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Hunting or habitat? Drivers of waterbird abundance and community structure in agricultural wetlands of southern India

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Abstract The relative impacts of hunting and habitat on waterbird community were studied in agricultural wetlands of southern India. We surveyed wetlands to document waterbird community, and interviewed hunters to document hunting intensity, targeted species, and the motivations for hunting. Our results show that hunting leads to drastic declines in waterbird diversity and numbers, and skew the community towards smaller species. Hunting intensity, water spread, and vegetation cover were the three most important determinants of waterbird abundance and community structure. Species richness, density of piscivorous species, and medium-sized species (31–65 cm) were most affected by hunting. Out of 53 species recorded, 47 were hunted, with a preference for larger birds. Although illegal, hunting has increased in recent years and is driven by market demand. This challenges the widely held belief that waterbird hunting in India is a low intensity, subsistence activity, and undermines the importance of agricultural wetlands in waterbird conservation.

Keywords Avifauna · Community structure · Illegal hunting · Tamil Nadu · Waterbird

INTRODUCTION

Wetlands are among the most threatened ecosystems in the world (Dudgeon et al. 2006). Globally, wetlands are impacted by a combination of anthropogenic pressures (Sala et al. 2000; Revenga et al. 2005; Pereira et al. 2010). Consequently, rates of the declines in fresh water fauna are

greater than those of any terrestrial ecosystem (Ricciardi and Rasmussen 1999). The vast majorities of tropical and subtropical wetlands occur in human dominated landscapes and are primarily managed for human use. Nevertheless, they provide vital habitats for several species of resident and migratory avifauna, including species of global conservation concern. The influence of habitat on waterbird assemblages is well documented (Nilsson and Nilsson 1978; Hoyer and Canfield 1994; Chimalakonda 2012; Sundar and Kittur 2013). Waterbirds use a mosaic of habitats whose utility of which differs during circadian cycles, annual cycles, and life stages (Amat et al. 2005; Haig et al. 2008; Roshier et al. 2008). Furthermore, patch-level factors such as lake morphology, vegetation cover, and trophic status are also known to influence waterbird assemblages (Hoyer and Canfield 1994; Chimalakonda 2012). However, both habitat factors and patch-level factors fail to holistically explain waterbird diversity patterns, as wetlands are often nested within larger landscapes and experience a wide range of anthropogenic pressures. About 30% of the wetlands in India are seminatural inland water bodies, created and managed to sustain agriculture (Space Applications Centre and Indian Space Research Organisation 2011). While their importance as habitats for biodiversity conservation is recognized, systematic efforts to understand the factors affecting their conservation importance are relatively recent (Sundar and Kittur 2011, 2013). Furthermore, studies on waterbirds are limited to a few landscapes and management regimes. This precludes a broader understanding of the role of wetlands as avian refugia in the context of increasing anthropogenic pressures.

Hunting is among the most serious anthropogenic threat to biodiversity conservation (Robinson and Redford 1991; Robinson and Bennett 2000). Beginning with the epoch of Pleistocene, hunting has driven several species to

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extinction (Diamond 1989). Based on the principal driver, hunting is often classified as commercial hunting and subsistence hunting. The former refers to well organized targeting of select species which is driven by regional and global markets. Subsistence hunting is a loosely organized activity driven by local traditional demand for wild meat and occasional sport (Kamins et al. 2011). Subsistence hunting can be a bigger threat to wildlife because it targets a wider variety of species and is carried out by more people (Madhusudan and Karanth 2002). There have been concerted attempts to understand and reduce commercial hunting (Menon et al. 1997; Kumar and Wright 1998). However, subsistence hunting and its biological impacts remain poorly understood. Even less is known about the process of transformation and impacts of traditional, subsistence hunting into a commercial activity. Historic declines of wildlife in India are attributed to hunting (Brander 1923; Gee 1964; Sankhala 1978; Rangarajan 1998; Schaller 2009). In fact, the enactment of “The Wildlife (Protection) Act, 1972” was largely in response to those declines. The enactment gradually restricted hunting and finally in 1991, prohibited all forms of hunting across the country. Nevertheless, hunting is widespread and continues to pose a serious threat to wildlife, but is often denied or discounted due to sociopolitical reasons (Velho et al. 2012). Presence of illegal waterbird hunting in agricultural wetlands of India is well documented (Singh 1998; Gupta 2004; Bhattacharyya and Kapil 2009; Pandit 2009; Chimalakonda 2012; Sundar and Kittur 2013). However, the scale, reasons, and the impacts of hunting on waterbird communities are unknown (Velho et al. 2012). Given the potential of agricultural wetlands as biodiversity refugia in human dominated landscapes, it is important to understand the impacts and drivers of hunting.

In this study, we set out to understand the relative importance of hunting and habitat in driving waterbird abundance and community structure. We documented waterbird communities in 27 wetlands and interviewed 272 active hunters in southern India to assess the impacts and scale of hunting. We also evaluated the factors that drive and sustain this illegal activity. Finally, based on our data, we provide some first tentative suggestions to achieve conservation outputs from agricultural wetlands for waterbird preservation.

MATERIALS AND METHODS

Study area

The study was conducted in Kanchipuram district in the south Indian state of Tamil Nadu, between 11°00'E to 12°00'E and 77°28'N to 78° 50'N (Fig. 1). We surveyed 27

wetlands which were all maintained as a source of irrigation for agriculture. The bulk (54%) of the total annual rainfall of about 1200 mm is received during the northeast monsoon around mid November is the primary source of water for the wetlands (Space Applications Centre and Indian Space Research Organisation 2011). The district has two bird sanctuaries, Vedanthangal and Karikilli, both falling within the study area. Agriculture is the main occupation engaging 47% of the population, and paddy is the most important crop (Ramasundaram et al. 2012).

Estimation of waterbird density

We selected 27 wetlands ranging from 0.05 to 35 ha, spread across an area of about 1200 Km² (Fig. 1). This was representative of all wetland types in the district in terms of size, water-spread area, vegetative cover, and shape. The two protected areas where the ban on hunting was strictly enforced were also part of the sample, providing a means of comparison. Point counts of waterbirds were done between February and April 2014 along the shore of each wetland (Thompson 2002). The number of point locations per wetland ranged between 2 and 8 depending on the perimeter and access to the shore. Each point was separated by about 300 meters, and the duration of every count was 15 min. Birds were counted by a single observer between 06:00 and 09:00H and 16:30 and 18:30H; care was taken to avoid double counting of the birds that were flushed out during sampling. Birds were identified to species using binoculars, and the distance to each cluster of birds was noted in meters using a rangefinder.

Following (Ali and Ripley 1987), we classified the birds into three size class viz. small (10–30 cm), medium (31–65 cm) and large (66–140 cm) and into three feeding guilds viz. herbivore, insectivore, and piscivore. Species of similar size class and feeding guild were combined to estimate joint detection probabilities of sets of species following (Allredge et al. 2006). We then estimated the total density and densities of each size class and feeding guild of each wetland using the computer program DISTANCE 6.0 (Thomas et al. 2010). During analyses, the observations were truncated at 175 m. The number of species recorded during all the point count surveys in a given wetland was considered to be the species richness of that wetland.

Measurement of habitat variables

We measured seven habitat variables identified a priori based on earlier work on the effect of habitat on wetland avifauna (Nilsson and Nilsson 1978; Hoyer and Canfield 1994). Wetland area, water-spread area, and area under surface vegetation were measured using Google Earth Pro

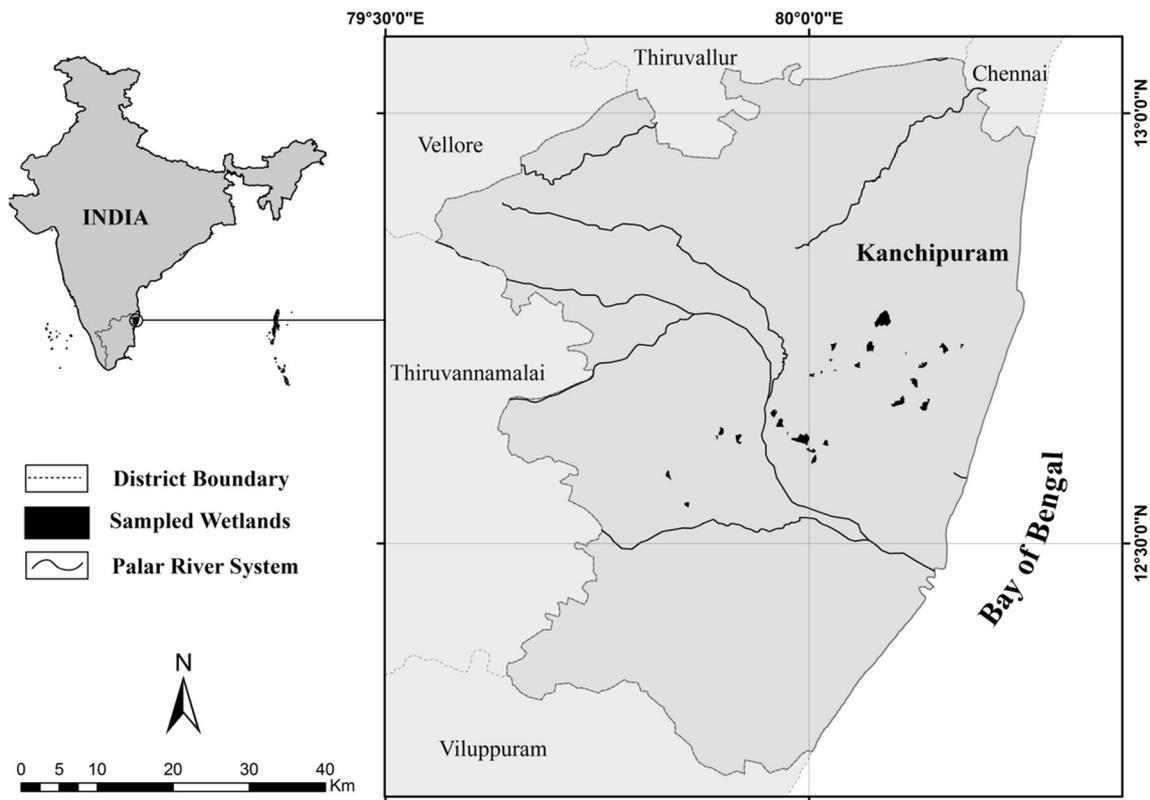


Fig. 1 The study area and distribution of sampled wetlands

with Google imagery dated 1st April 2014. The area to perimeter ratio was used as the shape factor. The proportion of water-spread area to wetland area and the proportion of area under surface vegetation to water-spread area were also estimated.

Estimation of hunting intensity

Trust was built with hunters through frequent visits to their hamlets for a period of three months (December 2013–February 2014) prior to administering questionnaire surveys. Questionnaires were administered verbally after obtaining the informed consent of each hunter. Anonymity of the hunters was maintained. Initially the hunters were identified through a network of wildlife enthusiasts and informers. Snowball sampling (Goodman 1961) was then used to increase the sample size, where initial respondents assisted in the identification of subsequent respondents. We estimated hunting intensity as a comprehensive index for each wetland:

$$H_i = \left(\frac{N \times H}{N_h} \right) S,$$

where H_i is the Hunting intensity of a wetland/hunting season, N is the Mean number of operating hunters/wetland, H is the Mean number of hunting forays per hunter/

wetland, N_h is the Mean number of hunters/foray, and S is the Mean number of birds hunted/foray.

The estimated hunting intensity of a wetland is the product of number of hunting events and success rate of a hunting event. (A hunting event is the product of total number of operating hunters and number of hunting forays of a hunter, divided by the number of hunters per hunting foray).

Hunting was observed to be a coordinated operation by a group of hunters, among whom only one hunter made the kills, and the other hunters assisted him in flushing the birds and collecting the hunted birds. Therefore, to account for the actual hunting intensity, the estimate of hunting events has been divided by the number of hunters per hunting foray; which otherwise would have been an overestimate.

First-hand measurements of all the parameters used to derive the hunting index were not possible. Consequently the data was triangulated by comparing direct observations of hunting events on 42 occasions. Furthermore, the strategy of snowball sampling ensured a complete or near-complete coverage of hunting groups in each wetland.

Market surveys

Data on markets and market trends for waterfowl, hunter perceptions of avifaunal populations, hunting practices,

and factors sustaining the occupation were also collected (see Appendix S1). Five markets were surveyed on seven occasions between April and May 2014. Observations were made on species, number of individuals per species, and price. We also surveyed 681 eateries to assess whether they served waterbirds. No purchase of game was made during this study.

Analyses

We assessed the independent contributions of the measured variables (hunting intensity index and seven habitat variables) to the measured waterbird metrics (density and species richness) using hierarchical variance partitioning (HVP) (Chevan and Sutherland 1991). The package “Hier.part” in R 3.1.0 (R Core Team 2013) was used to measure the independent effect of each covariate on (i) overall density and (ii) density of each of the three size classes and feeding guilds.

HVP is a method based on hierarchies that builds on previous efforts to decompose R^2 through incremental partitioning. The standard method of incremental partitioning follows one among the many possible orders available. Due to the use of all possible orders of variables in hierarchical partitioning, the average independent contribution of a variable is obtained as an exact partitioning result. HVP disentangles the effect of an individual variable from that of other confounding variables by accounting for all possible combinations of the explanatory variables included in the analysis. Thus, individual effects of a variable are computed separately as a percentage from the joint effects of confounding variables. This permits identification of the most significant explanatory variable (Chevan and Sutherland 1991). This is a robust technique to compute individual contributions of multiple explanatory variables accounting for joint effects. However, it does not provide the direction of association between the explanatory and response variables, for which we used scatter plots.

RESULTS

Waterbird community structure

We counted a total of 8279 individual birds from 53 species (Appendix S2) in the 27 wetlands surveyed. Cattle egret (*Bubulcus ibis*) was the only species that occurred at all sites. Species such as the spot-billed pelican (*Pelecanus philippensis*), painted stork (*Mycteria leucocephala*), gray heron (*Ardea cinerea*) and Eurasian spoonbill (*Platalea leucorodia*) occurred only in Vedanthangal, a protected bird sanctuary. The number of sightings per species varied

from 267 (cattle egret) to one, i.e. black-crowned night heron (*Nycticorax nycticorax*) and Indian cormorant (*Phalacrocorax fuscicollis*). Cattle egrets were the most abundant, comprising 36% of the total number of waterbirds observed. Insectivorous species were the most abundant (76.34%) and medium-sized species were the most abundant size class (56.84%). Insectivorous birds formed 73.58% of the total species observed while small-sized waterbirds (43.39%) were the most frequently occurring species.

Hunting intensity

We administered questionnaires to 272 active hunters. All interviewed hunters were male, aged about 40 years ($SD \pm 14.01$) with a hunting experience of 26 years ($SD \pm 14.01$); 50.73% of them had attended at least elementary school. Waterbird hunting was seasonal, occurring primarily between December and April. Most of the hunting (97%) occurred on weekends at dawn and dusk—coinciding with the peak activity periods of waterbirds. A variety of hunting methods were observed (Appendix S3); however, 92% of the hunting was done using locally crafted single-barrel muzzle-loading guns.

Although 67.64% of the interviewed hunters were aware that hunting is illegal, none of them expressed any fear of prosecution, and neither did anyone report to have encountered enforcement authorities during hunting forays. Monetary gain was reported to be the primary motive for hunting (73.52%); sport and subsistence were the other reported reasons. The average estimated monthly income of a hunter from hunting was US\$ 195.97 ($SD \pm 107.76$); 66.33% higher than the average monthly per capita income in India (US\$130) (The World Bank 2014). 70.95% respondents reported an increase in demand for waterbird meat over the past decade, and 66.91% attributed this to changes in prevalent food habits.

On average, 11.12 hunters (± 5.63 SD) operated in each wetland. Individuals hunted 4.6 times (± 1.15 SD) every month and bagged 20.84 birds (± 4.61 SD) per foray. The mean annual hunting intensity in the 27 wetlands was 1745.19 (± 925.38 SD) (site-level data presented in Appendix S4). None of the respondents reported hunting in Vedanthangal bird sanctuary, but five reported to have hunted in Karikilli bird sanctuary.

Hunters' choice of waterbirds

We recorded 47 species of waterbird being hunted (Appendix S2). On average, each respondent hunted 32 species (± 10.22 SD). Pond heron (*Ardeola grayii*) was the most hunted species (84.19% respondents). All respondents preferred hunting “large waterbirds,” which included

black-headed ibis (*Threskiornis melanocephalus*), Asian openbill (*Anastomus oscitans*), Eurasian spoonbill, glossy ibis (*Plegadis falcinellus*), great egret (*Ardea alba*), painted stork, and spot-billed pelican. 14.80% respondents preferred purple swamphen (*Porphyrio porphyrio*) over other species. 70.95% respondents reported decline in overall species richness and abundance of large-sized waterbirds over the past decade—specifically bar-headed goose (*Anser indicus*), Eurasian spoonbill, glossy ibis, painted stork, Indian black ibis (*Pseudibis papillosa*), and spot-billed pelican. Of these species, the bar-headed goose and the Indian black ibis were not detected during the bird counts. Furthermore, 64.33% of the respondents attributed illegal hunting to be the cause for the observed declines. However, none of the respondents reported changes in overall abundance of waterbirds. In addition to waterbird hunting, all respondents reported hunting of terrestrial avifauna, mammals, and monitor lizards (*Varanus bengalensis*) also.

Market

Hunted birds were primarily sold to local eateries, but were also sold in the open market. 74.63% of the interviewed hunters reported supplying birds to 426 eateries in the region. In stark contrast, only eight out of the surveyed 681 eateries acknowledged serving wild waterbird meat. All the eateries were reported to be small-scale roadside stalls often doubling as bars/liquor shacks. Five open markets were surveyed a total of seven times. 21,864 waterbirds falling under 47 taxa and valued at US\$ 127 289 were observed. Pond heron was observed to be the most commonly traded species ($n = 3077$). The price of the traded taxa varied greatly ranging from US\$ 0.83 for a little ringed plover (*Charadrius dubius*) to US\$ 41.66 for a spot-billed pelican. In stark contrast, eateries served waterbirds at an average price of US\$ 1.6 per 100 g serving.

Drivers of waterbird community

Hunting intensity explained the largest proportion of variance in three of the eight measured waterbird metric—species richness, medium-sized bird density, and piscivore density. Water-spread area accounted for the largest proportion in variance in overall density and that of insectivores. Vegetation cover area, total wetland area, and water-spread shape factor explained variance of only one metric each (Table 1). All measured variables except hunting intensity were positively correlated to the waterbird metrics. The independent effects of all the measured variables on waterbird metrics are presented in Fig. 2.

DISCUSSION

Unprotected and semimanaged agricultural wetlands in Tamil Nadu host a large number of waterbird species. We recorded 53 species in just 27 wetlands. Illegal waterbird hunting was very widely prevalent. We estimated 1745 waterbirds being hunted per wetland each season annually. Hunting was also prevalent in one of the two protected wetland sites suggesting that law enforcement was weak in the study area. Contrary to assumptions, hunting was driven by market demand and not subsistence. We estimated an average monthly income of US\$ 195.96 per hunter earned through hunting. Waterbirds were sold largely to local eateries and not to the open market. This was previously unknown. Hunting explained most of the observed variation in species richness as also densities of medium-sized and piscivorous birds.

We confirm the role of habitat features such as water-spread area and vegetation cover in affecting waterbird populations (Nilsson and Nilsson 1978; Hoyer and Canfield 1994; Chimalakonda 2012). Our findings are contrary to reports that wetlands managed for human use deter biodiversity (Gopal 1991; Middleton 2013). These wetlands

Table 1 Independent effects of measured variables capturing the largest fraction of variance in waterbird metrics

Predictor variable	Attributes of waterbird community	HVP	
		Independent effect (%)	Direction of effect
Hunting intensity	Species richness	31.58	–
	Medium size bird density	59.01	–
	Piscivore density	33.89	–
Water-spread area	Overall density	33.98	+
	Insectivore density	48.60	+
Vegetation cover area	Large size bird density	61.35	+
Total wetland area	Herbivore density	51.96	+
Water-spread shape factor	Small size bird density	25.32	+

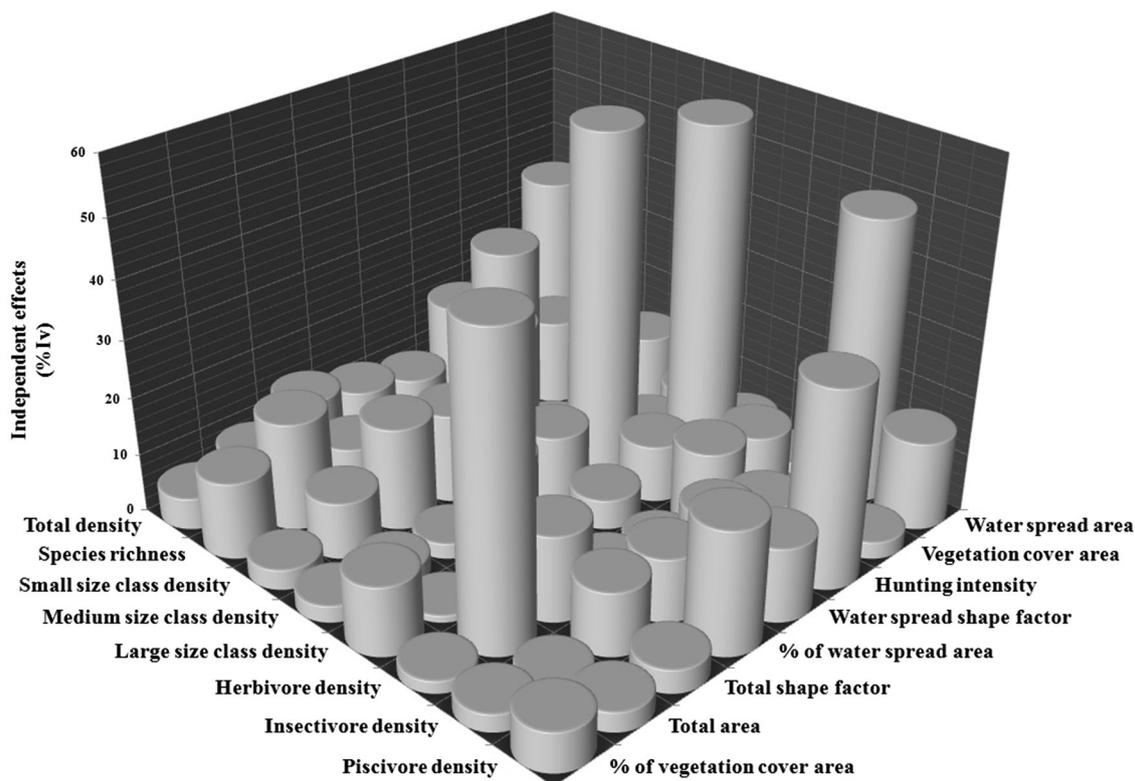


Fig. 2 The independent effects (%Iv) of all the measured covariates on all the measured waterbird metrics (See also Table 1)

could play a pivotal role in waterbird conservation, provided they are accorded adequate protection from illegal hunting. Wetlands are known to support waterbirds due to features at the patch and the landscape levels (Flather and Sauer 1996; Bakker et al. 2002; Winter et al. 2006; Sundar and Kittur 2013). This calls for revising current reserve designs and stresses the need to look beyond large natural wetlands and isolated protected areas as biodiversity refugia.

We discovered that waterbird hunting in the study area is driven by commerce rather than subsistence. Given that attraction of a cash income aggravates hunting pressures (Madhusudan and Karanth 2002), it is possible that subsistence hunting has changed to commercial hunting over time. Respondents suggested that a change in local food habits was resulting in increased demand. Food habits of people in India are known to be highly influenced by customs, caste, and religion (Gadgil and Berkes 1991). Some castes and religions forbid consumption of meat altogether, others prohibit the consumption of meat from several species (Madhusudan and Karanth 2002). While studies (Gadgil and Berkes 1991; Madhusudan and Karanth 2002) have established that erosion of cultural and religious taboos often mediates hunting, it would be worthwhile to further investigate the factors leading to the changes in food habits in the study area.

Is the preference for medium- and large-sized waterbirds leading to local, and potentially larger-scale changes in waterbird community structure? Can changes in demand lead to variation in hunting pressures? These questions beg to be answered considering the immense pressure that wetland habitats experience in south Asia. Habitat deterioration and wetland conversion are often cited as important pressures for waterbirds. Here, we demonstrate that illegal hunting is an additional and serious threat. Hunting is known to occur in wetlands of other parts of south Asia as well. However, the extent of hunting is currently unknown, and requires urgent attention. The widespread awareness among hunters regarding the illegal nature of their activity, and the reluctance of eateries to readily reveal that they serve waterbirds illegally, suggests that the illegally sourced meat could be substituted to legally farmed meat sources such as chicken and ducks. Effective law enforcement will be hugely important in curtailing this threat.

The few studies on unprotected wetlands in south Asia demonstrate novel patterns and processes affecting the structure of waterbird communities, often operating at landscape scales. These studies also highlight that human activities are an overwhelmingly important factor which either facilitates or hinders waterbirds to effectively use unprotected wetlands as habitats. The complex interaction

of wetlands with human use in this region requires more studies. This understanding is critical to ensure that laws and policies catering to wetland conservation in the region are based on regional evidence and not on interpretations of studies elsewhere.

CONCLUSION

Hunting is among the most serious threats to biodiversity and has driven several taxa to extinction. However, hunting remains one of the least studied aspects of biodiversity conservation. In this paper, we use primary information accessed through interviewing active hunters and measuring waterbird habitat quality to study the mechanisms shaping waterbird community. We demonstrate that hunting overrides the effect of habitat in shaping waterbird communities. Hunting results in decreased waterbird diversity and a community skewed in favor of smaller species. The present reserve designs for waterbirds focuses on isolated large wetlands with limited utility to waterbird conservation in a region. We suggest policy revisions to include wetlands across entire landscapes under protection to ensure long-term conservation of waterbirds. The fact that waterbird hunting is commercial in nature calls for improved law enforcement. We recommend substantial investment towards understanding the dynamics of illegal hunting to devise conservation strategies and legal policies for addressing this emerging threat.

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