Distribution and diet of wintering Tundra Bean Geese *Anser fabalis serrirostris* at Shengjin Lake, Yangtze River floodplain, China

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Abstract

More than half of the estimated global flyway population of Tundra Bean Geese *Anser fabalis serrirostris* was counted at the Shengjin Lake National Nature Reserve, Anhui Province, China, in winter 2008/2009, peaking at 41,500 birds in mid-December 2008. In October–November and March, when fewer geese were recorded, the birds were found on sedge *Carex* meadows, because high water levels restricted access to other food resources at this time. Much larger numbers coincided with lowest water levels in mid-winter, when faecal analysis showed that geese fed on a wide range of additional food items. These included the grass *Alopecurus aequalis*, submerged Water Chestnut *Trapa maximowiczii* fruits exposed by falling water levels, and fields of winter wheat. The extent of floating Water Chestnut in summer has more than doubled from 4.2 to 9.1 km^2 at Shengjin Lake since 2002 (potentially linked to eutrophication at the site), but more study is required to support the hypothesis that this source of winter food is responsible for dramatic recent increases in Bean Goose numbers at the site.

Key words: *Anser fabalis* Bean Goose, *Carex*, diet, distribution, Shengjin Lake, *Trapa maximowiczii*, winter wheat.

Two Bean Goose *Anser fabalis* subspecies winter in China: *middendorffi* and *serrirostris*, with flyway population estimates of 80,000 and 70,000 respectively. Numbers of both subspecies are considered to be in decline (Wetlands International 2006). The Yangtze River floodplain is the most important region within East Asia for wintering Bean Geese (Cao *et al.* 2008), but there has been only limited study of their habitat use and feeding ecology (Lu & Zhang 1996). The conditions which attract them to the area therefore are still unknown.

Regular surveys made in February in

winters 2002/2003–2007/2008 inclusive recorded 3,000–18,900 Bean Geese at Shengjin Lake within the Yangtze River floodplain (Barter & Lei 2003; Barter *et al.* 2004; Barter *et al.* 2006; L. Cao unpubl. data). Up to 42,000 *serrirostris* were counted in winter 2008/2009 (October to mid-April), *c.* 60% of the estimated flyway population, thus confirming Shengjin Lake as one of the most important wintering sites for the subspecies (Cheng *et al.* 2009).

Shengjin Lake was designated as a provincial nature reserve in 1986, and the Chinese Government designated Shengjin Lake as a National Nature Reserve (NNR) in 1997 specifically to protect Hooded Cranes *Grus monacha* and other wintering waterbirds, including Bean Geese. Whilst annual totals reported to date have highlighted the global significance of the site for the species, more detailed within-winter studies of the geese are essential, not only for determining any seasonal changes in Bean Goose abundance at Shengjin Lake, but for assessing whether variation in numbers and distribution are associated with changes in the birds' diet and habitat use during the winter. This paper therefore presents data on variation in the numbers of Bean Geese at Shengjin Lake throughout a winter season (October–April) and describes this in relation to changes in the birds' diet and feeding distribution.

Study area and methods

Shengjin Lake study site

Shengjin Lake is a shallow freshwater lake situated at approximately 11 m above sea level south of the Yangtze River (30º15'–30º30' N, 116º55'–117º15' E; Fig. 1). An area of 33,340 ha is designated as NNR for its importance for waterbirds. The lake extends to 165 km of shoreline and is recharged from a 1,548 km² catchment area and from the Yangtze River via a sluice built in 1965. Typically, Yangtze River water levels are high during the summer flood season (Shankman & Liang 2003), when the maximum lake area extends to *c.* 14,000 ha at a water level of *c.* 17 m above sea level (a.s.l.). Water levels fall to < 10 m a.s.l. during September–February (dry season) when the lake area decreases to *c.* 3,400 ha in area (Cheng & Xu 2005). Average annual rainfall at the site is *c.* 160 cm (most falling in April–August); average annual temperature is 16ºC; average monthly temperatures (over the last 10 years) during the winter period are October: 19ºC; November: 13ºC; December: 6ºC; January: 5ºC; February: 8ºC; and March: 12ºC (TuTiempo 2010).

Water flows in the Yangtze River have been affected by the commissioning of the Three Gorges Dam in June 2003. Downstream Yangtze River levels now rise up to one month later during the summer flood, and fall about a month earlier during the August–December period, with the summer flood peak about 2 m lower and less variable than in the five years immediately before the commissioning of the dam (Zhang *et al.* 2010). Water levels normally fall to < 10m a.s.l. in winter, but precipitation and a release of water from Three Gorges Dam caused abnormally high water levels in late November 2008. Precipitation and closure of the sluice again elevated water levels from February 2009

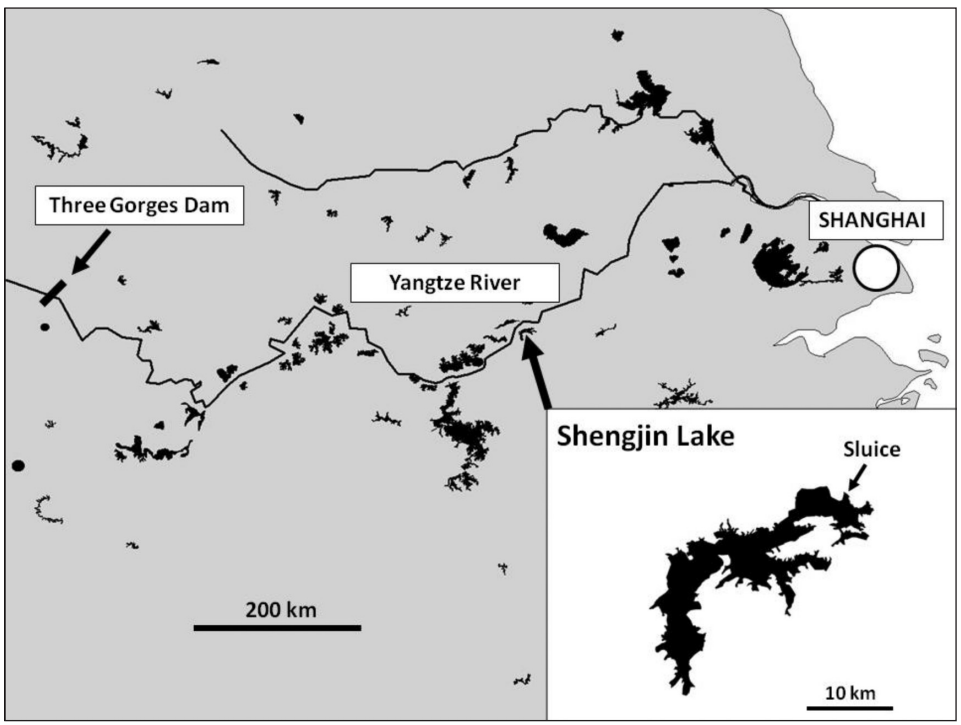

Figure 1. Location of Shengjin Lake in the Yangtze River floodplain, showing its position relative to the Three Gorges Dam and the outflow to the sea near Shanghai. Inset map shows the lake with the position of the sluice that controls flow to and from the Yangtze River.

onwards (Cheng *et al.* 2009; Zhang *et al.* 2010). Receding waters initially expose two large recessional sedge *Carex* meadows at Shengjin Lake: one in the southeast part of the Upper Lake and the other in the northeast corner of the Lower Lake (SE and NE sedge meadows, respectively; Fig. 2). These sedge meadows are dominated by *Carex heterolepis*, but other species, including *C. thunbergii*, *C. unisexualis*, *C.transversa*, *C. japonica* and C. *brachyathera*, also occur. The sedge meadows begin to accumulate new green biomass in autumn before the geese arrive, and again in late winter when temperatures rise; in both periods the sedge meadows provide important Bean Goose foraging habitats. Bean Geese also exploit non-native *Cynodon* grasslands, usually situated above the *Carex* meadows. Other habitats used include seasonally inundated mud flats where Water Chestnuts *Trapa maximowiczii* dominate during the wet season (a floating-leaved macrophyte, the area of which has increased enormously since 2002 at Shengjin Lake), winter wheat fields, and fishponds with submerged vegetation at several different locations about the periphery of the lake. Water Chestnut is of

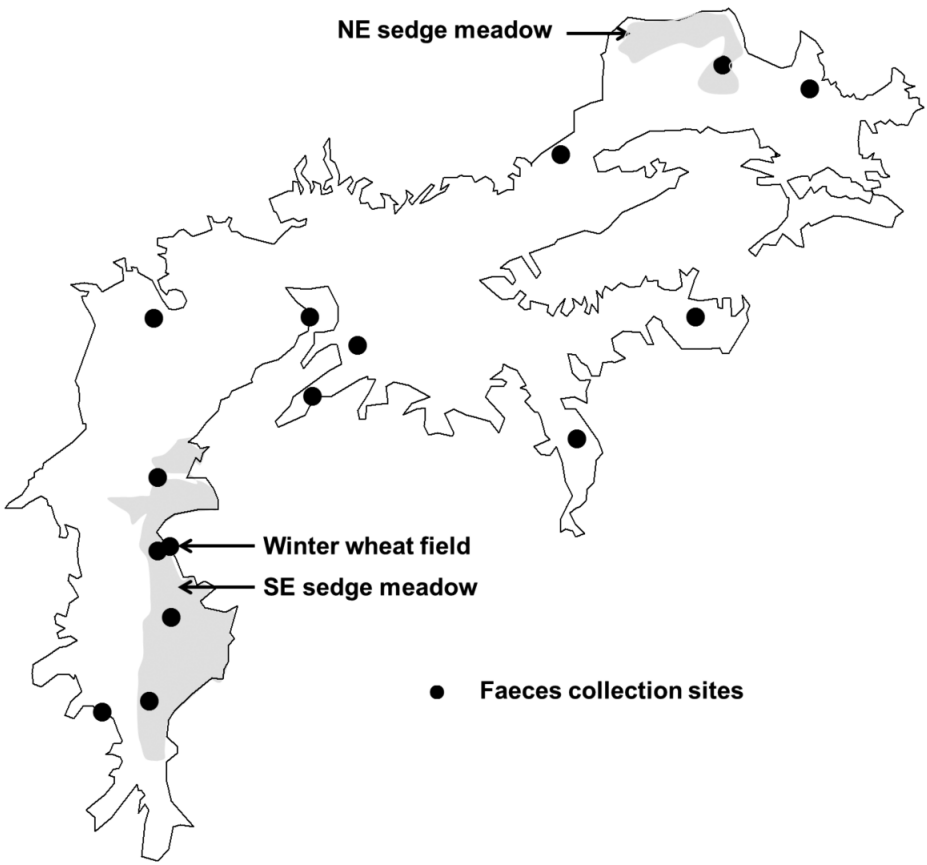

Figure 2. Location of sites within Shengjin Lake from which faeces were collected and the various named sites referred to in this study. The extent of the southeast and northeast *Carex* beds are shown shaded in grey.

particular significance because it produces abundant spiked fruits which are eaten by Bean Geese.

Winter waterbird counts

The study period in winter 2008/09 was divided into three parts: 1) early-winter: first half of November to mid-December; 2) mid-winter (the coldest period): late December to first half of February; and 3) late-winter: mid-February to mid-April. Systematic complete counts of Shengjin Lake were undertaken nine times from mid-October 2008 to mid-April 2009 using independent teams counting throughout the day to ensure consistent information on waterbird abundance and distribution across the lake (Cheng *et al.* 2009). For logistical reasons, it was not possible to visit the site in January 2009.

Diet composition

Reference epidermal slides were made from plants collected from Bean Goose foraging habitats and grown to florescence in a greenhouse for identification of leaf epidermal fragments in faeces to determine dietary composition. Fragments of these leaf parts, *Trapa* fruits and the tubers of the submerged macrophytic tapegrasses *Vallisneria spiralis, V. spinulosa* and *V. natans* (hereafter referred to as *Vallisneria* sp.) were ground in a mill and also prepared as slides to identify fragments in the faeces. Faeces were collected from the SE sedge meadow throughout the whole winter (Fig. 2) and opportunistically at 11 other habitats, mainly those used by geese in mid-winter, when access permitted. Faeces were dried for 48 h at 50°C. Samples comprised 10 droppings randomly selected from faeces collected at each site, which were mixed and ground to powder.

Faecal samples were analysed using the micro-histological techniques of Johnson *et al.* (1983) and Korschgen (1980). Most fragments were identifiable from the cell structures to species level when viewed under a microscope, although it was not possible to identify all *Carex* to species, so these were aggregated for this analysis. From each sample, 200 fragments were identified under 100 × magnification. Fragments of the outer shell of *Trapa* fruits were identified by their lack of cell structure, dense form and blackish coloration. *Vallisneria* tubers were identified by the diffuse cell patterns associated with these fragments, the lack of any cell structures, lighter coloration and by the fragments being far less dense in structure than those of *Trapa*.

Results

Seasonal distribution of Bean Goose

Main Bean Goose arrival occurred in the second week of November, with greatest numbers counted in mid-December (Cheng *et al.* 2009, Fig. 3). More than 60% of all geese counted on the lake were observed on the extensive *Carex* meadows in the southern part of the Upper Lake and the northeast part of the Lower Lake, rising to > 95% in early- and late-winter (Fig. 3). From late December to early February, lower water levels (Fig. 4) made alternative food resources accessible and geese were far more widely dispersed. At this time they used a wider array of other habitats (Fig. 3), for example, shallow water and bare mud containing abundant Water Chestnuts and submerged vegetation in fishponds. Winter wheat fields adjacent to the lake were also utilised from February until goose departure. Elevated water levels from mid-February were followed by a sharp decline in Bean Goose numbers until mid-March, by which time geese were again concentrated at the *Carex* meadows. Almost all of the geese had departed by early April (Fig. 3).

Diet composition

In periods of high water during early- and late-winter, faeces collected from the SE sedge meadow were dominated (>75%) by *Carex*, with lesser amounts of the grass *Cynodon dactylon* (Fig. 5). Diet composition became more diverse during exceptionally high water levels in mid-November when

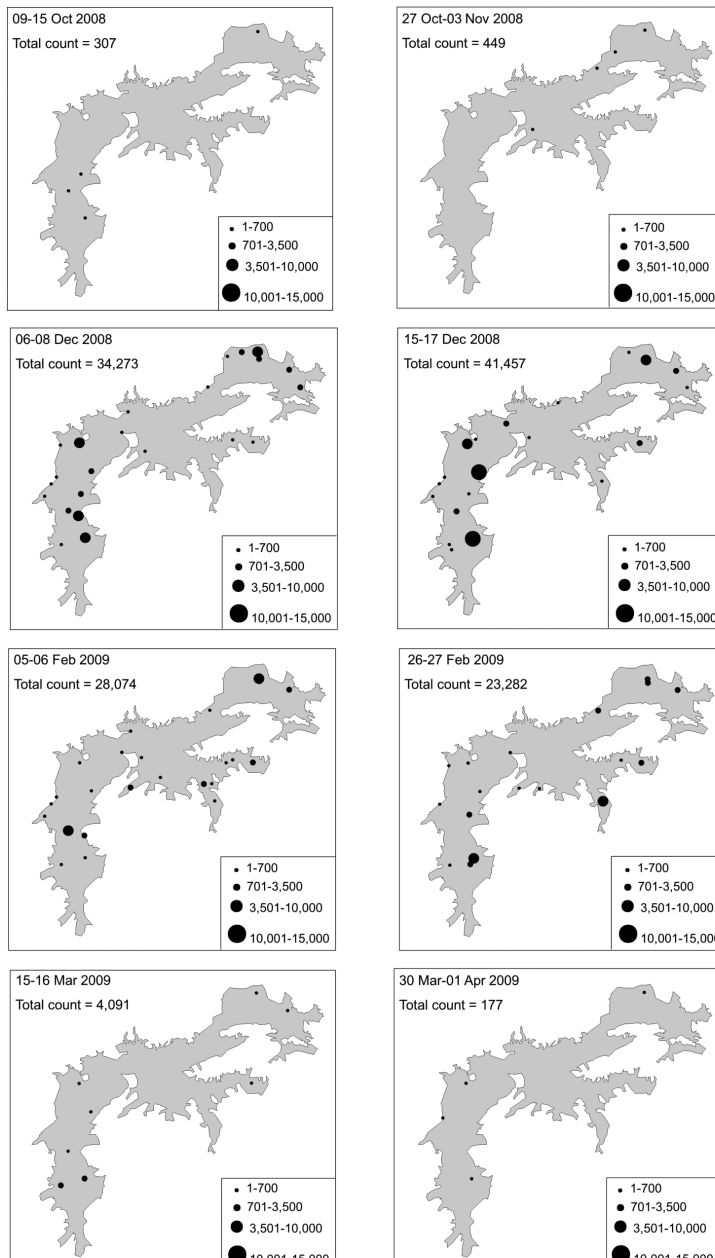

Figure 3. Seasonal changes in Bean Goose numbers and distributions during eight counts in winter 2008/2009. Survey dates and the maximum number of geese counted for each survey are given on the distribution maps. No Bean Geese were present during the final count (*i.e.* from April 15–16).

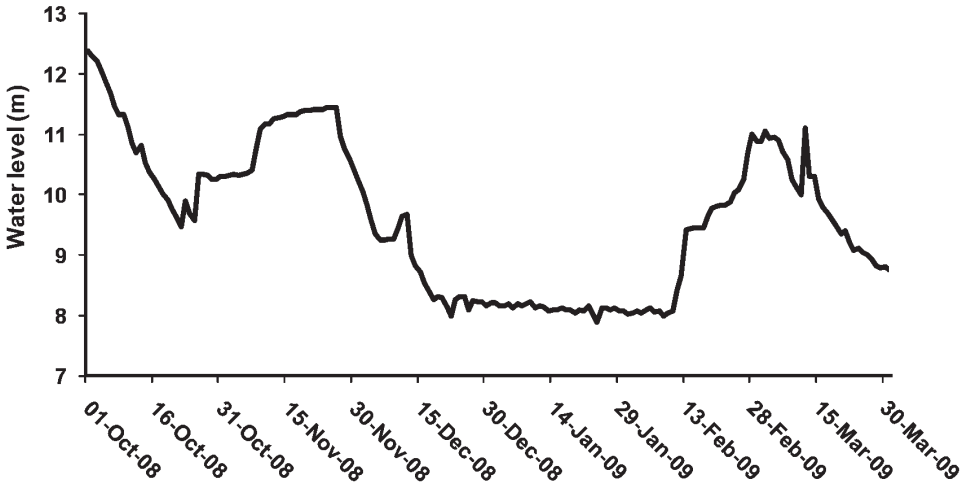

Figure 4. Water level (Wu Song datum) at Shengjin Lake from October 2008 to March 2009.

geese took the spike-rush *Eleocharis migoana* whilst the *Carex* was flooded. When water levels fell in December, the grass *Alopecurus aequalis* (an early coloniser of newly exposed mud) became the most important food item in this area but, as the *Carex* began to grow from February onwards, sedge fragments dominated the diet until spring departure in April (Fig. 5).

Analyses of diet composition from 11 other sites at the lake in mid-winter varied with location and water levels. Samples from four sites in Water Chestnut *Trapa* sp. areas were dominated by Water Chestnut (≥ 95%, note these fragments could not be assigned to species) when the fruits were accessible to geese during low water levels, or *Carex* (> 95%) when they were not. Faeces from other sites without *Trapa* contained *Carex* (*c.* 72%), *Vallisneria* tubers (*c.* 11%) and small quantities (individually < 5%) of the grasses *Phalaris arundinacea*, *Cynodon dactylon* and *Alopecurus aequalis*, dicotyledonous plants and some unidentified non-leaf items. Faeces were collected once from the winter wheat field and contained 67% wheat, 12% *Alopecurus aequalis*, 8% *Carex* sp., 6% *Cynodon dactylon* and small quantities of *Phalaris arundinacea*, dicotyledonous plants and non-leaf items (all < 5%).

Discussion

Food depletion, short day length and cold weather generally create challenges to herbivorous Bean Geese feeding on *Carex* at Shengjin Lake. Bean Geese grazing the SE sedge meadows studied here likely suffer mid-winter local food depletion, exacerbated by *c.* 1,000 water buffalos grazing on the same *Carex* swards. Short day length limits available diurnal feeding time and low temperatures during December to early February inhibit above ground production of food plants and enhances thermoregulatory demands,

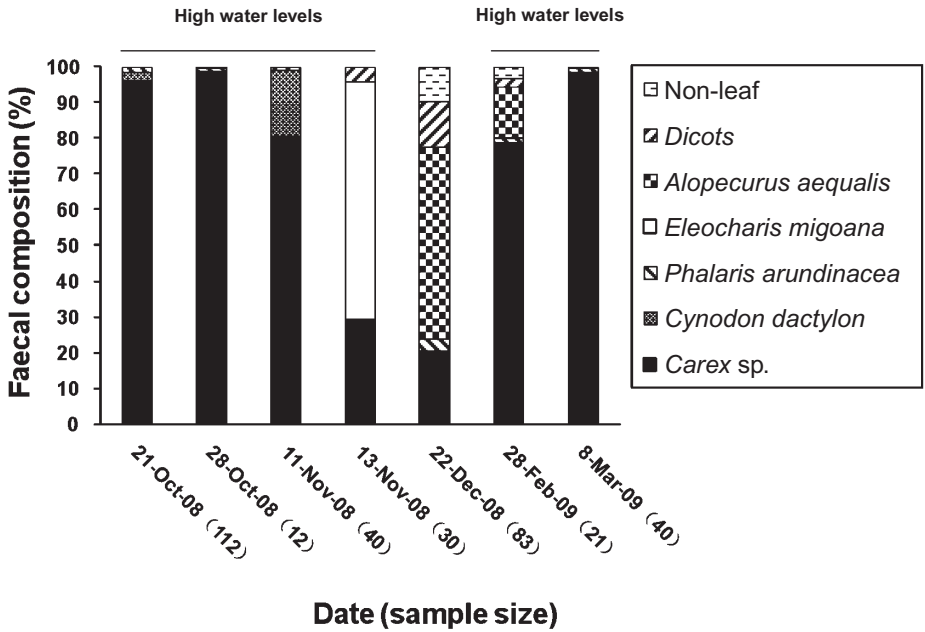

Figure 5. Percentage composition of vegetation fragments in faeces collected at the southeast *Carex* meadow at Shengjin Upper Lake on different dates. The category "*Carex*" was mainly composed of *Carex heterolepis*, with smaller proportions of *C. thunbergii*, *C. unisexualis*, *C.transversa*, *C. japonica* and *C. brachyathera*, but not all *Carex* fragments could be identified to species and so were amalgamated for this study. Each histogram is based on microscopic (100x) identification of epidermal cell wall structures for 200 fragments from each sample, taken from a mixture of 10 goose droppings collected at each site on the given date.

placing additional energetic stress on geese. Bean Geese generally flew to roost on open water at night, but we cannot exclude the possibility that they feed by night as well to supplement energetic intake. Bean Geese at Shengjin Lake responded to the reduced food supply by dispersing away from the two major *Carex* beds in mid-winter (Fig. 3) and those that remained were less reliant on *Carex* as the dominant food item until it began above ground green growth again later in February (Fig. 5).

So why does Shengjin Lake support the greatest numbers of Bean Geese in the period December–February and why have numbers during this period in particular increased dramatically in recent years? Falling water levels in mid-winter permit access to a wider range of food items, evident in the greater diversity in the diet shown by faecal analysis, not only from droppings collected on the SE sedge meadows but particularly for those collected elsewhere. Faeces from 11 sites away from the SE sedge meadows showed that Bean Geese consumed Water Chestnut *Trapa*

fruits in mid-winter; in four cases it dominated the faecal material. We suspect that this becomes an important food for the geese when exposed by falling water levels.

Feeding on *Carex* during the early- and late-winter periods is probably the most efficient means of foraging for the geese at these times. The geese seemed to be constrained to feeding on the *Carex* meadows by high water levels denying them access to most other sources of food. Dispersal to different habitats and increases in dietary diversity in mid-winter suggests that the relative profitability of *Carex* was reduced during that period for the reasons discussed above. Bean Geese switched to feed on *Alopecurus* (which only grows when exposed by recessional water levels) and Water Chestnut *Trapa* fruits (which only become available in muddy substrates at low water levels), suggesting these foods were not available to the geese before water levels dropped. However, when exposed, they likely represented a more profitable food than the depleted *Carex* which shows no regrowth in mid-winter (L. Cao, unpubl. data). Bean Geese exploited a greater variety of habitats using a greater range of foraging techniques and showed a far more diverse diet at this time, enabling many more geese to exploit Shengjin Lake in mid-winter. Most *Trapa*-feeding geese fed far out in soft substrates where faecal collection was not possible. It is therefore likely that this food was greatly under-represented in our samples of diet composition in relation to its importance to Bean Geese at the lake, especially in mid-winter at low water. It is unfortunate that our sampling of faeces cannot be related to the numbers of geese feeding on the different foods, because of the lack of accessibility to collect faecal material at all times. Nevertheless, we feel the data presented here offers some insight into the major shifts in distribution through the season and the food items responsible for these changes.

Geese were also observed foraging on winter wheat during mid-winter. It is known that at low soil surface temperatures the protein content of winter wheat may exceed that of natural grasses, providing nutritional reasons for switching to forage on this crop (Therkildsen & Madsen 2000). However, in grazing winter wheat fields at Shengjin Lake, the geese come into conflict with farmers who resort to scaring (by chasing the geese from fields and establishing scarecrows). With the increase in extent of winter wheat grown in the vicinity of the NNR and the greater numbers of Bean Geese at the site, it is clear that reserve staff and local farmers will have to consider means of alleviating agricultural conflict should this continue to be a problem in the future.

The reasons for the increase in Bean Goose numbers at Shengjin Lake in recent years need further investigation; it is not clear whether more birds winter here because of enhanced food availability or because habitat loss and declines in habitat quality elsewhere cause greater numbers to exploit the quality habitat at the site. Reliable counts indicate a substantial increase in peak numbers both at Shengjin Lake and at other water bodies in the Anhui Lakes part of the Yangtze catchment since 2004 and 2005, whereas the species has declined at Dongting Lake in Hunan

Province (400 km to the WSW), over the same period.

It has been suggested that the area of recessional *Carex* meadows has increased at Shengjin in recent years. The Three Gorges Dam has greatly modified the hydrology of the Yangtze River system, leading to a shorter flood season and lower flood height below the dam. This has been considered responsible for adding to widespread wetland habitat loss and degradation throughout the Yangtze River floodplain in recent decades (Cao *et al.* 2008). These changes could have led to alterations in *Carex* extent and distribution, which could, in turn, have caused a redistribution of Bean Geese. However, the results presented here suggest that although relatively small numbers of Bean Geese were dependent on *Carex* during high water periods in early winter and late winter/spring, changes in extent of *Carex* availability is an unlikely explanation for the very large increases in mid winter when the majority of these birds fed on other food items. A more detailed investigation of the degree of dependence on this food resource and analysis of remote sensing imagery to determine historical changes in the extent of the recessional *Carex* meadows would help confirm these relationships.

In contrast, submerged macrophytes that were a characteristic of the lake 10 years ago have seriously declined in extent within the lake at the same time as a dramatic expansion in the extent of floating and emergent vegetation has occurred. Floating *Trapa maximowiczii* is now a dominant species at Shengjin Lake, having increased in coverage from 4.2–9.1 km^2 between 2002 and 2007 (based on satellite imagery, discussions with local farmers, and surveys Cheng *et al.* 2009; Zhang *et al.* 2010; L. Cao unpubl. data). The reasons for this are not clear, but could be linked to eutrophication at the site, because *Trapa* sp. grow more rapidly under elevated nitrogen levels (Tsuchiya & Iwakuma 1993) and *T. maximowiczii* specifically has responded with dramatic expansions in coverage to elevated nutrient and sediment levels in surface waters at lakes further down the Yangtze River floodplain (*e.g.* Li *et al.* 2010). The fruit, the Water Chestnut, is produced in some abundance and is an important food item for Bean Geese in Japan (Miyabayashi 1994; Wantanabe *et al.* 2003) and Korea (Park & Won 1993). Water Chestnut plants flower on the water surface, but the ripe fruits fall to the lake bottom, where they are accessible to geese in mid-winter during prolonged periods of low water. These fruits are protected by sharp barbs and a horny exterior, but fertilised fruits contain seeds which comprise up to 10% protein and 50% starch and are therefore highly nutritious (Karg 2006). Hence, if geese can break through the horny exterior, the fruits represent highly profitable and nutritious food items. It therefore seems highly likely that the greatly increased availability of Water Chestnuts (which become available to grubbing Bean Geese in exposed mud flats during mid-winter water recession) has facilitated the increase in mid-winter Bean Geese numbers, aided by the extension of feeding habitat provided close to the lake in winter wheat fields. However, this clearly needs more detailed exploration, involving greater study of the precise feeding

behaviour and distribution of Bean Geese throughout the winter. Despite their nutritious qualities, Water Chestnuts are likely to demand prolonged search times (being buried in soft mud substrates) and extended handling times (because of their spines and the protective horny exterior). Geese breaking open the protective casing of the fruits with the bills and consuming *Trapa* fruits are highly conspicuous, so it would be possible to assign proportions of feeding birds in shallow water to those that were consuming this food item. An important immediate priority is to establish the proportion of the total numbers of geese feeding on the different habitats within the Shengjin Lake NNR within each winter (including confirming the timing of habitat use), to undertake an energetic analysis of the relative profitability offered by the various dietary items available to the geese throughout the winter and to establish the relative importance of feeding areas within the NNR to the geese. This will provide valuable information for developing management actions for protecting or enhancing these food resources, and also for indicating how conflict with the agricultural community might be reduced.

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