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Short communication

A network of small protected areas favoured generalist but not specialized wetland birds in a 30-year period

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ABSTRACT

Protected areas (PAs) have been established to promote the long-term conservation of biodiversity and ecosystems. Wetlands, which represent a key habitat worldwide, have been largely destroyed, particularly in more industrialized countries, and their remnants are now often preserved by PA networks, especially in the European Union. We tested the effectiveness of a PA network of 26 small wetlands in preserving wetland birds over a thirty-year period (1989–2019), by investigating changes in species occurrence and relating them to the species' ecological specialization. Out of 23 species, 10 showed an increase in occurrence, 7 remained stable and 6 declined. The number of occupied habitats (between 1 and 8) was significantly associated with the species' trend: specialized species decline, whereas generalists increased. Species with increasing occurrence mostly included common birds, whereas the declining ones were all species with an unfavourable conservation status at the national level. Generalist species increased their occurrence rates, whereas species with stricter, more specialized requirements, generally underwent contraction, suggesting that the conservation of isolated wetlands, managed according to criteria not strictly focused on birds, is not enough to preserve the more specialized species. The proper management of key habitats and the increase of ecological connectivity in the wetland system are crucial for the conservation of wetland-specialist birds.

1. Introduction

In large parts of the world, protected areas (PAs) have been established to promote the long-term conservation of biodiversity and ecosystems (Primack, 2012). The establishment of PAs is one of the main conservation tools, and should contribute to the conservation of all or most species (United Nations, 1992). In most regions, because of several constraints PAs cover a relatively limited amount of land, and in fragmented landscapes often there are no feasible alternatives for conservation to the creation of small protected areas, even if this could result in greater costs than the establishment of a few, larger, protected sites (Armsworth et al., 2011). This frequently leads to networks of sites, which are more or less interconnected among each other (Zisenis, 2017). This is particularly common in Europe, where the millenarian history of land-use and the high human density have resulted in a strong reduction and fragmentation of natural landscapes: no very large PAs occur (Cantú-Salazar and Gaston, 2010) and, despite the increase in the number of PAs thanks to the Natura 2000 policies, serious concerns exist on the degree to which the current PA systems can preserve biodiversity, on the light of the small size of most areas and of the climate change impacts (Gaston et al., 2008b). While small PAs may have a great relevance especially in highly fragmented landscapes and for future environmental restorations, their small extent limits the viability of many species' populations: the effectiveness of small PAs therefore decreases with increasingly isolation (i.e. lack of connection) from similar habitats (Cantú-Salazar and Gaston, 2010). Connectivity, i.e. the ease of movement within a landscape for organisms and the connection of processes at higher ecological levels (Lindenmayer and Fischer, 2007), has become a key component of modern conservation approaches, which should be taken into account in conservation planning (Gippoliti and Battisti, 2017). More specifically, habitat connectivity, i.e. that between patches of habitat suitable for a given species, is particularly important for the conservation of several animal species (Pulsford et al., 2015). The properties of PAs and relative networks (area, connectivity, management regime) are fundamental for effective conservation (Battisti, 2003), and PAs' effectiveness varies across species and contexts (Gaston et al., 2008a) and even according to methods adopted to test their impact (Ribas et al., 2020).

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Wetlands represent a key habitat worldwide, hosting a disproportionally high biodiversity and providing key ecosystem services (Zedler and Kercher, 2005). They have been largely destroyed in industrialized and densely populated areas (Prigent et al., 2012), where their remnants are now often preserved by PAs. Networks of protected wetlands have thus become relatively common, especially in the European Union, where Birds (2009/147/EC) and Habitats Directives (92/43/EEC) prompted the designation of PAs (the so-called Natura 2000 sites) that should realize a "coherent European ecological network" (Habitats Directive). In many European regions that underwent severe anthropogenic alterations, Natura 2000 PAs (and wetlands in particular) are made of relatively small, often isolated sites, not adequately protecting several species and where natural dynamics and processes frequently cannot take place (Zisenis, 2017). Wetland natural processes are largely prevented by anthropic interference (such as artificial river banks, channelling, dams, etc.), and active management plays a pivotal role in determining wetland features, especially in relation to the natural succession (Battisti et al., 2020; Beemster et al., 2010).

Birds, which occupy higher levels of the trophic chain and could be taken as indicators for lower-ranking species (Amat and Green, 2010), represent well the disproportionally high wetland biodiversity. Wetland birds are undergoing widespread declines (Wetlands International, 2020), and their local trends often mirror broader environmental changes (Brambilla and Jenkins, 2009; Martínez Fernández et al., 2005).

With this work, we test the effectiveness of a PA network made of mainly small and isolated wetlands, embedded in a matrix of largely human-altered landscapes, in preserving wetland birds over a thirty-year period. We also aim to evaluate whether the long-term changes in species occurrence are related to species' ecological requirements to shed light on the potentially different effectiveness of the PA network for species with different degrees of ecological specialization. We expected that the species with more specialized habits, which depend on particular and hence more localized habitats, should be more impacted by the increasing isolation (and potentially by the lack of targeted management), and hence could show less favourable occurrence trend.

2. Methods

Our study system consisted of 26 small PAs (average extent ± SD: 41 ± 46 ha; range: 2–170 ha) within the Trento province, N Italy, corresponding to entire wetlands or to semi-natural portions of larger areas where wetland vegetation had been largely cleared out. In the latter case (N = 5), PAs include riparian vegetation or wetland along rivers, or reedbeds and marshes bordering larger lakes (within which hunting is banned over the entire extent), generally covering the remaining wetland vegetation along main waterbodies (Table S1). The study wetlands have been set as PAs in 1986 according to a provincial regulation (law L.P. 23 giugno 1986, n. 14). The main aim of the regulation was the protection of the remaining wetlands to enhance the conservation of wild species and the regulatory services that wetlands provide. All sites are located in Alpine valley floors (see Figs. 1 and S1 for further details), which were regularly inundated by rivers, creating permanent wetlands and temporary marshes, until one century ago. Nowadays, in all main rivers the flow is regulated and wetlands are generally embedded within a matrix of intensively farmed and partly urbanized areas, with scattered forest patches, rocky cliffs and residual grassland. Drainage, reclamation and conversion into intensive crops (such as apple orchards or vineyards), as well as urbanization and infrastructure building, have occurred extensively within the landscape matrix surrounding the study wetlands in the last decades (Pedrini et al., 2005). The establishment of these protected areas had three main positive outcomes for birds, i) the preservation of the remaining wetland sites, ii) the hunting ban within such sites, and iii) active management and restoration to preserve wetland habitats, although not strictly focused on birds. Most of those sites have then become Natura 2000 sites. Habitat management is generally carried out by the same local authority across all sites and hence is relatively similar and largely targeted at the maintenance of wetland habitats, with a particular emphasis on habitats of community interest according to the Habitats Directive since the sites became Natura 2000 sites.

Data about the occurrence of wetland birds were collected by means of dedicated surveys carried out during the breeding season (May–July) in the period 1989–2019 (hence, after they were declared PAs) in the 26 wetlands. Both breeding and migrating species were surveyed, adopting the same methods within the context of different projects (Caldonazzi et al., 1997; Pedrini et al., 2014). However, statistically valid models (see below) were obtained only for breeding taxa plus purple heron *Ardea purpurea* and green sandpiper *Tringa ochropus*, regular migratory species commonly occurring in May. Each site was surveyed from a minimum of three to a maximum of five times per season (except for a few sites that were surveyed twice in 2019), between May and June/early July, i.e. during the breeding period of most wetland birds. Not all sites were visited all years, and in a few years no survey at all was carried out. Overall, data on species occurrence were available for 172 combinations of site/year (average number of years with surveys: 6.61 ± 2.76 DS per site). Each survey at a given site was carried out by one or two observers, who moved across the site following a pre-defined route established to cover the entire extent (or as much as possible) of each study wetland (Caldonazzi et al., 1997; Pedrini et al., 2014).

Generalized linear mixed models (GLMMs) were used to evaluate variation in occurrence. For each species, occurrence at a given site was the dependent binomial variable, whereas site area (log-transformed; referred to PA area) and decade (categorical; 1: 1989–1998; 2: 1999–2008; 3: 2009–2019) were tested as predictors. Site was entered as a random factor to correct for non-independence of data collected at the same wetland. Models were checked for convergence and overdispersion; for 23 species we obtained a valid model, and these species were used to explore i) the temporal variation in occurrence patterns among the three decades, ii) the link between variation and ecological specialization.

To investigate the occurrence trend for each species, we defined the trend as a function of the effects of the factor "decade" in the models, which was expressed as effect of a decade compared to the baseline (decade 1). With a consistent effect (positive or negative) of decade 2 and 3, significant (at $P < 0.1$) for at least one decade, we considered the trend as increase or decline. Null effect of one decade ($z \sim 0.00$ and $P \sim 1$) was considered as coherent irrespective of the sign of the coefficient (this applied only to great cormorant *Phalacrocorax carbo*). If there was no significant effect of decade, we considered the trend as stable. If there was a significant effect for decade 2 or 3, coupled with a non-consistent effect for the other decade, or if there were significant but opposite effects for decades 2 and 3, we considered the trend as fluctuation.

To investigate the link between occurrence trend and ecological specialization, we counted the number of habitats that each species regularly uses (hereafter, number of occupied habitats) within our study area (among the following ones: open water, shallow water, running water, river banks, lake banks, reedbed, transitional habitats reedbed-scrubland, scrubland; Table S2), and used it as a predictor in an ordinal regression with a logit-link function (Cumulative Link Model – CLM), where the dependent variable was trend, treated as an increasingly favourable factor (decline < stable < increment). GLMMs and CLMs were build using *lme4* (Bates et al., 2015) and *ordinal* packages (Christensen, 2019), respectively. Overdispersion was checked by means of the "check_overdispersion" command of *performance* package (Lüdecke et al., 2020).

3. Results and discussion

Out of 23 species, the occurrence in the wetland PA network during

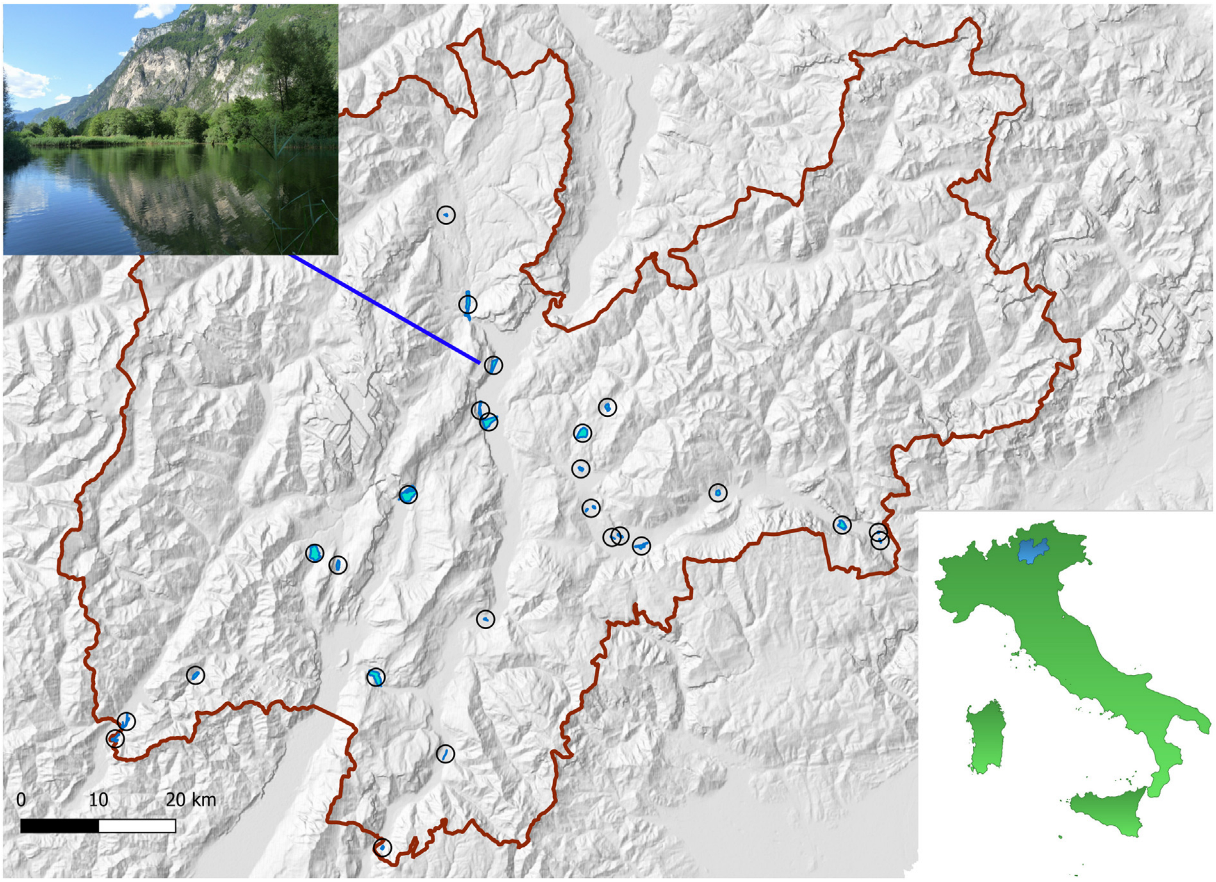

Fig. 1. Distribution of wetland PAs in the Trento province (in light blue with dark blue line, encircled black); the lower right inset shows the location of Trento province in Italy. The example wetland in the upper left corner is "La Rupe". (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
List of species for which a valid modal was obtained, effect of wetland size (area, in ha, log-transformed into models) and time (decade, factorial), occurrence trend in the study network of wetland PAs, conservation status in Italy and European trend (when available; see text). The number of symbols (+ or -) for the variables "Area" and the two decades indicate the significance level of the effect: one symbol for 0.1 < P < 0.05, two for 0.05 < P < 0.01, three for 0.01 < P < 0.001, four for P < 0.0001. A symbol within brackets indicates a coherent but non-significant (P > 0.1) effect (see text).

Species	No. habitats	Area	Decade 2	Decade 3	Trend	Conservation status in Italy	Trend in Europe (1980–2017)
Acrocephalus arundinaceus	1		− −	− − − −	Decline	Bad	Stable
Acrocephalus palustris	2		(−)	−	Decline	Inadequate	Stable
Acrocephalus scirpaceus	2				Stable	Inadequate	Stable
Actitis hypoleucos	2	+	+ +	(+)	Increase	Bad	Moderate decline
Alcedo atthis	2		− −	(−)	Decline	Inadequate	Stable
Anas platyrhynchos	6		(+)	+ + +	Increase	Favourable	Moderate increase
Ardea cinerea	5	+ + + +	+ + +	+ + + +	Increase	Favourable	Moderate increase
Ardea purpurea	3				Stable	Favourable	
Cettia cetti	2		+ + +	+	Increase	Favourable	Moderate increase
Charadrius dubius	2		(−)	− −	Decline	Inadequate	
Cinclus cinclus	1	+ +			Stable	Inadequate	
Cygnus olor	4				Stable	Favourable	Moderate increase
Emberiza schoeniclus	1		(−)	− − − −	Decline	Bad	Moderate decline
Fulica atra	4		+	+ + + +	Increase	Favourable	Moderate increase
Gallinula chloropus	8	−	+	(+)	Increase	Favourable	Stable
Ixobrychus minutus	1	− −			Stable	Bad	
Milvus migrans	5	+ +	+	(+)	Increase	Inadequate	
Motacilla cinerea	2	+ + +			Stable	Favourable	Stable
Phalacrocorax carbo	2		0	+ +	Increase	Favourable	
Podiceps cristatus	2		+ +	+ + +	Increase	Favourable	Moderate decline
Rallus aquaticus	1		(−)	− − −	Decline	Unknown	
Tachybaptus ruficollis	3		+ + +	+ + + +	Increase	Favourable	Stable
Tringa ochropus	3				Stable	Not evaluated	Moderate increase

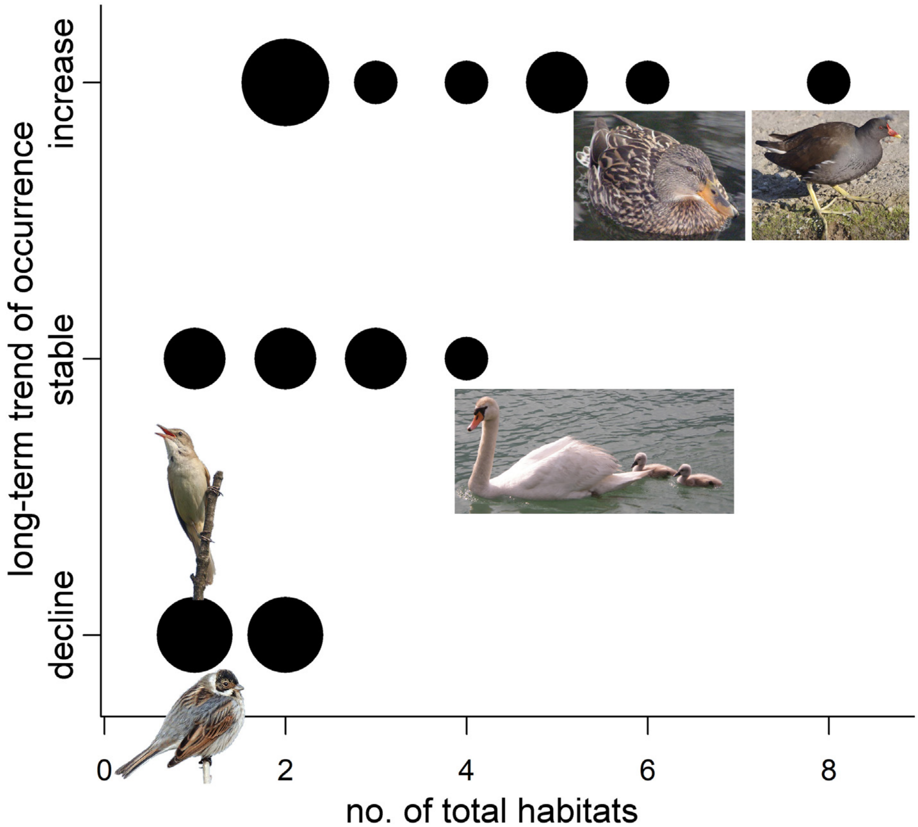

Fig. 2. Graphical representation of the relationship between the number of habitats used by a species and its long-term trend of occurrence within the study network of protected wetlands. Dot size is proportional to the number of species. Example species (from bottom to top, and from left to right) are reed bunting *Emberiza schoeniclus*, great reed warbler *Acrocephalus arundinaceus*, mute swan *Cygnus olor*, mallard *Anas platyrhynchos* and moorhen *Gallinula chloropus*.

the last 30 years increased for 10, was stable for seven species and declined for six (Table 1). No pattern corresponding to fluctuation was detected, whereas occurrence was affected by wetland size (area) in seven species (five positively and two negatively). The number of occupied habitats varied between one and eight, and was significantly related to the species' trend (overall $\beta = 1.06 \pm 0.43$, $z = 2.50$, $P = 0.012$). All species occupying more than four habitats increased, whereas all those declining were species using no more than two habitats (see Fig. 2 and Table S1 for further details).

Generalist species, which are able to use multiple wetland habitats, increased their occurrence rate in the last three decades in the network of wetland PAs in Trentino. These increasing species included some very common birds; eight out of 10 species have a favourable conservation status in Italy (Gustin et al., 2016), and six (out of eight for which the European trend is available, PECBMS, 2019) are stable (two) or increasing (four) at the European level. Stable species included a mix of species with different conservation status, whereas the declining ones were all species with an unfavourable (inadequate or bad) conservation status at the national level. This suggests that the PA network was not able to reverse negative trends, but with some exceptions: great crested grebe *Podiceps cristatus* and common sandpiper *Actitis hypoleucos* are declining moderately at the European level (PECBMS, 2019), but their occurrence increased within the study system (Table 1). Most of the increasing species were regularly hunted before the designation of the PA system, and mallard *Anas platyrhynchos* is still hunted outside the PA network. The protection ensured by PAs likely contributed to the increasing trend of species like mallard, coot *Fulica atra* and moorhen *Gallinula chloropus*, as well to the settlement of species previously not (or only irregularly) breeding in the area, such as grey heron *Ardea cinerea*, great cormorant, great crested and little grebe *Tachybaptus ruficollis* (Table 1) and tufted duck *Aythya fuligula* (Pedrini et al., 2005).

We are aware that our work has some potential limitations. In particular, fluctuations are hard to detect with the coarse (decade-based) temporal resolution adopted. In addition, changes in abundance may occur in species with stable occurrence. However, the limited extent of most wetlands, which strongly reduces the potential number of breeding pairs for several species, limits the potential differences between occurrence and abundance trends. Notably, PA size positively affected the occurrence in only 5 out of 23 species, this suggesting that for several species even small wetlands, if still harbouring suitable habitats, may be occupied by wetland birds. However, PA size did not necessarily coincided with wetland size (a critical factor for several wetland birds, Benassi et al., 2007), because 5 out of 26 PAs covered portions of larger lakes. Little bittern *Ixobrychus minutus*, in particular, a threatened species for the European Union (listed in the Annex I of the Birds Directive 2009/149) and for Italy (Gustin et al., 2016), was negatively affected by wetland size, but it largely occurred in PAs included in larger wetland ecosystems. The smallest wetland occupied by the species covered 5.55 ha. The negative effect of PA size for this rather sensitive species could also result from the stronger anthropic interference at largest sites, which generally undergo higher disturbance due to recreational activities and natural system modifications such as rip-rap on shoreline or beach construction (Brambilla and Pedrini, 2014).

Generalist species have recently increased in many different regions and environments (Davey et al., 2012; Le Viol et al., 2012). The increase of occurrence of generalist species, coupled with the contraction of species with stricter, more specialized requirements, suggests that the conservation of isolated wetlands, managed according to criteria not focused on birds, is not enough to preserve the more specialized species. In our study system, this phenomenon is perfectly exemplified by two rallid species, moorhen and water rail *Rallus aquaticus* (respectively increasing and declining), which show different effects of wetland isolation on the local abundance (Brambilla et al., 2012).

There are many cases of species disappeared from PAs because of habitat loss or degraded habitat quality (Gaston et al., 2008a), or because of isolation (e.g. Kouki and Väänänen, 2000). Specifically, the pattern we found in this system of protected wetlands embedded in an increasingly anthropized matrix, and managed according to criteria not targeted at birds' requirements, is fully consistent with evidence from other wetland systems (Gibbs, 2000; Paracuellos and Tellería, 2004) and from broader-scale studies, which reported how increasingly specialized species display more severe negative response to landscape fragmentation and disturbance (Devictor et al., 2008). In particular, the conservation of flooded *Phragmites australis* reedbeds of sufficient extent, interspersed with patches of open water, had been reported as a key measure for wetland birds in other areas in the Alpine (Morganti et al., 2019) and Mediterranean region (Benassi et al., 2009). Reedbeds represent a key habitat for wetland birds (Battisti et al., 2020) but are not recognised among the natural habitats that particularly require conservation according to the Habitats Directive, this implying that they are not target habitats for the designation of Special Areas of Conservation, and generally are not the object of conservation efforts and dedicated management. Within our study system, species relying exclusively on reedbeds and/or transitional habitats reedbed-scrubland were among those displaying the most negative trends (Table S2). In addition to the species for which a quantitative analysis was possible, other ones tied to reedbeds, *Carex* sp. and wet grasslands, such as little craze *Zapornia parva*, spotted crake *Porzana porzana* and yellow wagtail *Motacilla flava*, which occurred in a few sites at the beginning of the study, completely disappeared as breeding species from the study system. Nevertheless, it is likely that without the PA network the trend of species relying on reedbeds, transitional reedbed-scrublands and other 'marginal' habitats would have been even more negative: without PAs several reedbed patches along lakes or rivers and many wetlands would have been destroyed, or reclaimed and converted into crops, respectively, as occurred to most non-protected sites (Pedrini et al., 2005).

Thirty years of wetland conservation through the establishment and maintenance of rather small and isolated PAs, which covered the most valuable sites that escaped destruction in the past decades, have preserved the most relevant among the remaining wetlands from further drainage. The other, small, remnants have been almost completely reclaimed and converted into anthropic land-uses. This 30-year strategy resulted in the increase of generalist species, but was not enough to revert the negative trend of the most specialized species. Two complementary measures are urgently required to counteract the progressive disappearance of most specialized wetland species: targeted management to preserve key habitats and mosaics (Morganti et al., 2019) and the increase of ecological connectivity in the wetland system (Whited et al., 2000). Species-specific insights are required to quantify apart the independent and combined importance of local habitats and connectivity. Connectivity, a critical issue in the fragmented landscapes of western Europe (cf. Jongman et al., 2011), might be enhanced by corridors and/or stepping stones in the landscape between the main wetlands, by e.g. the partial restoration of drained wetlands, the improvement of residual elements in the matrix such as ditches, or the restoration of riparian vegetation along rivers and waterbodies (Worboys et al., 2016). The known impact of isolation on some target species (Brambilla et al., 2012) and future research on other specialized wetland birds may help set goals and indicators for connectivity restoration (Gippoliti and Battisti, 2017), while the provincial law L.P. 11/07, which encourages the realization of ecological networks connecting protected areas, provides the regulatory framework for interventions aimed at relaxing the strong isolation currently experienced by wetland PAs in the region.

Author statement

Mattia Brambilla: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Supervision; Validation; Visualization; Writing - original draft
Franco Rizzolli: Data curation; Investigation; Methodology; Supervision; Validation; Visualization; Writing - review & editing
Alessandro Franzoi: Data curation; Investigation; Methodology; Validation; Visualization; Writing - review & editing
Michele Caldonazzi: Data curation; Investigation; Visualization; Writing - review & editing
Sandro Zanghellini: Data curation; Investigation; Visualization; Writing - review & editing
Paolo Pedrini: Conceptualization; Data curation; Funding acquisition; Investigation; Methodology; Project administration; Resources; Supervision; Validation; Writing - review & editing.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2020.108699.

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