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Implications of Rice Agriculture for Wild Birds in China

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Abstract.—Data on wild birds in rice fields in China are scarce. The potential significance of Chinese rice fields, which represent about 6% of the world's wetland area, is considerable but whether this potential is met is largely unknown. In this review, traditional and modern Chinese rice agriculture are compared, including detailing historical changes and their implications for wild birds. Traditional practices, with one crop each year and long periods of fallow flooding, provide greater benefit to biodiversity and species such as the Crested Ibis (*Nipponia nippon*). The method and alternatives, such as rice-fish, duck-rice and swidden agriculture, are contrasted with modern techniques which, through associated water regimes and chemical use, have been implicated in the decline of biodiversity and of species such as the Black-faced Spoonbill (*Platalea minor*). Agrochemical use is particularly pertinent because China is likely to have been the world's largest pesticide consumer since the mid-1990s, with use greatest in rice (*Oryza sativa*). However, few studies have measured the direct effects of agro-chemicals on wild birds in China. The most detailed information on birds in China's rice fields comes from charismatic species such as the Crested Ibis and Red-crowned Crane (*Grus japonensis*). Preliminary data from possibly the first systematic bird survey of a Chinese rural county are presented. More detailed and widespread studies of the implications of rice agriculture to wild birds in China are required. *Received 19 August 2008, accepted 16 July 2009.*

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By 2000, rice (*Oryza sativa*), the world's most widely cultivated crop, covered 1.55 million km^2, over 11% of the world's arable land, and over 1% of the Earth's land surface (Donald 2004). Two rice-producing countries, China and India, together produced more than half of the global output, and since the 1970s China has accounted for nearly one-fourth of the total rice-sown area and more than one-third of total rice production in the world (State Environmental Protection Administration 2003a). In 2006, Chinese rice fields also represented nearly 20% of the global land area used for planting rice (Lu and Li 2006).

As of 2003, there were 659,400 km^2 of wetland (excluding rivers and ponds) in China, accounting for 10% of the world's total (State Environmental Protection Administration 2003b). The total included 259,400 km^2 of natural wetland (including marsh swamps, natural lakes, tidal beaches and shallow sea areas), 380,000 km^2 of rice fields and 20,000 km^2 of reservoirs. Overall, Chinese rice fields constitute approximately 6% of the world's total wetland area.

Of the 57 species of endangered birds in Asia, 31 (54%) have been found in China's wetlands. Similarly, 50 (30%) of the 166 species of geese and ducks in the world, and nine of the world's 15 crane species have been recorded in China's wetlands (State Environmental Protection Administration 2006). Information regarding bird use of rice fields specifically, rather than wetlands in general, however, remains scarce. Nonetheless, studies from elsewhere in the world suggest that Chinese ricelands have potential conservation value (Fasola and Ruiz 1996; Eadie *et al.* 2008), and that loss of rice habitat and intensification of agricultural practices are of concern.

RICELANDS IN CHINA

Chinese government statistics revealed a loss of over 25,000 km^2 of farmland in 2003 alone. Losses came primarily through conversion to other uses under the banner of ecological conservation (State Environmental Protection Administration 2003b). Most of this land (>21,000 km^2) was converted to forest, with other areas converted to grassland or lakes. During the same period, a policy to offset losses resulted in gains of about 3,100 km^2 of farmland. Despite the potential for conservation benefits from these changes, there was a clear net loss of flooded rice field habitat. By 2006, the rate of habitat conversion had slowed but net losses continued (State Environmental Protection Administration 2006).

Conversion to rice is often considered a major cause of the loss of natural wetlands (Donald 2004). In China, 2003 statistics suggest that significant areas of wetlands may have been claimed for conversion to agricultural fields (State Environmental Protection Administration 2006), but specific information on the exact nature of these transformations is lacking. In particular, there are limited data on the nature of the pre-existing wetlands or other areas that have been converted to rice, the nature and relative amounts of different forms of rice agriculture that are used on converted land, and the impacts on use of these areas by birds and other species.

Agricultural intensification is occurring in China. Conversion of wetlands to modern agricultural fields results in habitat simplification to favor the rice crop, creating a far from optimal situation for many species and ecosystem functions. In China, as elsewhere, intensive modern farming contrasts directly with the traditional agricultural systems that nevertheless persist in some areas.

Historically, rice production in China involved one crop per year followed by a long fallow period when fields were flooded, providing ideal feeding habitat, particularly for wading birds. Native vegetation recovered during such fallow periods, particularly in field margins, and birds were able to breed in overgrown areas. Many birds benefited from this system, including the Crested Ibis (*Nipponia nippon*). Modernization and intensification, however, began to change this model, particularly in the 1970s when a policy shift from collective farming to household-based farming instigated a major change in the nature of China's grain production. This shift brought China in line with the rest of the world where, despite urbanization and industrialization, more than half of the world's people still live as subsistence or small scale farmers (Donald 2004).

In China, following this policy change, resource use decisions have been largely transferred to individual households. How households have responded, and how policies can be shaped to encourage sustainable resource use, remain key questions (Heerink *et al.* 2006). Tax cuts, income subsidy and price changes all influence farmers' choices about methods of rice production, and the transfer of land and resources to alternative uses. In turn, these factors impact the quality and quantity of rice land available as bird habitat. Specific policies have included attempts since 1994 to shift production from other crops to grain; maintaining domestic fertilizer prices below world market prices; abolishing agricultural taxes; and direct income subsidies to farmers with grain crops, including rice (Lin and Zhang 1998; Heerink *et al.* 2006). In Jiangxi Province, one of China's main grain producing areas, such measures produced rapid increases in rice prices coupled with much lower increases in fertilizer prices, causing increased fertilizer use and conversion of land from other crops to rice. In more prosperous provinces, these policy changes have caused larger areas with two rice crops per year, at the expense of the more ecologically beneficial single-crop system (NBS 2004; Heerink *et al.* 2006).

Overall, the major changes brought by modern rice production, include more irrigation, artificial soil enrichment, increased chemical use, and multiple cropping cycles, usually resulting in decreased feeding and breeding opportunities for birds as fields are no longer left fallow and the periods when native vegetation can recover are drastically reduced (Fanslow 2006).

While large numbers of birds can be found in modern rice fields, species are not nearly as abundant as in undisturbed wetlands. Some species do occupy an ecological niche that is realized in the modern rice system, and some do extremely well. Thus, modern rice fields may provide excellent feeding habitat for certain species including many seasonal migrants, but for resident species breeding opportunities are limited and restricted to field margins; almost no birds actually breed in modern rice fields (Fanslow 2006).

AGROCHEMICAL USE

The impact of agrochemical use on birds can be highly significant (Parsons *et al.* 2010). In China, pesticide production increased from about 1,000 t in 1950 to a high of 537,000 t in 1980 (Huang *et al.* 2003). More than three-quarters of all pesticides produced in China in the 1980s were insecticides. Fungicides accounted for approximately 10%, and herbicides 6-7%. Since the mid-1980s, methamidophos, dimthypo, and parathionmethyl have been gradually replacing dichlorodiphenyltrichloroethane (DDT), benzene hexachloride (BHC), dichlorvos and dimethoate as the dominant insecticides. Herbicide production increased more than four-fold between 1985 and 1996, a factor linked to rising labor costs. Following the high of 1980 there was a seven-year decline in pesticide use, but use doubled again between 1987 and 1995. By 1996, the total pesticide supply reached 339,600 t (Huang *et al.* 2003).

Overall, China is likely to have been the largest pesticide consumer in the world since the mid-1990s, with rice having the greatest use and the greatest increase in use of all crops (Huang *et al.* 2003). Average application rates amounted to 27.7 kg/ha (12-14 kg of active ingredients), similar to that in Japan (14.3 kg of active ingredients) and the Republic of Korea (10.70 kg), but much higher than other Asian countries (Barker and Herdt 1985). Such use has been considered to be excessive and unnecessary (Huang *et al.* 2003).

Impacts of DDT

Perhaps the best known and most serious example of agrochemical impact on birds is the widespread use, prior to its ban in many countries, of the pesticide DDT. The use of this organochlorine pesticide for three decades led to it being labeled as "the most widespread and pernicious of all global pollutants" (Cox 1991: 2). DDT killed many birds through outright toxicity, resulted in the thinning of eggshells, and has been implicated as a primary cause of the decline for numerous endangered species (e.g. Safford and Jones 1997; Elphick *et al.* 2007). For example, DDT may have played a role in the decline of the endangered Black-faced Spoonbill (*Platalea minor*) in China. A demographic analysis showed that the scale of population reduction and the timing and pattern of recovery correspond clearly with the use and subsequent ban of DDT (Yeung *et al.* 2006). Though no such study has yet been carried out for the Crested Ibis, it is notable that they often feed with spoonbills in rice fields and also suffered a major decline in China over a similar period. Similar situations have been found for charismatic species in other countries (e.g. Poole 1989; Newton and Wyllie 1992), suggesting the possibility of much broader and more widespread impacts.

Beyond DDT

After the 1972 DDT ban, agrochemical use has not ceased to be of concern. Other organochlorine insecticides are still being used and are known to have detrimental effects on avian species (Cox 1991; Parsons *et al.* 2010). Notable studies in China include the use of waterbirds as potential bioindicators of such chemical impacts.

Dong *et al.* (2004) studied organochlorine compounds in the eggs of Black-crowned Night Herons (*Nycticorax nycticorax*), Little Egrets (*Egretta garzetta*), Eastern Cattle Egrets (*Bubulcus coromandus*) and Chinese Pond Herons (*Ardeola bacchus*) from Tai Lake on the border between Jiangsu and Zhejiang Provinces. This location was expected to be subject to serious pesticide and heavy metal pollution from both agriculture and industry, with most agricultural inputs thought to come from rice fields. The DDT derivative, DDE, was found at a higher level in these eggs than in many other studies worldwide, including those from Italy (Fasola *et al.* 1998), Romania (Aurigi *et al.* 2000) and most studies from the USA (Frank *et al.* 2001; Rattner *et al.* 2000, 2001); even higher values have been found in some USA studies (Custer and Custer 1995; Hothem *et al.* 1995). The DDE burdens in Tai Lake, however, were much lower than those thought to have significant adverse effects on reproductive success in adult Black-crowned Night Herons (8 µg/g wet weight; Henny *et al.* 1984; Ohlendorf and Marois 1990). Nevertheless, DDE concentrations in over half the Black-crowned Night Heron eggs sampled, 14% of Little Egret eggs, and 12% of Chinese Pond Heron eggs were above the critical threshold level of 1 µg/g (wet weight) established by Connell *et al.* (2003), indicating that chick survival could be adversely affected (Dong *et al.* 2004). Cyclodiene pesticides, compounds which include the most toxic organochlorine insecticides especially in terms of acute poisoning, are not used as frequently in China as in Europe and the USA. Burdens of hexachlorocyclohexane (HCH) at Tai Lake were generally higher, and those of cyclodienes generally lower, than those found elsewhere (Dong *et al.* 2004).

Zhang *et al.* (2006) compared Little Egret samples from the relatively unpolluted biodiversity hotspot of Poyang Lake in Jiangxi Province, which provides habitat for half a million migratory birds, with samples from Tai Lake and the Pearl River Delta (an area covering nine prefectures including Guandong, Hong Kong and Maccau), each of which are hotspots of pollution in central China. Eggs, body feathers from chicks, prey regurgitated by chicks and sediments at the areas most used by foraging egrets were collected and analyzed. Contrary to expectations, for each of these areas the concentrations of the various elements examined were below the threshold at which survival or reproduction effects on the birds are considered likely (Zhang *et al.* 2006).

Zuo *et al.* (2004) also mention a more direct case of poisoning for the Red-crowned Crane (*Grus japonensis*) in the Yancheng wetland region of Jiangsu Province. In that area, the loss of natural wetlands and the consequent increasing use of farmland and rice fields by cranes has led to the implication of agrochemicals in multiple cases of poisoning. The paper suggests an average of nearly ten cases a year since the early 1990s, but provides no further details. In the same area, Wang (1995) points to deliberate poisoning of cranes by duck hunters.

TRADITIONAL AGRICULTURAL PRACTICES

In China, as elsewhere, many areas of natural wetlands have been replaced by rice production resulting in waterbird populations becoming increasingly dependent on rice agriculture for their survival (Donald 2004). Traditional rice agriculture takes several forms and is usually considered to support more biodiversity than modern intensive systems, although little data exists. Traditionally-farmed paddies contain a variety of aquatic species, including many plants, fish, mollusks and crustaceans that in many cases are harvested in conjunction with rice.

Rice-Fish Systems

A key alternative to intensive rice agriculture is the traditional rice-fish farming model, in which the presence of fish and other aquatic fauna in flooded fields helps to control rice pests and decreases the need for pesticide use. Such organisms also aid in nutrient cycling, decreasing the need for fertilizer application and producing a more sustainable system conducive to the recovery of soil fertility and the prevention of soil degradation (Halwart and Gupta 2004). In some places, the aquatic fern *Azolla* is added to the agricultural mix (Lu and Li 2006). This floating pteridophyte has symbiotic nitrogen-fixing cyanobacteria, and can be turned into the paddy soils as green manure or harvested as feed for pig, chickens, ducks or fish.

Integrated rice-fish production systems have been used in China for 1700 years, and have been listed by the United Nations Food and Agriculture Organization and the United Nations Educational, Scientific and Cultural Organization as a Globally Important Ingenious Agricultural Heritage System. The total area of rice-fish farming in China is the highest in the world, having peaked at about 15,000 km^2 in 2000. Of 200,000 km^2 of rice agriculture in China, nearly 70,000 km^2 are considered suitable for rice-fish farming (Zhang *et al.* 2001; Lu and Li 2006).

The structural changes required for such a system are thought to benefit bird life. The horizontal field structure is changed into a ridge-ditch pattern, and the application of fertilizer and pesticides is reduced. The number of species in fields with these conditions is greater than in most other rice systems. Organisms benefiting from this system include weedy plants, plankton, various types of bacteria, aquatic insects, water mice, water snakes and potentially birds (Lu *et al.* 2001). Natural enemies of rice pests, such as spiders and parasitic wasps, also increase considerably (Lu and Li 2006). To date, such studies have made some attempt to examine fish biodiversity and other aquatic species, but detailed studies of the effects on birds are not available.

Research in Fujian Province, southeast China (Chen 1990) and Qingtian County, Zhejiang Province, eastern China (Lu and Li 2006) have found high yields of fish and rice, and the need for only small amounts of pesticide and fertilizer. In some cases, no pesticide application was required because natural enemies of rice pests were abundant, thus making biocontrol of rice diseases and pests feasible. Instead of depleting soil nutrients, nitrogen-fixation increased the amount of organic matter, total nitrogen, and total phosphorus in the soil, and reduced methane emissions when compared with most rice farming systems (Chen 1990; Wen *et al.* 1992; Lu and Li 2006). How birds respond in these areas, however, has not been documented.

Due to agricultural intensification the area of rice-fish habitat in China is declining by about 300 km^2 annually (Lu and Li 2006). Several studies have demonstrated that rice-fish systems either produce more rice than does rice monoculture, or that they produce more fish where the rise in rice production is insignificant (Wang and Lei 2000; Yang and Lu 2001; Lu and Li 2006). A complete accounting of the economic and environmental value of the two systems is, however, needed.

Other Traditional Systems

The small rural villages of Daka and Baka, in Xishuang-banna, southwest China have been heralded as providing important examples of swidden agriculture (Guo *et al.* 2002; Fu *et al.* 2005; Padoch *et al.* 2007). Swidden, with its cyclical agricultural system whereby fields are abandoned and left to recover for a period, allows the regeneration of habitat in fields and field margins that is likely to benefit birdlife more than would continuous cropping. Again, impacts to birdlife are not known, but a change from swidden to other agricultural systems has been associated with a loss of biodiversity (Padoch *et al.* 2007).

Tending ducks in rice paddies is another traditional practice in some southern provinces of China (Li *et al.* 2009; Muzaffar *et al.* 2010). Young ducks are placed in the fields at the rice tilling stage, and kept there day and night for about two months. Before the rice matures, ducks are removed from the fields and sold at market. While in the fields, ducks eat insects and weeds, thus reducing the need for insecticides and herbicides. The economic value of duck-rice systems is estimated as 30% greater than that from rice monoculture (Wen *et al.* 1992), providing a strong incentive to use this method. Again no detailed studies of the effects on wild bird species have been conducted and indeed one Japanese farmer's report suggests that the presence of ducks seems to deter herons, egrets and other "fish predators" from entering his paddy fields (Furuno 2001).

The presence of fallow fields and longer flooding periods are common aspects of traditional farming methods. One preliminary study of three rice field areas in Pakistan and two in China (Tai and Poyang), found that herons and egrets used fields as their main foraging habitat at the two sites that had been flooded for over 20 d, but used fields much less at the three sites that had been flooded for less than 10 d (M. Fasola, unpublished data). This result suggests that the duration of flooding matters to waterbirds (see also Elphick *et al.* 2010); further study of this issue is to be encouraged.

FOCAL SPECIES

Crested Ibis

Perhaps the best candidate for a species to promote sustainable rice-agriculture in east Asia is the Crested Ibis. This bird was once abundant throughout Japan, China, Korea and Siberia, but by 1981 only 13 individuals were known to remain (seven in the wild in China, six in captivity in Japan). A quarter of a century later, the original captive population had died out, but the wild population had risen to approximately 600 individuals, with a similar number in captivity, and the ibis has thus become one of China's major conservation success stories. The ibis was once abundant in rice fields and may serve, in both its historic decline and subsequent partial recovery in rural central China, as an indicator of environmental change.

Typical habitat has been described as a mix of forest, wetland and rice paddies (Liu 1981; Wang *et al.* 1985; Li *et al.* 2006). Historically, most of China provided ideal ibis habitat. Wetlands were full of Asian Pond Loach (*Misgurnus anguillicaudatus*), which together with worms and insects comprised the main prey for the ibis. Shrimps and crabs were also available in streams and rivers. Fallow rice fields provided ideal winter feeding grounds, and a further source of loach, worms and insects. By the 1930s, the species was still abundant in 14 provinces, including Taiwan and Hainan Island, but agricultural intensification reduced the area of fallow fields in subsequent decades. Probable causes of the population decline include logging of mature trees used for nesting, draining of rice paddies in winter, widespread use of fertilizers and other agrochemicals, hunting, reduction of food supply, and industrial pollution (Shi *et al.* 1991 in Yu *et al.* 2006).

The survival of the last few birds in a remote area of the Hanzhong Basin in Shaanxi Province, central China, has been linked to the more traditional and less intensive agricultural practices used there. The basin is characterized by broad rice fields and areas of drier farmland, combined with a complex network of small handmade reservoirs and rivers. Seasonally flooded grasslands and diverse forests help provide a good mix of feeding, nesting and roosting habitats. On the rediscovery of the ibis in this region, conservation teams moved in, decreasing pesticide use in rice fields in breeding areas, providing food supplements in regular feeding areas and protecting key trees for nesting (Lu 1989). Little by little, the population began to increase. In the last decade, the breeding, nesting, feeding and roosting areas have been enlarged and expanded beyond the initial nature reserve boundaries, and approximately 600 birds are now regularly seen across a 100 km spread of eight counties of the Hanzhong region.

As with the decline, population recovery has been closely related to rice farming, with local residents using fewer pesticides and fertilizers than in the past and almost never poaching Crested Ibises. In addition, farmers have reverted to the production of a single rice crop and now keep some paddies filled with water year-round to conserve aquatic animals for foraging ibises (Li *et al.* 2002). Earlier suggestions that ibises are prone to human disturbance have not been confirmed. Since ibises primarily feed in rice fields, their occurrence is often greatest in areas where people live and farm (Ma *et al.* 2000) and nest-sites are usually located near paddy fields (Yu *et al.* 2006). In general it seems that Crested Ibises select sites with moderate human activity at the landscape level (i.e. rice paddies), but low activity at the nest site level. In recent years, however, some Crested Ibises have even selected nest trees within farmers' yards (Li *et al.* 2002). Away from nesting sites, Crested Ibises are sometimes attracted by farming activities; for instance, they will follow plowing cows to feed on exposed worms (Li *et al.* 2006).

In the recovering wild population, winter feeding sites include paddy fields, river shoals, and reservoirs, with paddy fields being the main feeding sites for adults and river shoals for juveniles (Ma *et al.* 2001). Rice paddies are also the major feeding sites of Crested Ibises during the late pre-breeding and breeding season. Post-breeding, however, rice paddies were unsuitable because the rice was too dense and tall, a pattern seen with other waterbird species elsewhere (Pierluissi 2010). Near the end of the post-breeding season and at the beginning of the pre-breeding season, cropland was usually rotated to Oilseed Rape (*Brassica napus*), which was also seldom used by ibises.

Seasonal movements of ibises seem to be related to the availability of rice field habitat, particularly in the absence of other wetland habitats. In the early period of recovery in the early 1980s, ibises tended to retreat to mountainous regions in the breeding season. In such regions, rice paddies are the only wetland areas that attract ibises and it is clear that they provide the majority of their food (Li *et al.* 2002).

Food shortages have been reported suggesting that ibises are failing to find sufficient food throughout their range. During the 20 years since restoration began, hundreds of kg of loach have been purchased every spring and put into rice fields as supplemental food to help breeding ibises raise their chicks. In winters, deliberate re-flooding of the dried rice fields is attempted to maintain a suitable feeding environment. Nevertheless the expanding population still has to face food shortages, a problem often associated with pesticide and chemical use and further exacerbated by the dramatic decrease of invertebrates in rice fields during dryer years (Xi *et al.* 1997; Y. Xi, personal observation). Dissections of birds found dead in the wild have shown that 80% had very little food in their stomachs, and starvation and malnutrition could indeed be a significant cause of chick mortality (Zhang *et al.* 2000). This issue highlights the continuing need to decrease pesticide and other chemical use that would limit feeding options for ibises. Areas set aside for single-crop rice, where fields are left fallow and flooded over winter, the maintenance of other alternative traditional rice methods such as rice-fish and duck-rice systems and the setting aside of natural wetland areas, may also be effective measures to counter food shortages.

As the Chinese government has begun promoting the strategy of "harmonizing people and nature", with a particular focus on sustainable agriculture, there is a renewed focus on reintroducing the ibis into areas of its former range. Areas of the Demilitarized Zone in Korea and other potential sites in Japan and China are all under consideration. China has already translocated ibises to one new area and breeding has been confirmed there. Both Korea and Japan have also maintained a strong desire to reestablish wild populations (Fujioka *et al.* 2010). In September 2008, ten wild ibises were released on Sado Island, Japan, becoming the first ibis to fly free in Japan since 1981. They immediately began to feed in rice fields and now four have flown over to mainland Japan, four remain on Sado Island, one is confirmed dead and the location of one is currently unknown. Simultaneously, China and Korea have instigated efforts for a Korean captive breeding effort.

Other Focal Birds

The Yancheng Nature Reserve in Jiangsu province is China's largest coastal wetland reserve. About 3 million birds of 200 species, 29 of which are on the IUCN Red List of Threatened Species, migrate through the site annually. Much of the reserve's natural habitat, which originally consisted of intertidal mudflats, creeks, salt marshes and reed beds, has been enclosed by sea dykes and converted to other uses. Agriculture or aquaculture has replaced large areas of the original wetlands and agricultural, urban and industrial development continues. Pollution from local and upstream sources has caused declining water quality and flow and altered sedimentation patterns. Measures to address many of these issues are underway (ADB Project 2007).

In this area, rice fields provide feeding habitat for many migrant birds, such as cranes and storks. Many of the Red-crowned Cranes that breed in China migrate along the coast of the Bo and Yellow Seas to wintering grounds in Jiangsu using coastal salt marshes, rivers, freshwater marshes, rice paddies and cultivated fields (Swengel 2006). Rice fields in particular offer a mosaic of habitats with irrigation channels, ditches and levees harboring a diverse and rich fauna and flora. Every year, about 1,000 Red-crowned Cranes, representing 60% of the world total, along with Common (*Grus grus*) and White-naped Cranes (*Grus vipio*) migrate from the north of China and Russia and winter along the Yancheng coast. Over the last ten years, however, Red-crowned Cranes have lost nearly 60% of their natural habitat. As a result, an increasing reliance on farmlands and artificial fishponds for food and water, particularly in fallow winter areas, has been observed (Zuo *et al.* 2004).

Li *et al.* (2002) studied the feeding habits of Little Egrets, Black-crowned Night Herons, Chinese Pond Herons and Eastern Cattle Egrets around Taihu Lake, Jiangsu Province. The egrets sought prey mainly in fish ponds and lakes, and less in rice fields. Only Chinese Pond Herons were recorded to feed in rice fields and even this species used rice fields only 6% of the time. These investigations, however, were done in early June when field irrigation had only just began and may, therefore, underestimate use, which increases in fields that have been flooded for longer periods (M. Fasola, unpublished data). Oriental Storks (*Ciconia boyciana*) breeding in Anhui Province have also been reported to feed mainly in paddy fields and ponds (Hou *et al.* 2007).

A census of the heronries in several areas of eastern China (Fasola *et al.* 2004), concluded that herons were extremely abundant where rivers, fishponds, rice paddies and other water bodies provide foraging habitat. The censuses in these areas, which are representative of much of central and southeast China, with rice fields are a dominant land cover, suggested much higher numbers of breeding herons and egrets than previously estimated for China. Specifically large numbers of Little Egrets, Intermediate Egrets (*Egretta intermedia*), Eastern Great Egrets (*Ardea modesta*), Eastern Cattle Egrets, Chinese Pond Herons and Black-crowned Night Herons, were observed.

ZHEJIANG PROVINCE SURVEY

The paucity of systematic knowledge about Chinese birdlife in general, and particularly about the birds of rural environments, is a major limitation of the current review. Most existing knowledge comes from a few key reserves, hotspot areas or charismatic species. In 2006-2007, however, we completed what we believe to be the first systematic bird survey of an entire county in China. The survey took place in Lin'an County, Zhejiang Province, which is a major agricultural region of eastern China, and focused on the presence and absence of species. Detailed habitat data were not collected, and only a minority of records were specifically linked to rice fields. Nonetheless, many records were from agricultural areas, in which rice fields were common.

Lin'an County lies to the west of Hangzhou, the capital of Zhejiang Province (Fig. 1) and is roughly 30 km from north to

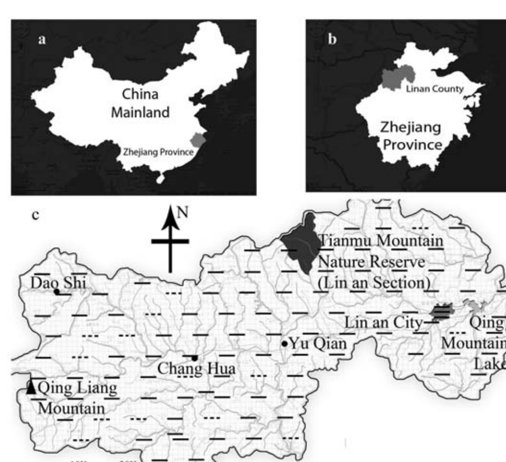

Figure 1. Study area surveyed in Lin'an County, Zhejiang Province. Solid lines represent transects surveyed; dashed lines those that could not be accessed. Major towns (circles), rivers, and the capital Lin'an City are shown.

south and almost 100 km wide (29°56’N to 30°23’N, 119°52’E to 118°51’E). Elevation ranges from 1,787 m on Qing Liang Mountain to 9 m and tends to be higher to the northwest (>1000 m, on average in the western region), and slope towards the southeast (50 m, on average in the eastern region). The county has an area of 3,127 km^2, over 70% of which is forested. Of the 191 km^2 of cultivated land, 169 km^2 contains irrigated fields most of which are predominantly rice, with some fields that include rice as part of a wider mosaic agricultural mix. Lin’an has a subtropical monsoon climate with high rainfall in spring, hot and wet summers, cool autumns and dry, cold winters.

Surveys were conducted by scientists from Zhejiang University, together with representatives from the Hong Kong Bird Watching Society and other zoological institutions, predominantly from the USA. One hundred and six 3-km east/west transects were evenly-spaced across the county, with a 4-km gap between transects in all directions (Fig. 1). Seven additional transects were placed in urban areas and three in areas of particular interest (e.g. around lake margins or across low lying floodlands). Twelve transects were not covered because they lay in inaccessible or restricted areas, leaving a total of 104 transects.

For each transect, the starting point was located using a GPS unit (Garmin ETrex), and a 3-km trail was slowly walked in the approximate direction, along an available route, until the end point was reached, again determined by GPS. Where no suitable route continued in the direction of the end point, the transect was terminated prematurely. Each survey group covered one transect in the early morning and one in the late afternoon. Data were gathered from 2-8 October 2006 for autumn migrants and early-arriving winter visitors, from 7-13 May 2007 to coincide with late spring, when most summer visitors had arrived and breeding begun, and from 29 August-1 September 2007 to fill in previously unsurveyed transects.

The primary data were all bird species seen or heard within approximately 100 m of the transect route. Species abundances were recorded for each transect, together with data on altitude, weather, brief information on habitat and any sources of disturbance. For this paper, transects were categorized as “High Rice” when at least 50% of records listed “rice” in the habitat description; “Some Rice”, when less rice was present; “High Agriculture” when agricultural terms were listed for at least 50% of records; “Some Agriculture” when less agricultural was present; and “No Agriculture” when there was no reference to rice or agriculture (Fig. 2). Avian species richness was calculated for each transect.

Overall, nearly 18,000 birds of at least 170 species were observed. At least 98 species were noted in the October survey, 154 in the May survey and 52 in the August survey. Species richness was generally lower in High Rice than in the other habitat categories (Table 1), but varied considerably among transects both within and among habitat types (Fig. 2). A total of 59 species were associated with rice habitats, although few were directly linked with High Rice areas (Table 2). Of those species associated with High Rice, only Black-crowned Night Heron was noted to have a high likelihood of rice dependency. The others—Greater Spotted Eagle (*Aquila clanga*), unidentified *Accipiter* sp., House Swift (*Apus*

Figure 2. Lin’an County, Zhejiang Province, showing areas of rice agriculture (medium gray background; solid lines indicate “High Rice”, dashed lines “Some Rice”), other agriculture (white background; solid lines indicate “High Agriculture”, dashed lines “Some Agriculture”), and “No Agriculture” (black). Areas not covered are white with no lines. Circles show locations of surveyed transects, with circle size proportional to the number of bird species detected.

Table 1. Number of bird species found in each habitat category and season during surveys in Lin'an County, Zhejiang Province. See text for habitat definitions.

	High Rice	Some Rice	High Agriculture	Some Agriculture	No Agriculture
All Seasons	5	54	109	71	108
2-8 Oct 2006	5	36	22	42	46
7-13 May 2007	2	39	57	60	66
29 Aug-1 Sept 2007	1	12	47	2	6

nipalensis), Lanceolated Warbler (*Locustella lanceolata*) and Common Reed Bunting (*Emberiza schoeniclus*)—all range over a variety of habitats.

The data summarized here clearly provide only a foundation for more detailed study. This survey was not designed to study use of rice fields and detailed habitat information was not systematically collected. Rice was frequently part of the agricultural mix and often the dominant crop around transects (C. Wood, personal observation). Many areas identified as High Agriculture may have contained substantial amounts of rice. Likewise, the activity or location of birds with respect to rice fields was not directly sampled.

There are notable absences from the list of species associated with rice and the list must be considered preliminary. Brown Bush-hens (*Amaurornis akool*) and White-breasted Waterhens (*Amaurornis phoenicurus*) are typical of wet agricultural areas in southern China, as are a range of ardeids, including Chinese Pond Heron, Little Egret and Eastern Cattle Egret. Also, Eurasian Tree Sparrow (*Passer montanus*) and Scaly-breasted Mannikin (*Lonchura punctulata*) were not listed in this category, nor are Yellow (*Ixobrychus sinensis*), Cinnamon (*Ixobrychus cinnamomeus*) or Black Bittern (*Dupetor flavicollis*), which are typically found in rice fields in this region. Clearly, further work, focusing specifically on habitat use and with the addition of winter surveys, is necessary. During the winter months, rice fields elsewhere in China are used by a range of species, including ardeids, ducks, larks, pipits, wagtails and buntings, and may also provide winter foraging for starlings and mynas.

CONCLUSIONS

Data on bird use of rice fields in China is scarce and the need for more intensive and widespread studies cannot be overstated. The potential significance of Chinese rice fields, which represent about 6% of the world's wetland area, is considerable but whether this potential is met is unknown. The contrast between traditional and modern rice agriculture is particularly important. Traditional practice, with one crop each year and long periods of fallow flooding, may be of considerable benefit to biodiversity generally and to species of high conservation interest (e.g. Crested Ibis). In contrast, modern intensive farming, with double-cropping, associated water regimes and greater chemical use, are implicated in the decline of biodiversity and of certain species (e.g. Black-faced Spoonbill). Where traditional and alternative techniques such as rice-fish agriculture have continued to be used, species such as the Crested Ibis and Red-crowned Crane have apparently benefited. We hope that this paper becomes a springboard for more studies of birds and biodiversity in rice fields in China and, more generally, that it will promote the further integration of Chinese agricultural development and governmental policy with biodiversity conservation.

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Table 2. Birds detected on transects containing rice habitats during surveys in Lin'an County, Zhejiang Province. High Rice indicates that a species was detected on a transect in which at least half the records were associated with rice; Some Rice indicates that rice was present, but associated with less than half the records on a transect.

Order	Family	Latin	English	High Rice	Some Rice
GALLIFORMES	Phasianidae	*Bambusicola thoracicus*	Chinese Bamboo Partridge		X
PELECANIFORMES	Ardeidae	*Nycticorax nycticorax*	Black-crowned Night Heron	X	
		Ardeola bacchus	Chinese Pond Heron		X
		Bubulcus coromandus	Eastern Cattle Egret		X
		Egretta modesta	Eastern Great Egret		X
		Egretta garzetta	Little Egret		X
FALCONIFORMES	Accipitridae	*Accipiter soloensis*	Chinese Sparrowhawk		X
		Aquila clanga	Greater Spotted Eagle	X	
GRUIFORMES	Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen		X
CHARADRIIFORMES	Scolopacidae	*Gallinago gallinago*	Common Snipe		X
COLUMBIFORMES	Columbidae	*Streptopelia orientalis*	Oriental Turtle Dove		X
		Streptopelia chinensis	Spotted Dove		X
STRIGIFORMES	Strigidae	*Glaucidium cuculoides*	Asian Barred Owlet		X
APODIFORMES	Apodidae	*Apus nipalensis*	House Swift	X	
CORACIIFORMES	Coraciidae	*Eurystomus orientalis*	Oriental Dollarbird		X
	Alcedinidae	*Alcedo atthis*	Common Kingfisher		X
PASSERIFORMES	Laniidae	*Lanius cristatus*	Brown Shrike		X
		Lanius schach	Long-tailed Shrike		X
	Dicruridae	*Dicrurus macrocercus*	Black Drongo		X
	Corvidae	*Urocissa erythrorhyncha*	Red-billed Blue Magpie		X
	Paridae	*Parus major*	Great Tit		X
	Pycnonotidae	*Spizixos semitorques*	Collared Finchbill		X
		Pycnonotus sinensis	Light-vented Bulbul		X
	Hirundinidae	*Cecropis daurica*	Red-rumped Swallow		X
	Cettidae	*Cettia canturians*	Manchurian Bush Warbler		X
		Cettia fortipes	Brownish-flanked Bush Warbler		X
		Abroscopus albogularis	Rufous-faced Warbler		X
	Aegithalidae	*Aegithalos concinnus*	Black-throated Bushtit		X
	Phylloscopidae	*Phylloscopus fuscatus*	Dusky Warbler		X
		Phylloscopus borealis	Arctic Warbler		X

Table 2. (Continued) Birds detected on transects containing rice habitats during surveys in Lin'an County, Zhejiang Province. High Rice indicates that a species was detected on a transect in which at least half the records were associated with rice; Some Rice indicates that rice was present, but associated with less than half the records on a transect.

Order	Family	Latin	English	High Rice	Some Rice
	Megaluridae	*Locustella lanceolata*	Lanceolated Warbler	X	
	Cisticolidae	*Prinia inornata*	Plain Prinia		X
	Timaliidae	*Pomatorhinus swinhoei*	Grey-sided Scimitar Babbler		X
		Stachyris ruficeps	Rufous-capped Babbler		X
		Garrulax canorus	Chinese Hwamei		X
		Paradoxornis webbianus	Vinous-throated Parrotbill		X
	Zosteropidae	*Zosterops japonicus*	Japanese White-eye		X
	Sturnidae	*Acridotheres cristatellus*	Crested Myna		X
		Spodiopsar sericeus	Red-billed Starling		X
	Turdidae	*Turdus merula mandarinus*	Common Blackbird		X
	Muscicapidae	*Copsychus saularis*	Oriental Magpie Robin		X
		Rhyacornis fuliginosa	Plumbeous Water Redstart		X
		Enicurus leschenaulti	White-crowned Forktail		X
		Saxicola maurus	Siberian Stonechat		X
	Cinclidae	*Cinclus pallasii*	Brown Dipper		X
	Passeridae	*Passer rutilans*	Russet Sparrow		X
		Passer montanus	Eurasian Tree Sparrow		X
	Estrildidae	*Lonchura striata*	White-rumped Munia		X
		Lonchura punctulata	Scaly-breasted Munia		X
	Motacillidae	*Motacilla cinerea*	Grey Wagtail		X
		Motacilla alba	White Wagtail		X
		Anthus richardi	Richard's Pipit		X
		Anthus hodgsoni	Olive-backed Pipit		X
	Fringillidae	*Carduelis sinica*	Grey-capped Greenfinch		X
	Emberizidae	*Emberiza cioides*	Meadow Bunting		X
		Emberiza pusilla	Little Bunting		X
		Emberiza aureola	Yellow-breasted Bunting		X
		Emberiza rutila	Chestnut Bunting		X
		Emberiza schoeniclus	Common Reed Bunting	X	

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