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ORIGINAL ARTICLE

Behaviour patterns of South American swans and potential ecosystem services supplied to salt production systems

Patrones de comportamiento de los cisnes sudamericanos y posibles servicios ecosistémicos suministrados a los sistemas de producción de sal

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ABSTRACT

Wetland salt works with handcrafted production are scarce in Chile. This activity is the base of the maintenance of some local communities' economy, establishing small rural groups and helping in the conservation of the cultural traditions. These wetlands provide an important habitat for southern hemisphere swan species. Salt workers point out that among the most laborious tasks to keep the salt pans running, is the removal of macrophytes from their production systems. We evaluated the behaviour of two threatened swan species in these wetlands to check if they provide an ecosystem service to salt workers. Our results showed that the main behaviour recorded was the activity of feeding, where the swans spend more than 45% of their time. Considering that each individual can ingest approx. 12-16 kg of food daily, it is shown that swans could provide an ecosystem service through the removal of macrophytes. There were no significant differences in behaviors between species, but between sampling sites, in behaviors such as self-maintenance, which was related to the degree of disturbance of these. Our findings are novelty evidence of the role of swans as ecosystem services providers for salt workers. These results highlight that the maintenance of traditional industries could be a win-win strategy for bird conservation.

Keywords: Black-necked swan, Chile, Coscoroba swan, feeding behaviour, salt works.

RESUMEN

Las salinas en los humedales con producción artesanal son escasas en Chile. Esta actividad es la base del mantenimiento de la economía de algunas comunidades locales, estableciendo pequeños grupos rurales y ayudando en la conservación de las tradiciones culturales. Estos humedales proporcionan un hábitat importante para las especies de cisnes del hemisferio sur. Los trabajadores de la sal señalan que dentro de las tareas más laboriosas para mantener en funcionamiento las salinas, se encuentra la remoción de macrófitas desde sus sistemas de producción. Analizamos el comportamiento de las dos especies de cisnes sudamericanos en estos humedales, para evaluar si proporcionan un servicio ecosistémico a los trabajadores de la sal. Nuestros resultados mostraron que el principal comportamiento registrado fue la actividad de alimentación, a la cual destinan más del 45% de su tiempo. Teniendo en cuenta que cada individuo puede ingerir aprox. 12-16 kg de alimento al día, se demuestra que los cisnes podrían proporcionan un servicio ecosistémico a través de la remoción de macrófitas. No se registraron diferencias significativas en los comportamientos entre especies, pero sí entre sitios de muestreo, en conductas como el acicalamiento, lo cual se relacionó al grado de perturbación de estos. Nuestros hallazgos son evidencia novedosa del rol de los cisnes como proveedores de servicios ecosistémicos para los trabajadores de la sal. Estos resultados destacan que el mantenimiento de las industrias tradicionales podría ser una estrategia de beneficio mutuo para la conservación de las aves.

Palabras clave: Chile, cisne coscoroba, cisne de cuello negro, comportamiento de alimentación, salinas.

INTRODUCTION

The wetlands formed by river estuaries are important zones for biodiversity conservation (Cienfuegos *et al.* 2012). These areas suffer significant changes of salinity which depend on tide cycles (Andrade & Grau 2005) and for this reason, they become ecotones between freshwater and saltwater, supporting high biodiversity levels (Mas *et al.* 2021). Also, they provide several ecosystem services such as regulation, feed provision, etc (TEEB 2010). In other hand, due to the high productivity, these areas have an important economic value such as seafood production zones, aquaculture, salt works, etc. In this context, saltpan provide key ecosystem services to coastal communities such as carbon sequestration, coastal protection, wave attenuation, trophic enrichment of coastal waters, nursery areas for fish species, permanent or transient habitat for aquatic invertebrates, and resting areas for migratory birds (Barbier *et al.* 2011). Despite their ecological and socio-economic importance, these habitats are threatened by multiple anthropogenic pressures (freshwater inflow reduction, land-use change, and development resulting in fragmentation and habitat loss, biological invasions, and pollution) and natural (sea storms, flooding, and sea-level rise, which are predicted to increase in intensity and frequency with climate change), which accounts for its fragile state (Lefeuvre *et al.* 2000; Castro & Alvarado 2009; Marquet *et al.* 2012; Silliman *et al.* 2015; IPCC 2021). For this reason, the study and restoration of these ecosystems have become increasingly relevant (Adams *et al.* 2021; Wassermann *et al.* 2022).

Wetland salt work are scarce in Chile (Fahrenkrog 2009), usually driven by local people who keep them running all year long. The production obtained from them is artisanal, being a low impact activity, providing of suitable habitats for birds to breed, feed, etc. At the same time, this activity allows the maintenance of local communities' economy, establishing small rural groups and helping in the conservation of the cultural traditions (Bengoa, 1983; Quiroz *et al.* 1986; Vera 2003; Araya 2006). However, since they are traditional industries, the manual procedures are very demanding in terms of time, effort and physical strength, causing the workers to leave if they find it is not profitable enough. An important issue for salt workers is the time invested in cleaning the ponds from vegetation (macrophytes) being this a very hard and demanding job.

The coscoroba swan (*Coscoroba coscoroba* Molina 1782) and black-necked swan (*Cygnus melancoryphus* Molina 1782) have a restricted distribution, being present only in the southern hemisphere of the American continent. Currently, according to the International Union for Conservation of Nature (IUCN), these species are classified as "Least Concern" (IUCN 2016) globally, as are all other swan species. However, the lack of data on their population trends and the poor quality of the existing data makes this assessment unsafe (Rees *et al.* 2019), since unlike the swan species of the northern hemisphere the information on the size of their populations and their population ecology (habit requirements; movements) is unclear, although they are recognized as susceptible to rapid habitat loss in wetlands, resulting from increasingly frequent drought events in recent years (Rees *et al.* 2019). To which, it is added that studies regarding habitat preference and variation in the temporal distribution of their populations are very scarce (Garay *et al.* 1991; Schlatter *et al.* 1991; Vilina *et al.* 2002; Muñoz-Pedreros 2003; Gibbons *et al.* 2007; Silva & Brewer 2007; Calabuig *et al.* 2010; González *et al.* 2011; Gómez *et al.* 2014; Miranda-Cavallieri *et al.* 2023), and practically null in productive environments of salt works.

These swans feed mainly on aquatic vegetation. However, their digestive efficiency is low and their digestion percentage ranges between 21-34% of the total (Corti 1996). This way, it is estimated that each *C. melancoryphus* individual is capable of eating between 1 to 3 times its weight on a daily basis (Corti 1996). This fact can lead to the conclusion that there must be some ecosystem service these swans bring to the salt workers, even though there is no study about it. It is possible to think that both species apply a strong suppression in the proliferation of aquatic vegetation in the salt pools, being this really beneficial for the workers. However, there is not much knowledge about the behaviour patterns of these swans and it is necessary to know how many time they devote to each one of these behaviours (Corti 1996; Brewer & Vilina 2002; Silva & Brewer 2007; Echevarria *et al.* 2013; Cursach *et al.* 2015; Velásquez *et al.* 2019). It is crucial to understand their role as ecosystem service providers.

Our hypothesis is that in salt pools both species spend most of their time feeding and this could have an effect in the regulation of aquatic vegetation as an ecosystem service in these productive areas. Our main aim is to analyse the behaviour patterns of *C. coscoroba* and *C. melancoryphus* in salt pools. Specifically, 1) to identify behavioural patterns of both species in salt works; 2) to quantify the time spent on each behaviour; 3) to assess differences between the various behaviours for each species and between sites; and, 4) to discuss the role of both swan species in the potential ecosystem service of regulation provided to salt workers.

MATERIAL AND METHODS

Study area

The study area is the estero Nilahue - laguna Cáhuil estuary in the O'Higgins region, Chile (34°29'3.59"S 72°0'54.61"W; Figure 1). This estuary is a coastal lagoon with a length of approx. 9 km (Andrade & Grau 2005). The climate is maritime Mediterranean with oceanic influence (Luebert & Pliscoff 2017). The mean annual temperature is 16°C and the mean precipitation is 479.8 mm. Its geographical and climatic characteristics allow the marine salt to precipitate and be harvested in a handcrafted manner (Fahrenkrog 2009). In this wetland there is a salinity gradient between the four sampling points. The sites 1 and 2 appear near to the coast and have relatively high salt concentrations (21.24 and 19.48 PSU, respectively). Site 3 has salt concentration something low (17.73 PSU), while site 4 has a low salt concentration (8.07 PSU) (Table 1; Pardo *et al.* 2015). The riparian vegetation is mainly represented by the presence of the species *Carex canescens*, *Salicornia maritima*, *Erodium cicutarium*, *Silybum marianum*, *Cotula coronopifolia*, while macrophytes are represented in dominance of cover by *Ulva intestinalis* (62.1%), *Achnanthes brevipes* (16.3%), *Melosira varians* (11.4%), *Oedogonium sp* (8.7%), *Carex sp* (1.2%) and *Macrocystis sp* (1.2%; Pardo *et al.* 2015). Regarding the populations of both species of swans in the study site, some estimates indicate 686 individuals of *Cygnus melancoryphus* and 128 individuals of *Coscoroba coscoroba* (National Waterfowl Census; Matus *et al.* 2010), establishing the Cahuil wetland as a site of national and international importance for the conservation of these species. Currently, the populations are estimated at 236 individuals of *C. melancoryphus* and 105 individuals of *C. coscoroba* (Imbernón 2023).

Behavioural monitoring of *C. coscoroba* and *C. melancoryphus*

We made behavioural observation of both species on a weekly basis, from March to August 2019 (n = 24) at each of the sampling sites, which were selected for their proximity to the salt works present in the area (Fig. 1). The sessions consisted of continuous monitoring of the activity of one or more adult individuals (depending on the abundance present at the site), selected at random, without distinction of sex, for a period of 10 minutes. The sessions were recorded through videos with a Nikon reflex camera model D5300, using a lens with a focal length of 70-300 mm. Then, the records were saved in a memory card for subsequent inspection. The recordings were always made at a focal length between 150 and 300mm. It was always privileged to cover the largest possible observation area, in order to record more than one individual during the 10 minutes of recording, with the purpose of increasing the hours of recording. For each video, all individuals within the video frame were watched separately, with the duration of each behaviour type noted for the duration that the focal individual remained visible. Therefore, the total recording time corresponds to the sum of the tracking of each focal bird that could be filmed. The surveys started by approx. 8:00 am and had a duration of 3 hours and considering the displacements between each sampling site, it had a complete duration of 3 hours. Each week, we reversed the initial survey point to avoid temporal bias in the measures due to the swan movements.

Behavioural analysis of each swan

We analysed and annotated the time spent on each behaviour for each individual during the recordings. The observed behaviors were classified according to the categories proposed in previous studies of swan behavior (Tatu *et al.* 2007; Krivtsov & Mineyev 2013). We counted a total of eleven different behaviours: 1) Feeding; 2) Self-maintenance; 3) Swimming; 4) Resting; 5) Vocalizing; 6) Agonistic behaviour; 7) Social behaviour; 8) Nest-building; 9) Disturbance induced; 10) Incubating; and 11) Defecating (Table 2).

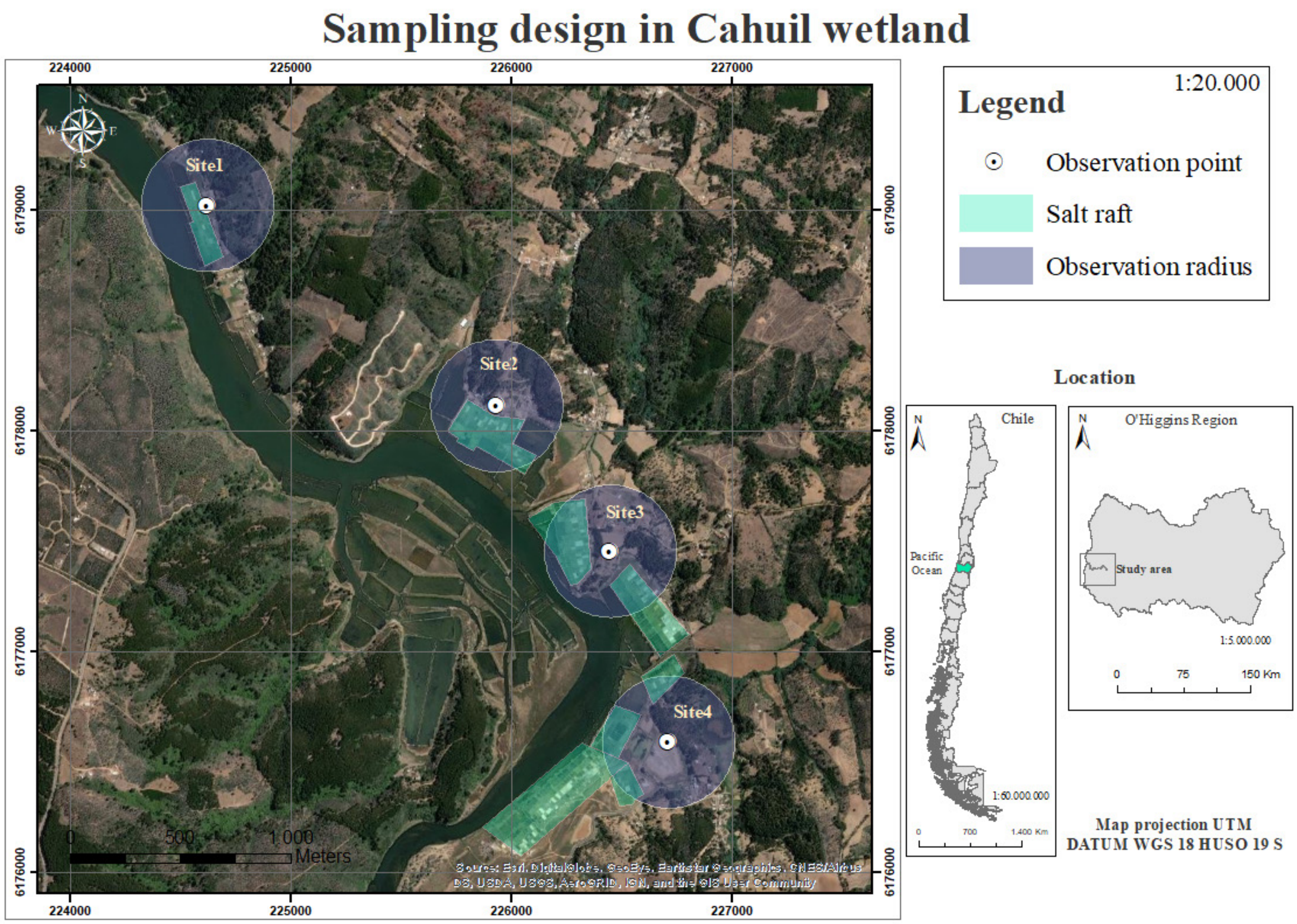

Figure 1. Study area and sampling design. / Área de studio y diseño de muestreo.

Table 1. Characterization of sampling sites (Edited from Pardo *et al.* 2015). / Caracterización de los sitios de muestreo (Editado de Pardo *et al.* 2015).

Sites	Geographic location	Depth (meters)	Salinity (PSU)	Chlorophyll a (µg/L)	Presence of anthropogenic interventions
Site 1	34°29'39.53"S 71°59'55.67"W	3.0	24.24	4.4	Greater urban coverage, greater number of homes, high presence of feral dogs and cats, high number of tourists, high vehicular flow, water activities.
Site 2	34°30'8.84"S 71°59'7.48"W	3.3	19.48	4.1	High presence of feral dogs, high number of tourists, high vehicular flow.
Site 3	34°30'31.73"S 71°58'47.33"W	3.1	17.73	4.7	Presence of feral dogs, high number of tourists, high vehicular flow.
Site 4	34°31'4.96"S 71°58'35.99"W	1.0	8.07	8.1	Less urban coverage, less number of homes, low number of tourists, low traffic flow.

TABLE 2. Time in seconds of the registered behaviours segregated by species, which was obtained as the sum of the time recorded per behavior for each individual observed throughout the 24 recording sessions and subsequent behavioral observation in the estero Nilahue - Laguna Cáhuil stuary in the Libertador Bernardo O'Higgins region. For each species, the number of individuals observed (*n*) is indicated. / Tiempo en segundos de las conductas registradas segregadas por especie, el cual fue obtenido como la sumatoria del tiempo registrado por conducta para cada individuo observado a lo largo de las 24 sesiones de grabación y posterior observación conductual en el estuario estero Nilahue – laguna Cáhuil, región del Libertador Bernardo O´Higgins. Para cada especie se indica el número de individuos observados (*n*).

Behaviours	**Detailed types of activities**	***C. coscoroba* (*n* = 151)**	***C. melancoryphus* (*n* = 118)**
Feeding	Dipping with head-neck submersed Dipping with head-only submersed Feeding from the water surface Feeding on shore	29695 (54.0%)	22727 (43.0%)
Self-maintenance	Preening Neck/wing stretching Wing-flapping	9907 (18.0%)	17109 (32.4%)
Swimming	Transport/locomotion	6144 (11.2%)	8711 (16.5%)
Resting	Standing/sitting on land Floating on water surface (loafing/sleeping)	6757 (12.3%)	3649 (6.9%)
Vocalizing	Emission of whistles and squawks during socialization moments.	402 (0.7%)	426 (0.8%)
Agonistic behaviour	Intraspecific (busking/threat display/fighting) Interspecific (hissing, flushing away)	231 (0.4%)	138 (0.3%)
Social behaviour	Mutual preening Game	269 (0.5%)	-
Nest-building	Adults transporting and using material to build the nest at the nest site	785 (1.4%)	-
Disturbance induced	Becoming alert/watchful Flying	449 (0.8%)	50 (0.1%)
Incubating	Incubation of eggs by one of two parents	365 (0.7%)	-
Defecating	Rapid tail movements and then excrete faeces	15 (0.03%)	-
Total		**55019 (100.0%)**	**52810 (100.0%)**

BEHAVIOURAL TIME ANALYSIS BETWEEN SPECIES AT LEVEL OF ESTUARY

We compared the time of the different behaviours between the two species at the estuary level using two-sample comparison statistical tests. For this, we used the t-Student test to compare the means and determine if the populations are equal. This test only was used if the samples accomplished the assumptions of normal distribution and homoscedasticity between samples (Supplementary Material 1). The assumption of normality was evaluated using the Shapiro-Wilk test on the residuals of linear regression models fitted using least squares for each behavior type, using as response variable the behaviour's observed time and as independent variable the species. In the case were the normality assumption was not accomplished but the homoscedasticity was so, we applied the non-parametric test of Mann-Whitney-Wilcoxon to determine if the populations were equal or not (Zar 1999). To estimate the variance equality between samples, we used Levene's and Bartlett's tests (Zar 1999). All analyses were implemented with a significance level of 0.05 in R software (R CORE TEAM 2019).

BEHAVIOUR TIME ANALYSIS BY SPECIES AT SITE LEVEL

To evaluate if there are differences in the time spent in each behaviour in the four sampling sites, we used an ANOVA to compare means. This test only was applied if the assumptions of normality and variance equality were fulfilled. In the case were normality assumption was not fulfilled but the variance was so, we applied a non-parametric Kruskal-Wallis test (Zar 1999).

If ANOVA test was applied, we compared the means between sites through HSD (Honestly-significant-difference) Tukey test. In the case of applying the non-parametric Kruskal-Wallis test, we used Mann–Whitney–Wilcoxon test pairwise comparisons between samples grouped based on sites (Zar 1999).

In those cases where we are over the normality assumption but not the variance equality, we directly applied the Scheffé test (Zar 1999). All the analyses were applied using the basic package of R software, except for the Cover-Iman test which was applied using the *PMCMR* package (R CORE TEAM 2019).

RESULTS

In total, we recorded the behaviour of 151 individuals of *C. coscoroba* and 118 individuals of *C. melancoryphus*, with a total of 44 hours and 50 minutes of observation. For *C. coscoroba* we assigned 55019 seconds to some behaviour type, representing a 77.7% of the total time. For *C. melancoryphus* we counted 52810 seconds in some behaviour type, which represent a 58.3% of the total time (Table 2). The results show that for both species, feeding appears as the main behaviour (54% and 43% for *C. coscoroba* and *C. melancoryphus*, respectively) while the second most observed behaviour type in both species was self-maintenance, followed by resting and swimming (Table 2).

When we analysed if there were differences between species in the behaviour types in the whole estuary, we did not find any differences between them (Self-maintenance p = 0.07; Resting p = 0.78; Vocalizing p = 0.58; Disturbance induced p = 0.11; and Agonistic behaviour p = 0.13; Fig. 2). The remaining behaviour types were not analysed because they were not over the normality and homoscedasticity assumptions or there was not enough data.

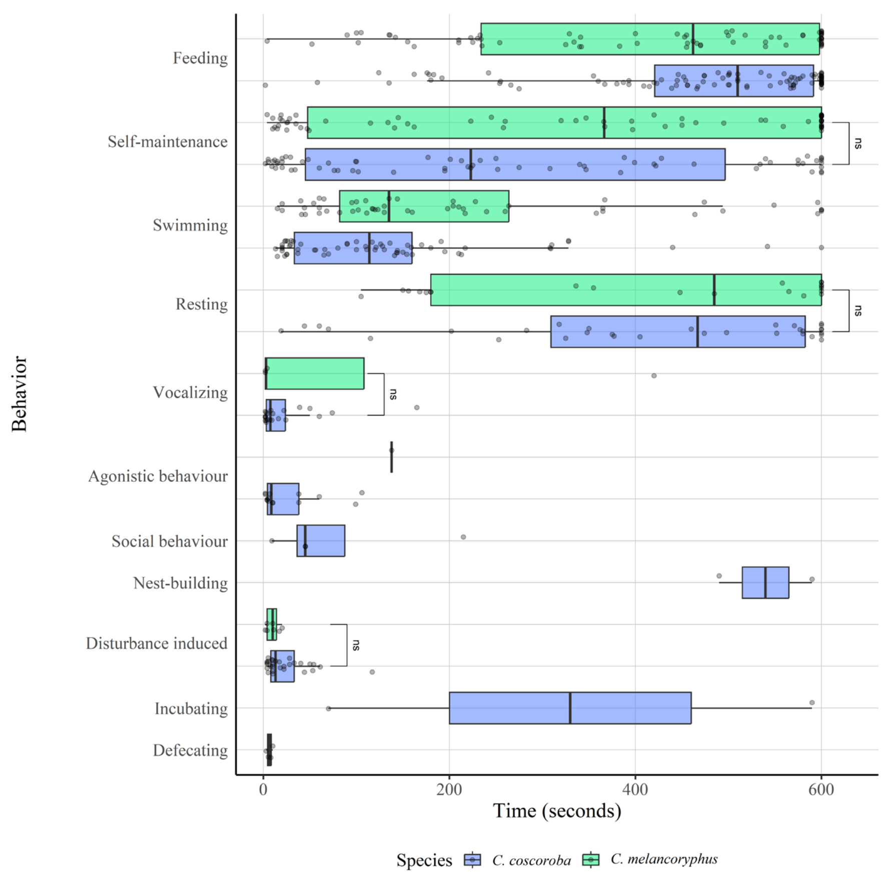

FIGURE 2. Boxplot for the time of each observed behaviour segregated by species. The abbreviation "ns" means that there were no significant differences according to the Mann-Whitney-Wilcoxon test (the test could not be applied to the other groups because the assumption of equality of variance was not met). / Boxplot para el tiempo de cada conducta observada segregada por especie. La abreviación "ns" significa que no hubo diferencias significativas según el test de Mann-Whitney-Wilcoxon (a los demás grupos no se pudo aplicar el test debido a que no se cumplió el supuesto de igualdad de varianza).

Nevertheless, when we analysed the time spent on each behaviour by sites, we found that *C. coscoroba* showed preferences for feeding at site 4 while avoided feeding at site 2 (p = 0.02). On the contrary, for *C. melancoryphus* we did not find significant differences for the feeding times by sites (p = 0.47; Fig. 3a).

For self-maintenance behaviour, we found that *C. coscoroba* showed preferences for sites 2 and 4 to develop this behaviour, while they avoided site 3. In the case of *C. melancoryphus*, it showed preferences for sites 1 and 2 (Fig. 3b). We found significant differences for both species in the sites 1 and 4 (p < 0.001 y p = 0.04, respectively).

For swimming behaviour there were significant differences only for *C. melancoryphus* in sites 3 and 4 (p = 0.014). However, *C. coscoroba* did not show any significant differences for this behaviour (p = 0.46; Fig. 3c).

For disturbance induced behaviour, we found that *C. coscoroba* mainly developed it in sites 1 and 2 while it was low in sites 3 and 4. *C. melancoryphus* showed this behaviour only in the sites 3 and 4, although for a very low amount of time (Fig. 3d).

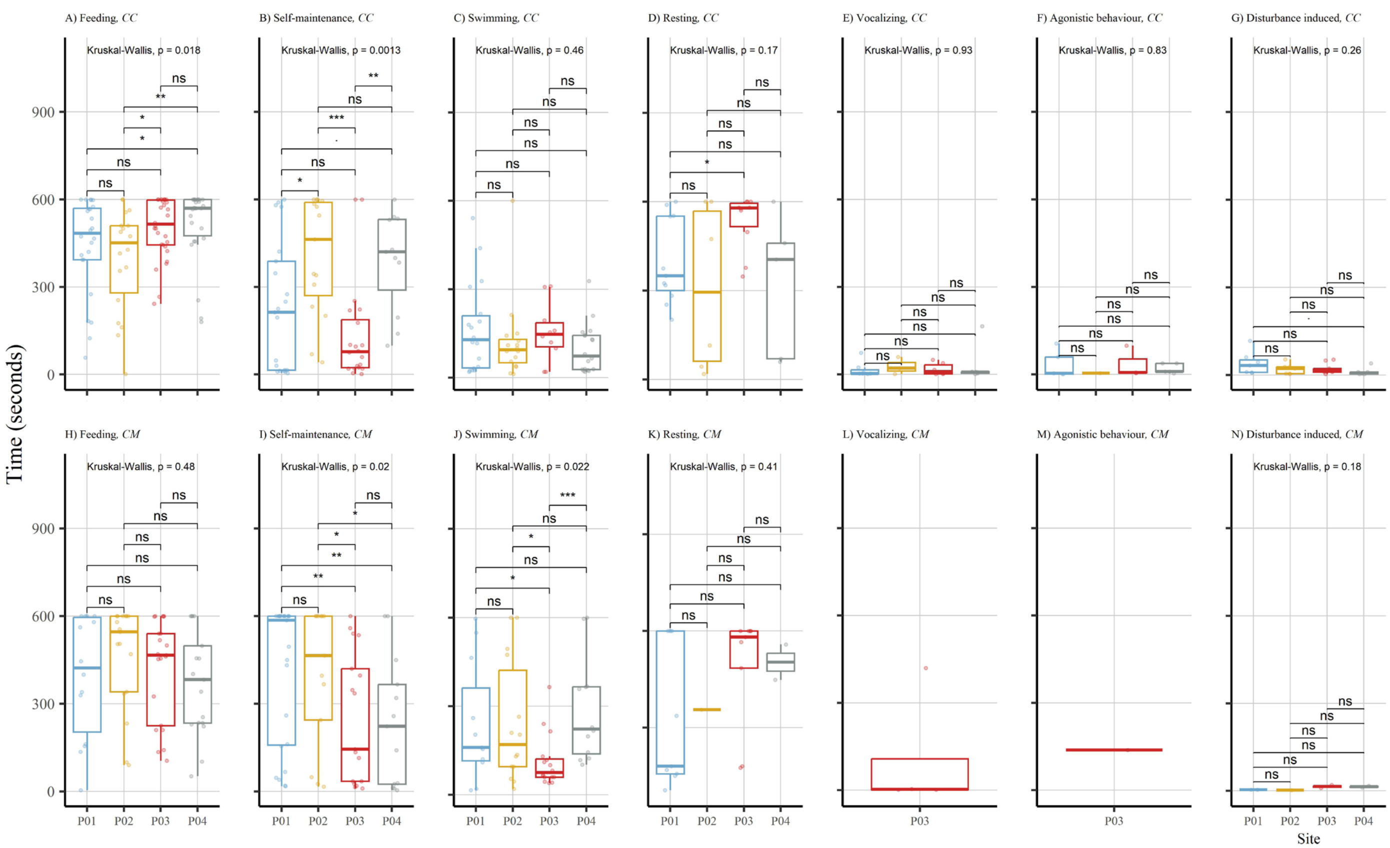

FIGURE 3. Boxplot for the observed time of each behaviour by species and site. The data was not normally distributed, therefore, the Kruskal-Wallis and pairwise Mann–Whitney–Wilcoxon test were applied. The symbols "*" and "·" indicate that there was a significant difference at 95% and 90% statistical confidence, respectively, while "ns" indicates that there was no difference. *CC* = *Coscoroba coscoroba* and *CM* = *Cygnus melancoryphus*. / Boxplot para el tiempo observado de cada comportamiento por especie y sitio. Los datos no se distribuyeron normalmente, por lo tanto, se aplicaron las pruebas de Kruskal-Wallis y Mann–Whitney–Wilcoxon por pares. Los símbolos "*" y "·" indican que hubo una diferencia significativa en el 95% y el 90% de confianza estadística, respectivamente, mientras que "ns" indica que no hubo diferencia. *CC* = *Coscoroba coscoroba* y *CM* = *Cygnus melancoryphus*.

DISCUSSION

The salty areas are scarce at global level (Fahrenkrog 2009), however, in some of them it is possible to combine a sustainable production of salt with the maintenance of a high bird biodiversity (Takekawa *et al.* 2001; Masero 2003; Navedo *et al.* 2013; Del Pezo 2018). Many of them are currently abandoned in Europe and elsewhere, consequently, the associated wetland is degraded and birds biodiversity suffers an important impact (Castro 1993; Paracuellos 1993; Zorrilla-Miras *et al.* 2014). For this reason, several conservation actions are focused on recovery and restoration of the salt production in an artisanal way and, in addition, maintaining and preserving the biodiversity. The National Plan for Wetland Protection 2018-2022 and Coastal Wetlands GEF Project, both lead by the Chilean Government, look for the trigger to develop these initiatives.

Currently in Chile, the wetlands with salt production activities are supported by small communities which extract the salt in an artisanal way. Therefore, the maintenance of these wetlands depends on the economic profitability of them and the salt workers perceiving that their effort is rewarded. This is especially important for establishing conservation plans for the avifauna of these wetlands (Grand *et al.* 2020) where the conservationists must find a narrow balance between both activities (conservation and salt production). In this context, it is necessary to establish the ecological role of the swans and their ecosystem services and to develop a win-win strategy.

Our results show that the main behaviour that both species develop in the salt ponds is feeding, where the swans spend more than 45% of their time. Due the low digestion efficiency of these species (Corti 1996), they consume great amounts of aquatic vegetation to satisfy their needs. This way, swans could provide an ecosystem service with appreciated value to the salt workers, because they are responsible for regulating the presence of macrophytes in the salt ponds. This is especially important if we take into account that each swan eats approx. 12-16 kg daily (Corti 1996). Given that this is the main behaviour recorded by us in relation with other behaviours, this result is significant to understand the contribution of swans in the macrophytes suppression as ecosystem service of regulation for the salt workers.

However, we found that all the salt ponds were not used in the same way by the swan species. *C. coscoroba* showed preferences by the less shallower ponds to feed in them, where they can find more macrophytes (Pardo *et al.* 2015). In other studies, they found that swans show preference by less shallower and with some degree of eutrophication (Corti 1996; Cursach *et al.* 2015). However, *C. melancoryphus* did not show differences between sites with regards to the feeding behaviour, because it is an opportunistic consumer that uses those habitats where the access to feed is easier and there is more abundance of food (Corti 1996; Corti & Schlatter 2002; Figueroa-Fábrega *et al.* 2006; Velásquez *et al.* 2019; Norambuena *et al.* 2023).

In other hand, our data is an evidence that the self-maintenance behaviour is very important for these swans and they spend a lot of time at this task, since it helps them reduce the stress caused by predators (Henson *et al.* 2012; Iannacone *et al.* 2012). We found significant differences for both species in the sites 1 and 4. Our results show that both species spent more time developing this behaviour at the sites 1 and 2, those where there were high traffic levels, more houses and more presence of feral dogs and cats. This could suggest that anthropic activity and feral dogs have a negative impact on the presence and behaviour of birds (Henson & Grant 1991; Davenport & Davenport 2006; Cornejo *et al.* 2018; Mella-Romero *et al.* 2018; Bravo-Naranjo *et al.* 2019; Miranda-Cavallieri *et al.* 2023). Associated to this behaviour, although we did not find significant differences between sites for alarm behaviour in our study area, we observed that *C. coscoroba* spent some time dedicated to this behaviour at site 1 in comparison with site 4. The disturbance induced behaviour is influenced mainly by distress events, and it is an stress indicator (Porto & Piratelli 2005). For this reason, it is necessary to provide landscape elements such as riparian vegetation which will help to reduce stress in swans (Osbahr & Gómez 2011). Also, this behaviour is high during pre-breeding and breeding seasons as a territoriality and defence response (Silva & Brewer 2007), especially, if there is a great affluence of tourists.

In other hand, the differences observed in the swimming behaviour by *C. melancoryphus* appear in those salt ponds where the macrophytes cover a small proportion of the area, and therefore the swan must swim for more time while looking for food. The agonistic behaviour was observed principally in *C. coscoroba*, mainly at sites 1, 3 and 4 during breeding season and it is a behaviour associated with the territoriality in the nest areas of this species (Rees & Brewer 2005; Silva & Brewer 2007), since, at all these sites, nesting areas were recorded, except for site 2, which could help us understand why this behaviour (associated with territoriality) was concentrated at these points.

In conclusion, our study provides an empirical evidence that *C. coscoroba* and *C. melancoryphus* developed, mainly, a feeding behaviour at the study site, which could have an important impact as ecosystem service for the salt workers, since they affirm that removing the macrophytes themselves is a demanding and time-consuming job. This way, the presence of these swans and the maintenance of the salt works could be a win-win situation for the bird conservation and the artisanal salt production. Also, the presence of species which are highly acknowledged by the society (flagship species), such as swans, could be an advantage to promote and give an added value to the salt produced in these wetlands. However, it is necessary to provide the Cáhuil's wetland with protective measures which will allow the development of conservation and management plans within a suitable juridical frame. Also, it is necessary to regulate the presence of urban areas and feral dogs, increasing the riparian vegetation in those troubled sites and developing a control plan for tourism to minimize its impact during the breeding season.

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REFERENCES

Adams, J., Raw, J., Riddin, T., Wasserman, J., Van Niekerk, L. 2021. Salt marsh restoration for the provision of multiple ecosystem services. Diversity 13: 680. DOI: 10.3390/d13120680

Andrade, B., Grau, S. 2005. La laguna de Cahuil, un ejemplo de estuario estacional en Chile Central. Revista de Geografía Norte Grande 33: 59-72.

Araya, C. 2006. Salineros de la laguna de Cahuil Cristalizadores de oro blanco. Tesis de pregrado. Universidad de Chile, Santiago, Chile.

Barbier, E., Hacker, S., Kennedy, C., Koch, E., Stier, A., Silliman, B. 2011. The value of estuarine and coastal ecosystem services. Ecological Monographs 81: 169-193.

Bengoa, J. 1983. El campesinado chileno después de la reforma agraria. Ediciones SUR. 204 pp.

Bravo-Naranjo, V., Jiménez, R., Zuleta, C., Rau, J., Valladares, P., Piñones, C. 2019. Selección de presas por perros callejeros en el humedal Estero Culebrón (Coquimbo, Chile). Gayana 83(2): 102-113. DOI: 10.4067/S0717-65382019000200102

Brewer, G., Vilina, Y. 2002. Parental Care Behavior and Double-Brooding in Coscoroba Swan in Central Chile. Waterbirds 25: 278-284.

Calabuig, C., Green, A., Menegheti, J., Abad, R., Patiño, J. 2010. Fenología del Coscoroba (*Coscoroba coscoroba*) en el sur de Brasil y sus movimientos hacia Argentina. Ornitología Neotropical 21: 555-566.

Castro, C., Alvarado, C. 2009. La gestión del litoral chileno: Un diagnóstico. CYTED-IBERMAR. Universidad Católica de Chile, Instituto de Geografía. 22 pp.

Castro, H. 1993. Las salinas de Cabo de Gata: Ecología y dinámica anual de las poblaciones de aves en las salinas de Cabo de Gata (Almería). Instituto de Estudios Almerienses, Almería. 529 pp.

Cienfuegos, R., Campino, J., Gironás, J., Almar, R., Villagran, M. 2012. Desembocaduras y Lagunas Costeras en la Zona Central de Chile. En: Fariña, J., Camaño, A. (Eds). Humedales Costeros de Chile, Aportes Científicos a su Gestión Sustentable: 21-66. Ediciones UC, Chile.

Cornejo, J., Rebolledo, L., Leyton, I., Allendes, C., Miranda, M. 2018. Relación entre la calidad del agua y la distribución de la avifauna del Humedal Petrel. Brotes Científicos 2(1): 37-44.

Corti, P. 1996. Conducta de alimentación y capacidad de forrajeo del cisne de cuello negro (*Cygnus melanocorypha* Molina, 1782) en humedales de Valdivia. Tesis de pregrado. Universidad Austral de Chile, Valdivia, Chile.

Corti, P., Schlatter, R. 2002. Feeding ecology of the Black-necked Swan *Cygnus melancoryphus* in Two Wetlands of Southern Chile. Studies on Neotropical Fauna and Environment 37(1): 9-14. DOI: 10.1076/snfe.37.1.9.2118

Couve, E., Vidal, C., Ruiz, J. 2016. Aves de Chile, sus islas oceánicas y Península Antártica. FS Editorial. 550 pp.

Cursach, J., Rau, J., Tobar, C., Vilugrón, J., De La Fuente, L. 2015. Alimentación del cisne de cuello negro *Cygnus melanocoryphus* (Aves: Anatidae) en un humedal marino de Chiloé, sur de Chile. Gayana 79(2): 137-146. DOI: 10.4067/S0717-65382015000200003

Davenport, J., Davenport, J. 2006. The impact of tourism and personal leisure transport on coastal environments: A review. Estuarine, Coastal and Shelf Science 67(1): 280-292. DOI: 10.1016/j.ecss.2005.11.026

Del Pezo, D. 2018. Abundancia y estructura comunitaria de aves playeras en las piscinas artificiales de una empresa salinera de Ecuador. Tesis de pregrado. Universidad Estatal Península de Santa Elena, La Libertad, Ecuador.

Echevarria, A., Cocimano, M., Chani, J., Marano, C. 2013. Nesting biology of Coscoroba Swan *Coscoroba coscoroba* at La Angostura Dam, Tafí del Valle, Tucumán, Argentina. Cotinga 35: 11-14.

Fahrenkrog, K. 2009. Salinas de Cahuil Una etnografía sobre la actividad salinera en Cáhuil, Barrancas y La Villa. Tesis de pregrado. Universidad Academia de Humanismo Cristiano, Santiago, Chile.

Figueroa-Fábrega, L., Galaz, J., Merino, C. 2006. Conocimiento y conservación del cisne de cuello negro *Cygnus melancoryphus* (Molina, 1782) en el humedal de río

Cruces, Valdivia, Chile. Gestión Ambiental 12: 77-89.

Garay, G., Johnson, W., Franklin, W. 1991. Relative abundance of aquatic birds and their use of wetlands in the Patagonia of southern Chile. Revista Chilena de Historia Natural 64: 127-137.

Gibbons, J., Vilina, Y., Cárcamo, J. 2007. Distribución y abundancia de cisne coscoroba (*Coscoroba coscoroba*), cisne de cuello negro (*Cygnus melancoryphus*) y del flamenco chileno (*Phoenicopterus chilensis*) en la Región de Magallanes. Anales Instituto Patagonia 35(2): 53-58.

Gómez G., Cortes, H., Cárcamo N., Vega T. 2014. Avifauna del humedal Tres Puentes reserva natural urbana, Punta Arenas (53°S), Chile. Anales del Instituto de la Patagonia 42(2): 93-101. DOI: 10.4067/S0718-686X2014000200010

González, A., Vukasovic, M., Estades, C. 2011. Variación temporal en la abundancia y diversidad de aves en el humedal del Río Itata, región del Bío-Bío, Chile. Gayana 75(2): 170-181.

Grand, J., Saunders, S., Michel, N., Elliott, L., Beilke, S., Bracey, A., Gehring, T., Gnass, E., Howe, R., Kasberg, B., Miller, N., Niemi, G., Norment, C., Tozer, D., Wu, J., Wilsey, C. 2020. Prioritizing coastal wetlands for marsh bird conservation in the U.S. Great Lakes. Biological Conservation 249: 108708. DOI: 10.1016/j.biocon.2020.108708.

Henson, P., Grant, T. 1991. The Effects of Human Disturbance on Trumpeter Swan Breeding Behavior. Wildlife Society Bulletin 19(3): 248-257.

Henson, S., Weldon, L., Hayward, J., Greene, D., Megna, L., Serem, M. 2012. Coping behaviour as an adaptation to stress: Post-disturbance preening in colonial seabirds. Journal of Biological Dynamics 6(1): 17-37. DOI: 10.1080/17513758.2011.605913

Iannacone, J., Villegas, W., Calderón, M., Huamán, J., Silva-Santiesteban, M., Alvariño, L. 2012. Patrones de comportamiento diurno de Huerequeque Burhinus superciliaris en hábitats modificados de la costa central del Perú. Acta Zoológica Mexicana 28(3): 507-524. DOI: 10.21829/azm.2012.283855

Imbernón, D. 2023. Informe Monitoreo de Avifauna del Humedal Laguna de Cáhuil. Proyecto GEF Humedales Costeros del Centro Sur de Chile. 22 pp.

International Panel on Climate Change (IPCC). 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, UK. 31 pp.

IUCN. 2016. Red List of Threatened Species, Version 2016.1. IUCN, Cambridge, UK. URL: https://www.iucnredlist.org Acceso 30 diciembre 2021.

Krivtsov, S., Mineyev, Y. 2013. Daily time and energy budgets in Whooper Swans *Cygnus cygnus* and Bewick's Swans *Cygnus bewickii* in the breeding season. Wildfowl 319-321.

Lefeuvre, J., Bouchard, V., Feunteun, E., Grare, S., Laffaille, P., Radureau, A. 2000. European salt marshes diversity and func-tioning: The case study of the Mont Saint-Michel bay, France. Wetlands Ecology and Management 8: 147-161.

Luebert, F., Pliscoff, P. 2017. Sinopsis bioclimática y vegetacional de Chile. Segunda Edición. Editorial Universitaria, Santiago de Chile. 384 pp.

Marquet, P., Abades, S., Barría, I. 2012. Distribución y conservación de humedales costeros: Una perspectiva geográfica. En: Fariña, J., Camaño, A. (Eds). Humedales Costeros de Chile, Aportes Científicos a su Gestión Sustentable: 1-19. Ediciones UC, Chile.

Mas, M., Flaquer, C., Rebelo, H., López-Baucells, A. 2021. Bats and wetlands: Synthesising gaps in current knowledge and future opportunities for conservation. Mammal Review 51(3): 369-384. DOI: 10.1111/mam.12243

Masero, J. 2003. Assessing alternative anthropogenic habitats for conserving waterbirds: Salinas as buffer areas against the impact of natural habitat loss for shorebirds. Biodiversity & Conservation, 12(6): 1157-1173. DOI: 10.1023/A:1023021320448

Matus, R., Díaz, F., Schmitt F. 2010. Censos Neotropicales de Aves Acuáticas en Chile. Red de Observadores de Aves y Vida Silvestre de Chile, Santiago. 52 pp.

Mella-Romero, J., Peña-Villalobos, I., Sallaberry, M. 2018. Aves acuáticas en laguna petrel (Región del Libertador Bernardo O'Higgins): Abundancia y propuesta de conservación. Boletín del Museo Nacional de Historia Natural, Chile 67(2): 77-89.

Miranda-Cavallieri, M., Allendes-Muñoz, C., Matus-Olivares, C., Lisón, F. 2023. Habitat preference and abundance of Coscoroba coscoroba and Cygnus melancoryphus in Petrel wetland (O'Higgins Region, Chile): Implications in the conservation. Gayana 87(1): 86-96. DOI: 10.4067/S0717-65382023000100086

Muñoz-Pedreros, A. 2003. Guía de los Humedales del Río Cruces. Cea Ediciones, Valdivia, Chile. 143 pp.

Navedo, J., Arranz, D., Herrera, A., Salmón, P., Juanes, J., Masero, J. 2013. Agroecosystems and conservation of migratory waterbirds: Importance of coastal pastures and factors influencing their use by wintering shorebirds. Biodiversity and Conservation 22(9): 1895-1907. DOI: 10.1007/s10531-013-0516-2

Norambuena, C., Jélvez, M., Mena, M., Ratto, M. 2023. Seasonality in the feeding ecology of Black-necked swans (*Cygnus melancoryphus*) in a temperate wetland of southern Chile. Gayana 87(1): 10-17. DOI: 10.4067/S0717-65382023000100010

Osbahr, K., Gómez, N. 2011. Abundancia, uso de hábitat y comportamiento de la tingua moteada (Gallinula melanops bogotensis Chapman 1914) en el humedal Guaymaral, Bogotá—Colombia. Revista U.D.C.A Actualidad & Divulgación Científica 14(1): 81-91. DOI: 10.31910/rudca.v14.n1.2011.760

Paracuellos, M. 1993. Fenología annual de la ornitofauna de las salinas de Guardias Viejas (Almería). Calidad ornítica. Alytes (4): 317-333.

Pardo, R., Sabando, M., Vargas, R. 2015. Actualización LB biológica, flora y fauna acuática, humedal de Cáhuil (Informe final). Aguaexpert. 83 pp.

Porto, G., Piratelli, A. 2005. Etograma da maria-preta, Molothrus bonariensis (Gmelin) (Aves, Emberizidae, Icterinae). Revista Brasileira de Zoologia 22(2): 306-312. DOI: 10.1590/S0101-81752005000200002

Quiroz, D., Poblete, P., Olivares, J. 1986. Los Salineros en la costa de Chile Central. Revista Chilena de Antropología 5: 103-120. DOI: 10.5354/rca.v0i5.17755

R CORE TEAM. 2019. R: A language and environment for statistical computing. R version 3.6.1. The R Foundation for Statistical Computing. URL: https://www.R-project.org/.

Ramírez-Álvarez, D. 2018. Fauna nativa de la Región O'Higgins, Chile, Vertebrados Terrestres. Rancagua, Chile. 504 pp.

Rees, E., Brewer, G. 2005. Coscoroba swan. En: Kear, J (Eds) Bird families of the world: Ducks, geese, and swans: 219-222. Oxford University. Press.

Rees, E., Cao, L., Clausen, P., Coleman, J., Cornely, J., Einarsson, O., Ely, C., Kingsford, R., Ma, M., Mitchell, C., Nagy, S., Shimada, T., Snyder, J., Solovyeva, D., Tijsen, W., Vilina, Y., Włodarczyk, R., Brides, K. 2019. Conservation status of the world's swan populations, *Cygnus sp*. and *Coscoroba sp.*: A review of current trends and gaps in knowledge. Wildfowl (Special Issue 5): 35-72.

Schlatter, R., Salazar, J., Villa, A., Meza, J. 1991. Demography of Black-necked Swans *Cygnus melancoryphus* in three Chilean wetland areas. Wildfowl (Special Supplement 1): 88-94.

Silliman, B., Schrack, E., He, Q., Cope, R., Santoni, A., van der Heide, T., Jacobi, R., Jacobi, M., van de Koppel, J. 2015. Facilitation shifts paradigms and can amplify coastal restoration efforts. Proceedings of the National Academy of Sciences 112: 14295-14300.

Silva, C., Brewer, G. 2007. Breeding behavior of the Coscoroba swan (*Coscoroba coscoroba*) in el Yali wetland, central Chile. Ornitología Neotropical 18: 573-585.

Takekawa, J., Lu, C., Pratt, R. 2001. Avian communities in baylands and artificial salt evaporation ponds of the San Francisco Bay estuary. Hidrobiology 466: 317-328. DOI: 10.1007/978-94-017-2934-5_29.

Tatu, K., Anderson, J., Hindman, L., Seidel, G. 2007. Diurnal foraging activities of Mute Swans in Chesapeake Bay, Maryland. Waterbirds 30: 121–8.

TEEB. 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

Velásquez, C., Jaramillo, E., Camus, P., Labra, F., San Martín, C. 2019. Dietary habits of the black-necked swan *Cygnus melancoryphus* (Birds: Anatidae) and variability of the aquatic macrophyte cover in the Río Cruces wetland, southern Chile. PLOS ONE 14(12): 1-15. DOI: 10.1371/journal.pone.0226331.

Vera, J. 2003. Sal y sociedad. Las salinas de Boyeruca 1644 - 2001. Tesis de Magíster, Universidad de Chile, Santiago, Chile. URL: http://repositorio.uchile.cl/handle/2250/108784

Vilina, Y., Cofré, H., Silva-García, C., García, M., Pérez-Friedenthal, C. 2002. Effects of El Niño on abundance and breeding of Black-necked swans on El Yali wetland in Chile. Waterbirds 25 (Special Publication 1): 123-127.

Wasserman, J., Adams, J., Lemley, D. 2022. Investigating the potential for saltpan restoration for the provision of multiple ecosystem services. African Journal of Aquatic Science 47(4): 436-446. DOI: 10.2989/16085914.2022.2067823

Zar, J. 1999. Biostatistical Analysis (Fourth edition). Englewood Cliffs, Prentice Hall, New Jersey. 929 pp.

Zorrilla-Miras, P., Palomo, I., Gómez-Baggethun, E., Martín-López, B., Lomas, P., Montes, C. 2014. Effects of land-use change on wetland ecosystem services: A case study in the Doñana marshes (SW Spain). Landscape and Urban Planning 122: 160-174. DOI: 10.1016/j.landurbplan.2013.09.013

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