Permanently inundated *Phragmites* reedbed supports higher abundance of wetland-dependent bird species than drier reedbed during southward migration through Hong Kong

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We compared the migrant bird community of reedbeds in Hong Kong under two different management regimes—a permanently inundated reedbed and one that was kept dry from September until May—by mist-netting at the two sites simultaneously during southward migration (September–December) over four years. Overall there was no difference between the wet and dry conditions in terms of the total number of individuals trapped or diversity of species, but habitat preferences were observed for certain species and foraging guilds. Insectivorous and piscivorous species were trapped more often in the wet reed stand, whereas granivorous species were trapped more often in the dry reed stand. Among five reedbed-dependent passerine species that were considered to be of particular interest in our study, four species (Black-browed Reed Warbler *Acrocephalus bistrigiceps*, White-browed Reed Warbler *A. tangorum*, Oriental Reed Warbler *A. orientalis* and Pallas's Grasshopper Warbler *Locustella certhiola*) were trapped significantly more often in the wet reed stand, whereas Chinese Penduline Tit *Remiz consobrinus* showed no preference for the wet or dry conditions. We recommend that reedbed bird diversity at this site would benefit from a long-term plan to excavate and regenerate reed stands on a cyclical basis over a number of years to maintain a mosaic of wet and dry reedbed habitats.

INTRODUCTION

The Common Reed Grass *Phragmites australis* forms dense, often monospecific, stands of vegetation that provide important habitat for a variety of wildlife, especially for birds (Hawke & José 1996). This species has an almost global distribution in wetland habitats, but large reedbed stands in eastern Asia have suffered a long-term decline in area and increased fragmentation (e.g. Dai *et al*. 2011, Brix *et al*. 2014). This decline may be a result of the drainage of wetlands, conversion of land to agriculture or development, or competition from other plant species such as the invasive cordgrass *Spartina alterniflora* (Xie & Gao 2013).

Research into the habitat preferences of reedbed-associated bird species has been carried out in many temperate parts of the world, particularly Europe (Cantos & Tellería 1994, Honza & Literák 1997, Martinez-Vilalta *et al*. 2002, Poulin & Lefebvre 2002, Poulin *et al*. 2002, Baldi 2006). In comparison, the ecology of birds using tropical and subtropical reedbeds, which are occupied during the non-breeding season by many of the migratory species studied in temperate regions, has been relatively neglected. Habitat requirements of migratory songbirds in the East Asian–Australasian Flyway are particularly poorly studied in comparison to other flyways, limiting the ability to identify potential threats and implement conservation measures (Yong *et al*. 2015).

There is estimated to be 182 ha of reedbed in Hong Kong, of which 28.9 ha (16%) is located in Mai Po Marshes Nature Reserve (hereafter Mai Po) (WWF-HK 2013). This reedbed provides stopover and wintering habitat for a large number of birds, especially during southward migration (Yu 2002, Wong & Young 2009, Allcock *et al*. 2013). The Vulnerable White-browed Reed Warbler (known locally as Manchurian Reed Warbler) *Acrocephalus tangorum*, the Vulnerable Pleske's Grasshopper Warbler (also known as Styan's Grasshopper Warbler) *Locustella pleskei* and the Critically Endangered Yellow-breasted Bunting *Emberiza aureola* all occur regularly in the Mai Po reedbeds.

Whilst they are protected from development and from human disturbance, reedbeds within Mai Po have been gradually changing in character following natural ecological succession, including the accumulation of leaf litter (leading to the reedbed floor becoming drier) and colonisation by non-reed vegetation, most commonly Mangrove Fern *Acrostichum aureum* and climbers, especially Chinese Fevervine *Paederia scandens*. These processes are similar to the succession of European reedbeds into carr woodland, which are often the focus of management to prevent a decline in value for reedbed species (Hawke & José 1996). Management of reedbeds to prevent or reverse this process of succession may be required at Mai Po as they are in Europe.

Although the management practices of reedbeds to reverse the impacts of vegetation succession have been studied in temperate regions, the applicability of these in tropical regions is not well understood. Previous research at Mai Po has found no change in the reedbed bird community in response to reedbed cutting as a management measure (WWF-HK & HKBRG 2008). The current study builds on that research to investigate the effects of another recognised technique in reedbed management—the excavation of the surface layer to create wet conditions in a reedbed that has been drying out (Hawke & José 1996).

In this study, we compared the bird community of an area of reedbed which is permanently inundated with an area where the ground is dry during the migration period. Our hypothesis was that the permanently inundated reedbed would support a higher abundance of reedbed-dependent birds than the drier reedbed. We were particularly interested in the requirements of five species which are known to occur regularly at the site and are considered to be reliant on wetland habitats, especially reedbeds: Black-browed Reed Warbler *A. bistrigiceps*, Oriental Reed Warbler *A. orientalis*, Manchurian Reed Warbler, Pallas's Grasshopper Warbler *L. certhiola* and Chinese Penduline Tit *Remiz consobrinus*. All five are long-distance Palearctic migrant species breeding to the north and migrating through Hong Kong. The four warbler species winter mostly to the south of Hong Kong, in South-East Asia (Kennerley & Pearson 2010), whereas Chinese Penduline Tit winters in Hong Kong, which is near the southern edge of this species's wintering range (Carey *et al*. 2001, Madge 2018).

As no other sites in the area were sufficiently accessible and comparable in habitat condition to the study site, replication of the experiment at another site was not feasible as part of our study. We encourage other researchers to conduct similar comparisons at other sites in the region. Further study would also be beneficial to investigate any differences in habitat use by species not trapped in sufficient numbers during our study (especially larger birds such as ardeids).

METHODS

Study site

The fieldwork for this study was carried out at Mai Po, the wetland reserve which forms the core part of the Mai Po Inner Deep Bay Ramsar Site in north-west Hong Kong (22.485°N 114.035°E). Our study site is located in a patch of reedbed with a total area of 6.9 ha, which is subdivided into discrete reed stands by terrestrial bunds and internal water channels. We compared the bird community of a wet reed stand, which was excavated in 2007 to remove accumulated leaf-litter so that reeds are standing in about 20 cm of water throughout the year, with the bird community of an adjacent dry reed stand, where the ground level was close to operational water level except during June to August when water levels were raised to help control terrestrial vegetation. Water levels in both stands were managed using a sluice to maintain a constant operational water level throughout the study period. Figures 1 and 2 provide a cross-section and an aerial view of the experimental design and plot layout. Water in the study site is brackish, although salinity drops significantly during the wet season (May–September) and increases over the course of the dry season (October–April) (WWF data).

Given the close proximity of the two trapping sites, other factors that may affect the activity of a species, such as climatic conditions or surrounding land use, are the same. Thus, any observed differences in the use of these two reed stands should be related only to the microhabitat differences resulting from the different water levels.

Trapping methodology

We sampled the bird communities of the wet and dry reed stands during the peak southward migration by trapping twice per week from the beginning of September until the end of December in four years (2011–2014). During this period, we were able to carry out trapping on a total of 118 dates (31 in 2011, 29 in 2012, 29 in 2013 and 29 in 2014). During each trapping session, we operated a line of 96 m of mist-nets (comprising eight nets, each 12 m long and 2 m high with a mesh size of 32 mm) in each of the wet and the dry reed stands (Figure 2). Both lines of nets were opened approximately 15–30 minutes before sunrise in each of the wet and dry reed stands, and trapping was carried out for a three-hour period. We checked the nets every 30–45 minutes, extracting all birds trapped and taking them to a processing site, where they were ringed, measured and released.

Data analysis

Birds trapped include resident species and winter visitors as well as passage migrants, and these three classes were not separated as part of the analysis, especially as individuals of some species may differ in their migration strategy at the site—for example, the population of Dusky Warbler *Phylloscopus fuscatus* includes both passage migrants and winter visitors. To avoid any influence from seasonal variation in species abundance, we carried out statistical tests using paired tests to compare the number of birds trapped in the wet reed stand against the number trapped in the dry reed stand on the same date. As the numbers of individuals are generally low and the assumptions of parametric tests are not met, most analysis was done using non-parametric Wilcoxon signed-rank tests.

With analysis for a relatively high number of species, the risk of reporting a Type I error (incorrectly rejecting the null hypothesis and finding a significant difference when none exists) is increased by using the standard p=0.05 threshold as a measure of significance

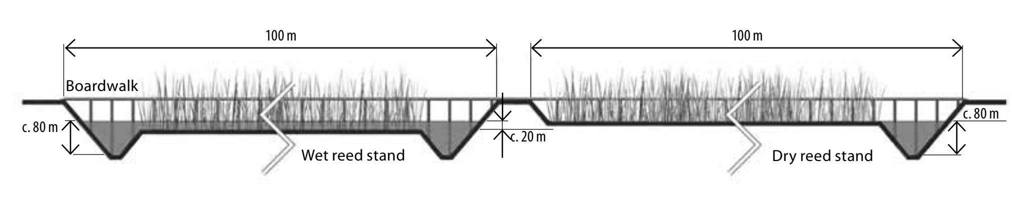

Figure 1. Cross-section of the reedbeds with the different management treatments for wet and dry stands.

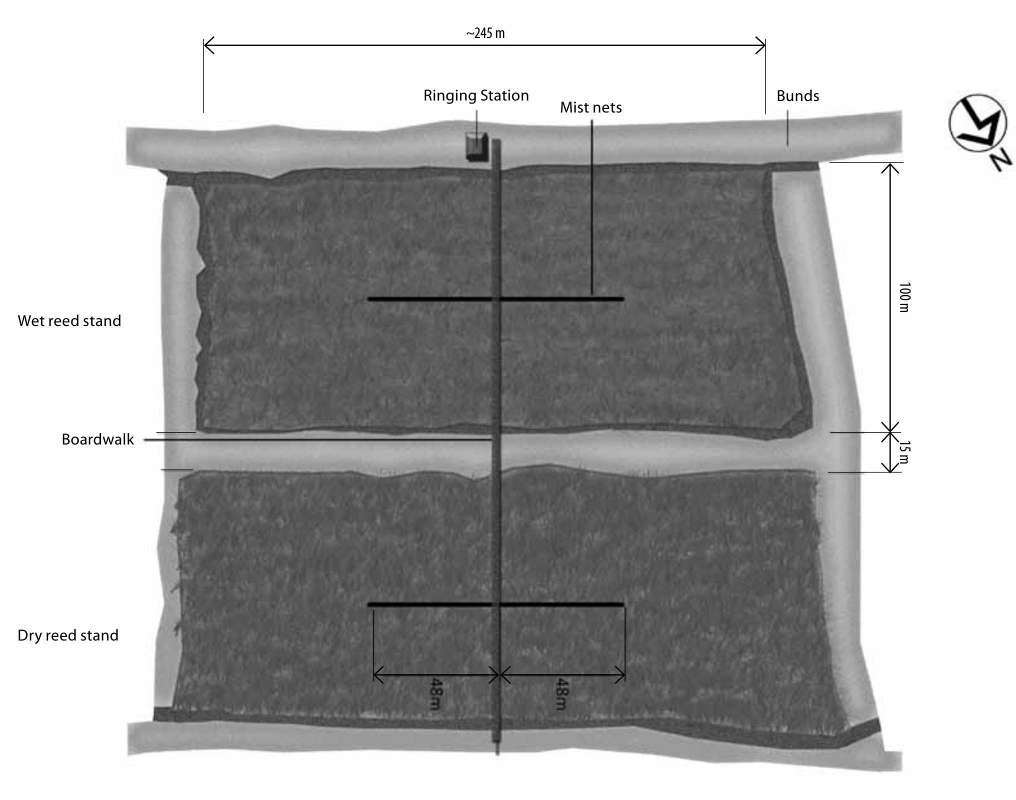

Figure 2. Aerial view of the reedbeds indicating their proximity and dimensions plus the position of the mist-nets.

(since 1 in 20 species would show this level of significance by chance). In order to minimise the risk of Type I error, only observations with a probability lower than p=0.01 are reported here as significant. Species with a probability between p=0.05 and p=0.01 are highlighted to indicate that a relationship may exist that may warrant further investigation.

RESULTS

A total of 6,752 captures of 78 species was made during the study; 3,699 were in the wet reed stand and 3,053 were in the dry reed stand. Statistical tests showed no difference between the reed stands in the total number of birds trapped (paired t-tests; p=1.00). A total of 59 species was trapped in the dry reed stand compared with 50 in the wet stand, but the difference in diversity was not significant (Wilcoxon signed-rank test; p=0.078).

Results are presented in Table 1 for each of the 20 most abundant species trapped during the study. Among the five wetland-dependent species we considered to be of particular interest, four—Black-browed Reed Warbler, Oriental Reed Warbler, Manchurian Reed Warbler and Pallas's Grasshopper Warbler—were present in higher numbers in the wet reed stand than in the dry reed stand (all p<0.0001, except Pallas's Grasshopper Warbler p=0.001). The fifth species, Chinese Penduline Tit, showed no preference for either reed stand over the course of the study (p=0.206); several other abundant insectivorous species (notably Dusky Warbler and Yellow-bellied Prinia *Prinia flaviventris*) were also equally abundant in both reed stands. Besides these species, a significant preference was shown by three species, Light-vented Bulbul *Pycnonotus sinensis*, Siberian Rubythroat *Calliope calliope* and Scaly-breasted Munia *Lonchura punctulata*, all of which were recorded in higher numbers in the dry reed stand.

As many species were not trapped in sufficient numbers to permit species-level comparison, species with similar food preferences were grouped into foraging guilds for further assessment (Table 2). Insectivorous species showed an overall preference for the wet reed stand (Wilcoxon signed-rank test; n = 118, p < 0.0001), although this may have been largely the result of the preference of the four species listed above, and there was no preference when these four species were excluded from the insectivore analysis (Wilcoxon signed-rank test; n = 118, p = 0.911). Piscivorous species (including kingfishers and *Ixobrychus* bitterns) also showed a preference for the wet reed stand (Wilcoxon signed-rank test; n = 33, p = 0.001). Granivorous species showed a preference for the dry reed stand (Wilcoxon signed-rank test; n = 97, p < 0.0001). Given recent concerns about buntings (*Emberiza* spp.) on the flyway (Kamp *et al*. 2015, Edenius *et al*. 2017), and the presence of the Critically Endangered Yellow-breasted Bunting at Mai Po, species in this genus were also combined for analysis; this also showed a preference for the dry reed stand (Wilcoxon signed-rank test; n = 57, p = 0.003).

Table 1. The 20 most numerous species trapped during the study. The P value derives from Wilcoxon signed-rank tests.

Species	No. in wet reedbed	No. in dry reedbed	% in wet reedbed	No. of paired comparisons	P value
Chinese Penduline Tit *Remiz consobrinus*	483	300	62	46	0.206
Light-vented Bulbul *Pycnonotus sinensis*	0	20	0	15	<0.0001
Barn Swallow *Hirundo rustica*	28	13	68	25	0.064
Dusky Warbler *Phylloscopus fuscatus*	673	588	53	98	0.333
Yellow-browed Warbler *Phylloscopus inornatus*	12	19	39	20	0.336
Oriental Reed Warbler *Acrocephalus orientalis*	573	316	64	89	<0.0001
Black-browed Reed Warbler *Acrocephalus bistrigiceps*	814	242	77	89	<0.0001
Manchurian Reed Warbler *Acrocephalus tangorum*	34	6	85	34	<0.0001
Lanceolated Warbler *Locustella lanceolata*	106	98	52	62	0.837
Pallas's Grasshopper Warbler *Locustella certhiola*	305	231	57	82	0.001
Zitting Cisticola *Cisticola juncidis*	18	34	35	29	0.073
Yellow-bellied Prinia *Prinia flaviventris*	147	153	49	101	0.927
Plain Prinia *Prinia inornata*	147	114	56	95	0.027
Japanese White-eye *Zosterops japonicus*	22	26	46	22	0.560
Bluethroat *Luscinia svecica*	8	11	42	17	0.553
Siberian Rubythroat *Calliope calliope*	66	166	28	63	<0.0001
Common Stonechat *Saxicola torquatus stejnegeri*	41	58	41	59	0.102
Scaly-breasted Munia *Lonchura punctulata*	81	480	14	75	<0.0001
Chestnut-eared Bunting *Emberiza fucata*	17	13	57	20	0.453
Black-faced Bunting *Emberiza spodocephala*	18	31	37	29	0.122

Table 2. Numbers of individual birds trapped per feeding guild. The P value derives from Wilcoxon signed-rank tests.

Feeding guild	No. in wet reedbed	No. in dry reedbed	% in wet reedbed	No. of paired comparisons	P value
Insectivorous	3,536	2,465	59	118	P<0.0001
Granivorous	127	555	19	97	P<0.0001
Piscivorous	30	8	79	33	P=0.001

DISCUSSION

Most of the species trapped during our study feed on insects and other small invertebrates, including all five of the wetland-specialist species that were the focus of our study. Poulin *et al*. (2002) found that French reedbeds with no surface water for a longer period supported fewer invertebrates, which in turn supported fewer birds during the breeding season, so we had expected that insectivorous species would show a preference for the wet reed stand. Overall, insectivorous species did indeed show a preference for the wet reed stand.

These results indicate that the distribution of these species between the two reedbeds is influenced by factors other than overall invertebrate abundance; such factors may include vegetative structure (Martinez-Vilalta *et al*. 2002, Poulin *et al*. 2002, Baldi 2006), foraging strategy, availability of preferred prey species (Bibby & Green 1981, Poulin & Lefebvre 2002) or differences in nutritional content of prey (Martinez del Rio & McWilliams 2016). Those species associated with reedbeds, all of which preferred the wet conditions, may have evolved species-specific differences in spatial distribution to permit the coexistence of several species, as has been reported among *Acrocephalus* warblers in European reedbeds (Honza & Literák 1997).

Piscivorous species also showed a preference for the wet reed stand. Their food could be captured throughout the wet reed stand, but only on the fringes of the dry reed stand along adjacent channels. The preference of Scaly-breasted Munia and other granivorous species, including buntings, for the dry reed stand most likely relates to the high abundance of Barnyard Millet *Echinochloa crusgalli* in the dry reed stand. This grass species is commonly found in Hong Kong wetlands and was common in the dry reed stand, especially in the more open area near the nets, but was seemingly unable to colonise the permanently flooded wet reed stand. Light-vented Bulbul, an insectivore-frugivore, was trapped exclusively in the dry reed stand during the course of the study, a preference that probably reflected roosting rather than foraging behaviour, as flocks of this species sometimes roost in the dry reed stand.

Conservation of globally threatened bird species

The Vulnerable Manchurian Reed Warbler, with a global population estimate of 2,500-9,999 individuals (BirdLife International 2018), was previously considered rare in Hong Kong, but regular trapping in the reedbeds at Mai Po since 2001 has revealed it to be a regular passage migrant in small numbers (up to seven individuals recorded at the site in a year); Mai Po may be an important migration stopover site for the species. Given the significantly higher numbers of Manchurian Reed Warblers trapped in the wet reed stand, availability of wet reed stands in Hong Kong may be beneficial for the global conservation of this species.

Although Yellow-breasted Bunting, a Critically Endangered species, was trapped during the study, the numbers involved were relatively low (a total of 15 individuals). This and other buntings showed a preference for the dry reed stand but, given the low number of individuals there compared to other habitats nearby, management of the reedbed for this species is not considered a priority.

Recommendations for management of reedbeds in Hong Kong

Reedbeds are one of the target habitats at Mai Po (WWF-HK 2013) and management practices at the reserve should aim to maximise the value of these reedbeds for wildlife. Many of the reed stands at Mai Po have previously been colonised by non-reed vegetation, including climbers (especially Chinese Fevervine and Oblong Gymnanthera *Gymnanthera oblonga*), terrestrial grasses and Mangrove Fern. Over time this has led to a progressive loss in the area of pure stands of *Phragmites* reedbed habitat, with potential impacts on species reliant upon reedbed habitats, not only birds but also invertebrates and other taxonomic groups.

Most wetland-specialist bird species in our study showed a clear preference for the wet reed stand over the dry reed stand (including Black-browed Reed Warbler, Oriental Reed Warbler, Manchurian Reed Warbler and Pallas's Grasshopper Warbler). Species with a preference for the dry reed stand (Light-vented Bulbul, Siberian Rubythroat and Scaly-breasted Munia) are not dependent on wetland habitats and commonly occur throughout Hong Kong. In order to better conserve the reedbed-dependent species, including the globally threatened Manchurian Reed Warbler, we suggest that reedbeds at Mai Po should be managed to maintain or, if necessary, restore wet conditions by lowering the ground level and/or raising water levels so that reeds are standing permanently in water. Birds that may be negatively impacted by this action are non-wetland species for which suitable habitat remains elsewhere in Hong Kong and are therefore of lower priority in the management of the reserve.

Of course, decisions on management actions should also take into consideration non-avian species reliant on the habitat, including invertebrates, fish and plants. While some species will benefit from the creation of wet conditions, as is reported here among birds, certain non-avian species may prefer the conditions in reedbeds later in the successional process as the conditions become drier. Thus, the overall biodiversity at the site would most likely benefit from the maintenance of a mosaic of wet and dry reedbed habitats with a plan to excavate and regenerate reed stands on a cyclical basis over a number of years. At the moment, little is known about the habitat requirements of most invertebrate and plant species at Mai Po, and further research into this is strongly encouraged so that a comprehensive management plan can be formulated for the reserve as a whole.

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