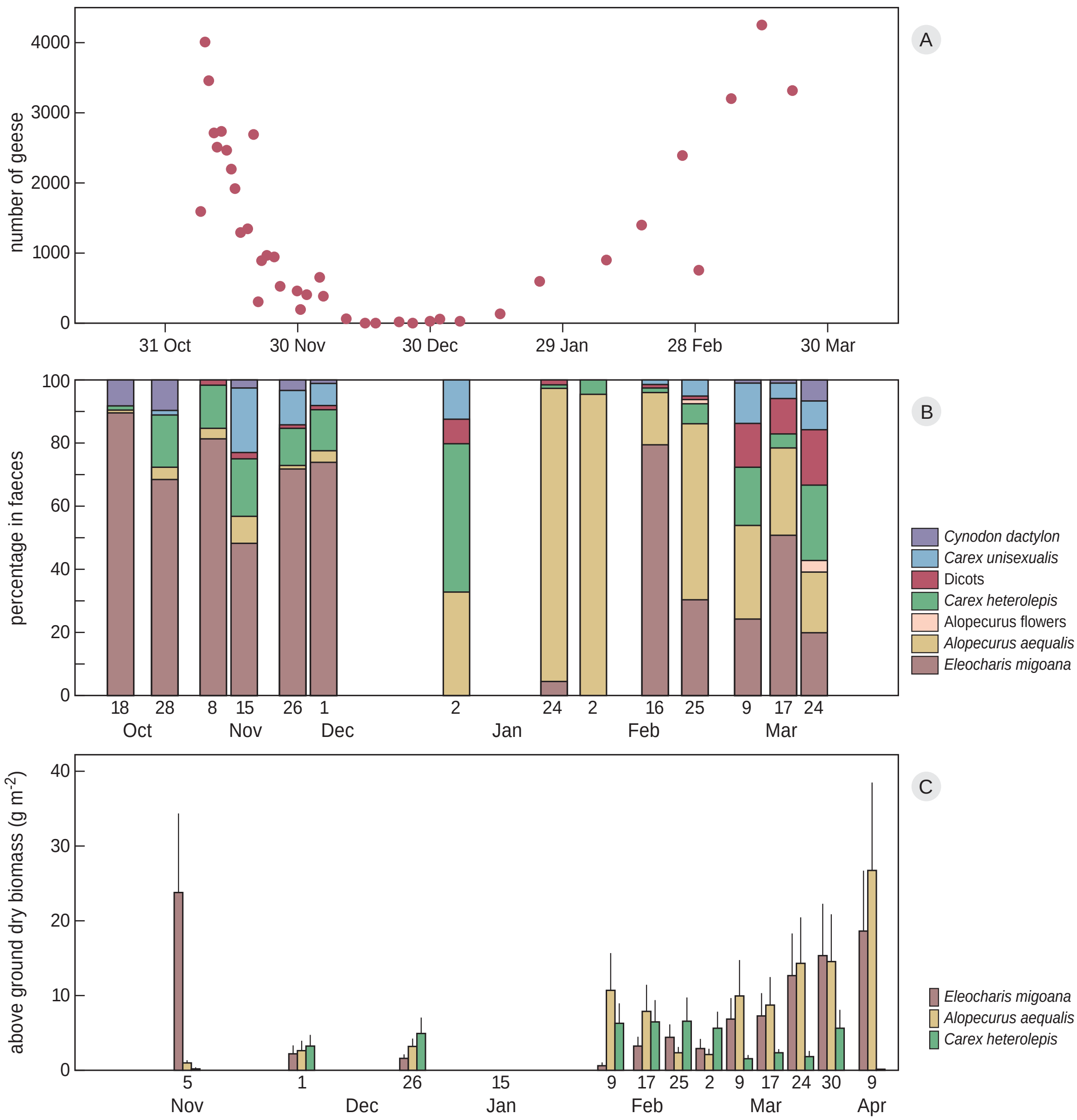

Figure 2. (A) Numbers of Lesser White-fronted Geese counted at Caisang Lake between 8 November 2008 and 21 March 2009. (B) Diet composition of Lesser White-fronted Geese at Caisang Lake during winter 2008/2009. (C) Mean above-ground biomass (± 95% CI) of the three most important plant species consumed by Lesser White-fronted Geese at Caisang Lake measured in unexclosed plots during 2008/2009 winter.

the dense beds at Caisang Lake as it does in Xiaoxi and Daxi Lakes) began to break dormancy and grow (Figure 2C), attracting small numbers of geese to Caisang Lake to feed on these items (Figure 2A). Increasing growth of *Alopecurus* and *Carex* attracted increasing numbers of Lesser White-fronted Geese through February as temperatures increased and precipitation rewetted desiccated substrates (Figure 3). Above-ground growth of *Eleocharis* resumed in mid-February (Figure 2C), which reappeared in the diet (Figure 2B). Increasing growth of all plant species responding to warm moist soil conditions, diversified the diet through late February and March (Figure 2B).

Grazing pressure in relation to food

Goose grazing pressure varied according to above-ground biomass of food plants (Figure 4). Geese showed bell-shaped responses to *Eleocharis* and *Carex*,

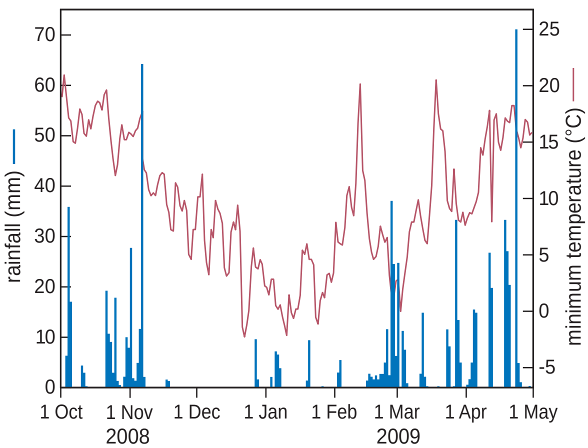

Figure 3. Daily precipitation (bars) and minimum temperatures (line) measured at Yueyang City (near to Caisang Lake) during winter 2008/2009.

but a positive and linear response to *Alopecurus* (Figure 4). The quadratic nature of the dropping density in response to both *Eleocharis* and *Carex* suggests declining profitability of feeding on these food items at higher biomasses, perhaps related to increasing handling time or structural fibre associated with elevated graminoid biomass levels. The shape of these relationships may also contribute to the increasing diversity of the diet as the spring progressed and overall biomass of all plants increased up to the departure time of the geese. The lack of a quadratic relationship in *Alopecurus* was probably due to the early date of sampling when only young, fresh leaves were present.

DISCUSSION

East Dongting Lake supports almost all wintering eastern Palearctic Lesser White-fronted Geese (two-thirds of global numbers), where the species relies upon ephemeral wetland communities exposed by water table recession patterns imposed by the Yangtze River. It is essential we understand their food and habitat choice to maintain and improve feeding conditions for this population in the future. This study indicated numerical and distributional shifts between different areas of EDTL, which support between a third and half of all the individuals of this species that winter at the site.

E. migoana vigorously colonises bare substrates exposed by late summer water level recession and is abundant in parts of Caisang Lake, where Lesser White-fronted Geese aggregate. This vegetation type is absent from the immediate surroundings of Caisang Lake, but

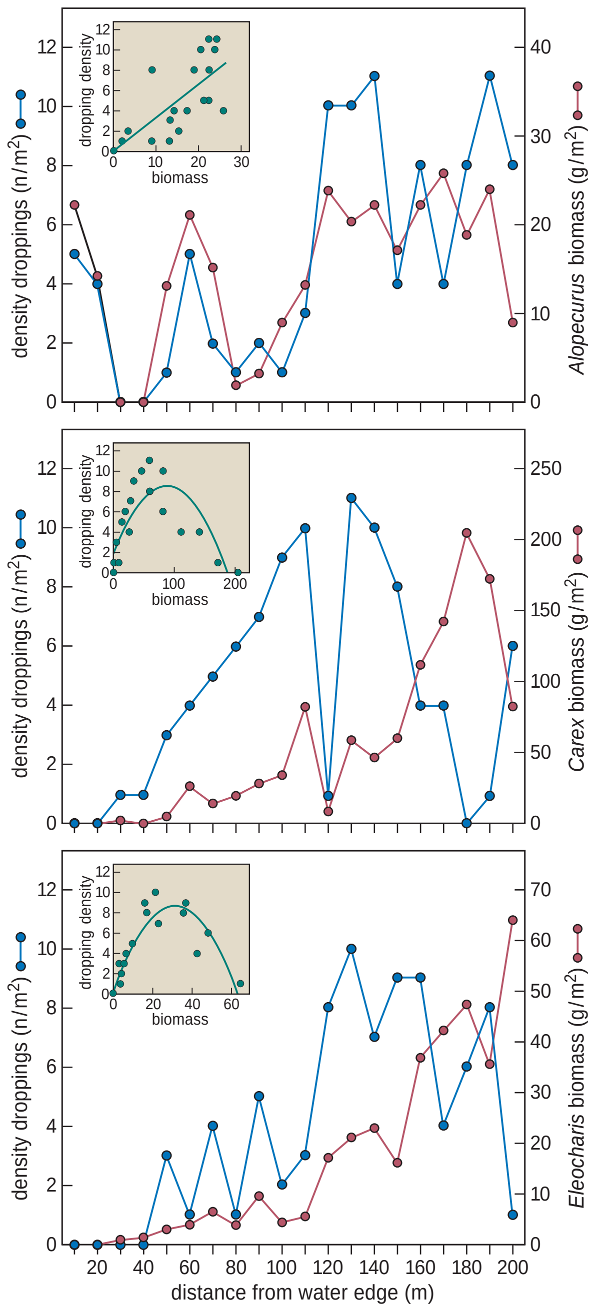

Figure 4. Gradients of Lesser White-fronted Goose dropping density and above-ground live biomass in single species stands of food items in transects starting close to the water edge, Caisang Lake. Insets show the relationships between dropping densities and biomass during the onset of growth (2 February 2009 for *Alopecurus*, 21 February 2009 for *Carex heterolepis* and 20 March 2009 for *Eleocharis*). Fitted regression models, where y = dropping density and x = above-ground green biomass, were: *Alopecurus* $y = 0.3280x + 0.0575$, $R^2 = 0.53$, $F_{1,18} = 20.54$, $P < 0.0001$; *Carex* $y = -0.0009x^2 + 0.1510x + 1.7605$, $R^2 = 0.65$, $F_{2,17} = 15.97$, $P < 0.0001$; *Eleocharis* $y = -0.0086x^2 + 0.5404x + 0.2177$, $R^2 = 0.85$, $F_{2,17} = 46.75$, $P < 0.0001$.

it is not known how common it is elsewhere in EDTL or in the Yangtze River floodplain system. Over 2,500 geese grazed c. 30 ha of abundant growing *Eleocharis* in early November, removing much of the above-ground green biomass. Geese left Caisang Lake in mid-November (when *Eleocharis* ceased growth), presumably for the less nutritious *Carex heterolepis* at nearby Daxi Lake which was apparently increasingly profitable as *Eleocharis* disappeared.

In January, *Alopecurus* began above-ground production, drawing geese back to Caisang Lake, although low biomass attracted less than 500 geese, when most geese remained on Daxi *Carex* beds. With elevated temperatures and precipitation, above-ground production in *Eleocharis* resumed and c. 1,500 Lesser White-fronted Geese returned in mid-February. Rising spring temperatures and precipitation encouraged growth of all dietary species, all of which increased in biomass in spite of heavy goose grazing pressure. Goose numbers increased, peaking in mid-March at 4,500 prior to departure for the breeding grounds. Substantial numbers of geese were also retained at Daxi Lake in March, where new growth of *Carex heterolepis* offered renewed feeding opportunities, with leaf elongation rates of 6 mm/d (during 23 March–6 April 2009) to 12 mm/d (16–20 April 2009, Zhao *et al.* 2011).

The importance of restoring depleted body stores after autumn migration and prior to spring migration confirms Caisang Lake as being of special importance to Lesser White-fronted Geese in their annual cycle. Mid-winter foraging on *Carex heterolepis* beds at nearby Xiaoxi and Daxi Lakes during the period of lowest temperatures (i.e. a time of no plant growth, shortest daylength and enhanced thermoregulatory costs) is likely a strategy to at least maintain body stocks (rather than gain stores of nutrient or energy) until such time as geese can resume harvesting new above-ground primary production in spring. Studies on the energetic consequences of feeding on the different plants at different times of year would address this hypothesis.

Lesser White-fronted Geese only overlapped with other species of geese at EDTL at Xiaoxi and Daxi Lakes in mid-winter, when they fed with Greater White-fronted Geese *Anser albifrons* and some Bean Geese *Anser fabalis*. Even then, Lesser White-fronted Geese foraged separately on the shortest *Carex heterolepis* swards (generally <60 mm high, compared to 120–200 mm generally available; unpubl. data), not used by the larger goose species. The Lesser White-fronted Goose was the only species seen feeding on the ephemeral short sward graminoid communities of Caisang Lake. These short (generally <60 mm) swards on bare mud are similar to those in Hungarian recessional wetlands and fish ponds after autumn water level drawdown (Tar *et al.* 2009), ephemeral recession meadows of Lake Kerkini and the Evros Delta in Greece (Øien *et al.* 2009), the steppes and ephemeral wetlands of Azerbaijan and spring staging areas in Finland (Markkola *et al.* 2003), which are also used by this species. This suggests that Lesser White-fronted Geese may avoid competition with larger-bodied, more numerous goose populations precisely by selecting dense swards of short ephemeral graminoids (especially those associated with recessional wetlands which expose shallow bare substrates). Such short swards may enable a small specialist herbivore, like the Lesser White-fronted Goose, to maintain high rates of food intake, which larger geese cannot achieve (e.g. Durant *et al.* 2004). This may enable the species to avoid competition, but may equally contribute to their clumped distribution and rarity because of the scarcity of such vegetation types in the northern hemisphere. Lesser White-fronted Goose dropping densities declined with increasing biomass of both *C. heterolepis* and *E. migoana*, consistent with observations of their avoidance of feeding on taller plants (Figure 4). This again fits with earlier observations that suggest short-billed grazing herbivores have an optimal bite size when predating graminoid leaves above which feeding efficiency declines (e.g. Durant *et al.* 2004), suggesting the species may abandon feeding when the sward becomes too tall and suggests management should aim to ensure provision of swards of optimal length for Lesser White-fronted Geese.

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SAMENVATTING

Het Oostelijke Dongting Meer, gelegen in het stroomdal van de rivier de Jangtsekiang in China, vormt het overwinteringsgebied van 20.000 Dwergganzen *Anser erythropus*. In een van de kerngebieden (het Caisang Meer) werd onderzoek gedaan naar de verspreiding en voedselkeuze door de ganzen. Kenmerkend voor het gebied zijn de jaarlijkse fluctuaties in waterniveau, waarbij in het najaar uitgestrekte gebieden droogvallen en bedekt worden door homogene vegetaties van het gras *Alopecurus aequalis*, de zegge *Carex heterolepis* en de waterbies *Eleocharis migoana*. Waterbies is de favoriete voedselplant van de ganzen, maar de planten worden na aankomst van de ganzen in november zo sterk begraasd dat binnen een maand het voedsel opraakt. De ganzen wijken in december dan uit naar omringende meren, waar vooral zegge op het menu staat. Het onderzoeksgebied ligt in de subtropische klimaatzone, waarbij midden in de winter de temperaturen zakken tot rond het vriespunt. De plantengroei ligt dan stil. Als in de loop van januari de groei van gras en zegge weer op gang komt, gaan de ganzen daar op foerageren. Vanaf het moment dat ook waterbiezen beginnen te groeien, nemen de aantallen Dwergganzen snel toe. De ganzen blijken kritisch te zijn in de keuze van hun foerageerplekken. Ze mijden plaatsen waar de hoeveelheid biomassa gering of juist hoog is. Omdat de hoeveelheid biomassa een gradiënt laat zien van weinig op de laagst gelegen plekken naar veel op de hoogste, is het voorkomen van de ganzen beperkt tot smalle zones die aan hun behoeftes voldoen. (JP)

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