THE USE OF RICE FIELDS BY THE ENDANGERED AUSTRALIAN PAINTED SNIPE (*ROSTRATULA AUSTRALIS*): A RARE OPPORTUNITY TO COMBINE FOOD PRODUCTION AND CONSERVATION?

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We document widespread use of rice fields by the globally endangered Australian Painted Snipe (*Rostratula australis*), highlighting the potential for 'wildlife-friendly' food production in Australia. A total of 44 Australian Painted Snipe from five of 93 surveyed rice field study sites, and an additional 43 Australian Painted Snipe from three other rice fields, were recorded during the 2012-2013 rice-growing season in the Riverina region of New South Wales. The overall total of 87 birds at these eight widely distributed sites was likely to be indicative of at least several hundred Australian Painted Snipe using the 113 500 ha of rice fields during the period, particularly given the limited survey effort. This is remarkable given the most recent estimate of total population size for the species ranges only from 1 000 to 2 500 birds. The birds were primarily recorded using the shallow edges of rice fields, along banks and channels. Future research should focus on (1) determining if significant numbers of Australian Painted Snipe use rice fields regularly, (2) whether or not rice fields provide suboptimal habitat, (3) the extent to which Australian Painted Snipe breed in these habitats, and (4) optimal rice-growing practices that benefit Australian Painted Snipe without hindering conservation management of the Endangered Australasian Bittern (*Botaurus poiciloptilus*), which also occurs in these habitats. There are clear environmental costs of extracting water from rivers for irrigation and rice fields are no substitute for natural wetlands. However, given the recognised need for food production and the large area where rice is still grown, targeted management of rice fields to benefit Australian Painted Snipe and other species may be important in complementing traditional conservation measures like protected areas and ecological restoration.

INTRODUCTION

The modification of natural ecosystems to develop modern agriculture is recognised globally as a major cause of biodiversity loss (Millennium Ecosystem Assessment 2005). However, the potential biodiversity conservation value of the resulting novel, anthropogenic habitats and landscapes is often overlooked. They may also support populations of rare or threatened species, thus providing opportunities for both viable agricultural production and biodiversity conservation (e.g. Longoni *et al.* 2011, Chester & Robson 2013, Luck *et al.* 2013). Central to the 'land-sparing' and 'land-sharing' debates in conservation science is the inevitable need for increased agricultural production (Green *et al.* 2005, Fischer *et al*. 2008, Phalan *et al*. 2011). The ensuing question is how effectively can the expansion of 'wildlife-friendly' farming ('land-sharing') conserve biodiversity compared to more intensive farming with protected conservation areas ('land-sparing').

Globally, rice fields are well known for their value as waterbird habitat, and although they are no substitute for natural wetlands, their potential contribution to conservation as agricultural wetlands is well established in the literature (e.g. Fasola & Ruiz 1996, Elphick 2000, Elphick *et al.* 2010, Tourenq *et al.* 2001, Czech & Parsons 2002). Despite this, little is known of the use of rice fields by cryptic and threatened waterbird species (Taylor & Schultz 2010).

The Australian Painted Snipe (*Rostratula australis*), referred to hereafter as 'APS', is a poorly known, cryptic shorebird, primarily an inhabitant of shallow freshwater wetlands (Marchant & Higgins 1993, Department of the Environment 2013a). It was only recently recognised as a full species, distinct from its closest relative the Greater Painted Snipe (*Rostratula benghalensis*) of Asia and Africa. This distinction was made initially by morphological differences and subsequently confirmed by mitochondrial-DNA analysis (Lane & Rogers 2000, Baker *et al*. 2007). It is endemic to Australia and has been recorded using a wide range of freshwater wetland habitats. However, its breeding habitat requirements are more specific: temporarily inundated wetlands, during the transitional stage after flooding when drying out, at which time they have a combination of shallow receding water levels, open mudflats, patches of dense low cover, complex shorelines and small islands (Rogers *et al.* 2005).

APS is listed as Endangered by the International Union for the Conservation of Nature because it has a single, small population that has declined rapidly

(BirdLife International 2012). The decline of the APS has been primarily attributed to the loss of suitable wetland habitat through drainage and the diversion of water for agriculture and other human uses. In Australia, its conservation status was upgraded from Vulnerable to Endangered under the *Environmental Protection and Biodiversity Conservation Act 1999* in May 2013 following continued evidence of significant decline (Department of the Environment 2013a). There is only one other Australian wetland bird species – the Australasian Bittern (*Botaurus poiciloptilus*) – that is listed as Endangered at the global or national level (Department of the Environment 2013b; Birdlife International 2014).

The reporting rate of the APS has declined steadily since the 1950s, with its apparent stronghold – the Murray-Darling Basin – sustaining the largest decline (Lane & Rogers 2000). In 2005, it was suggested the total APS population could be a tenth of what it was in the 1970s – a 90% decline – but there were significant limitations in the dataset used (Rogers *et al*. 2005). In 2010, the total population was estimated to be 1250 mature individuals (1000-1500, medium reliability), and highly unlikely to exceed 2500 mature individuals (Garnett *et al.* 2011).

Rice fields are known to be of importance to the Greater Painted Snipe, which nest on embankments in inundated rice fields (Ali 1968, Fujioka & Yoshida 2001, Amano *et al.* 2010). APS have also been recorded using rice fields (Marchant & Higgins 1993) although their abundance in rice fields and the relative importance of this habitat are not known. The most recent major work on the ecology and conservation of the species found no evidence to suggest that rice fields were important to the APS (Rogers *et al.* 2005).

In Australia, approximately 95% of rice is produced in the Riverina region of southern New South Wales, which is a region containing wetlands known to support substantial numbers of waterbirds (Kingsford *et al*. 2013). Rice is grown from September to May in irrigated bays (Figure 1) with water that has been stored in upstream reservoirs (or diverted directly from rivers), then distributed through networks of channels. Seed is usually sown aerially into flooded bays (approximately 5 cm deep). After about four weeks the water level is increased. By around 12 weeks, water levels are approximately 25-30 cm and are maintained at this level until about March, when water levels gradually recede in preparation for harvest, with any excess water drained. The agronomic practice of 'lasering' (the use of geographic information systems with earth-moving machinery to implement desired microtopography) results in relatively uniform water levels in each rice bay except in toe furrows, which are deeper (Figure 1). The total area of rice crop varies greatly between years and depends on the amount of water available for irrigation, which is determined through regional allocations that are strongly influenced by dam levels as a result of floods and droughts. The rice crop area ranged from approximately 180 000 ha in 2000-2001 (prior to the millennium drought and environmental water recovery), to 2160 ha in 2007-2008. The largest crop since 2001–2002 was 113

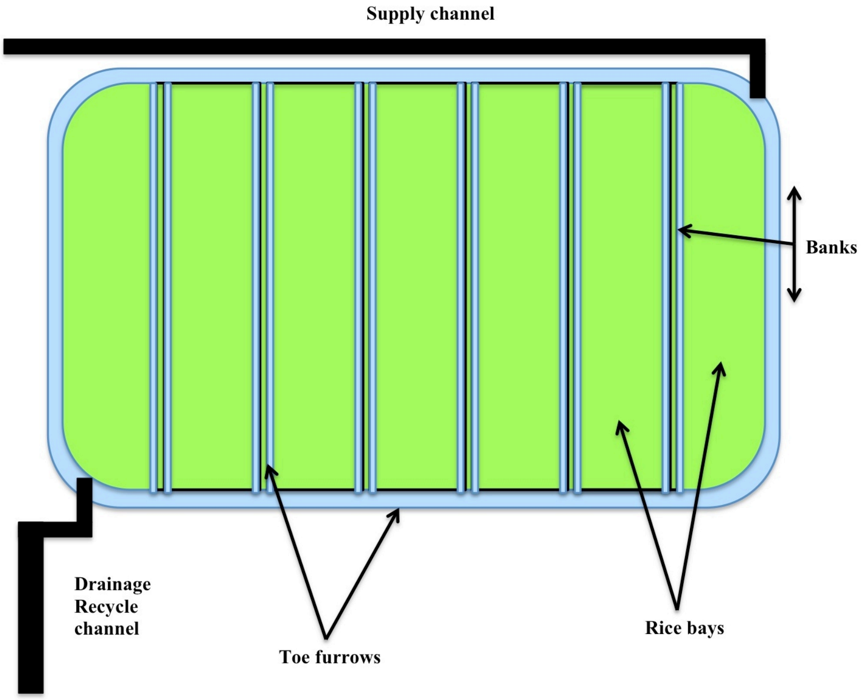

Figure 1. Schematic diagram of a rice field, typical of a single study site, with seven rice bays, each surrounded by toe furrows (a thin area surrounding the bay, deeper than the crop) and banks, and with the supply and drainage/recycle channels. Surveys were conducted by walking and driving along banks.

500 ha in 2012–2013 (RGA 2013, Sunrice 2013, Sunrice *unpubl. data*).

The aim of this paper is to report unexpected and widespread APS records made during waterbird surveys in rice fields in the NSW Riverina during the 2012-2013 season, along with additional records. We describe methods that we applied and the observations made, review the knowledge of use of rice fields by APS prior to our study period, and discuss the significance and implications of the results.

METHODS

Study region

The Riverina region of southern New South Wales, Australia, is recognised as one of Australia's most important agricultural regions and now contains heavily modified landscapes, including vast irrigation areas. The Riverina incorporates the Murrumbidgee and Murray Rivers, once they have flowed out of the Great Dividing Range in the east, until their confluence in the west near Boundary Bend in Victoria. Major regional centres of the NSW Riverina include Griffith, Leeton and Deniliquin, with Albury and Wagga Wagga on the eastern edge of the region. As the Riverina is characterised by broad floodplains with braided channels, it contains numerous wetland systems. Its flat plains support chenopod shrubland, grassland, and woodlands of Boree (*Acacia pendula*), Grey Box (*Eucalyptus microcarpa*), Black Box (*E. largiflorens*) and River Red Gum (*E. camaldulensis*) (Kent *et al.* 2002). It is classified as a hot dry zone (with cooler winters), with mean monthly rainfall similar throughout the year. The mean daily maximum temperature for Deniliquin is 32.5°C in January and 14.4°C in July with 405 mm rainfall, with similar ures for Griffith of 32.9°C, 14.5°C and 403 mm, respectively (BOM 2014a).

Study Design

During the 2012-2013 rice-growing season, 93 study sites were established in rice fields throughout the Riverina as part of a study targeting Australasian Bittern (Herring *et al.* 2014) (Figure 2). Community engagement activities in November and December 2012 led to new records of bittern sightings. Each of the 93 study sites was a discrete rice field (encompassing multiple bays) situated greater than 30 metres from an adjacent rice field (Figure 1). Most sites were between 20 ha and 40 ha, typical of a rice field, but ranged in area from 7.3 to 93.5 ha. The precise area for some sites was not determined but the area of the 93 sites accounted for somewhere between 3 and 4 per cent of the total 2012-2013 rice crop area of 113 500 ha.

There were four different site types, each specifically related to the bittern study: (1) sites based on reported bittern sightings with the aim of verifying these records (n=28); (2) control sites where no sightings had been made, located adjacent

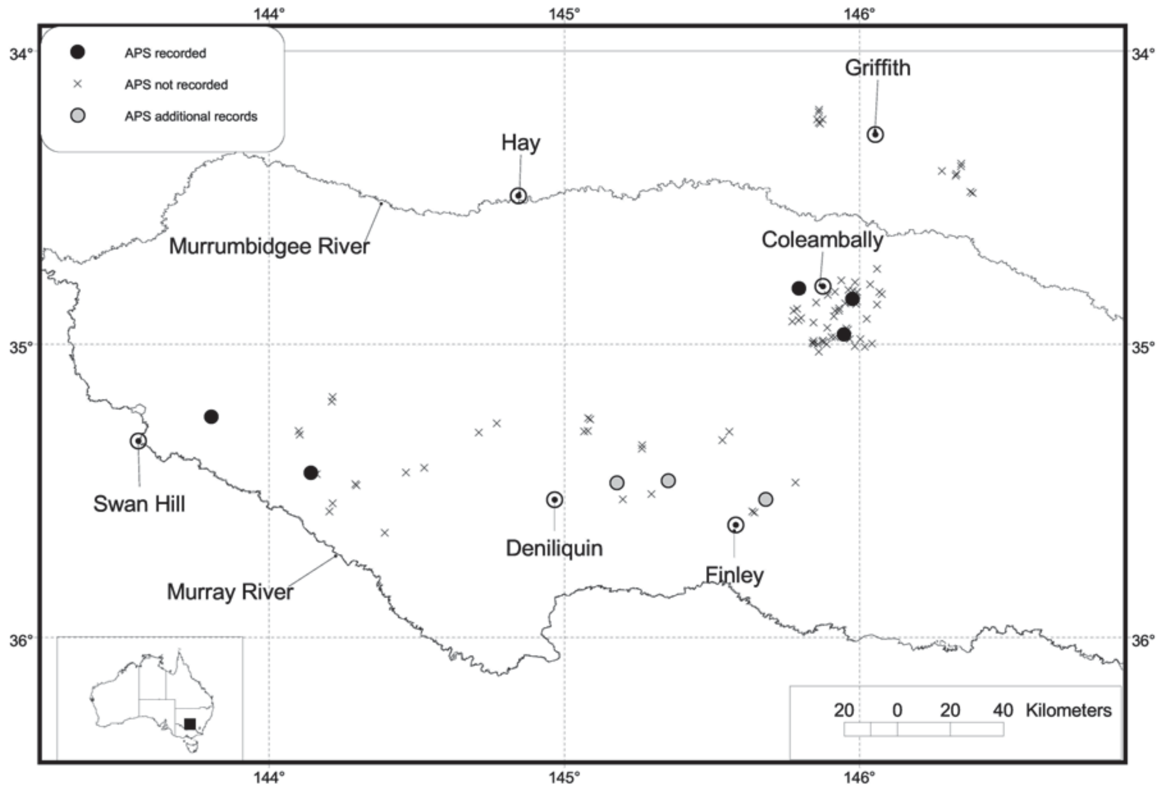

Figure 2. Records of the Australian Painted Snipe (APS) associated with rice fields during the 2012-2013 rice-growing season in the Riverina region of New South Wales, including the 93 study sites (grey crosses), five of which produced APS (black dots), along with three additional APS sites (grey dots).

to the above verified sites (n=13); (3) targeted sites where there were either previous confirmed bittern reports or which were visited to ensure coverage of the study area (n=22); and (4) sites from randomly selected rice farms (n=30). The 30 randomly selected rice farms were exclusively in the Coleambally region because of the relatively high densities of bitterns in that region. The remaining 63 sites included 34 in the Murrumbidgee catchment and 29 in the Murray catchment. Of the 34 Murrumbidgee sites, 24 were verification sites based on reported sightings, while the remaining ten were control sites. Only four of the 29 Murray sites were verification sites based on reported sightings, with three control sites, and the remaining 22 being targeted sites.

Waterbird surveys

All waterbirds were surveyed once at each of the 93 study sites between 11 December 2012 and 8 February 2013. This retrospectively formed the basis for identifying sites where APS were present for subsequent repeat surveying. Each survey entailed one hour of scanning for birds from banks adjacent to rice bays in a vehicle and on foot. The only surveying that took place within the crop itself was from these banks. All surveys were conducted within three hours of first light in the morning or three hours before sunset, with the exception of six surveys that were conducted mid-afternoon.

Australian Painted Snipe sites

Once APS sites had been identified, the detection method was noted and a second count was made to determine the minimum number of individuals and, where possible, the gender of each bird (this was not possible for some sub-adult or poorly seen individuals). Views were not sufficient to determine if there were any juvenile birds present. In order to obtain accurate minimum counts of the number of individuals and determine sex ratio, the observer flushed birds by walking along banks. The specific microhabitat was recorded (e.g. toe furrow, adjacent channel). Subsequent visits, where possible, helped determine minimum length of stay at each site. Further information on habitat use was also recorded. These additional visits are detailed in the results.

Review of the APS database

Birdlife Australia established the APS Project in 2001 and has been encouraging birdwatchers to undertake targeted surveys for the species. It maintains a database of all reported records of the species and endeavours to include those not directly contributed to Birdlife Australia. The database was searched for APS records associated with rice fields.

RESULTS

A total of 44 APS was recorded at five of the 93 study sites in 2012-2013. The APS database revealed an additional 43 birds within this same period at three different rice fields (‘Mayrung 1 & 2’ and ‘Finley’) located within the study area. Thus, the overall total was 87 APS associated with rice fields during the 2012-2013 rice-growing season. The 87 birds comprised 19 females, 19 males and 49 individuals where sex could not be determined or was not recorded (Table 1). APS observations at the five sites where they were recorded during the core study (93 sites) included two from morning surveys and three from afternoon surveys. All eight APS sites (our five plus the three in the APS database) were distributed across the rice growing regions of the Riverina in New South Wales, except for the northern Murrumbidgee region around Griffith (Figure 2). Three of the five APS sites (from the 93 study sites) were from randomly selected rice farms in Coleambally.

The initial detection was as a result of either walking or driving around the edges of rice fields, where APS were seen or, most often, flushed as a result of that disturbance. The majority of observations were of birds using the edges of bays within rice fields (Figure 3), particularly the toe furrows, which are the surrounding channels within individual rice bays (Figure 1, Table 1). At four sites, the drainage or supply channels were used, while at two sites, areas where water had overflowed or seeped from the rice field were used. APS were recorded in the actual crop, rather than the toe furrow, at only one site, where 12 birds were flushed from the crop edge (Figure 4, Table 1). The rice height at this site was considerably shorter than at least four of the other seven APS sites (‘Coleambally 2 & 3’, ‘Barham’ and ‘Swan Hill’), which supported rice over 30 cm in height, with water depths of 12-17 cm at the time APS were present.

The observations were made in a period ranging from 1 to 102 days. This represents the best estimate of minimum duration of APS occupancy in rice fields as systematic monitoring of each site was not possible, and it was unknown how long APS were present before detection. A return visit to the Coleambally 1 site (Figure 2, Figure 4) on 5 January 2013 failed to relocate any of the 12 birds seen previously, while return visits were not possible to the ‘Coleambally 3’ and ‘Swan Hill’ sites, meaning the observation period for all three of these sites was only 1 day. At the ‘Coleambally 2’ site, only two birds were initially found, with a return visit yielding four on the 14 January 2013, but no birds on 13 March 2013. At all other sites, the observation period has been deduced by the observations made by other people.

Figure 3. An Australian Painted Snipe foraging on dusk, using the shallows on the edge of a rice field adjacent to the crop. Photo: M. Herring.

Figure 4. One of 12 Australian Painted Snipe recorded using this rice field (in the shade, at the bottom, centre of image), found roosting within the crop edge. Photo: M. Herring.

Figure 5. Australian Painted Snipe nesting on the bank of a rice field in 1974, including incubating male, three eggs and recently hatched chick (Thomas 1975). This rice farm produced seven of the ten Riverina records associated with rice, prior to the 2012-2013 season and spanning 39 years, on the Birdlife Australia APS database. The apparent significance of this particular rice farm is probably best explained by the family that owns it, which includes several avid birdwatchers who have reported their sightings. It was also one of the eight 2012-2013 APS sites. Photos: E. Thomas.

Table 1. Records of the Australian Painted Snipe associated with rice fields during the 2012-2013 rice-growing season, showing the minimum number of birds, their habitat use and observation period. M=Male, F=Female & U=Unknown sex.

Location (Site Name)	Minimum number of birds	Habitat use	How were APS initially located?	Observation period (first and last obs.)
Coleambally 1	12 (2F, 2M, 8U)	Crop edge, edges of toe furrows, along supply channel	Walking	1 day *23 Dec. 2013*
Coleambally 2	4 (1F, 3U)	Along drainage channel and edges of toe furrows	Walking	24 days *22 Dec. 2012 -14 Jan. 2013*
Coleambally 3	2 (1F, 1M)	Edges of toe furrows	Driving	1 day *22 Dec. 2012*
Barham	25 (5F, 3M, 17U)	Edges of toe furrows, as well as seepage/ overflow and adjacent grassland	Driving	46 days *19 Dec. 2012 - 23 Jan. 2013*
Swan Hill	1 (1U)	Edges of toe furrows and adjacent overflow/seepage	Driving	1 day *6 Jan. 2013*
Mayrung 1	4 (1M, 3U)	Edges of toe furrows	Walking	102 days *15 Dec. 2012 - 27 March 2013*
Mayrung 2	34 (10F, 10M, 14U)	Along drainage channel, edges of toe furrows	Driving	14 Days *30 Dec. 2012 - 13 Jan. 2013*
Finley	5 (2M, 3U)	Drainage channel, edges of toe furrows	Driving	14 days *15-29 Nov. 2012*

Records prior to 2012-2013

Prior to the 2012-2013 season the Birdlife Australia APS database held 13 records associated with rice fields. Three of these records were from outside of the Riverina region of New South Wales: one on the Gwydir River floodplain in north-eastern New South Wales, and two from Queensland. Seven of the 10 historical Riverina records were from the same farm near Barham where 25 APS were recorded during the 2012-2013 season; they include the only documented case of Australian Painted Snipe nesting in rice fields (Thomas 1975, Figure 5). The 10 Riverina records span six different rice-growing seasons: 1974-75, 1978-79, 1979-80, 1992-93, 2003-04 and 2004-05.

DISCUSSION

The large numbers and widespread distribution of APS found during the 2012-2013 rice-growing season suggest that rice fields are more important as habitat for the species than previously recognised (Marchant & Higgins 1993, Rogers *et al.* 2005, Department of the Environment 2013a). The value of rice fields as APS habitat appears to have been overlooked because of a lack of broad scale surveys by observers familiar with the species and its conservation status.

The total of 87 APS recorded at eight widely distributed rice paddocks during the 2012-2013 season was likely to be indicative of many more, probably at least several hundred, using rice fields during that period in the Riverina region of New South Wales. We make this inference because of:

1. the limited primary survey effort of 93 1-hour surveys (which yielded 44 birds).
2. the rice crop area of the 93 sites was less than 4 per cent of the total rice crop area of 113 500 ha.
3. the limited total rice field edge surveyed. A coarse estimate of the entire length of edges for a 42 ha (600 m x 700 m) rice field with seven bays, is 6.2 km (not including both sides of bay edges). So during the 2012-2013 season there was approximately 16 755 km of rice field edge across the 113 500 ha crop, not including the edges of adjacent supply and drainage channels. A maximum of approximately 2.5 km was surveyed at each of the 93 sites, representing 1.4% (232.5 km of 16 755 km) of the estimated total rice field edge in the Riverina.
4. the occurrence of APS at three of the 30 randomly selected rice farms in Coleambally.
5. the likelihood of double counting is considered very low because many of the observation periods occurred concurrently (Table 1), including the two sites with the largest numbers (‘Barham’ and ‘Mayrung 2’). Additionally, there are large distances between the sites (Figure 2), with substantial intervening areas of potentially suitable habitat.
6. the APS is a cryptic species and often difficult to detect, so some individuals were probably overlooked.
7. the likelihood of rice farmers or other observers at rice fields being aware of the species, its significance and reporting sightings is considered very low.
8. the relatively homogenous nature of rice field habitat means that extrapolation of the results at this scale is much more reasonable than with other wetland types.

The likelihood of rice fields supporting hundreds of APS is highly significant for a globally endangered species with a very small estimated population size (1250 mature individuals; Garnett *et al.* 2011). Indeed, the apparent adaptability of APS to novel, anthropogenic habitat is encouraging and this provides numerous opportunities for targeted conservation management on rice farms. However, there are important questions that need to be addressed.

How regularly do APS use rice fields?

It is unclear how regularly APS use rice fields, especially in significant numbers. Prior to the 2012-2013 rice-growing season, the Birdlife Australia APS database held only ten Riverina records (spanning six seasons over 39 years) where birds were associated with rice fields, seven of which came from a single rice farm that is owned by a family that includes several avid birdwatchers. It would appear that the 2012-2013 season was an exceptional year but the increased survey effort as a result of the 'Bitterns in Rice Project' (Herring *et al.* 2014) at least partly explains this. APS may use rice fields in most or all seasons, sometimes in significant numbers, but until now this has gone undetected. On 29 December 2013, four APS were observed approximately three kilometres from the 'Mayrung 2' site (L. Moore, *pers. comm.*), confirming the use of rice fields following the season described in detail in this paper. In November 2011, a group of at least 30 APS were found using a rice field in the Jerilderie region, New South Wales (P. Merritt, *pers. comm.* – note this record was not contained in the APS database at the time of searching). In sum, APS have been recorded using rice fields in each of the last three rice-growing seasons, with large numbers found in two of them (30 and 87).

What roles do rainfall and natural wetland availability play?

Overall abundance of APS is known to fluctuate substantially between wet and dry periods in Australia. The relatively large numbers recorded using rice fields during the 2012-2013 season are consistent with a documented recovery for the species after two exceptionally wet years following the millennium drought of 2001-2009 (Purnell *et al.* 2014). Toward the end of the drought, during the 2008-2009 survey period, only 11 APS were reported nationally to BirdLife Australia, whereas in the record two-year high rainfall period prior to May 2012, there were over 400 individual APS recorded (APS Database, Birdlife Australia; BOM 2014b).

The use of rice fields by the APS might be determined by the extent of suitable natural wetland habitat during the rice-growing season in the surrounding region. In the Riverina region of New South Wales, almost all of the natural wetland areas had dried out before the 2012-2013 season and had no habitat suitable for the APS. The 100% water allocations in the 2012-2013 rice-growing season were largely as a result of water captured during the floods of 2010-2012 (RGA 2013, Sunrice 2013). During dry periods in the Riverina prior to rice-growing, the APS may have simply moved elsewhere in their large Australian range. Rice fields may represent alternative, sub-optimal habitat that only support APS in relatively large numbers during dry periods (following a population boom) when their preferred habitat is unavailable.

How do APS use rice field habitats?

Our results show that rice fields can provide suitable temporary wetland habitat to support large numbers of APS. The edges of rice fields appear to be most important to the APS. The edges surrounding individual bays and their toe furrows, bank and channel edges, and areas where water from overflow or seepage had pooled adjacent to the rice field, all supported the APS. APS is known to avoid habitats dominated by tall, dense wetland vegetation and prefers substantial areas of patchy, low vegetation in combination with exposed mud and shallow water (Rogers *et al.* 2005). Any use of the actual rice crop by the APS (e.g. Figure 4) is therefore likely to occur only for a short period some time after sowing when water depths remain sufficiently low and before the crop has grown prohibitively tall. Thus, APS may primarily be associated with rice fields during the early and mid-season periods.

How regularly do APS breed in rice fields?

Breeding habitat appears to be critical in limiting the APS population and is probably the most important conservation challenge for the species (Rogers *et al.* 2005). There is one published record of APS breeding in association with rice: on the bank of a rice field near Barham during the early-mid season (December) of 1974 (Thomas 1975; Figure 5). It seems unlikely that this record is a 'one-off', with other breeding events having gone undetected or unreported. The comparatively well-studied congener of the APS, Greater Painted Snipe, is known to nest on the banks of rice fields (Ali 1968). However, rice fields typically lack sustained provision of some of the key breeding habitat attributes for APS identified by Rogers *et al.* (2005), notably the small islands, shallow water and exposed mud that is associated with receding water levels during a successional stage of temporarily inundated wetlands. Nevertheless, the banks between rice bays may provide a similar role to islands, as they are almost entirely surrounded by water, and the shallow water, exposed mud and short, dense cover often found along the edges of rice fields may be an adequate linear alternative to that found in natural wetlands. If the single published breeding record is indicative of a lack of breeding, then there are numerous habitat management opportunities to enhance the potential for APS to breed in association with rice fields.

Could rice fields affect APS negatively?

The concept of ecological traps (Dwernych & Boag 1972, Donovan & Thompson 2001) may apply to rice fields and the APS. For example, birds might be lured away from better quality habitat in natural wetlands where their chances of breeding successfully are higher. Agronomic practices, including the speed at which modern rice varieties grow, could alter the required habitats before successful breeding is completed. Similarly, increased water levels after the APS have started nesting in a rice field might result in chicks hatching in a habitat where they cannot forage. There is also a potential risk associated with the use of pesticides in rice fields (Suhling *et al.* 2000, Wilson *et al.* 2005), which may impact on APS, either via their prey or through changes in water quality. The risk of pesticide contamination or rice fields acting as ecological traps should be a target for further research as there are likely to be numerous opportunities to ameliorate these risks through careful management.

How can rice fields be managed to benefit APS?

Rice-growing methods and the configuration of rice fields could be altered to benefit APS. Management prescriptions with little or no impact on production would likely result in the greatest uptake. Targeted management of toe furrows, banks, channels and overflows/seepage could increase the amount of potential APS habitat in rice fields. For example, rice farmers could be encouraged to have smaller bays and wider, shallower toe furrows, which would result in more edges and mudflats. Sheep grazing could be used to keep vegetation at heights that are not prohibitively tall for APS. In Japan, the Greater Painted Snipe is closely associated with rice fields and appears to have declined severely from changes to rice field management (Fujioka & Yoshida 2001, Amano *et al.* 2010). This highlights the need to monitor agronomic developments in the Riverina rice industry.

In developing APS-friendly rice-growing guidelines, it will be important not to hinder conservation efforts for the Australasian Bittern. Taylor & Schultz (2010) highlight the importance of the early stages of the rice-growing season for shorebirds. At this time, the water depth and rice height are both low. They advocate the development of new varieties of rice that would reduce the need for increasing water depths later in the season. While these recommendations may benefit the APS, they are likely to disadvantage the Australasian Bittern. Similarly, toe furrows and banks managed to benefit the Australasian Bittern presently include the retention of Cumbungi (*Typha* spp.) and the promotion of Barnyard Grass (*Echinochloa* spp.) (Bitterns in Rice Project 2014a), which would both likely render areas less suitable or unsuitable for the APS. The potential habitat management trade-offs for these key threatened species now represent one of the primary challenges for biodiversity conservation in Australian rice fields.

The potential for 'wildlife-friendly' rice farming

Our findings highlight the potential for 'land sharing' and 'wildlife-friendly farming' approaches (Green *et al.* 2005, Fischer *et al*. 2008, Phalan *et al*. 2011) to conserve biodiversity using agricultural wetlands in Australia. More specifically, the results identify the potential role that rice farmers can play in the conservation of Australia's most threatened shorebird. There are clear environmental costs of extracting water from rivers for irrigation, and rice fields are no substitute for natural wetlands. However, given the recognised need for food production and the large area where rice is still grown, targeted management of rice fields to benefit Australian Painted Snipe and other species may be important in complementing traditional conservation measures like protected areas and ecological restoration.

Future research priorities

We recommend the following interrelated priorities for future research of the use of rice fields by the APS in the Riverina region of New South Wales:

1. To determine spatial and temporal variation in abundance of the APS in rice fields throughout and between rice-growing seasons through an extensive long-term targeted monitoring program. Ideally, sites could be surveyed weekly or fortnightly and include all sites with previous APS records. Potentially, this work could be incorporated into the *Bitterns in Rice Project* (Bitterns in Rice Project 2014b), although the survey method for APS would need to be different, incorporating the association of APS with shallow edges. We recommend that a standardised 1-hour APS survey in rice fields consist of approximately 30 minutes of driving along tracks adjacent to rice fields and approximately 30 minutes of walking 1 km, both in an attempt to flush birds. Surveys could begin as early as one month after sowing, when some cover would have emerged, and be conducted throughout the day to maximise the number of sites covered each day.
2. To explore the relationship between the APS, rice fields and natural wetlands. This work could test the sub-optimal habitat hypothesis and investigate the potential association of significant numbers in rice fields with population booms following exceptionally wet periods.

3. When APS are located in rice fields, intensive systematic monitoring should aim to determine the extent to which they breed therein and the factors affecting breeding success.
4. To investigate which agronomic factors, such as water management and pesticide application, influence APS use of rice fields and any potential impacts, with particular attention being paid to prey availability and breeding. This would inform the development of APS-friendly rice-growing guidelines in conjunction with guidelines for managing habitat for the Australasian Bittern.

Raising awareness of the APS among rice farmers and encouraging them to report sightings to Birdlife Australia is a priority for education and advocacy.

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