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Status of the Northern Silvery Grebe *Podiceps juninensis* in the northern Andes: recent changes in distribution, population trends and conservation needs

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Summary

The Northern Silvery Grebe *Podiceps juninensis* is an aquatic bird species considered Vulnerable to extinction in Ecuador and Endangered in Colombia. Globally the species is considered Near Threatened. Herein we report recent changes in distribution and population trends for the subpopulation in the northern Andes (Ecuador, Colombia), which is small and isolated. The Northern Silvery Grebe has undergone two documented extirpations, and at least one colonisation event, over the last three decades. More than 90% of the subpopulation relies on two wetlands, La Mica and Colta lakes in Ecuador, with the latter facing an accelerated sedimentation process which jeopardizes the fate of the wetland, and the species, in the mid-term. The population of La Mica lost 80% of its birds in 2000 after the damming of the lake, but then remained stable over our census period (2004–2013). In contrast, the Colta population results from a recent colonisation in the early 2000s, and has experienced an exponential growth since then (annual population multiplication rate: 1.464). The growth of this population is so fast that it must include an important contribution of immigrants. The temporal coincidence between the drop in population size at lake La Mica and the colonisation of lake Colta suggests that the Colta population was founded by immigrants from La Mica. Finally, the absence of current reports of the species at wetlands in Colombia suggests that the species remains at very low numbers, bolstering the shrinkage in northern distribution.

Resumen

El Zambullidor Plateado Norteño *Podiceps juninensis* es una especie acuática considerada Vulnerable en Ecuador y En Peligro en Colombia, globalmente la especie se considera Casi Amenazada. En este artículo presentamos una revisión sobre cambios recientes en la distribución y tendencias poblacionales de la especie en la subpoblación del norte la cual es pequeña y aislada. El Zambullidor Plateado Norteño ha sufrido extirpaciones locales y procesos de colonización durante las últimas tres décadas. Más del 90% de la subpoblación se reparte entre dos humedales, La Mica y Colta ambos en Ecuador, este último afronta un acelerado proceso de colmatación y reducción del espejo de agua que pone en peligro el destino del humedal y la especie en el mediano plazo. La tendencia de la población se ha mantenido estable en La Mica durante nuestro periodo de muestreo (2004–2013), mientras que en Colta exhibe un rápido crecimiento (tasa de multiplicación anual: 1.464) probablemente relacionado con la inmigración de individuos desde otras poblaciones. La coincidencia temporal entre el declive de la población en La Mica y la colonización en Colta, sugiere que la población en Colta fue fundada por inmigrantes provenientes de La Mica.

Finalmente la ausencia de reportes recientes en humedales de Colombia, sugiere que la especie permanece en números muy bajos, lo cual resalta la contracción que ha sufrido la porción más norteña de la distribución de la especie.

Introduction

Grebes (Order Podicipediformes) are among the most vulnerable groups to man-made changes in their habitats, mainly because of their high level of dependence on wetlands, which are one of the most threatened habitats worldwide (Turner *et al.* 2000), and their low propensity to dispersal (O'Donnell and Fjeldså 1997, Fjeldså 2004), although the superspecies *P. occipitalis* / *nigricollis* / *andinus* (Remsen *et al.* 2014) is known to undergo irruptive movements between distant locations as local conditions become less suitable (Fjeldsa 2004). Out of 23 known grebe species, six are listed under some category of threat and three other species are currently considered extinct (Fjeldså 1993, BirdLife International 2015a). A noteworthy fact is that three of the five threatened species and two of the three already extinct species are from the Neotropical region (Roesler *et al.* 2012). Distribution of the Silvery Grebe complex (*Podiceps occipitalis* / *juninensis*) encompasses the Andean wetlands from southern Colombia to the pampas in central Argentina, and the lowlands of Patagonia and Tierra del Fuego, with a few localities in southern and south-eastern Brazil and Paraguay (Darrieu *et al.* 2001, Bornschein *et al.* 2004, Fjeldså 2004). A taxonomic review considers the Northern Silvery Grebe as a separate species from Southern Silvery Grebe (*Podiceps occipitalis*; del Hoyo *et al.* 1992).

The Southern Silvery Grebe inhabits wetlands in the Patagonian region, central Argentina, Uruguay and Southern Brazil whereas the Northern Silvery Grebe inhabits high Andean lakes from southern Colombia to northern Chile and Argentina (Fjeldså 2004). Both species breed in fresh to slightly salty wetlands (Fjeldsa 2004). BirdLife International (2015b) considered the Northern Silvery Grebe as 'Near Threatened' due to its suspected population decline owing to loss and degradation of wetland habitat, and the impact of invasive species. The northernmost populations of the Northern Silvery Grebe (Colombia, Ecuador) appear to be highly geographically isolated from the southern populations (Bolivia, Chile, Perú and Argentina), and may also have diverged genetically (Ogawa *et al.* 2015). Their conservation status is a cause of concern. In Colombia, the Northern Silvery Grebe has been regarded as 'Endangered', and is known to occur at very few sites, including La Cocha and Cumbal lakes in Nariño department and Otún lake in Risaralda department (Angarita and Estela 2002; Table S1 in the online supplementary material). In Ecuador, the species is uncommon and very local, and has been classified as 'Vulnerable' to extinction due to its small population size, inferred population decline, and ongoing habitat loss and degradation (Muñoz 2002). The overall population size in Ecuador was estimated at around 300 individuals, scattered among 4–6 extant subpopulations in open wetlands in the Ecuadorian Andes (Ridgely and Greenfield 2001, Muñoz 2002), most of them containing less than 10 individuals (Henry 2012). Population size was suspected to have been declining in recent decades although no quantitative evaluation has been performed (Ridgely and Greenfield 2001). The introduction and rapid expansion of exotic fish species has been proposed as a threat to Northern Silvery Grebe since they are known to compete for the same invertebrate prey and modify the structure of aquatic vegetation (O'Donnell and Fjeldså 1997). Exotic fish populations may also alter the trophic structure of wetlands as their feeding pressure may lead to a predominance of microplankton which is unsuitable for grebes especially when they feed young, as they can only bring one prey item per feeding bout (Fjeldså 2004). This problem applies especially to *P. occipitalis*, *P. gallardoi* and *P. nigricollis*, which are specialised to feed on macroinvertebrates (amphipods, insects), gleaned from underwater vegetation, and emerging Chironomidae midges picked from the water surface (Fjeldså 2004). For other similar sized grebe species, introduced fish species could even act as predators of chicks and eggs (Roesler *et al.* 2012).

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The aims of this paper are to assess the current distribution and population trends of the populations of Northern Silvery Grebe in the Northern Andes, and to review the conservation threats and proposed management actions in each of the main wetlands. Ultimately we aim to provide soundly based management tools to enhance the survival prospects of the species over the long term.

Methods

Historical data collection and distribution

We collected information concerning recent and historical presence of the species by consulting bibliographic sources, museum collections, public databases (eBird, GBIF) and our own database from the Neotropical Waterbird Census (NWC). In addition, we asked ornithologists and birdwatchers working both in Ecuador and Colombia for sightings of the species. Records obtained were mapped (Figure 1) and are detailed in Table S1.

Censuses

Bird count data came from the NWC at five high Andean lakes in Ecuador (Table S1). Due to logistical constraints that prevented regular visits to all potential sites of occurrence, we selected wetlands to be surveyed on the basis of waterbirds concentration and accessibility. Bird counts were carried out in February and July over the period 2004–2013. We carried out censuses of adult-sized birds in the morning (08h00), lasting from two to three hours. Immature individuals could not be distinguished from adults, and fledglings have been excluded from the counts. There was no census at San Pablo in February 2009, 2010, La Mica in February 2010, 2011, and Colta in February 2007, and July 2008, 2011. At Yahuarcocha and San Pablo lakes, observations were conducted from a boat. The total perimeters of these lakes were covered at a constant velocity. At Colta, La Mica and Yambo lakes, the censuses were carried out by hiking along the lake shore. If more than one observer counted birds simultaneously the highest value was considered. For Colta lake, PYH performed independent censuses: February 2003, March and June 2004, January 2005, February 2006, September 2008, December 2010. During each visit, counts were performed from exactly the same seven sites, regularly spread along the total perimeter of the lake. Birds were identified and counted with binoculars (8 x 42) and a spotting scope (x 20–45). Moreover TSG performed an independent census at Colta lake on 1 October 2013 from a boat, covering the interior area of open water surface, which is usually not counted during NWC because vegetation obstructs the view.

Statistical analysis of bird counts

The analysis of bird counts was performed only for lakes with regular occurrence of the species, i.e. La Mica and Colta lakes (Table S1). Bird counts were analysed using generalized linear models with quasi-Poisson distribution and log-link function (appropriate for count data; O'Hara and Kotze 2010, Guevara *et al.* 2011). The deviance-inflation factor indicated overdispersion ($c\hat{} = 21.3$). Statistical inference about the sources of changes in bird counts were hence assessed by model comparisons using quasi-Akaike Information Criterion (QAICc, a formula of AIC adjusted for overdispersion and small sample size; Burnham and Anderson 1998). We used a multi-model inference procedure to build all possible simplifications of a starting model, to identify the most parsimonious ('best') model adequately describing count variations (i.e. the model with the lowest QAICc value) and to obtain coefficients for effects, adjusted for model selection uncertainty (i.e. model-averaging among models within 10 points of QAICc from the best model; reported as mean ± standard error). The starting model included the additive effects of Site (Colta versus La Mica), Year (linear temporal trend in numbers through years), and Season (July versus

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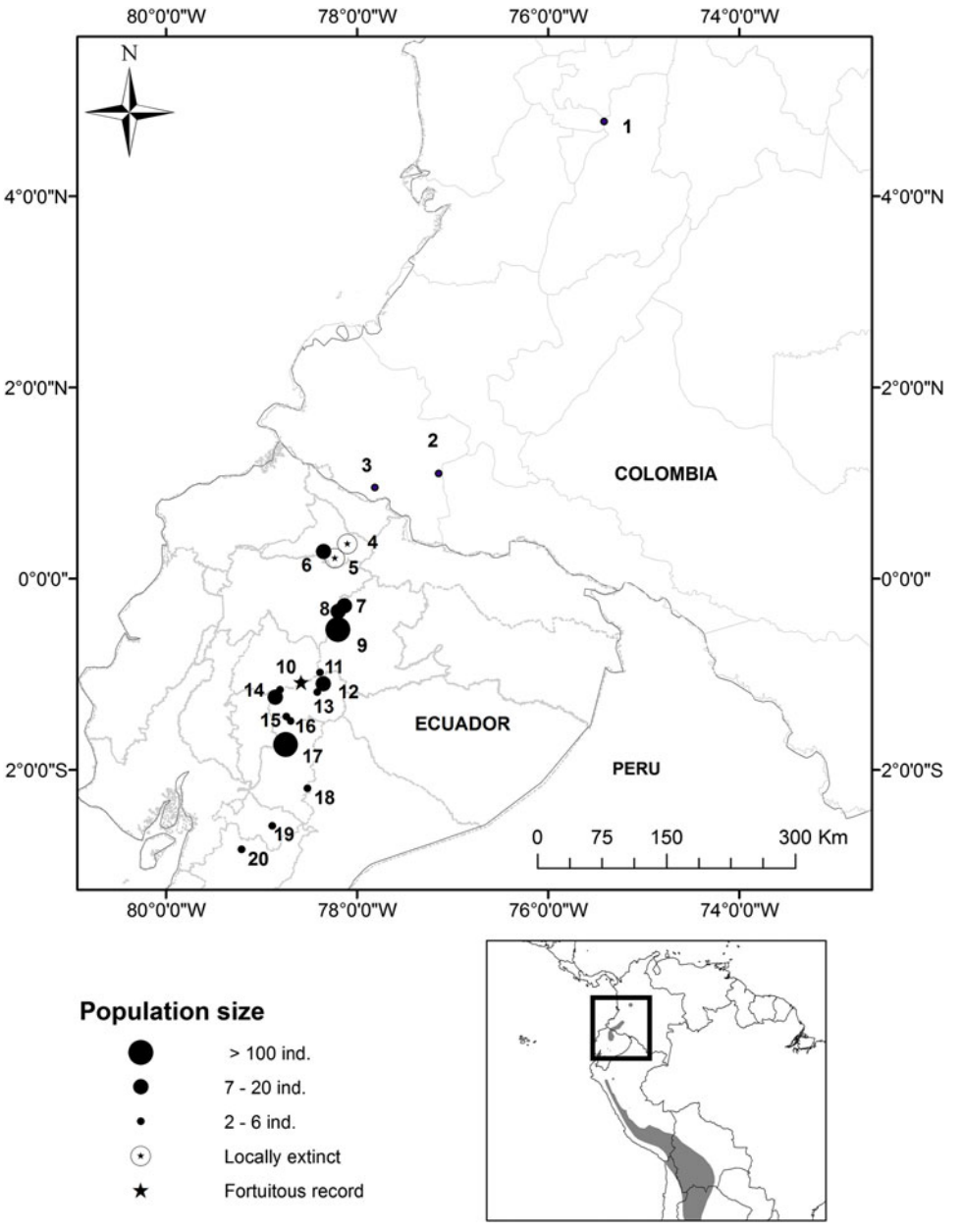

Figure 1. Current distribution and population size of the Northern Silvery Grebe in the northern Andes. Sites numbers correspond to those used in Table S1.

February counts), and two interaction terms: (1) Site x Year, to assess if population growth rates differed between sites, and (2) Site x Season to adjust counts for potential site-specific, seasonal fluctuations in counted numbers. When a model included an interaction term, both additive terms were also included. Analyses were performed using 'MuMIn' package ver. 1.15.1 (Bartoń 2015) with software R ver. 3.2.2 (R Development Core Team 2015).

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Results

Distribution and population size

Historical and current presence / absence data (Table S1, Figure 1) indicate that La Mica and Colta currently hold the largest and most stable Northern Silvery Grebe populations in the northern Andes. Elsewhere, the species occurs in small numbers of individuals at 15 other Andean wetlands (no more than 20 individuals per site).

Historical data combined with our own censuses also show that the Northern Silvery Grebe subpopulations have undergone a drastic reduction at Imbabura province in Ecuador. Hilsenbeck (1979) reported 44 individuals at lake Cuicocha during the mid-1970s; Scott and Carbonell (1986) reported the presence of 25 individuals at lake Yahuarcocha, and Ridgely and Greenfield (2001) mentioned the existence of this species at lake San Pablo. Populations at these sites have undergone a serious decline: extirpation from Yahuarcocha and San Pablo, and up to 82% decrease in population size at Cuicocha (Table S1). On the other hand, the species has recently been reported in new wetlands from central Ecuador (Tungurahua and Chimborazo provinces; Henry 2012, AS unpubl. data) although in small numbers (Table S1). The Colta population is the only ascertained case of colonisation of a new wetland over the past decade. The species has been recorded sporadically and in small numbers in the Cajas area, suggesting that this area is not of major numerical importance for the species (Astudillo *et al.* 2015). In Colombia, the species has been reported at La Cocha, and Cumbal lakes in Nariño department and at Otún lake in Risaralda department (Angarita and Estela 2002, Arzuza *et al.* 2008). We failed to obtain recent information from these wetlands.

Trends in counted numbers

The best model included only additive and multiplicative effects of Year and Site (QAICc = 48.5, QAICc weight = 0.638), providing statistical support for the observed difference in population growth rate between the two sites (Figure 2): at lake La Mica, population size remained stable (slope for the linear effect of time, $r = 0.047 \pm 0.095$), whereas the Colta population increased in size at an extremely high rate ($r = 0.381 \pm 0.087$). The second supported model indicated that counts may differ between seasons (ΔQAICc = 1.6, QAICc weight = 0.286), with a trend for smaller censuses in July than in February (-0.271 ± 0.247). The 10 remaining models received low statistical support ($\Delta QAICc \geq 4.3$, QAICc weights ≤ 0.074).

Discussion

Changes in distribution

The Northern Silvery Grebe distribution has experienced noteworthy changes over the last three decades. It is no longer found in large numbers below 3,100 m asl (extirpated from Yahuarcocha and San Pablo lakes). We regard the Yambo record as casual since despite regular monitoring the species was recorded only once. Extirpation at those two wetlands indicates an upward shrinkage in its altitudinal range. The lower boundary of the Ecuadorian altitudinal range was 2,200 m in the early 1980s (Ridgely and Greenfield 2001). The drastic decline of the species at lake Cuicocha is also of concern, as this site hosted one of the main former populations in the country (Table S1). Furthermore, the absence of recent records in Colombian wetlands suggests that the species faces a severe risk of extirpation in this country. These figures demonstrate that the northern distributional limit of the species has seriously shrunk over the past two decades.

Two sites hold small populations of between 20 and 30 adults. The Ñucanchi-Turupamba complex at the Cayambe–Coca Ecological Reserve in north-east Ecuador holds a group of c.30 ponds that together make up an area of 672 ha (Freile and Santander 2005); at this site the species has been recorded regularly, but in small numbers (Table S1). In central Ecuador, the Llanganates

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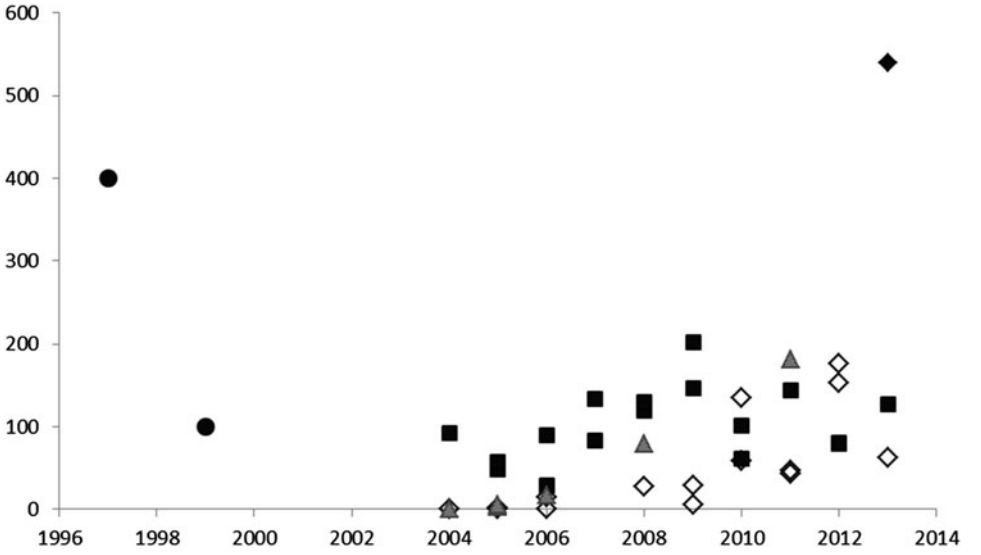

Figure 2. Annual variations in minimum counts of the Northern Silvery Grebe: Black squares = Neotropical Waterbird Census at La Mica, white rhombus = Neotropical Waterbird Census at Colta, black rhombus = census at Colta based on a full view of the lake surface, grey triangles = PYH counts at Colta and black circles = Yolanda Celleri counts at La Mica two years before the dam construction (1997) and the year after dam inauguration (1998).

National Park encompasses ~ 80 small lakes (Freile and Santander 2005). Individually, each wetland may harbour small numbers of birds. However, according to our counts at six lakes, it may hold around 30 individuals. These two sites constitute the third and fourth largest (although still small) populations in Ecuador and probably in the whole northern Andes. Southern Ecuadorian high-altitude wetlands may also harbour small populations, according to historical and recent reports (Table S1).

Until the 2000s, the only large known population for the northern Andes was at lake La Mica, with a concentration of over 90% of the individuals. In 2003, a new breeding population was discovered at lake Colta, in the central inter-Andean valleys (Henry 2012). Our census data suggest that these two wetlands now host over 90% of the northern Andes population. This makes these sites the most important in securing the long-term fate of the species in this region.

Population trends

A striking feature of the recent dynamics of the Northern Silvery Grebe in Ecuador is the colonisation of lake Colta in the early 2000s (Henry 2012), followed by a rapid exponential growth. The annual multiplication rate (calculated as $\lambda = e^r$) since the foundation is 1.464. Niel and Lebreton (2005) showed that the maximum annual λ for birds can be inferred from the adult survival rate, fecundity and breeding success parameters. Only small passerine birds, like sparrows or tits, are likely to have a maximum annual λ of 1.5 without immigration, whereas for gulls, geese, cormorants, the maximum annual λ would be 1.2 or lower (see also Doxa *et al.* 2013). For a species like a Black-necked/Eared Grebe *Podiceps nigricollis*, with an annual adult survival rate around 0.7, and 1-2 fledglings per year per pair (Jehl *et al.* 2002, Abt and Konter 2009), an annual multiplication rate of 1.5 therefore is unlikely to be achieved by the sole recruitment of locally born birds. There must have been a major contribution of immigration of new breeders. Indeed, the foundation of

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the Colta population coincides in time with the disappearance of 80% of La Mica population (i.e. about 400 individuals) after the damming of the lake in 1999 (Yolanda Celleri *in litt.*; Figure 2). Current habitat conditions at La Mica (exposed and steep shores, deep water levels and presence of trout [Salmonidae]) no longer matched the usual habitat characteristics of the Northern Silvery Grebe (Fjeldså 2004). In contrast, lake Colta could be considered as a typical lake for this grebe: shallow, set in a flat landscape, with rich submerged vegetation, and a tendency to eutrophication (Fjeldså 2004). Damming of lake La Mica is also suspected to have generated unfavourable water level fluctuations that caused massive breeding failures. Colony-wide breeding failure events are known to induce massive emigration in colonial birds (e.g. Boulinier *et al.* 2008, Doxa *et al.* 2013). Massive dispersive movements of entire populations have already been documented for closely related grebe species, such as the colonisation of Western Europe by Black-necked Grebes (*Podiceps nigricollis*; Fjeldså 2004). The straight line distance between La Mica and Colta populations is 146 km. We hypothesise that the Colta population has indeed been founded by immigrants that had left lake La Mica after the damming. All other known populations in Ecuador hold less than 20 individuals and are unlikely to have provided enough immigrants to found the Colta population (Figure 2). Note also that all small, recently discovered populations of Northern Silvery Grebes are scattered between lakes La Mica and Colta and may have served as stepping-stone sites, further supporting the hypothesis of a massive southward emigration from lake La Mica after the damming. If the hypothesis of massive immigration from La Mica to Colta is right, it would imply that few remaining wetlands can hold a breeding population of some hundreds of Northern Silvery Grebes in central Ecuador. The remarkable population growth at lake Colta may also have resulted partly from a high local reproductive rate, thanks to the high-quality of the habitat, with reduced competition and abundant food availability (see Jehl *et al.* 2002 for Eared Grebe).

Conservation assessment

Sixteen populations each hold fewer than 20 individuals, with only two where breeding has been observed (Pujín and Chiliquinga lakes). As most of the extant small populations (88%) are scattered across wide *paramo* wetlands, already included in protected areas, their fate depends on the implementation of existing conservation plans targeted at preserving high-altitude wetlands. Basically these rely on regulation policies and the conservation of water sources to guarantee freshwater supply, electricity, tourism and fish farming (Cañar *et al.* 1998, Paredes *et al.* 1998). For the three small populations that are not under protection, the only opportunity to secure their stability in the long term is through either negotiating an appropriate water management agreement or backing the creation of municipal protected areas.

La Mica is under the protection regime of Antisana Ecological Reserve and managed by Quito Metropolitan Water Company (EMAAP-Q). The main conservation problems originated from the construction of a dam in 1999. The original floating vegetation, where grebes used to anchor their nest and forage, has almost disappeared (Tufiño *et al.* 2011), and in the remaining suitable areas, unplanned water level fluctuations may have caused breeding failures in some years. Since Northern Silvery Grebes depend on the existence of shallow areas with dense waterweeds (*Myriophyllum*, *Potamogeton*; Fjeldså 2004), the increase in water depth as a consequence of damming may also have reduced the area of suitable foraging habitat. Finally introduction of trout would have further reduced the suitability of the lake (see Introduction). One of the key conservation actions of the management plan elaborated by the EMAAP-Q is the control or eradication of introduced trout (Tufiño *et al.* 2011). We also recommend controlling water level fluctuations during the breeding season. However this may not be compatible with economic requirements as the lake serves as the major water reserve for the capital of the country. From an organizational point of view, it is necessary that all stakeholders (EMAAP-Q, the Ministry of Environmental, NGOs and local users) collaborate to design effective adaptive management actions of the lake in favour of the waterfowl over the long term.

Colta lake is not included in any official programme of protection, although it is an Important Bird Area (IBA) for waterbirds in central Ecuador (Freile and Santander 2005). Deforestation and soil erosion in the surroundings of the lake have accelerated the sedimentation process, leading to a reduction of the area of open water by 2.5 ha per year. Soil erosion may also have increased water turbidity that indirectly reduces the area of foraging habitat for grebes (Fjeldså 2004). Simultaneously, the area of totora *Scirpus californicus* is expanding, contributing to the loss of open water surface (Andrade 2011). Lake Colta has a management plan, administered by Colta municipality, where these key environmental problems are identified. But the only actions that are being implemented are dredging and totora extraction (Aldás *et al.* 2009). It is planned to remove 80% of totora, leaving the remaining 20% (17 ha) for bird nesting. The massive removal of totora will jeopardize nesting sites and might also affect submerged vegetation which is important for Northern Silvery Grebe (Fjeldså 2004). In addition, an ambitious tourism project has started to turn the wetland into a vast aquatic recreational area (Andrade 2011). The project includes the building of piers and sports fields. Considering that Colta holds the main population of the species in the country, and is an IBA, we suggest adding conservation actions to the current management plan: spatial and temporal planning of (i) totora removal; (ii) development of tourism infrastructure and activities (e.g. boat rides), according to the location of nesting and foraging sites of aquatic species, in coordination with local populations, and adaptively adjusted according to diagnosed short-term impacts on bird populations and hydrological properties; and (iii) the establishment of an environmental education programme to ensure that conservation actions are well understood, and accepted by local populations.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S0959270915000362

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