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Changing distribution and abundance of Swan Goose *Anser cygnoides* in the Yangtze River floodplain: the likely loss of a very important wintering site

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Summary

Virtually the entire population of the globally 'Vulnerable' Swan Goose *Anser cygnoides* winters in the Yangtze floodplain. Historically, the species was widely distributed throughout the floodplain but now approximately 95% of the population is confined to three closely-situated wetlands in Anhui and Jiangxi Provinces. Recent counts indicate that at one of these sites, Shengjin Lake (in Anhui), a decline of about 10,000–20,000 birds, to about 1,000 currently, has taken place during the last five years. The likely cause of the decline in Swan Goose abundance at Shengjin Lake is the recent decrease in submerged vegetation, particularly tuber-producing *Vallisneria* which is the species's main food; this decrease has been linked with the introduction of intensive aquaculture in the main areas used by Swan Geese within the lake. Earlier range contractions in the Yangtze floodplain may also be linked to reductions in submerged vegetation cover at other sites, where intensive aquaculture has also been implicated. Changes in lake hydrology following construction of the Three Gorges Dam may also have adversely affected submerged vegetation productivity. Key information needs for the effective implementation of conservation measures for Swan Goose include an understanding of (1) the fitness consequences of Swan Geese being forced to switch to different foods; (2) how aquaculture can be managed to minimise impacts on submerged vegetation; (3) the impact of changing lake hydrology on key Swan Goose food plants; and (4) the optimal management of wetlands to ensure that adequate food is both produced during the summer period and is available throughout the winter.

Introduction

The globally 'Vulnerable' Swan Goose *Anser cygnoides* breeds in central and eastern Mongolia and adjacent regions of China and Russia (Primorye and Sakhalin Island) (BirdLife International 2009). Recent contraction and fragmentation of the breeding range and declines in abundance and breeding success justify concern for the species (Lu 1996, Miyabayashi and Munkdur 1999, Goroshko 2001, Poyarkov 2001, Kear 2005, BirdLife International 2009). The main wintering area for the species has always been eastern China, although formerly it was found in small numbers in Japan and Korea (Kear 2005). The entire global population now winters only in eastern China; non-breeding season surveys in winters 2003/2004 and 2004/2005 found 95% of the estimated world population in the Yangtze floodplain, located at fewer than ten sites (Barter *et al.* 2004, 2006, Cao *et al.* 2008).

The Yangtze floodplain wetlands are globally unique: nowhere is such an enormous region subject to summer monsoonal flooding followed by autumn/winter water level recession

(Shankman and Liang 2003). This hydrological cycle creates numerous, shallow, ephemeral and highly productive wetlands extending to *c.*10,500 km² (He and Zhang 2001).

Swan Geese extract nutritious storage organs of submerged macrophytes, particularly those of *Vallisneria spiralis,* made successively available from muddy lake sediments by winter water level recession (Zhang and Lu 1999, Fox *et al.* 2008, Barzen *et al.* 2009). This unique combination of food source and water level behaviour makes the species highly sensitive to hydrological change in the seasonally flooded wetlands of the Yangtze floodplain. The annual influx of monsoonal water, sediment and nutrients has maintained these wetlands until now, but recent major hydrological change caused by hydroelectric and water diversion projects, such as the Three Gorges Dam (TGD, which commenced operation in June 2003) has modified these patterns. The TGD has affected water levels by delaying the summer peak monsoonal flows in the Yangtze River. These changes in water regime have a number of consequences for the hydrology of the vast ephemeral wetlands of the Yangtze catchment. Lower summer water levels caused by delayed periods of highest water level may reduce the competitive ability of submerged water plants, such as *Vallisnaria* and *Potamogeton* which may be overshadowed by floating plants such as *Trapa* and shallow water emergent plants such as *Zizania*. However, some lake systems, particularly those under sluice control, also experience enhanced water levels in the autumn and winter which may deny Swan Geese access to shallow water areas where they grub for *Vallisnaria.* Hence, changes in water regime may have profound effects on the relative abundance of dominant macrophytes in these wetland systems which may have potential impacts on higher taxa, including waterbirds.

In this paper we examine the changes that have occurred in numbers and distribution of Swan Geese at a well-studied site over the last five years and, historically, throughout the Yangtze floodplain, investigate the changes that have taken place in submerged vegetation communities and hydrological regimes within the floodplain, discuss possible reasons for the observed changes in Swan Goose status and list a number of key questions that need answers to underpin effective conservation measures for the Swan Goose.

Methods

Study site

The Shengjin Lake National Nature Reserve (116°55′ to 117°15′E; 30°15′ to 30°30′N) lies south of the Yangtze River and is the only wetland national nature reserve in Anhui Province (Figure 1). The reserve covers 333 km² and includes Shengjin Lake – a large and shallow, permanent, fresh water lake with a 165 km shoreline – as well as small lakes, fishponds, rice paddies and forests. Lake water comes from three rivers flowing directly into the lake (catchment area 1,548 km²) and from the Yangtze River via a sluice built in 1965. During the summer flood season the maximum lake area is 140 km² (water level = 17.0 m asl, Wusong datum); the water level falls to less than 10 m during September to February (dry season) causing the lake area to decrease to approximately 34 km² (Cheng and Xu 2005).

The average annual rainfall is 1,600 mm, varying from 759 mm to 2,022 mm; most rain falls April–August. The average annual temperature is 16.1° C; average January temperature is 4.0° C.

Data sources

Swan Geese were counted at Shengjin Lake nine times during the 2008/2009 winter (October to mid-April) (Cheng *et al.* 2009) and the counts were compared with those made in February 2004 and February 2005 as part of two comprehensive, synchronous waterbird surveys conducted throughout the Yangtze floodplain (Barter *et al.* 2004, 2006).

Shengjin Lake is one of many Yangtze floodplain wetlands, so to assess whether changes in numbers were confined to Shengjin Lake, or reflected a general population redistribution, Swan

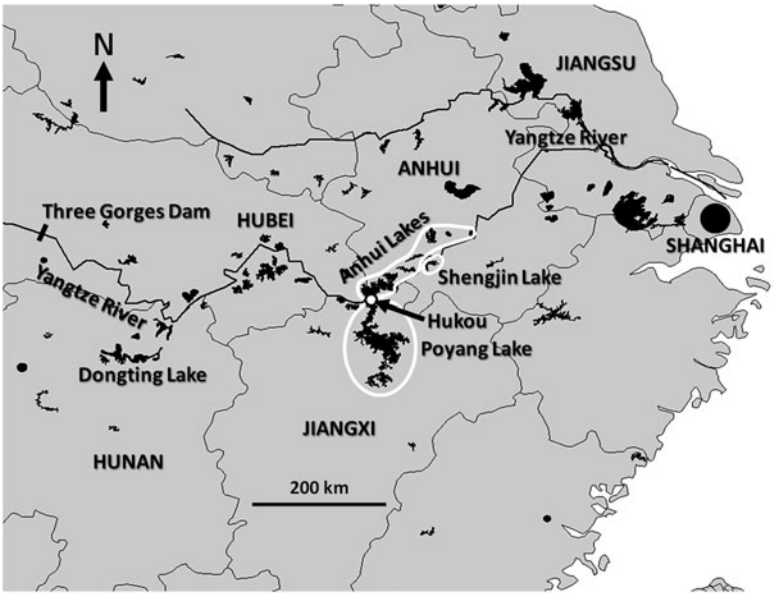

Figure 1. The three key wintering locations for Swan Geese in the Yangtze floodplain in 2004 and 2005 (outlined in white). The site of the Three Gorges Dam, Hukou, the five floodplain provinces and Shanghai are also shown.

Goose counts were obtained during winters 2005/2006- 2008/2009 from other key sites (Ji and Zeng 2006, Xu *et al.* 2006b, Ji and Wang 2007, Ji *et al.* 2007, Xu *et al.* 2007, Yu *et al.* 2008, Y. Jiang unpubl. data, W. Z. Zhu unpubl. data). Interpretation of these more recent data is complicated, as counts were conducted non-synchronously during December–March. However, satellite tracking of six marked birds suggests that Swan Geese generally do not move long distances once settled in winter (two birds < 4 km, one < 20 km, two 40–60 km, one about 250 km; USGS 2009) suggesting that these counts provide a reasonable indication of wintering numbers and distribution.

We studied winter Swan Goose foraging behaviour at Shengjin Lake in 2008/2009 to assess how this varied depending on food supply and water levels. We scan-sampled geese (see methods in Fox *et al.* 2008) at three major sites: Dazhou, the ''grazing site'' and the ''grubbing site'', and assigned individuals as ''dip-feeding'' (probing in the substrate in shallow water), ''grubbing'' (digging in wet exposed substrate above the water line) or ''grazing'' (feeding on dry terrestrial vegetation). For simplicity, here we present data on the most frequent feeding method at the three study sites under contrasting hydrological conditions.

As wintering Swan Geese feed largely on submerged macrophyte tubers, we reviewed published literature to obtain information on changes in submerged vegetation communities at Shengjin Lake in recent decades; we also conducted vegetation surveys of the entire lake in July 2008 and 2009 during the summer flood period. Changes in the extent of emergent and floating vegetation in the central and southern parts of the Upper Lake were measured from Landsat ETM+ colour composite images (RGB = 4,3,2) obtained on 11 July 2002 and 10 August 2007.

Large disturbances to the normal hydrological regime may affect submerged vegetation productivity. In order to assess the impacts of TGD on water levels at Shengjin Lake and in the Yangtze River, we obtained data from the Yangtze River Water Resources Commission on Shengjin Lake levels for January 2001–April 2009 (pre- and post-TGD) at the Huangpen Sluice, located on the entry canal to Shengjin Lake, and for the Yangtze River at the Hukou Hydrological Station, located about 130 km upstream from Shengjin Lake (Figure 1).

Results

Swan Goose abundance and distribution in the Yangtze floodplain

About 61,000 Swan Geese were counted in the Yangtze floodplain in 2004 and 2005 (Barter *et al.* 2004, 2006) distributed between the same group of wetlands: Shengjin Lake and the Anhui Lakes in Anhui Province, and Poyang Lake in Jiangxi Province, all within 260 km of each other and holding 94–97% of the total number counted (Figure 1 and Table 1).

Changes in Swan Goose numbers and distribution at Shengjin Lake

Swan Goose numbers have declined greatly at Shengjin Lake since winter 2006/2007, but have remained high at Poyang Lake and the Anhui Lakes (Table 1). The maximum Shengjin Lake count of 1,184 (early December 2008) indicates that a decline of the order of 10,000-20,000 birds has occurred in the last five years at this site. The ''grazing site'' was the most important foraging area during the 2008/2009 winter (Table 2 and Figure 2).

The Upper Lake was more important than the Lower Lake in both 2004 and 2005 and 10 sites held > 1,000 birds during the two counts (Figure 2). However, in the 2008/2009 winter those areas that had held large numbers of Swan Geese in the earlier counts held few or no birds.

Water levels pre- and post-TGD

There was a significant difference in the average timing of flows and maximum river levels of the Yangtze River at Hukou pre- and post-TGD (Figure 3): river levels rose up to a month later during the April-June period and fell about a month earlier during August-December; the summer flood peak is about 2 m lower; and winter levels are 0.5–1 m lower. The difference between winter and summer water levels has decreased from 10 m to 8 m.

Within Shengjin Lake there was also a spring flood delay of about one month post-TGD. However, the difference between pre- and post-TGD flood levels (1 m) was less than in the Yangtze whilst winter levels were similar pre-and post-TGD, indicating that sluice control moderated changes in lake water levels (Figure 4).

Shengjin Lake water levels in winter 2008–2009

In winter, the Yangtze water level is normally lower than in the lake. Winter water levels varied considerably due to release of TGD water and rainfall in the catchments, moderated by sluice operation (Figure 5). Following the usual October decline in Yangtze River levels, the river rose quickly in early November following a large release from the TGD. This, plus local rainfall, led to

Table 1. Swan goose count data from the key sites during 2003/2004–2008/2009 winters.

WETLAND	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009
Shengjin Lake	11,483	24,211	13,452	8,361	2,400	1,184
Anhui Lakes	19,714	13,308	17,937	13,570	14,619	26,398
Poyang Lake	28,204	19,994	56,973	70,830	58,753	36,967
Total at key sites	59,401	57,513	88,362	91,931	75,772	64,549
Yangtze floodplain total	61,449	61,178	n/a	n/a	n/a	n/a
% at key sites	97	94	n/a	n/a	n/a	n/a

Table 2. Swan Goose total numbers and numbers present at the key Shengjin Lake sites during the 2008/2009 winter, with lake water levels at the time of the counts.

Date	Water levels (m)	Total	Grazing site	Grubbing site	Dazhou
12 Oct.	10.9	33	0	0	0
31 Oct.	10.4	335	335	0	100
7 Dec.	9.3	1,184	387	785	173
16 Dec.	8.6	774	660	0	55
5 Feb.	8.1	503	0	123	0
26 Feb.	10.5	854	551	28	400
15 Mar.	9.9	76	0	10	18
30 Mar.	8.8	0	0	0	0
15 Apr.	7.7	0	0	0	0

a significant rise in the lake level until the sluice was closed. The lake water level then fell steadily to a mid-winter level of approximately 8 m. Heavy and continuous rainfall in February elevated lake levels until the sluice was closed, whereupon the level declined until late March. Lake levels are lowered annually to facilitate fishing during the winter months and raised in spring to supply irrigation water.

Impact of water levels on Swan Goose feeding behaviour

Swan Goose feeding behaviour was sensitive to changes in water levels, which differed between sites. At the ''grubbing site'', a low lying muddy area, geese fed by dip-feeding in shallow water when this area was exposed at lowest water levels throughout the mid-winter period (Figure 6); at higher water levels, the birds were forced to graze on grasslands above the normal feeding area. At the slightly higher ''grazing site'', geese fed first by dip-feeding at high water levels, later switching to grubbing in exposed mud as water levels dropped away, finally only using the site to graze later in the season. At Dazhou, one of the higher sites in the system, the mudflats were exposed much earlier in the season, so geese could only grub during the brief periods of winter inundation in early November and again in late February. During the rest of the winter, this area was too dry for them to feed on *Vallisneria* so geese only briefly remained to graze.

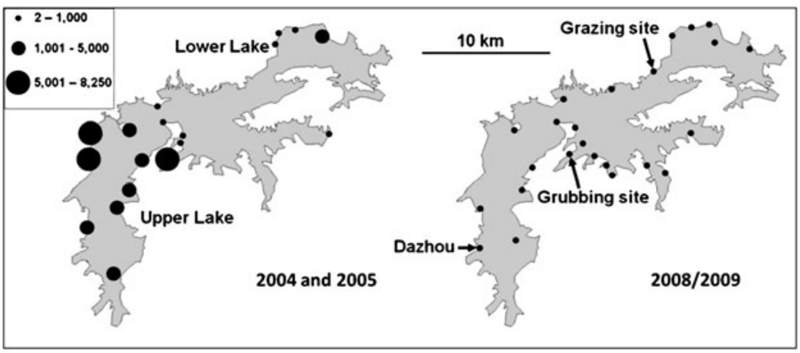

Figure 2. Swan Goose distribution in Shengjin Lake in 2004 and 2005 (combined data) (left) and during the 2008/2009 winter (right). All sites at which Swan Geese were found during the surveys are shown. Note differences in distribution as well as abundance between years.

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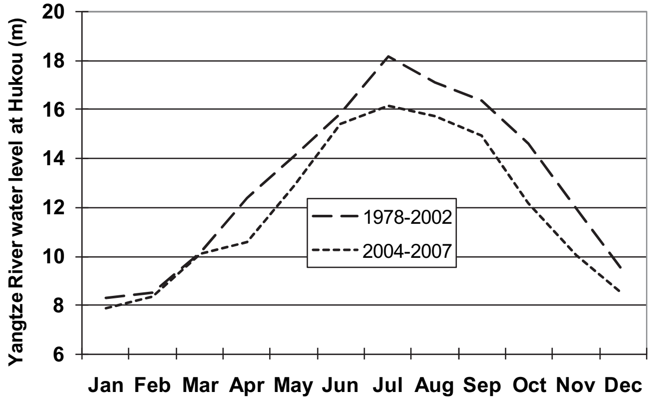

Figure 3. Average monthly Yangtze River water levels (Wusong, Shanghai, datum) at the Hukou Hydrological Station; the 1978–2002 and 2004–2007 curves represent the periods before and after the TGD was commissioned (1 June 2003).

Changes in vegetation communities at Shengjin Hu

There is evidence of very large declines in the extent of *Vallisneria* at Shengjin Lake in recent years, especially in the Upper Lake. In 1974, the whole lake was covered by the submerged macrophytes *Vallisneria* and *Potamogeton* (Meng 1979); 70% of the Upper Lake in 1996–1998 was still dominated by *Vallisneria* and *Potamogeton* (Liu *et al.* 2001). Thus, sluice operation since 1965 does not appear to have affected submerged macrophyte coverage. However, surveys throughout the lake in July 2008 and 2009 found little submerged macrophyte vegetation present (USTC unpubl. data). The decline appears to be associated with increases in aggressively

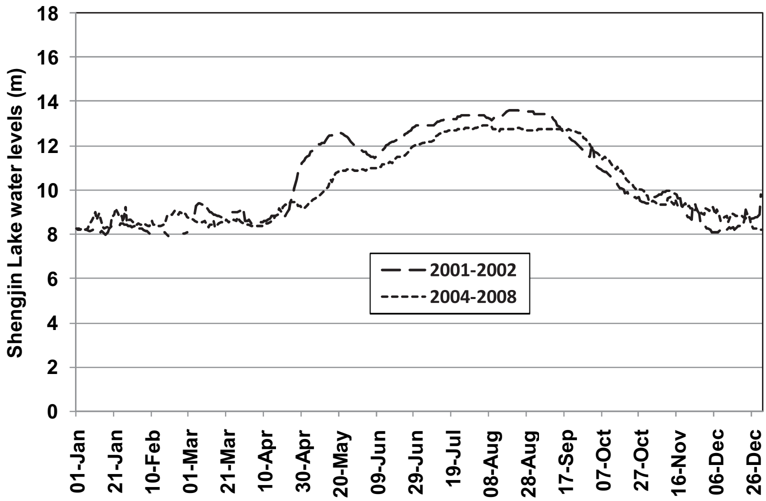

Figure 4. Average daily Shengjin Lake water levels (Wusong, Shanghai, datum); the 2001–2002 and 2004–2008 curves represent the periods before and after the TGD was commissioned (1 June 2003).

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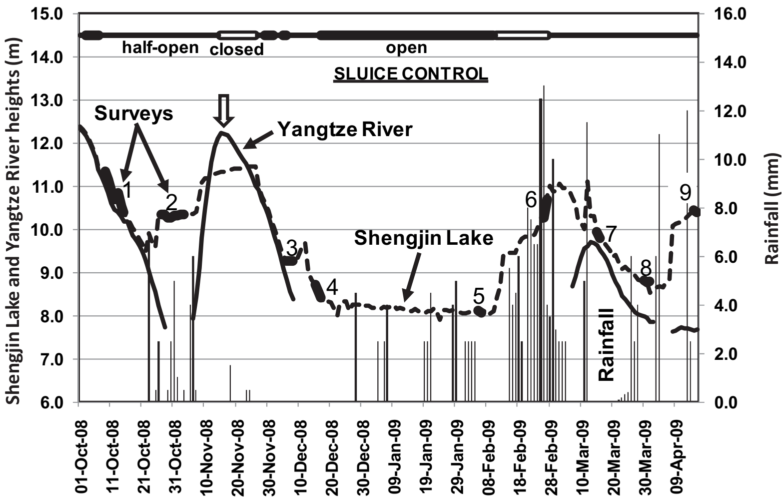

Figure 5. Water levels (Wusong, Shanghai, datum) at the Shengjin Lake sluice (Yangtze River and Shengjin Lake sides), rainfall, sluice control and timing of the nine surveys during 2008/2009 winter. Open arrow shows when the Yangtze River rose quickly due to release of water from the TGD. N.B. Yangtze River water levels are not measured when they are lower than about 7.8 m.

expanding floating macrophyte (*Trapa*) and emergent grass species (*Zizania*) systems, both of very low biodiversity significance. The expansion in area of floating and emergent vegetation is clearly evident in satellite images (Figure 7); the marked regions increased by more than 100% in area between 2002 and 2007, from 4.2 to 9.1 km^2.

Discussion

The decline in Swan Goose numbers at Shengjin Lake appears to be a continuation of a general range contraction that has occurred during the last two decades. Recent count data for East Dongting Hu confirms a decline in Swan Goose numbers to a few hundred currently, compared to *c.*3,100–5,600 birds in 1992–1996 (Lei and Qian 1998, Y. Jiang unpubl. data). Numbers have also decreased on the Jiangsu coast from a mean of 10,800 during 1987–91 to less than 1,000 now (Perennou *et al.* 1994; Cao *et al.* in press). Swan Geese were amongst the commonest waterbirds in hunting bags at Hong Lake, Hubei, during 1951–1970 (Hu and Cui 1990), yet none were present in February 2004 and 2005 when only 139 and 1,260 individuals, respectively, were counted throughout Hubei Province (Barter *et al.* 2004, 2006). Poyang Lake and the Anhui Lakes are now the only key global wintering sites for the species.

Whilst it appears that overall population numbers may not have declined (Table 1) and that the decrease at Shengjin Lake is caused by local factors, we lack the synchronous census data from throughout the wintering range, as collected in February 2004 and February 2005, to positively determine whether the change represents a global population decline or a distribution shift. A priority must be to conduct similar coordinated counts throughout the winter range as soon as possible.

The likely explanation for the decline in Swan Goose abundance at Shengjin Lake is the recent decrease in submerged vegetation, particularly tuber-producing *Vallisneria* which is the species's main food. Xu *et al.* (2008) believe that the commencement of intensive aquaculture (crab and fish farming) was probably the main reason for the disappearance of submerged plants in

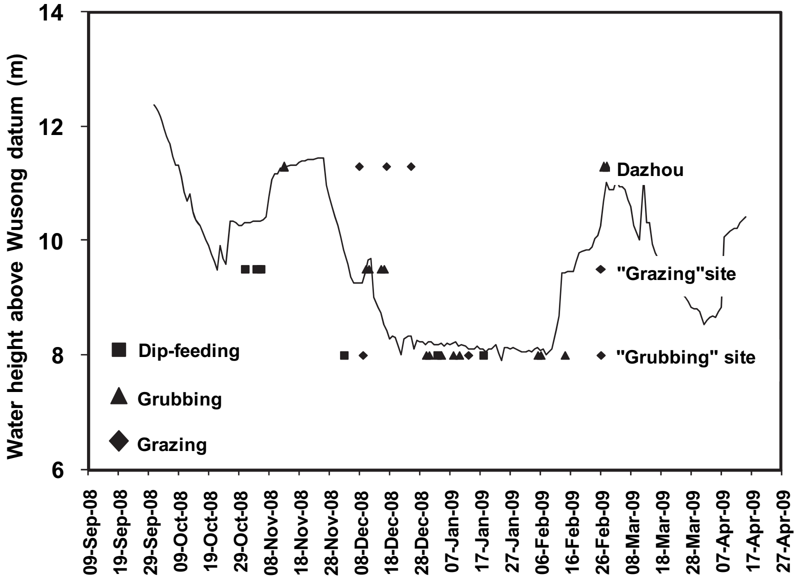

Figure 6. Schematic representation of the feeding behaviour of Swan Geese foraging at Shengjin Hu in winter 2008/2009. Solid line shows the water level measured in the lake relative to the Wusong, Shanghai, datum. Superimposed symbols show the dates when large numbers of Swan Geese were present at each of three different sites within the lake (birds were absent from these sites at other times) and the symbols indicate the predominant type of feeding used on each occasion at each site. Note that Dazhou is higher than the ''grazing site'', which is higher above datum than the ''grubbing site''.

Shengjin Lake. Aquaculture started in the Upper Lake in 1995, changing from extensive to intensive farming in 2002 (Zhou *et al.* 2009); intensive aquaculture started in the Lower Lake in 2006. Recently, Swan Geese have been observed grazing in *Carex/Phalaris* meadows; thus they may be responding to the decline in their traditional tuber food source by switching to a less nutritious diet. The fitness consequences of this dietary change are unknown (Fox *et al.* 2008). The decrease also appears to be affecting Hooded Cranes *Grus monacha*, which typically have fed on tubers around the lake edge but since 2006 have mainly resorted to spilt rice in lakeside paddies (Zhou *et al.* 2009); Tundra Swans *Cygnus columbianus*, which also feed on tubers (Barzen *et al.* 2009), have decreased in numbers at Shengjin Lake during the same period (Cheng *et al.* 2009).

The range contraction that has occurred over recent decades in the Yangtze floodplain was also probably caused by reductions in the extent of submerged vegetation. Submerged plants dominated the Yangtze floodplain lakes in the 1970–1980s (e.g. Poyang Lake: Guan *et al.* 1987; Hubei lakes: Peng *et al.* 2004; Shengjin Lake: Meng 1979; Longgan Lake: Zhang *et al.* 1996; Jiangsu: Liu and Huang 1984) and were abundant at Dongting Lake (Scott 1989), but submerged macrophytes have decreased in abundance and distribution throughout most of the floodplain during past 20–30 years due to increasing human activity (Wang *et al.* 2005a; Xu *et al.* 2006a). The major reasons presented for the vegetation decline are intensive aquaculture, harvest of aquatic plants, water pollution, land claim and sedimentation (Wu *et al.* 2007; Ge and Wang 2008; Yang *et al.* 2004).

Hydrological changes, such as those now being caused by TGD, could also impact on submerged macrophyte productivity through alterations to water depth and turbidity which

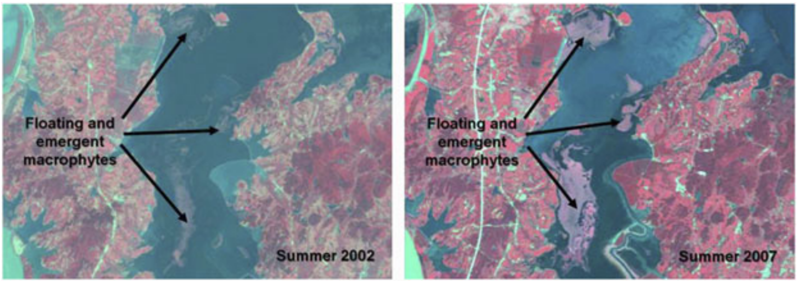

Figure 7. Difference in area of floating and emergent macrophytes in the Upper Lake between summer 2002 and summer 2007 (Landsat ETM+ composite images (RGB = 4,3,2) for 11 July 2002 and 10 August 2007).

can affect the light intensity reaching the plant canopy, water temperature and nutrient availability (Best *et al.* 2001). Wang *et al.* (2005a) found that March–June was the critical macrophyte growth period in four Yangtze floodplain lakes; therefore, the one month delay in the flood season post-TGD will shorten the growth period and likely reduce macrophyte growth. Additionally the lower flood height post-TGD may cause re-suspension of sediments through wave action on muddy shorelines (Wu *et al.* 2009a), increasing turbidity and further reducing photosynthesis; during previous higher water levels, the water edge penetrated into the upper *Carex* and summer grass zones reducing sediment re-suspension from wave action. Thus, it is predicted that the delayed water level rise during the peak growth stages, the shortened summer growth period and the possibility of sediment re-suspension due to lower water levels, will lead to lower submerged macrophyte productivity at Shengjin Lake, with wider consequences for freshwater trophic relationships throughout the lake.

In their study of the impact of the TGD on *Vallisneria spiralis* at Dahuchi (part of Poyang Lake), Wu *et al.* (2009b) concluded that the predicted higher summer water levels (Wang *et al.* 2005b) would lead to an earlier switch from turbid to clear water and that this might lead to an increase in the production of *V. spiralis*. However, water levels post-TGD are in fact lower than pre-TGD at Hukou (mouth of Poyang Lake) (Figure 3) and it is likely that the duration of turbidity is longer due to re-suspension which, in combination with the delayed and shortened flood season, will likely impact on *V. spiralis* productivity. This is of particular concern as Poyang Lake is one of the two remaining key Swan Goose sites.

Rapid changes in lake water level can impact adversely on Swan Geese. Those that occurred during the 2008/2009 winter at Shengjin Lake restricted use of the species' highly specialist feeding technique (grubbing in shallow water and/or soft mud) to a few specific sites within the lake; these occasions were totally associated with periods of water level recession which softened the substrate in a way necessary for food extraction. Consequently, it is desirable for a lake water level management strategy which allows Swan Geese to use their preferred foraging method. Additionally, lake edge habitats of low slope should be protected as these allow for the maximum extent of soft mud needed for efficient grubbing as water level recession occurs.

There is an urgent requirement to survey the Anhui Lakes, the other key Swan Goose wintering area, to assess the current status of submerged vegetation and determine whether there are any threats to this vegetation. Like Shengjin Lake, these lakes are sluice-controlled and thus have the same potential for intensive aquaculture. This problem is much less serious at Poyang Lake as it is not under sluice control and the large change in water level between the flood and dry seasons prohibits intensive aquaculture.

The evidence indicates that the Swan Goose range contraction and the decline in numbers at Shengjin Lake are likely linked with the historical decrease in submerged plant coverage throught the Yangtze floodplain and the more recent decrease at Shengjin Lake. It has been suggested that a major reason for the decline in submerged vegetation at Shengjin Lake is the introduction of intensive aquaculture, which has also been implicated in vegetation declines elsewhere in the floodplain. It seems that the changed hydrology post-TGD may also adversely affect submerged vegetation productivity.

There remain a number of key questions that need answers before we can adequately implement effective conservation measures for the Swan Goose in its highly restricted global distribution. These include:

1. What are the fitness consequences of Swan Geese being forced to switch to different foods? Can they survive as a species without *Vallisneria*?
2. What is the impact of intensive aquaculture on submerged vegetation? Do crabs and fish have preferred foods? Is it possible for crabs, fish and Swan Geese (and other waterbirds) to coexist through controlling aquaculture intensity?
3. Will the changing hydrology post-TGD have a serious effect on submerged vegetation, particularly on key Swan Goose food plants?
4. What is the best way to manage sluice-controlled wetlands (such as Shengjin Lake and the Anhui lakes) to ensure that adequate food is produced during the summer period and that it is available throughout the winter?

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References

Barter, M., Chen, L., Cao, L. and Lei, G. (2004) *Waterbird survey of the middle and lower Yangtze River floodplain in late January and early February* 2004. Beijing, China: China Forestry Publishing House.

Barter, M., Lei, G. and Cao, L. (2006) *Waterbird survey of the middle and lower Yangtze River floodplain (February 2005)*. Beijing, China: China Forestry Publishing House.

Barzen, J., Engels, M., Burnham, J., Harris, J. and Wu, G. F. (2009) *Potential impacts of a water control structure on the abundance and distribution of wintering waterbirds at Poyang Lake*. Baraboo, Wisconsin: International Crane Foundation.

Best, E. P. H., Buzzelli, C. P., Bartell, S. M., Wetzel, R. L., Boyd, W. A., Doyle, R. D. and Campbell, K. R. (2001) Modeling submersed macrophyte growth in relation to underwater light climate: modeling approaches and application potential. *Hydrobiologia* 444: 43–70.

BirdLife International (2009) Species factsheet: *Anser cygnoides*. http://www.birdlife.org (accessed 15 Aug 2009).

Cao, L., Barter, M. and Lei, G. (2008) New Anatidae population estimates for eastern China: implications for flyway population sizes. *Biol. Conserv.* 141: 2301–2309.

Cao, L. Zhang, J., Barter, M. and Lei, G. (in press) Anatidae in eastern China during the non-breeding season: geographical distributions and protection status. *Biol. Conserv.* 143: 650–659.

Cheng, Y. Q. and Xu, W. B. (2005) *Shengjin Hu National Nature Reserve site information sheet*. Canberra, Australia: Wetlands International – Oceania.

Cheng, Y. Q., Xu, W. B., Cao, L. and Barter, M. (2009) *Wintering waterbirds at the Anhui Shengjin Hu National Nature Reserve, China*. Hefei, China: University of Science and Technology of China Press. (In Chinese and English).

Fox, A. D., Hearn, R., Cao, L. Cong, P. H., Wang, X., Zhang, Y., Dou, S. T., Shao, X. F., Barter, M. and Rees, E. (2008) Preliminary observations of diurnal feeding patterns of Swan Geese *Anser cygnoides* using two different habitats at Shengjin Lake, Anhui Province, China. *Wildfowl* 58: 20–30.

Ge, X. V. and Wang, G. Q. (2008) The ecological problems facing Hongzehu and the causes. *Yangtze River* 39: 28–30. (In Chinese).

Goroshko, O. A. (2001) Swan Goose in the Eastern Transbaikalia and Mongolia. *Casarca* 7: 68–98. (In Russian with English abstract).

Guan, S. F., Lang, Q. and Zhang, B. (1987) Aquatic vegetation of Poyang Lake. *Acta Hydrobiol.* 11: 9–21. (In Chinese with English abstract).

He, Y. and Zhang, M. X. (2001) Study on wetland loss and its reasons in China. *Chi. Geogr. Sci.* 11: 241–245.

Hu, H. X. and Cui, Y. B. (1990) The effect of habitat destruction on the waterfowl of lakes in the Yangtze and the Han River basins. Pp 189–193 in G. V. T. Matthews, ed. *Managing waterfowl populations*. IWRB Symposium, Astrakhan 1989. Slimbridge, UK: International Wetlands Research Bureau. (IWRB Publication No.12).

Ji, W. T. and Wang, Y. B. (2007) Survey on species and the number of wintering waterbirds in surrounding Poyang Lake area in 2006. *China Crane News* 11: 36–38.

Ji, W. T. and Zeng, N. J. (2006) Report on wintering waterfowls in Poyang Lake, 2005/2006. *China Crane News* 10: 7–8.

Ji, W. T., Zeng, N. J., Wang, Y. B., Gong, P., Xu, B. and Bao, S. M. (2007) Analysis on the waterbirds community survey of Poyang Lake in winter. *Geogr. Inf. Sci.* 13: 51–64.

Kear, J., ed. (2005) *Ducks, geese and swans*. Oxford: Oxford University Press.

Lei, G. and Qian, W. R. (1998) Status of international endangered birds in East Dongting Lake, Hunan Province. Pp 104–107 in *Wetland and waterbird conservation—proceedings of an international workshop on wetland and waterbird conservation in North East Asia*. Beijing, China: China Forestry Publishing House. (In Chinese).

Liu, F. X. and Huang, Z. Y. (1984) A study on the lake vegetation of Jiangsu Province. *Acta Phytoecol. Geobotan. Sin.* 8: 207–216 (in Chinese with English abstract).

Liu, Z. Y., Xu, W. B., Wang, Q. S., Shi, K. C., Xu, J. S. and Yu, G. Q. (2001) Environmental carrying capacity of over-wintering Hooded Cranes at Shengjin Lake. *Resources and Environment in the Yangtze Basin* 10: 454–459. (In Chinese).

Lu, J. (1996) Distribution and bioenergetics of wintering swan geese (Anser cygnoides) in the Yangtze river valley, China. *Gibier Faune Sauvage* 13: 327–335.

Meng, R. X. (1979) The aquatic vegetation of Shengjin Lake. *Anhui Univ. Trans. (Nat. Sci. Section)* 3: 71–80. (In Chinese).

Miyabayashi, Y. and Mundkur, T. (1999) *Atlas of key sites for Anatidae in the East Asian flyway*. Tokyo, Japan and Kuala Lumpur, Malaysia: Wetlands International - Japan and Wetlands International - Asia Pacific. Available at: http://www.jawgp.org/anet/aaa1999/aaaendx.htm (accessed 21 Aug 2009).

Peng, Y. H., Jian, Y. X., Wang, J. B. and Ni, L. Y. (2004) A comparative study on aquatic plant diversity in five largest lakes of Hubei Province in China. *Acta Hydrobiol. Sin.* 28: 464–470. (In Chinese with English abstract).

Perennou, C., Mundkur, T., Scott, D. A., Follestad, A. and Kvelnid, L. (1994) *The Asian waterfowl census* 1987–91*: Distribution and status of Asian waterfowl*. Kuala Lumpur, Malaysia and Slimbridge, UK:

Asian Wetland Bureau and International Wetlands Research Bureau. (AWB Publication No. 86; IWRB Publication No. 24).

Poyarkov, N. D. (2001) The Swan Goose: its origin, numbers, dynamics, biology and conservation. *Casarca* 7: 51–67. (In Russian with English abstract).

Scott, D. A., ed. (1989) *A directory of Asian wetlands*. Gland, Switzerland and Cambridge, UK: IUCN.

Shankman, D. and Liang, Q. (2003) Landscape changes and increasing flood frequency in China's Poyang Lake region. *The Professional Geographer* 55: 434–445.

USGS (2009) Wild bird migratory ecology, emerging disease risk and physiology in Mongolia http://www.werc.usgs.gov/sattrack/swangoose/overallmaps08.html (accessed 17 August 2009).

Wang, H. Z., Wang, H. J., Liang, X. M., Ni, L. Y., Liu, X. Q. and Cui, Y. D. (2005a) Empirical modelling of submersed macrophytes in Yangtze lakes. *Ecol. Modell.* 188: 483–491.

Wang, Z. Y., Lee, J. H. W. and Cheng, D. S. (2005b) Impacts of the TGP project on the Yangtze River ecology and management strategies. *Intl. J. River Basin Manage.* 3: 237–246.

Wu, C., Tang, W. P., Shi, Y. H., Zhang, F. Z. and Yuan, C. W. (2007) The succession of aquatic vegetation in Changhu Lake wetland, Hubei province. *Wetland Sci.* 5: 188–191. (In Chinese with English abstract).

Wu, G. F., de Leeuw, J. and Liu, Y. L. (2009a) Understanding seasonal water clarity dynamics of Lake Dahuchi from in situ and remote sensing data. *Water Res. Manage.* 23: 1849–1861.

Wu, G., de Leeuw, J., Skidmore, A. K., Prins, H. H. T., Best, E. P. H. and Liu, Y. (2009b) Will the Three Gorges Dam affect the underwater light climate of Vallisnaria spiralis L. and food habitat of Siberian Crane in Poyang Lake? *Hydrobiologia* 623: 213–222.

Xu, Q. J., Jin, X. C. and Yan, C. Z. (2006a) Macrophyte degradation status and countermeasures in China. *Ecol. Environ.* 15: 1126–1130. (In Chinese with English abstract).

Xu, W. B., Cheng, Y. Q. and Long, X. C. (2006b) The monitoring on wintering waterfowls in Anhui Shengjin Lake National N.R. *China Crane News* 10: 11–13.

Xu, W. B., Zhao, F. W., Long, X. C. and Yin, L. (2007) Survey on wintering waterbirds in Anhui Shengjin Lake N.R. *China Crane News* 11: 39–42.

Xu, W. B. and Zhou, B. (2008) Monitoring data on wintering waterbirds in Anhui Shengjin Lake National N.R. 2007/2008. *China Crane News* 12: 17–19.

Yang, Z. F., Shi, W. G., Chen, L. G., Chen, Y., Zhou, Z. L. and Liu, H. (2004) Effect of pen fish culture on the ecological environment of Taihu lake. *Scientia Agricultura Sin.* 37: 928–932. (In Chinese with English abstract).

Yu, C. H., Wu, Y. H. and Ying, Q. (2008) Land survey on waterbirds in Poyang Lake region in the winter of 2007. *China Crane News* 12: 1–16.

Zhang, J. X. and Lu, J. J. (1999) Feeding ecology of two wintering geese species at Poyang Lake, China. *J. Freshwater Ecol.* 14: 439–445.

Zhang, S. Z., Dou, H. S. and Jiang, J. H. (1996) Aquatic vegetation in Longgan Lake. *J. Lake Sci.* 8: 161–168. (In Chinese).

Zhou, B., Zhou, L. Z., Chen, J. Y., Xu, W. B. and Cheng, Y. Q. (2009) The assemblage dynamic and territorial behaviors of wintering Hooded Crane (Grus monacha) in Shengjin Lake. *Wildlife* 30: 133–136. (In Chinese with English abstract).

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