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Individual and demographic responses of a marsh bird assemblage to habitat loss and subsequent restoration

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Abstract

Background: The alteration and loss of habitats are two of the main threats that biodiversity conservation is currently facing up to. The present study describes the effects of a perturbation and restoration in a reedbed habitat on a bird assemblage. We studied the bird community of a wetland of central Spain between 1995 and 2009, during which time an anthropic perturbation altered the original structure of the habitat; subsequently, as a result of restoration works, the habitat returned to its original state.

Methods: We evaluated the effects on six population and physical parameters of the birds at three different phases of their life cycles (breeding, wintering and post-breeding migration seasons) before, during and after the habitat alteration. GLM was used to analyze the influence of three independent variables (year, perturbation phase and temperature).

Results: The relative abundance and the species richness values decreased when habitat was altered, but then recovered as a result of the regeneration works. This pattern was the clearest amongst specialist species. Breeding success also declined during the perturbation phase and then increased; likewise, the sex ratio changed given that the proportion of male birds increased when habitat was altered. These results are discussed in relation to changes on availability of resources in altered habitats, to the adaptive mechanisms in the exploitation of ecological requirements and to the selection of optimum and sub-optimum habitats by generalist and specialist species.

Conclusions: Ecosystem restoration can favour the recovery of population indexes of specialist passerines, although it depends on the efficiency of the type of restoration activity performed and on the complexity of the habitat.

Keywords: Habitat loss, Land-use planning, Marsh, Restoration, Ringing station, Reedbed

Background

Habitat loss is the main factor behind the simplification and deterioration of biological diversity (Laurence and Useche 2009). In general, biodiversity indexes and indicators are chosen for quantifying the impacts that the two mentioned threats may provoke as well as for assessing their consequences in relation to the environmental global change (Henle et al. 2004; Santos and Tellería 2006).

In terms of wildlife, studies of habitat alteration have revealed consequences such as the loss of species richness and diversity (Ockinger et al. 2010), shifts in behavioural parameters, and changes in population dynamics (Tellería and Santos 1999). The latter process may include the decline of breeding success, the increase of mortality rates due to depredation, the deterioration of physical condition, the replacement of specialist by generalist species and shifts in population structure in terms of age and sex ratios (Andrén 1994; Dale 2001; Díaz et al. 2005).

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In this sense, the magnitude of the impact of habitat alteration depends on the ecological requirements of the studied species (Lampila et al. 2005). So, most specialist species are the most affected (Tellería and Santos 1999).

The majority of studies investigating the negative impacts of habitat loss on wildlife have been performed in forest environments (McGarigal and Cushman 2002; Santos and Tellería 2006). Mature forests are more intuitive to identify and host a large amount of biomass, which makes easier checking changes in the tree and shrub layers composition and abundance after a perturbation (Skole and Tucker 1993; Loiselle et al. 2010). Moreover, this knowledge on the effects of changes in forests traits has enabled precautionary strategies when planning potentially threatening projects towards these forest habitats (e.g. territorial plans, infrastructure projects; Stouffer et al. 2006). By contrast, less detailed knowledge exists regarding other ecosystems such as those occupying small-scale areas, those that have been managed by humans secularly, those relatively inaccessible to humans or those in an intermediate phase of evolution towards potential climax habitats (Santos and Tellería 2006). Despite this lesser attention to non-forest habitat, they are home to many singular or key biodiversity elements (Soulé et al. 1988).

Most previous studies on the effects of habitat alteration have been carried out on two well-defined phases: before and just after happening an ecological impact (Saunders et al. 1991) without considering a further third potential phase such as the restoration of the original habitat traits. Little is known about the recovery patterns of wildlife in ecosystems where restoration works have been implemented (Lindenmayer et al. 2010). Thus, the response of wildlife to a further phase characterized by the recovery of the initial traits of the studied habitat has been occasionally analyzed using predictive models (e.g. Rey-Benayas et al. 2010). But from a practical perspective, only few studies have shown the processes occurring in a *before-during-after* sequence of habitat perturbation and recovery, especially when the period *after* includes active land management (e.g. Hoover 2009; Golet et al. 2008, 2011). This lack of previous knowledge could be due to the inherent hardness in studying a whole regeneration process in environments such as forests, whose restoration to full functionality requires long-term monitoring (Honnay et al. 2002), or given the difficulty in identifying the habitat characteristics before the impact.

This study aimed to evaluate the effects of habitat alteration and subsequent regeneration on different population and ecological parameters of a passerine bird community in a marsh reedbed. Reedbeds are very productive environments since they receive high levels of solar radiation together with high humidity. Their vegetation structure is dense and, therefore, inaccessible to many animals including human. For this reason, several bird species select this habitat to carry out almost all or part of their life-cycles. So reedbeds are important feeding, breeding and resting places for many birds (Hawke and José 1995; Poulin et al. 2002).

The objectives of this study were: (1) to understand the impact of an anthropic perturbation on a marsh-dwelling bird community and its response to subsequent habitat restoration; (2) to evaluate the factors influencing the population dynamics of the affected species by habitat alteration; and (3) to analyze the effects that habitat management could have on the recovery of certain parameters of the studied species.

Methods

Study area

Data were collected at Las Minas ringing station in San Martín de la Vega (Madrid, Central Spain, 40° 13′ 29″ N, 03° 32′ 51″ W, 510 m a.s.l.). The area consists of a wetland, dominated by reed (*Phragmites australis*) from the shore of the Jarama river up to 200 m where there are several types of crops dominated by cornfields *Zea mays*. Aside from the reeds, there are bush stands of *Typha* sp., *Scirpus* sp., *Juncus* sp. and *Rubus* sp. as well as trees (*Salix alba*, *Populus alba* and *Tamarix* sp.). The study area occupies a reedbed in a continuous patch of 8.10 ha (De la Puente et al. 2002; Bermejo 2004).

Habitat loss and restoration work

The perturbation that caused the habitat alteration occurred in July 2002, when the hydro-dynamics of the reedbed was affected by the change of the irrigation practices on neighbouring crops, from a flood to a drip system. The water supply was reduced and, as a result, groundwater levels fell, thereby preventing the reedbed from flooding. Hence, the regeneration rates of the reeds diminished notably and the occupation and density of plants were affected. In October 2006, we started restoration works aiming at regenerating the area's hydrological dynamics through leading of excess water from local irrigation crops to gravel pits near the study area. Thus, from autumn 2006 onwards changes in water availability and a rise in groundwater levels began to occur, which encouraged the reedbed to spread back. Between 2007 and 2009, the reedbed grew and flooded, and there was also an increase in the number of new-growth plants; eventually, the reedbed returned to its original state.

Given that the habitat alteration process could not be predicted, no data-gathering aimed at quantifying the magnitude of habitat changes could be undertaken. Thus, the habitat alteration was studied in terms of the following periods:

1. *before* the perturbation (April 1995–first half July 2002), when the reedbed was in its original state with its traditional hydrological dynamics;
2. *during* the perturbation (second half July 2002–October 2006), when the irrigation of the area was reduced and reedbed's initial structure changed, reducing both in size and density; and
3. *after* the perturbation (November 2006–December 2009), starting with the works to restoring the area's hydrological dynamics and leading to the flooding and reoccupation by reeds of the degraded areas of reedbed.

Field work and studied variables

Bird sampling

From 1st April 1995 to 27th December 2009 we sampled birds of the study area at a constant effort ringing station (Pinilla 2000). Eleven mist-nets covering a lineal distance of 138 m were placed at the same sites. Data collection took place periodically once a week, throughout 5 h from dawn onwards (De la Puente et al. 2002). Trapped birds were handled by expert ringers, who took the following data:

(1) details of capture: date, time, weather conditions.
(2) identification of the sampled bird: species, age (into two categories: *juveniles*—birds in their first calendar year or first winter after fledging and *adults*—the rest of the birds) and sex (*male*, *female* or *unknown*; Svensson 1992; Jenni and Winkler 1994).
(3) biometric measurements: lengths of wing, third primary feather and tarsus (in mm, with the help of a millimeter ruler and a digital caliper), weight (in g, with a 0.1 g precision digital scale), and codes of subcutaneous fat levels and pectoral muscle projection (Barlein 1995; Deustche Ornithologen-Gesellschaft 2011).

Population dynamics variables

The experimental unit selected was the bird ringing day. The days were grouped into three life-cycle seasons: (1) *breeding* (15th April–15th July); (2) *post-nuptial/autumn migration* (16th July–15th October), and (3) *winter* (15th November–15th February). This distribution of dates enabled us to evaluate the effects of habitat alteration and subsequent restoration on population parameters of the species selected in each season because some bird species exhibit differing phenological patterns and ecological requirements (Table 1). The pre-nuptial migration season was not analyzed due to a lack of captures for each of the selected representative species for this period (De la Puente et al. 2002).

Then, we evaluated six dependent variables related to population dynamics and structure and to physical condition (Table 1). We considered all the bird species jointly ("All") for the dependent variables *relative abundance* and *species richness*, as well as different model species for the whole dependent variables. We chose the model species for each life-cycle season according to the following species-selection criteria: (1) most number of captures, (2) representatives of different migratory strategies (long and short distance migrant, or sedentary), and (3) habitat selection specificity (habitat generalist or reedbed specialist, see Table 1 for description). For the breeding season, we selected the Common Reed Warbler (*Acrocephalus scirpaceus*) and the Cetti's Warbler (*Cettia cetti*) as model species, while the Reed Bunting (*Emberiza schoeniclus*), the Common Chiffchaff (*Phylloscopus collybita*) and *C. cetti* were chosen as representative of wintering species. The most abundant species during post-nuptial migration selected as models were *A. scirpaceus*, the Sedge Warbler (*Acrocephalus schoenobaenus*) and the Willow Warbler (*Phylloscopus trochilus*) (a detailed ecological description for each species could be checked in Cramp 1998).

The dependent variables were analysed in relation to four explanatory covariates. First, the phase of habitat alteration (*before, during* and *after* the perturbation) was considered as categorical classification factor. The year or wintering period of the ringing day was also included as classification factor. Weather conditions were recorded with the purpose of knowing its influence on the capture rates and the physical conditions of trapped birds; thus, we collected the *temperature* and *relative humidity* during each ringing day from the nearest meteorological station (82240 (LEGT), 11.2 km to the study area, www.tutiempo.net). These two variables were considered as quantitative covariates in the analyses.

Statistical analyses

The quantitative response variables and covariates were logarithmically converted to suit them to a normal distribution that were checked through Kolmogorov–Smirnov tests. Subsequently, Generalized Linear Models (GLM) with a normal probability distribution and log-link function were performed for each of the response variables, for the different model species and for each life-cycle season. The categorical classification factors were *phase* (*before, during* and *after*) and *year* or *wintering period*, the latter being nested into each corresponding *phase.* This way, we tried to integrate in the analysis the greatest amount of variability recorded for each ringing day. As independent quantitative covariate we included

Table 1 Dependent variables considered in this study and their description, as well as the model species considered for each of the season (breeding: 15th April to 15th July, post-breeding migration: 16th July to 15th October and wintering: 15th November to 15th February) that were included in the statistical analyses (all = every sampled bird of all species)

Dependent variable	Description	Breeding species	Post-breeding migratory species	Wintering species
Relative abundance	Sampled birds (*n*)/ringing days (*n*)	All, *Acrocephalus scirpaceus*[a,c], *Cettia cetti*[a,e]	All, *Acrocephalus schoenobaenus*[a,c], *Acrocephalus scirpaceus*[a,c], *Phylloscopus trochilus*[b,c]	All, *Cettia cetti*[a,e], *Emberiza schoeniclus*[a,d], *Phylloscopus collybita*[b,d]
Species richness	Sampled species (*n*)/ringing days (*n*)	All	All	All
Proportion of juvenile birds[1]	[Juvenile birds (*n*)/adult birds (*n*)]/ringing days (*n*)	*Acrocephalus scripaceus*[a,c], *Cettia cetti*[a,e]	*Acrocephalus schoenobaenus*[a c], *Acrocephalus scirpaceus*[a c], *Phylloscopus trochilus*[b c]	*Cettia cetti*[a,e], *Emberiza schoeniclus,*[a,d], *Phylloscopus collybita*[b,d]
Sex ratio	[Males (*n*)/females (*n*)]/ringing days (*n*)	*Acrocephalus scripaceus*[a,c], *Cettia cetti*[a,e]	None[2]	*Cettia cetti*[a,e], *Emberiza schoeniclus*[a,d]
Subcutaneous fat	Average fat score of the sampled birds/ringing days (*n*)	*Acrocephalus scripaceus*[a,c], *Cettia cetti*[a,e]	*Acrocephalus schoenobaenus*[a,c], *Acrocephalus scirpaceus*, *Phylloscopus trochilus*[b,c]	*Cettia cetti*[a,e], *Emberiza schoeniclus*[a,d], *Phylloscopus collybita*[b,d]
Body condition	[Average values of residuals of weight (g)/length of third primary feather (mm)]/ringing days (*n*)	*Acrocephalus scripaceus*[a,c], *Cettia cetti*[a,e]	*Acrocephalus schoenobaenus*[a,c], *Acrocephalus scirpaceus*[a,c], *Phylloscopus trochilus*[b,c]	*Cettia cetti*[a,e], *Emberiza schoeniclus*[a,d], *Phylloscopus collybita*[b,d]

[a] reedbed specialist; [b]habitat generalist; [c]long-distance migrant; [d]short-distance migrant; [e]sedentary

[1] During breeding season, this parameter was considered as an index of breeding success. [2] Differences in sex determination cannot be addressed by observational procedures for the most common migratory species at the study area (Svensson 1992; Jenni and Winkler 1994)

temperature of the ringing day and discarded *relative humidity* because both variables were significantly and negatively correlated (Spearman correlation test = −0.74; $p < 0.05$). We chose to maintain *temperature* as its values change seasonally and influence to a greater extent the responses of non-tropical avian species to environmental variability (Perrins 1970; Ball and Ketterson 2008). As a result, 42 different models were performed. The statistical analyses were conducted with the software Statistica 6.1 (StatSoft 2004).

For each model, the results of the univariate significance tests adjusted to a Type-III model were considered, along with the comparative tests of the sums of squares of the model with that of their residues, generated by the R^2 statistic as an index of the variability of the model.

Results

Data were collected on 621 ringing days during the breeding (189), wintering (175) and post-nuptial migration periods (257). In all, 36,984 birds were sampled, 10,311 in the breeding season, 8247 in winter and 18,426 on migration, for a total of 99 different species. Given the large number of GLM applied, only the results of the models with statistical significance ($p < 0.05$) are shown.

Breeding season

Regarding the breeding season, habitat alteration led to a reduction in the relative abundance of birds but subsequently the situation changed and the number of captures increased after starting the habitat regeneration works ($F_{2,171} = 23.75$; $p < 0.001$ for all species jointly; $F_{2,171} = 55.38$; $p < 0.001$ for *A. scirpaceus*; $F_{2,171} = 7.91$; $p < 0.001$ for *C. cetti*; Figs. 1, 2 and 3). The *temperature* influenced the abundance of sampled birds in a positive and direct way ($F_{1,171} = 94.53$; $p < 0.001$ for all species jointly).

The alteration in the reedbed led to a reduction in the body condition of *A. scirpaceus* ($F_{2,120} = 9.14$; $p = 0.001$) which could not recover with the return of the reedbed to the initial conditions. In the case of *C. cetti*, during the period of habitat disturbance the proportion of juvenile birds in relation to adults decreased but then rose again during habitat recovery, despite only marginally ($F_{2,171} = 2.72$; $p = 0.059$; Fig. 4). The sex ratio also changed in the *C. cetti* during the breeding season and the number of males in relation to females increased when habitat was altered ($F_{2,114} = 5.20$; $p = 0.006$; Fig. 4).

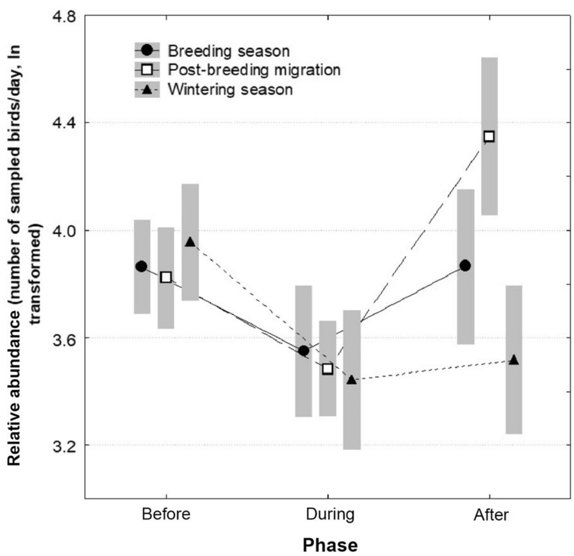

Fig. 1 Relative abundance of birds (number of sampled birds/day, Ln transformed, 95% confidence interval—grey bars) before, during and after the perturbation of the studied habitat for all species jointly during the breeding season (black circles), the post-breeding migration season (white squares) and the wintering season (black triangles)

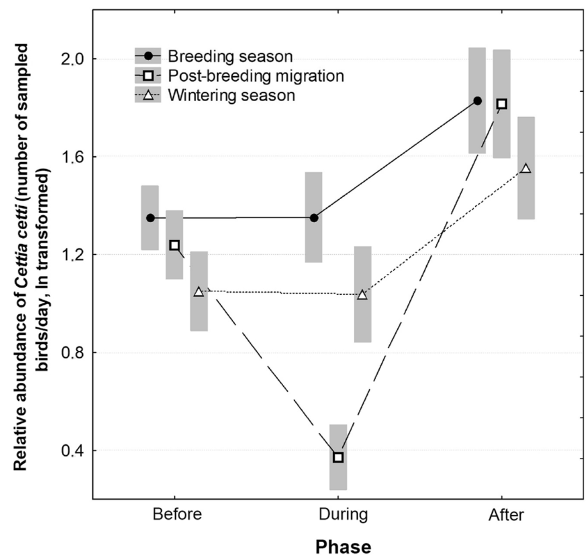

Fig. 3 Relative abundance of the Cetti's Warbler *Cettia cetti* (number of sampled birds/day, Ln transformed, 95% confidence interval—grey bars) before, during and after the perturbation of the studied habitat during the breeding season (black circles), the post-breeding migration season (white squares) and the wintering season (white triangles)

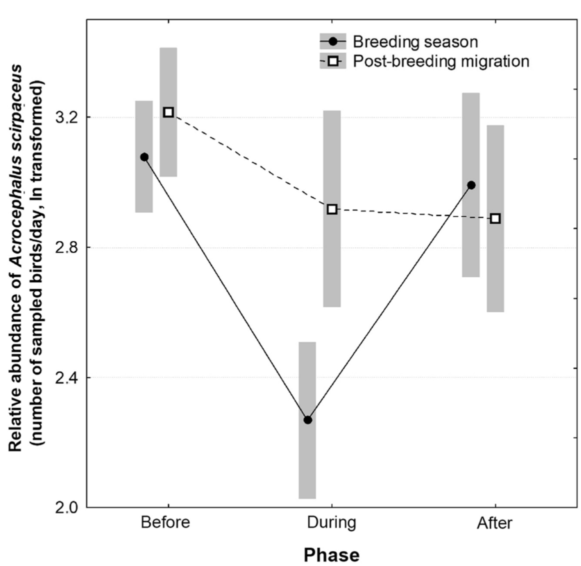

Fig. 2 Relative abundance of the Common Reed Warbler *Acrocephalus scirpaceus* (number of sampled birds/day, Ln transformed, 95% confidence interval—grey bars) before, during and after the perturbation of the studied habitat during the breeding season (black circles) and the post-breeding migration season (white squares)

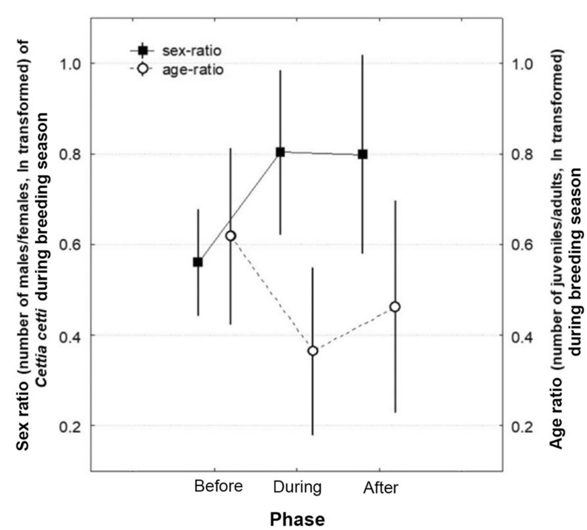

Fig. 4 Sex ratio in Cetti's Warbler *Cettia cetti* (males/females, Ln transformed, 95% confidence interval, black squares, left *Y*-axis) and age ratio in Cetti's Warbler (juveniles/adults, Ln transformed, 95% confidence interval, white circles, right *Y*-axis) before, during and after the disturbance of the studied habitat during the breeding season

Post-breeding migration season

Our results showed a reduction in the number of migrant birds and species that visited the study area during the habitat disturbance; nevertheless, these values subsequently recovered during the phase *after* ($F_{2,228} = 7.00$; $p = 0.001$ for abundance of all species jointly; $F_{2,228} = 51.96$; $p < 0.001$ for species richness;

Figs. 1 and 5). Both *A. scirpaceus* and *A. schoenobaenus* followed the same pattern of relative abundance decrease, and a subsequent increase was apparently noticed after habitat regeneration works ($F_{2,139}=8.05$; $p<0.001$ for *A. scirpaceus*, Fig. 2; $F_{2,61}=4.40$; $p=0.016$ for *A. schoenobaenus*). Similarly to the breeding season, higher *temperature* values positively related with more birds sampled during the post-breeding migration period ($F_{1,228}=6.18$; $p=0.014$ for abundance of all species jointly).

The physical condition of several studied species also changed during the habitat deterioration period. Values of body condition in *A. scirpaceus* altered ($F_{2,74}=6.19$; $p=0.003$). Physical condition was also negatively affected in *P. trochilus* during the disturbance, but improved after habitat regeneration ($F_{2,56}=3.33$; $p=0.042$ for subcutaneous fat; $F_{2,68}=3.40$; $p=0.038$ for body condition).

Wintering season

The modification in the characteristics of the reedbed diminished the abundance of birds and species present, though the latter only marginally ($F_{2,153}=20.55$; $p<0.001$ for abundance of all species jointly; $F_{2,153}=2.74$; $p=0.061$ for species richness; Figs. 1 and 5). The targeted wintering species decreased their abundances during the drought phase of the reedbed and then recovered ($F_{2,153}=10.21$; $p<0.001$ for *C. cetti*; $F_{2,150}=18.50$; $p<0.001$ for *E. schoeniclus*; and $F_{2,148}=4.95$; $p=0.008$ for *P. collybita*). Unlike the rest of studied seasons, *temperature* did not condition the number of birds at the study site.

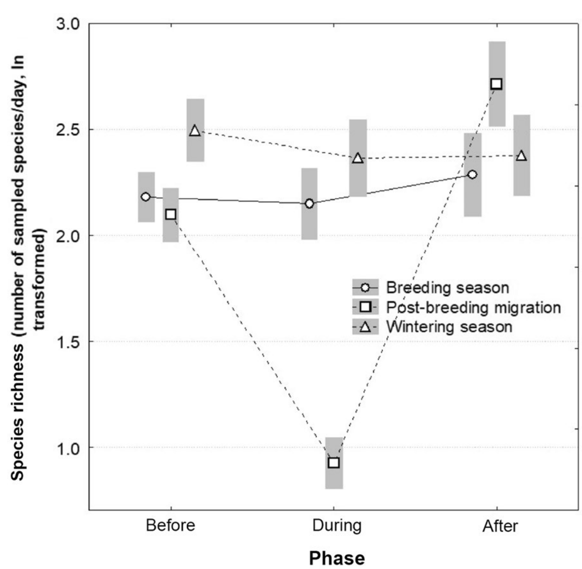

Fig. 5 Species richness (number of sampled species/day, Ln transformed, 95% confidence interval—grey bars) before, during and after the perturbation of the studied habitat during the breeding season (white circles), the post-breeding migration season (white squares) and the wintering season (white triangles)

Habitat disturbance had significant consequences on the variables related with birds' physical condition during winter: values of subcutaneous fat were lower in *E. schoeniclus* and *P. collybita* ($F_{2,146}=8.46$; $p<0.001$ for *E. schoeniclus*; $F_{2,136}=16.09$; $p<0.001$ for *P. collybita*) while body condition was also negatively affected in *C. cetti* ($F_{2,110}=3.29$; $p=0.040$). For these species, the restoration works did not get the recovery of physical condition values previous to the habitat perturbation. The proportion of juveniles in relation to adult birds also increased in *E. schoeniclus* ($F_{2,144}=3.65$; $p=0.028$), while in *C. cetti* the number of males in relation to females also increased during habitat alteration period ($F_{2,98}=6.97$; $p=0.001$).

Discussion

It was not possible to quantify the degree to which the habitat was degraded given that the change in the site's hydrological regime was unexpected. Thus, conclusions regarding the influence of the processes of habitat loss and alteration would have been more clear-cut if quantified data on changes in habitat structure and functionality had been available (Stouffer et al. 2006, 2009). Nevertheless, the phases in which the disturbance and subsequent habitat regeneration occurred were clearly identified which, along with the large amount of data collected, allow the performed analyses providing conclusions regarding population trends. Furthermore, we could not assess the results of our study in relation to other comparable surrounding sites since bird-monitoring programs in marsh habitats with similar methodology were not implemented during our field work. This information might have contributed to test if the results of the studied parameters in our birds were certainly caused by the local habitat alteration or were based on demographic processes occurring at a wider geographic scale.

Effect on the relative abundances and species richness

Both the relative abundance and the species richness of birds were affected negatively by the loss of quality in the original habitat (Figs. 1, 5). This decrease in numbers was the most obvious in the specialist reedbed species (*A. scirpaceus*, *C. cetti*, *A. schoenobaenus* and *E. schoeniclus*; Santos et al. 2002; Figs. 2, 3). The reduction in the availability of trophic resources, the increase of competition for these resources with other generalist species and the changes in vegetation structure are effects associated to habitat fragmentation or loss that leads to a decline in total bird abundance (Saunders et al. 1991). Moreover, the reduced abundance was linked to a drop in the number of species inhabiting the site due to the possible simplification of the habitat and lack of resources (Dolman and Sutherland 1994; Zanette et al. 2000). This alteration of relative abundances and species richness occurred in the three life-cycle seasons studied, although the species richness was only affected during the winter and migratory periods. Site fidelity and habitat selection during the breeding season could determine that specialist reedbed bird species remained to the study area despite the reduction in habitat quality (Schmidt 2001; Hoover 2003). Outside breeding season, birds generally show a greater plasticity in their habitat selection patterns and can satisfy their ecological requirements visiting other habitats with a greater resource availability (Rey and Valera 1999; Pérez-Tris and Tellería 2002).

The restoration works in the reedbed ensured an increase of the relative abundance and species richness, particularly during the breeding season. Again, reed specialists were more sensitive to the habitat improvements and likewise responded more positively to the management works. This situation could imply that restoration of a specific, more homogenous habitat benefits specialist species, whereas the species with a greater adaptive flexibility could react to restoration works in a more attenuated way and over the long-term (Wood et al. 2004).

Effect on other demographic parameters

In terms of population dynamics, *C. cetti* became the most sensitive species to habitat changes, especially during the breeding season. The number of juveniles born in the study site dropped significantly when the habitat deteriorated, but then recovered with restoration works. The lack of available resources could condition breeding success (Dolman and Sutherland 1994; Oro et al. 2004; Granborn and Smith 2006) and thus reduce the proportion of new born individuals. Similarly, the decrease in the proportion of breeding females during habitat degradation could also trigger a drop in productivity due to the total lower number of chicks fledged. The rationale behind the increase in the proportion of males could be the differences in the way males and females select optimum territories (Morales et al. 2008): females increase their presence in areas that best fit their ecological requirements, whilst males are apparently less site specific and continue occupying the same sites regardless of their poorer quality (Møller 2002).

Another consequence of the habitat alteration was the increase in the proportion of juvenile *E. schoeniclus* during winter. Due to lack of experience, more inexperienced birds are less able to detect optimum areas, while dominant birds (adults > juveniles) occupy more suitable areas and despotically drive subordinates out into areas of suboptimum habitat (Sol et al. 1998; Grande et al. 2009).

Effects on physical condition

The mean scores of subcutaneous fat, closely linked to the feeding possibilities in and around the study area (Pérez-Tris 1999), fell significantly during the habitat alteration phase. This decrease mainly occurred outside the breeding season when migrants have the greatest need to accumulate fat reserves (e.g. *A. schoenobaenus* and *P. trochilus*) or to survive during the winter (e.g. *P. collybita*, *E. schoeniclus* and *C. cetti*; Alerstam and Hedenstrom 1998). Fat scores did not recover after the regeneration of the reedbed which reveals the existence of factors that could not be controlled. Proof of this is the low variability values (R^2) contained in the models in relation to fat scores (see Additional file 1: Table S1, S2, S3).

In terms of bird's body condition, which is a better variable for assessing the overall fitness (Pérez-Tris 1999), our results differed between species and periods. This suggests that the variables considered are subject to a great environmental variability and to individual differences not controlled in this study (Bearhop et al. 2004).

Conclusions

The results revealed that less studied habitats such as reedbeds respond to alteration and loss of habitat like other more studied environments such as forests. So species inhabiting reedbeds, some of which are highly selective (Poulin et al. 2002; Paracuellos 2006), may become globally threatened as a result of reedbed depletion (Hawke and José 1995; Cramp 1998). Specialist species at the site were probably the first to disappear, which reveals how habitat change led to both a loss in relative abundance and in species richness (Santos and Tellería 2006).

Species seemed to be sensitive to habitat restoration works, being able to detect areas offering more ecological resources (Fahrig 2003; Hoover 2009; Lindenmayer et al. 2010). Both generalist and specialist species increased in abundance and richness after the start of the recovery of the original conditions of the reedbed. On the other hand, the recovery of values of the demographic variables studied seemed to take place more slowly (Selwood et al. 2009). Overall productivity recovered after the increase in habitat quality, although the sex and age ratios outside the breeding season remained at similar levels to those detected during the alteration period. It is possible that the functionality of the ecosystem was not yet fully fulfilled during the phase *after* so changes of sex-ratio in some species still remain after finishing our study. This fact could be based on the differential habitat selection by different population groups: females and adults tend to have more specific habitat requirements than, respectively, males and non-adult birds (Cody 1987).

Conservation implications

With the purpose of ensuring that habitat loss and fragmentation have as little impact as possible on biological diversity in habitats such as reedbeds, we recommend that:

(1) Projects including the monitoring of wildlife species are linked to the study of habitat characteristics and their trends, taking into consideration parameters such as the structure, abundance and regeneration of the vegetation (Poulin et al. 2002).
(2) It is important to identify what habitat traits are key with the purpose of recreating such characteristics when restoration is to be applied (Rey et al. 2003; Golet et al. 2011).
(3) Before carrying out works aimed at restoring habitats, it is important to select which are the target species and communities to be benefitted.
(4) Restoration works might favour most ecological processes (e.g. water quality, soil protection). However, if the concrete functionality of these processes cannot be determined, the best option is to recreate the situation existing before the disturbance as faithfully as possible (Allen 2003).
(5) Monitoring programmes for species and populations should be implemented as part of any ecosystem restoration programme (Golet et al. 2011).

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s40657-020-00190-0.

Additional file 1: Table S1. General Linear Models (GLM) with statistically significant results ($p < 0.05$) during breeding season. **Table S2.** General Linear Models (GLM) with statistically significant results ($p < 0.05$) during wintering season. **Table S3.** General Linear Models (GLM) with statistically significant results ($p < 0.05$) during autumn migration season.

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Authors' contributions
The author read and approved the final manuscript.

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Availability of data and materials
The datasets used in the present study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
This work complies with the current laws regarding wild species protection of Spain (Act 42/2007) and the European Union (Birds Directive 2009/147/CE). The experimental capture and study in hand of the birds were performed counting on permits granted by the competent authority (Comunidad de Madrid) based on derogations for research purposes (art. 61 of Spanish Act 42/2007).

Consent for publication
Not applicable.

Competing interests
The author declares that he has no competing interests.

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