Chapter 15
Amphibians and Waterbirds as Bridges to Conserve Aquatic, Wetland and Terrestrial Habitats in Patagonia

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1 Introduction

Management strategies that consider multiple realms (i.e. marine, terrestrial or freshwater) have potential co-benefits for biodiversity conservation (Hazlitt et al. 2010; Klein et al. 2013). However, conservation planning and management strategies have been historically focused on single realms. Governmental and non-governmental environmental organisations (NGOs) often are lacking an interinstitutional working approach as well as a lack of generalised cross-realm conservation planning due to governance and technical capability issues (Adams et al. 2014). For example, in the Argentinean Patagonian provinces, land and freshwater resource management usually depends upon different environmental agencies with no clear interaction policies among them (see Chap. 9). These technical barriers owe to a poor understanding of ecological relationships. In a world wherein conservation resources are often limited, it is crucial to wisely allocate management efforts to increase conservation achievements (Carwardine et al. 2008). A better understanding of the ecological linkages and benefits of different actions across realms is crucial for a better and cost-effective resource allocation.

Freshwater and terrestrial ecosystems are linked by several ecological processes and are affected by similar threats. Biotic processes such as complex predator-prey mechanisms include interactions among species adapted to live both on land and in

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water during their life cycles. Within the vertebrates, amphibians and waterbirds have a crucial relevance within ecosystems as indicators of threats that can come from water and/or land (Duellman and Trueb 1994; Amat and Green 2010; Green and Elmberg 2014).

Amphibians are currently among the most endangered animals worldwide. With at least 37 extinct species and almost 34% of species under a threat category, amphibians are a high priority in terms of species conservation planning. On the other hand, waterbirds' dependence on freshwater habitats makes them especially vulnerable to several threats affecting aquatic, wetland and terrestrial resources globally (Young et al. 2001). In addition, the congregatory behaviour of several waterbird species increases population risks by concentrating individuals in limited areas (Ma et al. 2010). The conservation of these taxa can lead to finding cost-effectiveness management actions that integrate the protection across freshwater and terrestrial realms; thus, they can act as flagship species for sound conservation strategies (Roesler 2016; Velasco 2018).

Patagonia is home to amphibians and waterbirds highly adapted to live in seasonally extreme weather (Cei 1980; Vuilleumier 1991). Within amphibians, severe weather conditions are the cause of a low richness of species. Also, there is a high percentage of endangered species inhabiting Patagonia compared to other regions (Úbeda and Grigera 2007; Vaira et al. 2012). Regarding waterbirds, a higher number of species can be found in this region, with a lower percentage of endangered species (MAyDS and AA 2017). Nevertheless, some of the threatened waterbirds are considered among the most endangered birds worldwide (e.g. *Podiceps gallardoi* – hooded grebe; see Roesler (2016)). Most of these species also show population declines due to human-related threats and the changing environmental conditions associated with global climate change (Lancelotti et al. 2020).

In this chapter, we describe basic information about diversity, ecology and conservation traits related to some of Patagonian amphibians and waterbirds, focusing on how they represent bridges between freshwater and terrestrial environments. We also show the importance of these species in supporting ecological processes that link freshwater and terrestrial ecosystems and how conservation planning should integrate both realms to conserve threatened species. This chapter is focused on the Argentine Patagonian sector, but we consider that the conclusions can be helpful to further conservation strategies for the entire Patagonian region.

2 Amphibians From Patagonian Freshwaters: History, Diversity and Ecology

South America has the largest diversity of amphibians worldwide (Young et al. 2004). Of the 40 Neotropical countries, Argentina is among the top 10 with the largest amphibian fauna in the region (Vaira et al. 2017), up to 30% of which are endemic (Bolaños et al. 2008; Lavilla and Heatwole 2010; Vaira et al. 2017). Despite the low amphibian diversity of Argentinean Patagonia, the area is important in terms of conservation because of the high level of endemism and endangered amphibians (Úbeda and Grigera 2007) (Table 15.1 and Fig. 15.1).

The fossil record of South American anurans is biased, having a poor representation of most neobatracians. Some exceptions exist within the clades Calyptocephalellidae and Pipidae, which have extensive records after the late Cretaceous (Rolando et al. 2019). Some of the oldest records of anurans from South America are found in Patagonian provinces (e.g. *Vieraella herbstii*, from the lower Jurassic of northern Santa Cruz, and *Notobatrachus degiustoi*, from the middle Jurassic of northeast Santa Cruz (Cei 1980; Úbeda 1998)). Other examples such as *Shelania pascuali* in Chubut and *Calyptocephalella gayi* in Neuquén highlight Patagonia's relevance for the history of amphibians (Cei 1980). Other relevant records are *Avitabatrachus uliana* in Neuquén province (Baéz et al. 2000, 2022); *Calyptocephalella pichileufensis* (Gómez et al. 2011), *Calyptocephalella satan* (Agnolin 2012) and *Llankibatrachus truebae* (Baez et al. 2003) in Río Negro province; and *Calyptocephalella sabrosa* (Muzzopappa et al. 2021) in Chubut province.

Three hypotheses were proposed to explain the current distribution pattern of anurans in southern South America: (i) the impoverished hypothesis (Darlington 1965), which suggests that the Patagonian forest amphibians constitute a poorly differentiated group from extant clades; (ii) the ancient assembly hypothesis (Cei 1962), which states that the *Nothofagus* forest anurans are a remnant of the tertiary amphibians isolated by ecological barriers and (iii) the complex history hypothesis (Vuilleumier 1968), which indicates that the current amphibian assembly is the result from a sum of the evolutionary histories of the different groups that compose it. However, a recent different hypothesis considers that the current diversity and distribution of Patagonian amphibians can be explained by two main anuran components. The first group would be composed by survivors of widely distributed Gondwanan taxa (e.g. *Calyptocephalella and Telmatobius*) while the second composed by *Rhinella* and *Pleurodema*. This last genus probably got into Patagonia during Plio-Pleistocene times when Chacoan environments expanded southwards (Agnolin 2012). Regarding to the genus *Atelognathus*, some researchers assume a recent expansion in association with a favourable period, from a single source population restricted to the southernmost part of its distributional range (Barraso and Basso 2018).

Summarising, the current Patagonian amphibian fauna is considered both relictual and with a high level of endemism and microendemism (Úbeda and Grigera 2007). The two most diverse genera are *Eupsophus*, with species restricted to forested areas in southern latitudes, and *Alsodes*, with species also distributing along the arid Andean slopes of Central Chile and Argentina (Blotto et al. 2013).

The highest richness of amphibian species is found in the northern region of Patagonia, with a decreasing number towards the south. In Argentina, the lowest richness is found in Santa Cruz province, with only four known species, while this group is absent from insular Tierra del Fuego (Vaira et al. 2012). On the other hand, the amphibian diversity declines from the west to east, associated with the drastic decrease in environmental complexity (Perotti et al. 2005). Amphibians from Patagonia are distributed in two main habitats, the Valdivian and southern forests

Table 15.1 Amphibian species from the Argentinean Patagonia, conservation status and population trends listed in the IUCN (International Union for Conservation of Nature) Red List and Argentinean Red List (Source: Vaira et al. 2012)

	Population trend	
Families and species	IUCN category	Argentinean category
Alsodidae		
Alsodes gargola	Least concern	**Vulnerable**
Alsodes neuquensis	**Endangered – decreasing**	**Endangered**
Alsodes pehuenche	**Critically endangered – decreasing**	**Critically endangered**
Alsodes verrucosus[a]	**Endangered – decreasing**	Data deficient
Eupsophus calcaratus	Least concern – **decreasing**	Least concern
Eupsophus emiliopugini	Least concern – **decreasing**	**Vulnerable**
Eupsophus roseus	Least concern – **decreasing**	Not assessed
Eupsophus vertebralis	Least concern – **decreasing**	Data deficient
Batrachylidae		
Atelognathus nitoi	**Vulnerable**	**Vulnerable**
Atelognathus patagonicus	**Critically endangered – decreasing**	**Critically endangered**
Atelognathus praebasalticus	**Endangered – decreasing**	Data deficient
Atelognathus reverberii	**Vulnerable – decreasing**	**Vulnerable**
Atelognathus solitarius	Data deficient	Data deficient
Batrachyla antartandica	Least concern	**Vulnerable**
Batrachyla fitzroya	**Vulnerable**	**Vulnerable**
Batrachyla leptopus	Least concern	Least concern
Batrachyla taeniata	**Least concern – decreasing**	Least concern
Chaltenobatrachus grandisonae	Least concern	Data deficient
Hylorina sylvatica	**Least concern – decreasing**	**Vulnerable**
Bufonidae		
Nannophryne variegata	**Least concern – decreasing**	Least concern
Rhinella arenarum	Least concern	Least concern
Rhinella papillosa[b]	Not assessed	Least concern
Rhinella rubropunctata	**Vulnerable – decreasing**	**Vulnerable**
Leptodactylidae		
Leptodactylus luctator	Least concern	Least concern
Leptodactylus mystacinus	Least concern	Least concern
Pleurodema bufoninum	Least concern	Least concern
Pleurodema nebulosum	Least concern	Least concern
Pleurodema somuncurense	**Critically endangered – decreasing**	**Critically endangered**
Pleurodema thaul	Least concern	Least concern
Odontophrynidae		
Odontophrynus americanus	Least concern	Least concern
Odontophrynus occidentalis	Least concern	Least concern
Rhinodermatidae		
Rhinoderma darwinii	**Endangered – decreasing**	**Endangered**

[a]Uncertain presence in Argentina (Blotto et al. 2013)
[b]Could be a synonym of *Rhinella spinulosa* (Vera Candioti et al. 2020)

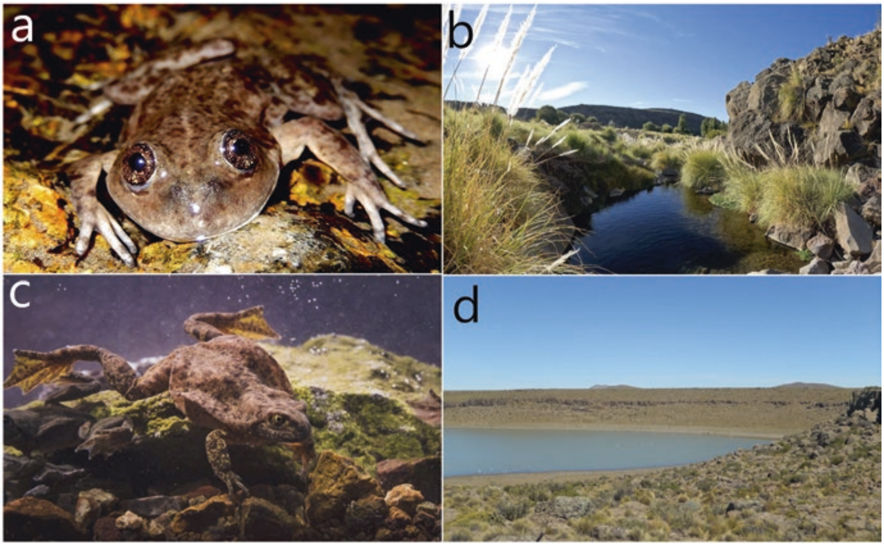

Fig. 15.1 Examples of emblematic threatened Patagonian amphibians in their freshwater and wetland habitats. (**a**) The El Rincon stream frog, *Pleurodema somuncurense.* (Photo by Federico Kacoliris) in (**b**) the thermal waters of the Valcheta Stream. (Photo by Melina Velasco, upper right). (**c**) The Patagonia frog, *Atelognathus patagonicus.* (Photo by Rodrigo Calvo, down left) in (**d**) the temporary steppe lagoons. (Photo by Federico Kacoliris, down right)

and the steppe and mountain wetlands (Cei 1980; Perotti et al. 2005). The four amphibians with the southernmost distribution at global level (*Batrachyla antartandica*, *Chaltenobatrachus grandisonae*, *Nannophryne variegata* and *Pleurodema bufoninum*) are found in both Argentinian and Chilean Patagonia (Atalah and Sielfeld 1976; Úbeda et al. 2010; Ortiz 2015; Cisternas-Medina et al. 2019). The Argentinean Patagonia hosts 32 amphibian species (Table 15.1) belonging to 6 families, within which Batrachylidae and Alsodidae have the greatest richness. Approximately a quarter of these is endemic, including *Batrachyla fitzroya* in Chubut province; *Alsodes neuquensis*, *Atelognathus patagonicus* and *Atelognathus praebasalticus* in Neuquén province; and *Atelognathus solitarius* and *Pleurodema somuncurense* in Río Negro province. In turn, *Atelognathus reverberii* is endemic from the Somuncura Plateau (see Chap. 9) shared by Rio Negro and Chubut provinces.

There are recent studies that propose new taxonomical arrangements for some Patagonian amphibians; thus, there is some controversy between information exposed in the IUCN Red List, and scientific literature published later than IUCN assessments were made, thus reducing the number of enlisted species. This is the case of *Atelognathus nitoi*, which has recently been considered as a senior synonym of *A. ceii* and *A. salai* (Barrasso and Basso 2018), and the Argentinean populations of *Alsodes australis*, now considered as *A. gargola* (Blotto et al. 2013). The record of *Alsodes verrucosus*, from Argentina, is based on two populations (Cei 1987) of dubious identity, and hence its presence should be considered as still uncertain (Blotto et al. 2013).

Among the amphibians living in Patagonia, 44% occur in freshwater and wetlands (e.g. streams, lakes and ponds) or humid soil within forest areas, while only 18% live in streams or ponds located in tablelands or plateaus dominated by steppe vegetation.

Amphibians show a particular life cycle that depends upon the existence of freshwaters. This feature could be considered a drawback for Patagonian amphibians, since these habitat types occupy merely 5% of the region (Perotti et al. 2005). However, Patagonian species are highly adapted to these extreme conditions. The Patagonian freshwater ecosystems are mainly represented by lakes, ponds, rivers, streams, "mallines" and several kinds of ponds (see Chaps. 3, 9 and 10). Lakes are more common near the Andean Mountain range and are surrounded by forest (see Chap. 3). Some species prefer these forestry areas, where they find refuge under tree bark, trunks, dry branches or inside caves and pits (Ghirardi and López 2017). In turn, wetlands such as ponds and *mallines* are common in arid areas such as tablelands or plateaus and show several amphibian species adapted to live under contrasting seasonal conditions including dry periods. In particular, mallines are an essential habitat for native amphibian species (Perotti et al. 2005).

Some Patagonian amphibian species such as *Rhinoderma darwinii*, *Batrachyla antartandica* and *Hylorina sylvatica* have a distribution range restricted to the Valdivian refuges (Úbeda and Grigera 2007). Other species like *Rhinella rubropunctata*, *Nannophryne variegata*, *Pleurodema thaul*, *Alsodes gargola*, *A. monticola*, *A. verrucosus*, *B. leptopus*, *B. taeniata*, *Eupsophus roseus*, *E. calcaratus and E. vertebralis* just occur in high-altitude ponds of Argentina and Chile (Perotti et al. 2005). The presence of *Atelognathus nitoi* was considered as a strict microendemism for the Laguna Verde in the Nahuel Huapi National Park, Río Negro, Argentina. At present, this species is also found in Chile, since populations of *A. ceii* and *A. salai* now belong to this specific taxon (Barrasso and Basso 2018; Alveal and Díaz-Páez 2021).

Atelognathus reberverii is endemic from temporary and/or permanent clay ponds located in the Somuncura Plateau, provinces of Río Negro and Chubut. This species, as most amphibians, depends on water for reproduction and larval development. However, it has adaptations to spend extensive periods in terrestrial habitats when ponds are dry. Even when ponds have water, it is common to find individuals under rocks at long distances from the pond boundary. *Atelognathus patagonicus* is another micro-endemic species that only occurs at endorheic ponds in Neuquén province. This species exhibits two morphotypes, aquatic and terrestrial, adapted to significant seasonal changes when ponds become dry. The aquatic form, with loose skin and interdigital membranes on the hind legs, shows a yellow-orange coloration on the belly and lower thighs and stays all the time within ponds while they have water. When ponds are dry, individuals exhibit some external changes (e.g. loss of skin and reduction of interdigital membrane) in order to reduce water loss. This so-called terrestrial morphotype or littoral form is more resistant to dry conditions and usually lives under rocks due to the moisture of this microhabitat (Cei 1980).

Pleurodema somuncurense is a case of a micro-endemic species only occurring in a small stream (Valcheta Stream) located in a dry ecotonal physiognomy between forest and steppe in Rio Negro province (León et al. 1998). This stream is fed by hot springs located in the headwaters and thus shows warm temperatures all year round. *P. somuncurense* evolved to live in these constantly warm waters, becoming an almost fully aquatic species with adaptations such as interdigital membranes on the hind legs and some loose skin that improves oxygen exchange. This frog is active all year-round and lays eggs on the slow-flowing stream banks.

Alsodes neuquensis is a semiaquatic species, endemic from Neuquén province. This frog occurs and breeds in small mountain ponds and streams located in volcanic plateaus. These habitats are surrounded by open forests of *Araucaria araucana* and *Nothofagus antarctica*. This species has a long larval development of one year or even longer which is likely an adaptation to face the extreme weather of Patagonia (Cei 1976).

Some species, such as *Eupsophus calcaratus* and *Rhinoderma darwinii*, live in wet habitats but not necessarily close to freshwater ecosystems. The former is found in temperate forests of Chile and Argentina, under fallen logs and rocks, in dark, cold and wet sites with woody vegetation, generally near but not in streams, ponds and rivers. Its reproductive cycle (i.e. egg-laying and larval cycle) is developed in water-filled cavities in the soil, under stones and logs. For this reason, individuals require very humid or water-saturated soils (Úbeda 2000). *R. darwinii* is an almost fully terrestrial species that lives in temperate forests of Argentina and Chile. As *E. calcaratus*, *R darwinii* does not require freshwater habitats to complete its development. However, unlike the former, females of *R. darwinii* lay the eggs in small shelters located on the humid soil, among the litter, in the same site where males vocalise (Busse 1970). After two weeks, when the muscular movement of the embryos begins, males incorporate them into their vocal sacs, where the larval cycle completes. Subsequently, juveniles are expelled to the terrestrial environment (Busse 1970; Cei 1980).

One of the most widespread species, *Pleurodema bufoninum*, can be found in several habitat types because of its adaptation to face low temperatures and droughts by spending long periods underground or under rocks in the bushy steppe, usually far away from the water.

The remaining species are not habitat-specific and can occur in forests, *mallines*, steppes, grasslands and shrubs, mostly near freshwaters (Cei 1980).

3 Waterbirds From Patagonian Freshwaters: History, Diversity and Ecology

Waterbirds' diversity from Patagonian freshwaters includes at least 76 species of 15 families (Table 15.2 and Fig. 15.2). Research on waterbird communities in Patagonia has mainly concerned habitat diversity, population structure and the importance of

Table 15.2 Waterbirds' species of the Argentinean Patagonia, conservation status and population trends listed in the IUCN Red List and the Argentinean Red List (MAyDS and AA 2017)

	Population trend	
Families and species	IUCN category	Argentinean category
Anatidae		
Dendrocygna viduata	Least concern	Least concern
Cygnus melanocoryphus	Least concern	Least concern
Coscoroba	Least concern	Least concern
Chloephaga picta	**Least concern – decreasing**	**Vulnerable**
Chloephaga poliocephala	**Least concern – decreasing**	**Vulnerable**
Chloephaga rubidiceps	**Least concern – decreasing**	**Critically endangered**
Merganetta armata	**Least concern – decreasing**	Least concern
Tachyeres patachonicus	**Least concern – decreasing**	Least concern
Lophonetta specularioides	Least concern	Least concern
Speculanas specularis	Least concern	Least concern
Spatula versicolor	Least concern	Least concern
Spatula platalea	Least concern	Least concern
Spatula discors	**Least concern – decreasing**	Least concern
Spatula cyanoptera	Least concern	Least concern
Mareca sibilatrix	Least concern	Least concern
Anas bahamensis	**Least concern – decreasing**	Least concern
Anas georgica	**Least concern – decreasing**	Least concern
Anas flavirostris	**Least concern – decreasing**	Least concern
Netta peposaca	Least concern	Least concern
Heteronetta atricapilla	Least concern	Least concern
Oxyura jamaicensis	Least concern	Least concern
Oxyura vittata	Least concern	Least concern
Aramidae		
Aramus guarauna	Least concern	Least concern
Rallidae		
Rallus antarcticus	**Vulnerable**	**Endangered**
Pardirallus sanguinolentus	Least concern	Least concern
Porphyriops melanops	Least concern	Least concern
Porzana spiloptera	Least concern	Least concern
Gallinula galeata	Least concern	Least concern
Fulica rufifrons	Least concern	Least concern
Fulica armillata	Least concern	Least concern
Fulica leucoptera	Least concern	Least concern
Phoenicopteridae		
Phoenicopterus chilensis	**Near threatened**	**Near threatened**
Podicipedidae		
Rollandia rolland	**Least concern – decreasing**	Least concern
Podilymbus podiceps	Least concern	Least concern
Podiceps major	Least concern	Least concern

(continued)

Table 15.2 (continued)

	Population trend	
Families and species	IUCN category	Argentinean category
Podiceps occipitalis	**Least concern – decreasing**	Least concern
Podiceps gallardoi	**Critically endangered**	**Critically endangered**
Charadriidae		
Pluvialis dominica	**Least concern – decreasing**	Least concern
Charadrius semipalmatus	Least concern	Least concern
Charadrius collaris	**Least concern – decreasing**	Least concern
Recurvirostridae		
Himantopus mexicanus	Least concern	Least concern
Pluvianellidae		
Pluvianellus socialis	**Near threatened**	Least concern
Scolopacidae		
Limosa haemastica	Least concern	Least concern
Calidris bairdii	Least concern	Least concern
Calidris fuscicollis	**Least concern – decreasing**	Least concern
Calidris melanotos	Least concern	Least concern
Gallinago paraguaiae	Least concern	Least concern
Gallinago stricklandii	**Near threatened**	**Endangered**
Phalaropus tricolor	Least concern	Least concern
Phalaropus fulicarius	Least concern	Least concern
Tringa flavipes	**Least concern – decreasing**	Least concern
Tringa melanoleuca	Least concern	Least concern
Rostratulidae		
Nycticryphes semicollaris	**Least concern – decreasing**	Least concern
Laridae		
Chroicocephalus serranus	Least concern	Least concern
Chroicocephalus maculipennis	Least concern	Least concern
Leucophaeus pipixcan	Least concern	Least concern
Chroicocephalus chirocephalus	Least concern	Least concern
Larus dominicanus	Least concern	Least concern
Gelochelidon nilotica	**Least concern – decreasing**	Least concern
Sterna hirundinacea	Least concern	Least concern
Sterna trudeau	Least concern	Least concern
Ciconiidae		
Ciconia maguari	Least concern	Least concern
Mycteria americana	**Least concern – decreasing**	Least concern
Phalacrocoracidae		
Phalacrocorax brasilianus	Least concern	Least concern
Phalacrocorax atriceps	Least concern	Least concern
Ardeidae		
Ixobrychus involucris	Least concern	Least concern
Nycticorax	**Least concern – decreasing**	Least concern

(continued)

Table 15.2 (continued)

	Population trend	
Families and species	IUCN category	Argentinean category
Butorides striata	**Least concern – decreasing**	Least concern
Bubulcus ibis	Least concern	Least concern
Ardea cocoi	Least concern	Least concern
Ardea alba	Least concern	Least concern
Syrigma sibilatrix	Least concern	Least concern
Egretta thula	Least concern	Least concern
Threskiornithidae		
Plegadis chihi	Least concern	Least concern
Theristicus melanopis	Least concern	Least concern
Platalea ajaja	Least concern	Least concern

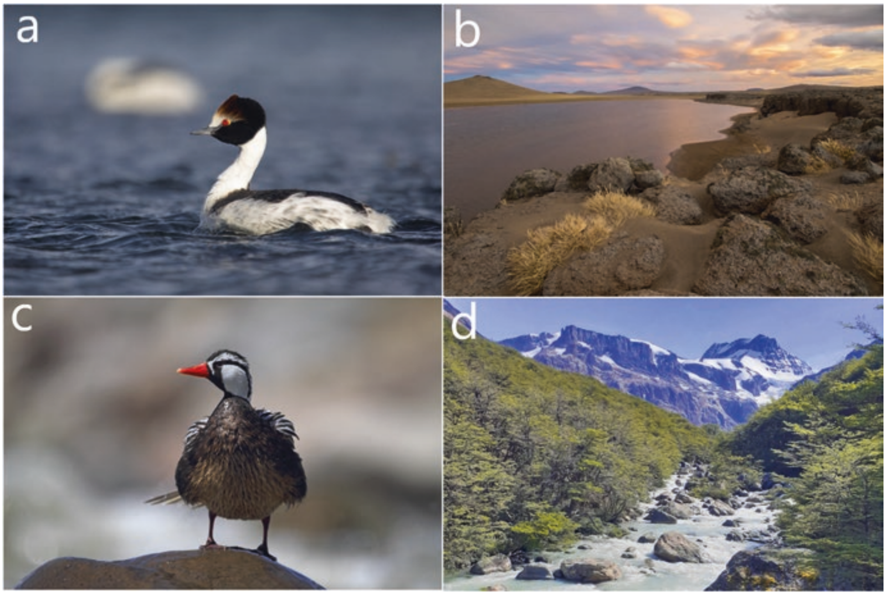

Fig. 15.2 Examples of emblematic Patagonian threatened waterbirds in their freshwater and wetland habitats. (**a**) The hooded grebe, *Podiceps gllardoi.* (Photo by Gonzalo Pardo), in (**b**) a shalow lake of Santa Cruz plateau. (Photo by Gonzalo Ignazi, upper right). (**c**) The torrent duck *Merganetta armata.* (Photo by Hernán Povedano) (**d**) in Las Vueltas River. (Photo by Soledad Ovando)

migratory species for ecological processes in continental freshwater ecosystems, essentially in the northern and central areas of the country (Bucher and Herrera 1981; Echevarria and Chani 2000; Romano et al. 2005).

Along the Andes, most waterbodies are oligotrophic (see Chaps. 3, 4, 10 and 14) and therefore of little importance for maintaining large flocks of birds. However, certain characteristic species can be found there, such as *Podiceps major* (great grebe), *Theristicus melanopis* (black-faced ibis), *Chloephaga poliocephala* (ashy-headed goose), *Tachyeres patachonicus* (flying steamer duck) and *Anas specularis* (spectacled duck) (Scott and Carbonell 1986).

The presence and abundance of waterbirds are influenced by local environmental characteristics and the specific demands of each species (Weller 1999). In Patagonia, large lakes and rivers are prominent in the Andean region (Iglesias and Pérez 1998). In contrast, the Patagonian steppe receives less than 300 mm of rain per year, thus representing one of the aridest extensions in Argentina (Cabrera 1976; Morello et al. 2012) (see Chap. 1). Whereas permanent waterbodies are rare in this area, a system of several basaltic plateaus, dotted with natural depressions that collect water from snow and ice melt, is prominent in the region (Iriondo 1989, Chap. 9). The topography of such plateaus facilitates the development of complex shallow lake assemblages, with a relatively high environmental heterogeneity (Lancelotti et al. 2009) (see Chaps. 10, 11 and 14).

Waterbird abundance at local scales depends on habitat characteristics, food abundance and the availability of suitable sites for reproduction or resting (Wiens 1989). Other factors affecting freshwaters used by waterbirds include sex, dominance, pairing status, flocking and stage of the life cycle. Species composition is usually associated with the arrival of migratory species which are added to those already present in the area. All these parameters influence the resources needed and the birds' access to habitats where such resources are available (Canziani and Derlindati 2000; Romano et al. 2005).

Some studies on the population and ecology of migratory Nearctic shorebirds have included abundance patterns at continental sites (Laredo 1996; Montalti et al. 2003; Lanctot et al. 2004). A few species overwinter in inland lakes and several sites of importance for shorebirds have been identified (Di Giacomo 2005). In addition, waterbird surveys conducted in isolated shallow lakes, provided general information on waterbird occurrence (Fjeldså 1985, 1986; Imberti 2005).

Patagonia has had a complex geological and vegetational history in the Tertiary (Romero 1986) and the Quaternary (Pleistocene-Holocene; Heusser 1989). During the Late Pleistocene, western Patagonia was covered by the largest icecap in South America (480,000 km^2; Hollin and Schilling 1981), rendering a substantial area of Patagonia uninhabitable. In consequence, the fauna species must have either retreated their distribution range or suffered extinctions (Markgraf 1989). By greatly affecting the distribution of vegetation types and markedly altering the width of continental margins, glacial-interglacial cycles must have had a major impact on the avifauna (Lei et al. 2014).

Different authors (Vuilleumier 1972, 1985, 1991; Acosta et al. 2021) demonstrated that past environmental factors, probably Pleistocene in age, have indeed promoted speciation of both waterbirds and landbirds in Patagonia. Because the climate and vegetation of the Patagonian Pleistocene-Holocene period are well known (Markgraf 1989), this region offers great promise for studies in bird evolution.

Hypotheses on speciation patterns in *Phalacrocorax* and *Tachyeres* involve vicariance events associated with glaciation and deglaciation cycles over the last 100,000 years (Livezey 1986). In these scenarios, the western Patagonian icecap was the main barrier that isolated Pacific and Atlantic coast populations of ancestral taxa. Subsequent melting of that ice barrier allowed a new contact, and a later glacial advance led to another cycle of vicariance or geographic isolation.

Speciation has occurred across a broad taxonomic spectrum, from caracaras and ducks to furnariids and buntings (Fjeldså 1985). Thirty-four percent of the Patagonian bird species (73 out of 217) show some evidence of speciation caused by at least one of the following four processes: (i) range disjunctions accompanied by weak differentiation, (ii) parapatry and hybridisation, (iii) secondary range overlaps and (iv) isolation in habitat relicts (Vuilleumier 1991). Vicariance events have therefore played an important role in the evolution of the Patagonian avifauna (Vuilleumier 1991; Acosta et al. 2021). Whereas the occurrence of vicariance patterns and of overlaps highlights the role of speciation or increase in species numbers, the occurrence of relicts underscores the role of extinction or loss of diversity (Acosta et al. 2021).

Species richness and abundance of Patagonian waterbirds are fundamentally affected by the size and productivity of freshwater ecosystems. Habitat heterogeneity determines the assemblage complexity in terms of species diversity. Species richness and abundance increase with shoreline length and waterbody size. While shoreline length presents a close relationship with species number and abundance during autumn and winter, wetland area was the main variable influencing waterbird populations during spring and summer. A close relationship between species richness and area was described, wherein larger wetlands support a higher number of bird species (González-Gajardo et al. 2009). Additionally, bird abundance is related to water level fluctuation and wetland area (Froneman et al. 2001). Although bigger freshwater ecosystems can provide more microhabitats, thereby attracting a greater number of species, Garay et al. (1991) showed that smaller freshwater habitats maintained higher waterbird density and diversity than larger ones. In this context, the structural and vegetation heterogeneity shows an important relationship with bird assemblages. Shoreline length and shoreline development indices were considered as determinants of bird abundance by Hudson (1983), who suggested that in similar-sized wetlands, bird abundance will be higher in those that present a more irregular perimeter, thus offering more refugees. The waterbird communities located in the Patagonian steppe display a heterogeneous species structure and relative species abundance (González 1996; Gatto et al. 2005). Further south in Patagonia, the highest abundance of waterbirds is found in volcanic foothill plateaus, which are rich in minerals and highly productive (Fjeldså 1985). Lakes harbouring the most species and individuals were those with alkaline waters and reed beds (Fjeldså 1985).

4 Conservation Status and Threats Affecting Amphibians and Waterbirds in Patagonian Freshwaters

4.1 Amphibians

The amphibian fauna of Patagonia is one of the most threatened in the country. According to the National Assessment of Native Amphibians, 75% and 65% of species of the Patagonian steppe and forests, respectively, are included in a threat category (Vaira et al. 2017). Neuquén and Río Negro provinces have the highest percentage of amphibian threatened species (Vaira et al. 2012). The IUCN Red List assessment includes 11 species falling within a threat category, three of them listed as critically endangered, four as endangered species and four as vulnerable species (Table 15.1). Another seven Patagonian amphibians considered as of least concern show decreasing populations while two species are listed as data deficient, and one was still not assessed (*Rhinella papillosa*).[1] These last species can likely be assessed or be moved (in the case of those showing a declining trend) into a threatened category in the near future, even increasing the percentage of Patagonian endangered amphibians.

The high percentage of endangered amphibian species is likely related to the high degree of endemism, with some species restricted to very small areas (Úbeda and Grigera 2007). The small distribution range is associated with small population sizes and a high degree of specialisation. These conditions contribute to increase susceptibility of endemic Patagonian amphibians to anthropogenic threats. According to Lavilla (2000) and Lavilla and Heatwole (2010), the main threats affecting amphibian populations in Argentina are habitat loss or fragmentation, chemical and biological contamination of freshwater ecosystems, invasive species, illegal pet trade and several factors related to climate change (e.g. increasing UV radiation, temperature and frequency of droughts). Among these threats, livestock breeding, invasive fishes, emerging diseases and climate change were recognized as the main negative factors affecting amphibian species in Patagonia (Úbeda and Grigera 2007; Vaira et al. 2012; Velasco 2018).

As for the three most endangered Patagonian amphibians, local extinctions of *A. patagonicus* and *P. somuncurense* subpopulations have been recorded. Although both species occur in different habitat types (*A. patagonicus* inhabits tableland ponds while *P. somuncurense* is found in a small endorheic stream), both are threatened by similar factors (impacts on their habitat by livestock and predation by invasive fish species) (Velasco 2018; Cuello et al. 2009) (see Chap. 14).

Sheep and cattle rising is widespread in Patagonia (Instituto Nacional de Tecnología Agropecuaria 2015). Lack of appropriate management of livestock has promoted overgrazing and consequent desertification (Mazzoni and Vazquez 2009; Nanni et al. 2020). As documented in other regions (Burton et al. 2009; Schmutzer

[1] Although this species could be a synonym of *Rhinella spinulosa* (Vera Candioti et al. 2020)

et al. 2008), livestock also affects the Patagonian amphibian freshwater habitats by trampling, drinking, polluting with urine and faeces and grazing over hydrophytic vegetation, thus causing water eutrophication and loss of reproductive habitats. At least 8 out of the 11 Patagonian threatened amphibian species are affected by this threat. *Pleurodema somuncurense* is a good example of this type of impact. The small stream inhabited by this frog is under a high livestock pressure due to an exchange of sheep and goats for cattle, in combination with other threats like works for water management (e.g. small dams and channels) which have caused a relictual subpopulation of this species to lose a number of key locations and even promoted local extinctions (Velasco 2018). Because of livestock impacts, a stream portion was fenced off to avoid animal access, promoting a quick recovery of both hydrophilic and riparian vegetation (Arellano et al. 2017b). Subsequent translocation of frogs into this restored habitat resulted in the re-establishment of that population as recorded of reproductive events and natural recruitments, which confirmed suitable habitat conditions for frogs (Martínez Aguirre et al. 2019).

Invasive fish species are one of the main drivers of the current extinction of amphibians (Collins 2010). In Patagonia, invasive fish species represent 43% of the total freshwater fish species (Macchi and Vigliano 2014) (for details, see Chaps. 13 and 14). Most of these are salmonids that have caused negative changes in native biota due to predation, competition and changes in trophic webs (Ortubay et al. 2006; Cussac et al. 2012) and are among the main causes of extirpation and decline of many native freshwater species (Buria et al. 2007, 2009). Despite this negative impact, few studies in Argentina have addressed the effect of this threat on amphibians. One of such studies was carried out in the Valcheta Stream, Somuncurá Plateau, by Velasco et al. (2018). A negative effect of invasive rainbow trout (*Oncorhynchus mykiss*) on *Rhinella arenarum* and *P. somuncurense* was observed, with a decrease in occupancy recorded for both species.

Two emerging infectious diseases (ranavirus and chytridiomycosis), caused by microparasites *Iridovirus* and *Batrachochytrium dendrobatidis* (chytrid fungus), were associated with amphibian decline in almost all continents (Collins 2010). Amphibian ranaviruses were reported in at least 105 species of amphibians in 25 countries. Gross signs of ranavirus infection are not always apparent; they can be confused with other factors, and mortality events are not easily observed due to their rapid progression and the fast decomposition of dead hosts (Duffus et al. 2015). In Argentina, ranavirus was only described in the Patagonian *Atelognathus patagonicus* (Fox et al. 2005). *B. dendrobatidis* was already reported for eight Patagonian amphibians, four of which are within a threatened category (*A. pehuenche*, *A. patagonicus*, *A. reverberii* and *P. somuncurense*) (Arellano et al. 2015, 2017a; Ghirardi et al. 2014). Although this pathogen can be very harmful to many species, there is no evidence that it is causing a population decline, except for an *A. patagonicus* mortality event recorded in Laguna Blanca (Ghirardi et al. 2014).

Climate change is also a main driver of the global amphibian decline (Blaustein and Wake 1990; Stuart et al. 2004; Schivo et al. 2019). Environmental temperature and moisture patterns can influence amphibian ecology, physiology and behaviour because they must maintain the moist skin for oxygen and ionic exchange (Lips et al. 2005). In Argentina, climate projections for the next two or three decades show a general warming of 0.5–1.0 °C all over the country and reductions of precipitation in the dry area comprising the central-western region and Patagonia (Barros et al. 2015). Studies conducted in the lakes of the Austral Patagonia plateaus evidenced a water level decrease as a consequence of reduced precipitation, affecting macrophyte and plankton communities (Izaguirre et al. 2018) (see Chap. 5). Unfortunately, at present, studies assessing the effect of climate change on Patagonian amphibians are lacking. However, evidence demonstrates negative impacts, as in the case of *A. patagonicus*, where a severe and uncommon drought caused a decline of almost 90% of the extant population (Cuello et al. 2009; IUCN 2019b).

4.2 Waterbirds

Even though most waterbirds are categorised as least concern by the IUCN, at least 20 species (33%) inhabiting Patagonia are experiencing a global decline (Table 15.2). Besides, five species are under a threat category: *P. gallardoi*, *R. antacticus*, *P. socialis*, *G. stricklandii* and *P. chilensis* (Table 15.2).

The waterbirds from Patagonia are exposed to a combination of threats which includes logging and livestock grazing and trampling in their watersheds, introduction of alien species, volcanic eruptions in breeding areas, agrochemical pollution, oil exploitation, light pollution, mining and hydroelectric dams (del Hoyo et al. 1992; O'Donnell and Fjeldså 1997; Imberti and Casañas 2010; Roesler et al. 2014; Roesler et al. 2016; Fasola and Roesler 2018). Increasing projects of wind farms represent a potential new threat for birds and other biota like bats (Berkunsky pers.obs.).

The destruction and degradation of Patagonian natural grassland by livestock grazing and trampling as well as by other introduced herbivores have negatively impacted the mainland breeding habitat of many bird species such as the *P. socialis* and species of genus *Chloephaga* (sheldgeese) (Fjeldså 1986; Dinerstein et al. 1995; Cossa et al. 2018). Livestock is responsible for at least 14% of sheldgeese nest losses and disturbances of breeding pairs (Cossa et al. 2018). Trampling of nests and chicks by grazing animals is a potential threat to *Pluvianellus socialis* (Magellanic Plovers) (Ferrari et al. 2003). Moreover, intensive grazing of the steppes also affects wetlands because bare soils are dragged by wind and deposited in ponds and mallines (Fjeldså 1986). In addition, waterbirds have been affected in some places wherein hydrophytic vegetation has been grazed and trampled by cattle (Fjeldså 1986).

Rainbow trout shape the community of aquatic invertebrates, affecting species' dominance and size structure. These invertebrates represent the primary prey item of many waterbird species, including endangered species such as the hooded grebe (see Chaps. 11 and 14). In turn, zooplankton grazing pressure on phytoplankton may be reduced by trout, thus promoting phytoplankton growth, increasing nutrient recycling and potentially causing a trophic cascade effect (Eby et al. 2006). A recent study in the Lake Strobel plateau found that stocked lakes have substantially higher cyanobacteria abundances than fishless lakes (Izaguirre and Saad 2014), indicating changes in the phytoplankton communities (see Chaps. 5 and 14). These processes may be more severe in vegetated lakes, where the abundance and quality of macrophytes can be affected, altering the suitability of these waterbodies as reproductive habitats for grebes. The introduction of trout has been correlated with a decline in breeding numbers of hooded grebe and other waterbirds at certain lakes (Konter 2008) (see Chap. 14).

Recently introduced predators such as the American mink (*Neovison vison*) (Peris et al. 2009) have changed the trophic structure of freshwater ecosystems in Patagonia. This species is a predator introduced extensively into Europe, Asia and southern areas of South America. In Argentina, mink farms were started in the 1950s in the southern province of Chubut. Because of successive escapes, either accidental or through the abandonment of nurseries (Pagnoni et al. 1986), this mustelid has increased its range to the north and east, following the Andean numerous rivers and lakes. The impact of American mink on native Patagonian freshwater species is well documented. This alien mammal has already caused a pronounced decline of the critically endangered *P. gallardoi* all over its distribution range (Fasola and Roesler 2018).

Among other introduced predators, the Patagonian grey fox (*Dusicyon griseus*), introduced in Tierra del Fuego as a control for the European rabbit (*Oryctolagus cuniculus*), is perhaps contributing to the decline of *Chloephaga rubidiceps* (Ruddy-headed goose) (Chebez and Bertonatti 1994). Predation by feral cats and dogs was also reported as a severe threat for *P. socialis* in non-breeding sites (Ferrari et al. 2003).

5 Needs for the Long-Term Conservation of Amphibians and Waterbirds in Patagonian Freshwaters

The current situation of Patagonian amphibians and waterbirds is of great concern. Therefore, development of management strategies is urgent in order to promote the long-term conservation of these species and their habitats. This section aims to review the progress made in planning and application of management actions and necessary research on these taxa. Information provided by the IUCN website was summarised for each of the species identified above, taking into account conservation actions and research needed, and conservation actions in place were taken into account. We also included information from the National Red List for amphibians (Vaira et al. 2012) and the national action plan for amphibians and suggestions pointed out by Úbeda and Grigera (2007). Finally, some of these actions and others not specified in the IUCN framework are discussed.

5.1 Actions Needed

The IUCN recognises different types of conservation and research needed and actions in place (actions that are being or were conducted) (Table 15.3). Therefore, during the assessment process, specialists are asked to use this classification scheme to indicate both conservation actions and research needed for the evaluated species. In addition, specialists are also asked to consider the most urgent and essential actions that can be taken in the short term.

Table 15.3 First- and second-order categories of (**a**) conservation actions, (**b**) research needed and (**c**) actions in place recognised by the IUCN Red List

a Conservation actions	
1. Land and water protection (***6***)	1.1. Site/area protection (**13**) (***5***); 1.2. Resource and habitat protection (**9**)
2. Land and water management (***4***)	2.1. Site and area management (**5**) (***3***); 2.2. Invasive/problematic species control (**5**); 2.3. Habitat and natural processes restoration
3. Species management (***4***)	3.1. Species management (**1**); 3.2. Species recovery; 3.3. Species reintroduction; 3.4. Ex situ conservation
4. Education and awareness (***2***)	4.1. Formal education; 4.2. Training; 4.3. Awareness and communication
5. Law and policy (***2***)	5.1. Legislation (**2**); 5.2 Policies and regulations; 5.3. Private sectors standard and codes; 5.4. Compliance and enforcements
6. Livelihood, economics & other incentives	6.1. Linked enterprises and livelihood alternatives; 6.2. Substitution; 6.3. Market forces; 6.4. Conservation payments; 6.5. Non-monetary values
b Research	
1. Fundamental research (***13***)	1.1. Taxonomy; 1.2. Population size, distribution and trends (**14**) (***13***); 1.3. Life history and ecology; 1.4. Harvest, use and livelihoods; 1.5. Threats (**10**); 1.6. Actions
2. Conservation planning	2.1. Species action/recovery plan; 2.2. Area-based management plan; 2.3. Harvest and trade management plan
3. Monitoring (***1***)	3.1. Population trends (**7**) (***1***); 3.2. Harvest level trends; 3.3. Trade trends; 3.4. Habitat trends
c Actions in place	
1. Research and monitoring	1.1. Action recovery plan (**1**) (***2***); 1.2. Systematic monitoring scheme (**2**) (***17***)
2. Species management	2.1. Successfully reintroduced or introduced benignly (**1**); 2.2. Subject to ex situ conservation (**3**)
3. Land/water protection	3.1. Conservation sites identified (**2**) (***22***); 3.2. Area-based regional management plan (**2**); 3.3. Occurs in at least one protected area (***21***); 3.4. Invasive species control or prevention
4. Education	4.1. Subject to recent education and awareness programmes; 4.2. Included in international legislation (***12***); 4.3. Subject to any global management/trade controls (***1***)

Numbers between parentheses following some actions indicate the number of species of amphibians **(bold)** and waterbirds ***(bold italics)*** for which the need of that action ((**a**) and (**b**)) or its progress (**c**) has been identified

For amphibians, the evaluations carried out to date indicate that among the conservation actions needed, most of the specialists recognised as main actions those related to area protection and as secondary ones those associated with area management (Úbeda and Grigera 2007) (Fig. 15.3). Vaira et al. (2012, 2018) recognise a strong need to alleviate threats on amphibians' habitats, managing invasive species and monitoring the effects of emerging diseases. According to the IUCN, this implies actions to identify, establish or expand national parks and other legally protected areas by conserving or restoring sites and habitats in the first case and the environment in general in the second.

Among the first-order research needs listed for Patagonian amphibians, basic research is recognised as a priority, followed by studies based on monitoring and, finally, those that involve planning (Fig. 15.3). Regarding second-order research needs, category 1.2 refers to studies of past and current trends, and category 3.1 indicates studies of future trends.

As for Patagonian waterbirds, a lack of information on conservation and research actions needed is observed in the IUCN assessments for most species. Of the total species assessed for Argentinean Patagonia, only eight (10%) show detailed information regarding these items.

The IUCN classifies actions in place in two order categories. The first- and second-order categories contain 4 and 11 actions, respectively (Table 15.3). Among amphibians, distribution of at least 15 species fully or partially overlaps with at least one protected area of any category in Argentina or Chile.

In the case of waterbirds, the in-place action assessment is much more detailed than for amphibians. In summary, for approximately 29% (22) of the Patagonian waterbird species, conservation sites have been identified; 28% (21) of the species

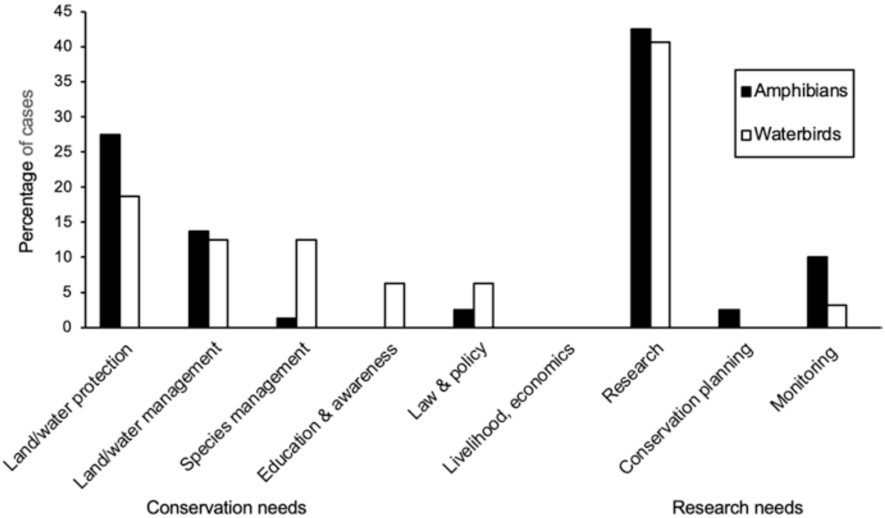

Fig. 15.3 Percentage of cases for each category of conservation and research needs identified in the IUCN Red List. (Source IUCN 2021)

occur in at least one protected area; for 22% (17), there is a systematic monitoring scheme. Actually, the recent creation of the Patagonia National Park had as main objective the protection of nesting sites of the critically endangered *P. gallardoi* (BirdLife International 2019). At least 16% (12) are included within international legislation. Nevertheless, only 3% (2) of species are included in an action recovery plan, while barely 1% (1) is subject to international management/trade control.

These assessments indicate that the protection and management of aquatic, wetland and terrestrial habitats are recognised as a priority for both amphibians and waterbirds. Studies to evaluate past, present and future population trends were also highlighted as a priority for both taxa. Despite the documented effectiveness of highly endangered species management, this action was only considered as a priority for a strikingly low number of amphibian species (Arellano et al. 2017b; Martínez Aguirre et al. 2019). This could be related to the lack of information at national level regarding the effectiveness of management actions to improve the conservation status of threatened populations and species. In fact, at a national scale, few projects are pragmatically including species management actions although it is worth mentioning that some of the most important ones are being developed in Patagonian freshwaters (see details in Sect. 7).

6 Conservation Priorities Based on Endangered Species and Habitats

Because conservation resources are limited, it is mandatory to decide where to focus the management and conservation efforts. There are several ways to determine conservation priorities (Fattorini 2006; Álvarez-Berastegui et al. 2014; Kacoliris et al. 2016). In this section, we will focus on one of the simplest methods for prioritisation, based on the protection priority of species and their habitats considering their conservation status. A list of priority species is provided below, whose distribution range is showed in Fig. 15.4 in order to identify priority areas for their protection.

Priority Amphibian Species

- *Alsodes verrucosus* (endangered). This species is known from two localities in Andean Chile: Cautin and Puyehue, along 11 km of the El Salto Basin estuary, on the west side of the Puyehue volcano and adjacent to Puyehue National Park. It occurs in rivers, streams and creeks associated with forests (IUCN SSC Amphibian Specialist Group 2019a).
- *Alsodes neuquensis* (endangered). This species occurs in small alpine/montane lakes and streams in volcanic tablelands from Lonco Luan Plateau, Primeros Pinos, and nearby areas, Moquehue stream, Batea Mahuida Pond and Caviahue, in Neuquén province, Argentina (Cei 1976, 1987; Úbeda et al. 2012; IUCN SSC Amphibian Specialist Group 2019b).

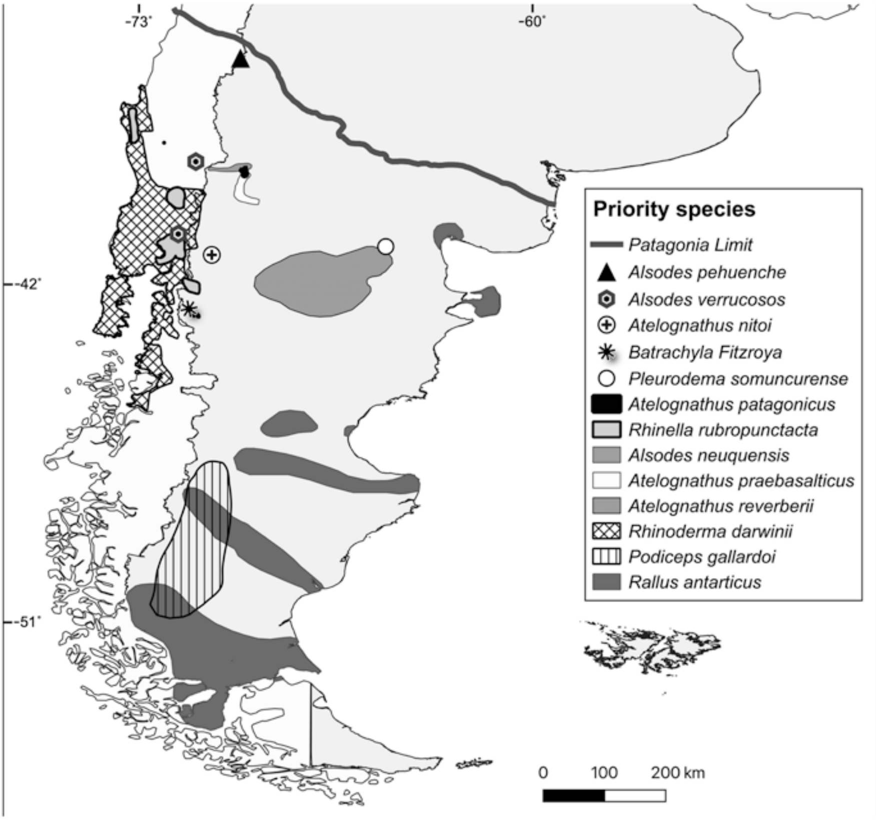

Fig. 15.4 Range of priority species among amphibians and waterbirds from Patagonia with a focus on Argentinean species

- *Alsodes pehuenche* (critically endangered). This species occurs in Chile and Argentina. In Argentina, this amphibian species was recorded in several streams of the Pehuenche Valley, in Malargüe Department, Mendoza province, Argentina (Corbalán et al. 2010).
- *Atelognathus patagonicus* (critically endangered) and *A. praebasalticus* (endangered). Both species are endemic from a system of endorheic and isolated lagoons scattered on the basaltic plateau in and around Laguna Blanca National Park, in midwestern Neuquén province (Cuello et al. 2017; IUCN SSC Amphibian Specialist Group 2019c, d).
- *Atelognathus reverberii* (vulnerable). This species is endemic from isolated and temporary lagoons scattered over the Somuncurá Plateau in Río Negro and Chubut provinces (Cei 1969; Martinazzo et al. 2011).
- *Batrachyla fitzroya* (vulnerable). This species was recorded just in the type locality (Isla Grande in Lake Menéndez; Basso 1994), a protected island located in

Los Alerces National Park, Chubut province. This species reproduces in ponds and vegetated and shallow shores of the lake (Pastore et al. 2013).

- *Pleurodema somuncurense* (critically endangered). This species is known only from the headwaters of Arroyo Valcheta in Somuncura Plateau, Río Negro province (Velasco et al. 2016).
- *Rhinella rubropunctata* (vulnerable). This species occurs in seasonal freshwater marshes and pools located in the temperate forests of Chile and Argentina. In Chile, it is currently recorded in the following five sites: Lago Todos Los Santos and nearby Petrohué (Los Lagos region), Lanalhue Lake in Arauco Province and Cerro Adencul (Araucania Region) and Puelo (M. Mora pers. comm. 2018). In Argentina, the species is restricted to southern Río Negro and northern Chubut provinces, consisting of a single record from Los Alerces National Park (Úbeda and Basso 2012).
- *Rhinoderma darwinii* (endangered). It occurs mainly in Chile and tangentially in Argentina, where it is known from 11 localities in Neuquén, Chubut and Río Negro provinces. It occurs in wet forests and wetlands inside forests like bogs, marshes, swamps, fens and peatlands (Soto-Azat et al. 2013).

Priority Waterbird Species

- *Rallus antarcticus* (vulnerable). This species occurs in Chile and Argentina. In Argentina, it inhabits marshy Patagonian steppe wetlands located in Santa Cruz and Chubut provinces (de Miguel et al. 2019).
- *Podiceps gallardoi* (critically endangered). This species occurs in Chile and Argentina and in Argentina breeds on a few basaltic lakes in the interior of Santa Cruz, extreme southwest Argentina. The only known wintering grounds are located in the estuaries of Río Coyle, Río Gallegos and Río Chico on the Atlantic coast of Santa Cruz (Roesler et al. 2011; Roesler 2016).

The conservation of the amphibians and waterbirds identified as priority species for Patagonian freshwaters implies the protection of different aquatic, wetland and terrestrial habitats distributed throughout their ranges. That is, this prioritisation of species also implies a prioritisation of sites to be protected. In turn, the efforts to conserve some of these priority species can also protect others. For example, the endeavours to protect *Rhinoderma darwinii* contribute to the protection of other species inhabiting within their range (e.g. *Alsodes verrucosus* and *Rhinella rubropunctata*) as well as the remaining biodiversity (Fig. 15.4). In this sense, some of the Patagonian priority amphibians and waterbirds can be considered as umbrella species.

However, protecting areas through the establishment of natural reserves is not always enough to effectively conserve endangered species. Pragmatic management aimed at recovering species and restoring habitats is urgently needed as well. The following section gives some examples of conservation projects focused on priority amphibians and waterbirds in Patagonian freshwaters.

7 Amphibians and Waterbirds as Flagships to Conserve Freshwaters and Terrestrial Habitats

In this section, we will describe, through some concrete examples, how some species of amphibians and waterbirds have served as flagship species for the protection of habitats and their biodiversity. Particularly, we highlight the hooded grebe (*Podiceps gallardoi)* conservation project, which is one of the main species-framed conservation projects in Patagonia.

El Rincón Stream Frog Conservation Project

The El Rincón stream frog (*P. somuncurense*) is endemic of the hot springs of the headwaters of the Valcheta Stream at the Somuncurá plateau in northern Patagonia. This species is currently restricted to a few isolated subpopulations along the headwaters of this stream (IUCN SSC Amphibian Specialist Group 2016; Velasco et al. 2016; Velasco 2018). In the last four decades, the frog population has dramatically declined, resulting in the extinction of some subpopulations (Velasco 2018). A total of 70% of the current subpopulations have small sizes (less than 250 mature individuals), which threatens their long-term viability (Velasco et al. 2019).

The drastic decline of this frog was mainly caused by (i) the expansion of the invasive rainbow trout (see Chap. 14), an aggressive predator, associated with the extinction of the frogs along the stream (Velasco et al. 2018), and (ii) the habitat destruction by livestock, which overgrazes and tramples vegetation, reducing the availability of food, shelter and breeding sites. In addition, decomposition of livestock faeces in the water promotes eutrophication (IUCN SSC Amphibian Specialist Group 2016; Velasco et al. 2017; Arellano et al. 2017b).

The IUCN lists this species as critically endangered; the Zoological Society of London includes the species in the top 100 EDGE (evolutionary distinct and globally endangered) species, and the Amphibian ARK identified the urgent need for its captive rescue and management (IUCN SSC Amphibian Specialist Group 2016). Furthermore, conservation experts from the Amphibian Survival Alliance and the IUCN-SSC Amphibian Specialist Group recommended urgent conservation actions to protect this species (http://www.amphibians.org). Based on priorities stated in the Amphibian Conservation Action Plan of the IUCN-SSC-Amphibian Specialist Group (Wren et al. 2015), the El Rincón Stream Frog Conservation Action Plan listed the main threats and necessary conservation actions (Kacoliris et al. 2018). This latter plan also followed the suggestions of the Argentinean Conservation Action Plan for Amphibians (Vaira et al. 2018).

In 2012, a work team started a conservation programme with the overall goal of ensuring the long-term viability of this species and its habitat through three main objectives:

(1) Alleviate the main aquatic threat to frogs by removing invasive trout from the stream headwaters and restoring the habitat for this frog and other aquatic species. Removal of trout is being achieved by creating fish barriers to restrict access of trout upstream and removing trout upstream those barriers.

(2) Improve terrestrial and wetland habitat quality. This objective focuses on increasing food availability, shelter and breeding sites and reducing the eutrophication in critical habitats for frogs (i.e. hot springs). Actions included avoidance of livestock access to hot springs by fencing, which contributed to a quick habitat restoration (Arellano et al. 2017b).
(3) Recover frog subpopulations in restored habitats wherefrom the species had been extirpated. This objective combines ex situ breeding followed by reintroduction of individuals in restored sites. Between 2017 and 2021, four reintroductions were conducted with at least one subpopulation successfully re-established in the wild (Martínez Aguirre et al. 2019).

Another component of this project is the effective implementation of a natural reserve by acquiring land to protect habitats. Since the conservation of El Rincón stream frog depends upon the alleviation of both aquatic and terrestrial threats, the conservation of this single species leads to the protection of the entire habitat and its biodiversity. In summary, the current achievements of this project demonstrate how an amphibian, because of its particular life cycle that integers aquatic, wetland and terrestrial environments, can be successfully used as a flagship to promote conservation at a bigger scale.

Patagonian Frog Conservation Project
The Patagonian frog (*A. patagonicus*) is an endemic species that only lives in a small number of isolated shallow lakes scattered over the volcanic tablelands of north-western Argentinean Patagonia (Cuello et al. 2009). This species used to be common in these freshwater ecosystems, with the largest subpopulation (50% of the total number of individuals) inhabiting the Laguna Blanca shallow lake located in the homonymous National Park, the main and unique permanent waterbody in the area. Unfortunately, exotic predatory fishes were introduced in this shallow lake for touristic purposes, even though the area was declared as National Park in 1945 (Fox et al. 2005). The effect of these top predators was evident, and after a decade of surveys without a single record, in 2004, this subpopulation was declared extinct (Fox et al. 2005). Smaller subpopulations remain in temporary and isolated ponds, facing human-related threats. Moreover, between 2010 and 2016, an unusually prolonged and severe drought desiccated these ponds, increasing the estimated population decline of the species from 50% to more than 90% (Cuello et al. 2017).

Based on the available information regarding the status of the Patagonia frog, the National Park Agency implemented a management plan for its conservation, based on habitat protection and fish control. Habitat protection focused on small ponds and included fences to avoid habitat destruction by livestock. The fish control is conducted to reduce fish numbers (Buria, Pers. Comm.). However, the natural recolonisation by frogs is unlikely because of the poor condition of the corridors and the remaining stock of introduced fish in the shallow lake. Furthermore, summer droughts are now more frequent due to climate change, thus increasing the extinction risk for this species unless subpopulations can be re-established in the Laguna Blanca National Park.

In 2018, after a series of workshops with stakeholders, an action plan to ensure the long-term viability of this species was proposed (Kacoliris et al. 2020), with the vision of ensuring meta-population dynamics by creating sanctuaries within the National Park based on habitat restoration, management of threats and re-establishment of subpopulations. As part of this vision, in 2018, an ex situ survival colony of Patagonia frog was established in the Laguna Blanca National Park. Current activities aim to continue in this direction in order to have individuals for future reintroductions.

Hooded Grebe Conservation Project

The hooded grebe (*P. gallardoi*) inhabits and breeds in a few lakes in the Santa Cruz province, Argentina. The species might also be a summer visitor in Torres del Paine National Park, southern Chile, but at present, there are not confirmed records in that country (Roesler et al. 2011; Roesler 2015). This species makes floating nests over aquatic vegetation which also supports the thrive of several aquatic invertebrates which are part of its diet (Chebez and Bertonati 1994). Hooded grebes breed in colonies but have a very low reproductive rate (0.2 chicks year 1 per adult; O'Donnell and Fjeldså (1997)). Although colonies can establish in marginal areas of its distribution range (O'Donnell and Fjeldså 1997), individuals commonly show a high fidelity towards the plateaus where they were born (Roesler et al. 2016).

In the 1980s, the total population of this waterbird was of up to 5,000 individuals (Fjeldså 1984; O'Donnell and Fjeldså 1997), but during the past 25 years, it has suffered a population decline of about 80% (Roesler 2016). The main threats driving this decline seem to be the predation impact by invasive species (American mink and exotic salmon and trout) as well as habitat loss by climate change (Imberti and Casañas 2010; Casañas et al. 2013; Roesler et al. 2016) (see also Chap. 14). American mink threaten grebes during all their life stages by predating on nests, chicks and adults (Roesler 2015; Fasola and Roesler 2018). This impact is very high, since just one mink can kill more than half the adults in a breeding colony (Roesler et al. 2011). Invasive fish (trout) not only can predate on chicks (Konter 2008) but also competes with this waterbird for food and modifies water conditions, making lakes unsuitable habitats to grebes (Roesler 2015; Izaguirre et al. 2018; Francisco et al. 2019). Like endangered frogs, hooded grebes (as well as other waterbirds) are also being impacted by climate change. Unpublished data as well as some climate predictions show a decrease in winter snowfall, increase in temperatures and decrease in precipitations for Patagonian plateaus (Burgos and Ponce 1991). These scenarios foresee longer dry seasons which will result in a loss of aquatic habitats for this species (Konter 2008). Therefore, the hooded grebe was listed as a critically endangered species in the IUCN Red List and is considered one of the most endangered bird species in Argentina.

NGO Aves Argentinas along with Ambiente Sur are coordinating conservation efforts to ensure long-term survival of hooded grebes. In 2014, these NGOs boosted the creation of Patagonia National Park, a 52,000 ha protected area that covers half of the breeding colonies of hooded grebes (Roesler 2015; BirdLife International 2019).

Since 2009, intense research and monitoring activities have been conducted to understand hooded grebe distribution, ecology and the impact of threats in order to help guiding conservation efforts (Roesler 2015; Roesler et al. 2016). A programme called "Colony Guardians" has also been established to protect nests from invasive predators, achieving a significant increase in survival rates among several colonies (Roesler et al. 2016). Also, awareness raising activities, including displays, theatre productions, video and outreach material reached over 100,000 people.

At present, management plans to eradicate American minks and invasive trout from the high plateau areas are in place (Roesler et al. 2016). Current data gathered through these programmes showed that minks are decreasing in target areas. Moreover, a captive rearing programme is conducted with the aim of raising wild eggs in captivity and releasing them back to its habitat as a way to increase survival and recruitment (Roesler 2015). However, as for 2020, no captive-reared chicks had so far been released (Roesler com pers). Extensive conservation efforts are showing that management actions applied were successful and now the population is stable. If an increase in hooded grebes is achieved in the future, this endemic species might have a higher chance of avoiding extinction.

8 Final Remarks

More basic information concerning ecological linkages, benefits, off-site effects and cost-effectiveness of different actions across realms is much needed to enhance biodiversity conservation (Adams et al. 2014). On a specific level, deepening current ecological knowledge of those taxa linked to both freshwater and terrestrial environments would be helpful to develop cross-realm conservation strategies. Amphibians and waterbirds can be used as models and flagships for this purpose. Argentinean Patagonia hosts several priority species among these groups, including some of the most endangered amphibians and waterbirds worldwide. These species act as ecological linkages between almost all the freshwater types from this region and the terrestrial habitats, as most of them occur in shallow lakes, ponds and other wetlands, and some of them also inhabit rivers and streams. Considering that aquatic, wetland and terrestrial environments often share the same threats, the efforts needed to protect these species from those threats will also help to protect their freshwater and terrestrial habitats.

Among the mentioned threats, habitat disturbances caused by livestock overgrazing and trampling, and invasive species, mainly predatory fish and minks, are causing population decline in several endangered native species. Some studies already account for the impact of these threats. For instance, Cossa et al. (2020) identified the negative effect of livestock on *Chloephaga* spp., and Velasco et al. (2018) recorded a decrease in occupancy of native amphibians due to trout presence. In addition, climate change was also recognised as an important threat for critically endangered species with effects already observed, like in the case of *A. patagonicus* and *P. gallardoi* (IUCN SSC Amphibian Specialist Group 2019b; Lancelotti et al.

2020). Projected scenarios should be used to assess the potential impact of climate change on most of the priority species of amphibians and waterbirds from Patagonia to urgently develop conservation strategies to mitigate its effects. Particularly, damming and mining projects located in areas with presence of endangered amphibians and waterbirds should be closely monitored, and compensatory strategies for their conservation should be put in place.

Regarding conservation actions required to protect these species and their habitats, researchers, conservationists and managers consider the creation of new protected areas and management of these areas and existing ones. However, the establishment of new protected areas is not always the best strategy to ensure long-term biodiversity conservation (Montesino-Pouzols 2012). On the other hand, recovery strategies framed on species management have proven effective for some Patagonian amphibians and waterbirds (Roesler et al. 2016; Martínez-Aguirre et al. 2019). In the former case, species management was poorly identified as a main need during the assessment conducted by the IUCN. This may be due to the absence of conservation projects that apply species management, with the consequent lack of detailed information about the effectiveness of these methods at local scale (see Arellano et al. (2017b) and Martínez-Aguirre et al. (2019)). Adaptive management and data from successful examples from other countries should be used as starting points to fill this gap.

Conservation priorities in the Argentine Patagonia were identified for, at least, nine amphibian's and five waterbird's species due to their conservation status. These species can be used as flagships to effectively protect their freshwater and terrestrial habitats and so protect all the biodiversity they contain. Some of the most significant conservation projects based on endangered species are being carried on with Patagonian species (El Rincón stream frog and the hooded grebe projects). These conservation projects are removing and/or alleviating the main threats for both species, and consequently, they are also promoting the protection of all biodiversity. These conservation projects have demonstrated how single species can act as flagships and umbrellas, acting as bridges to conserve aquatic, wetland and terrestrial environments.

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References

Acosta I, Cabanne GS, Noll D, González-Acuña D, Pliscoff P, Vianna JA (2021) Patagonian glacial effects on the endemic Green-backed Firecrown, *Sephanoides sephaniodes* (Aves: Trochilidae): evidence from species distribution models and molecular data. J Ornithol 162:289–301. https://doi.org/10.1007/s10336-020-01822-4

Adams VM, lvarez-Romero JGA, Carwardine J, Cattarino L, Hermoso V, Kennard MJ, Linke S, Pressey RL, Stoeckl N (2014) Planning across freshwater and terrestrial realms: cobenefits and tradeoffs between conservation actions. Conserv Lett 7:425–440. https://doi.org/10.1111/conl.12080

Agnolin FL (2012) A new Calyptocephalellidae (Anura, Neobatrachia) from the Upper Cretaceous of Patagonia, Argentina, with comments on its systematic position. Studia geologica salmanticensia 48:129–178

Álvarez-Berastegui D, Amengual J, Coll J, Reñones O, Moreno-Navasd J, Agardy T (2014) Multidisciplinary rapid assessment of coastal areas as a tool for the design and management of marine protected areas. J Nat Conserv 22:1–14. https://doi.org/10.1016/j.jnc.2013.07.003

Alveal N, Díaz-Páez H (2021) Diet composition of *Atelognathus nitoi* (Barrio, 1973) in the Chilean Patagonia. Herpetol Notes 14:231–237

Amat JA, Green AJ (2010) Waterbirds as bioindicators of environmental conditions. In: Hurford C, Schneider M, Cowx I (eds) Conservation monitoring in freshwater habitats. Springer, Dordrecht, pp 45–52

Arellano ML, Akmentins MS, Velasco MA, Kass CA, Kacoliris FP (2015) First report of *Batrachochytrium dendrobatidis* in a threatened species, *Atelognathus reverberii*, in Argentina. Herpetol Rev 46:354–356

Arellano ML, Velasco MA, Kacoliris FP, Belasen AM, James TY (2017a) First record of *Batrachochytrium dendrobatidis* in *Pleurodema somuncurense*, a Critically Endangered species from Argentina. Herpetol Rev *48*:68–70

Arellano ML, Velasco MA, Quiroga S, Kass CA, Kass NA, Kacoliris FP (2017b) Livestock management and dam removal allowed the recovery of an aquatic habitat for endangered frog and fish species in Argentinian Patagonia. Conserv Evid 14:67–67

Atalah A, Sielfeld W (1976) Presencia de *Batrachyla antartandica* Barrio en Magallanes. An Inst Patagon (Chile) 7:168–170

Báez AM, Pugener LA (2003) Ontogeny of a new Palaeogene pipid frog from southern South America and xenopodinomorph evolution.

Báez AM, Trueb L, Calvo JO (2000) The earliest known pipoid frog from South America: a new genus from the middle Cretaceous of Argentina. J Vertebr Paleontol 20:490–500. https://doi.org/10.1671/0272-4634(2000)020[0490:TEKPFF]2.0.CO;2

Báez AM, Muzzopappa P, dos Santos Araújo OG (2022) New remains from the Cenomanian Candeleros Formation, Neuquén Basin (Patagonia, Argentina) provide insights into the formation of the sacro-urostylic complex in early pipimorph frogs (Amphibia, Anura). Cretac Res 129:105026. https://doi.org/10.1016/j.cretres.2021.105026

Basso NG (1994) Una nueva especie de Batrachyla (Anura: leptodactylidae: telmatobiinae) de Argentina. Cuad herpetol 8

Barrasso DA, Basso NG (2018) Low genetic divergence but many names in the endemic Patagonian frogs of the genus *Atelognathus* (Anura, Batrachylidae): A molecular genetic and morphological perspective. J Zoolog Syst Evol Res 1-17. https://doi.org/10.1111/jzs.12259

Barros VR, Boninsegna JA, Camilloni IA, Chidiak M, Magrín GO, Rusticucci M (2015) Climate change in Argentina: trends, projections, impacts and adaptation. Wiley Interdiscip Rev Clim Change 6:151–169. https://doi.org/10.1002/wcc.316

BirdLife International (2019) *Podiceps gallardoi*. The IUCN Red List of Threatened Species 2019: e.T22696628A145837361. https://doi.org/10.2305/IUCN.UK.2019-3.RLTS.T22696628A145837361.en. Downloaded on 19 November 2021.

Blaustein AR, Wake DB (1990) Declining amphibian populations: a global phenomenon? Trends Ecol Evol 5:203

Blotto BL, Úbeda C, Basso NG (2012) *Alsodes verrucosus* (Philippi, 1902). In: Categorización del Estado de Conservación de la Herpetofauna de la República Argentina. Ficha de los Taxones. Anfibios. Cuad Herpetol 26: 187

Blotto BL, Nunez JJ, Basso NG, Úbeda CA, Wheeler WC, Faivovich J (2013) Phylogenetic relationships of a Patagonian frog radiation, the Alsodes+ Eupsophus clade (Anura: Alsodidae),

with comments on the supposed paraphyly of Eupsophus. Cladistics 29:13–131. https://doi.org/10.1111/j.1096-0031.2012.00417.x
Bolaños F, Castro F, Cortéz C, De La Riva I, Grant T, Hedges B, Heyer R, Ibañez R, La Marca E, Lavilla E (2008) Amphibians of the Neotropical realm. In: Chanson JS, Cox NA, Berridge RJ, Ramani P, Young B (eds) Threatened amphibians of the world. Lynx Ediciones, IUCN, Conservation International, Barcelona, Gland, Arlington, Spain, Switzerland, pp 92–105
Bucher EH, Herrera G (1981) Comunidades de aves acuáticas de la laguna Mar Chiquita (Córdoba, Argentina). Ecosur 8:91–120
Buria L, Albariño RJ, Díaz Villanueva V, Modenutti BE, Balseiro EG (2007) Impact of exotic rainbow trout on the benthic macroinvertebrate community from Andean-Patagonian headwater streams. Fundam Appl Limnol 168:145–154
Buria L, Albariño RJ, Modenutti BE, Balseiro EG (2009) Variación temporal en la dieta de la trucha exótica arco iris (*Oncorhynchus mykiss*) en un arroyo forestado de los Andes patagónicos. Rev Chil Hist Nat 82:3–15
Burgos JJ, Ponce HF (1991) Climate change predictions for South America. Clim Change 18:223–239
Burton EC, Gray MJ, Schmutzer AC, Miller DL (2009) Differential responses of postmetamorphic amphibians to cattle grazing in wetlands. J Wildl Manage 73:269–277. https://doi.org/10.2193/2007-562
Busse K (1970) Care of the young by male *Rhinoderma darwini*. Copeia 395
Cabrera AL (1976) Regiones fitogeogrÁficas argentinas. in: Enciclopedia argentina de agricultura y jardinería. Tomo II. Fascículo 1. ACME, Buenos Aires, pp 1-85
Casañas H, Imberti S, Roesler I (2013) Hooded Grebe Report. March 2013. Conicet, Asociación Ambiente Sur, Aves Argentinas, Santa Cruz, Argentina.
Canziani S, Derlindati EJ (2000) Abundance and habitat of High Andes Flamingos in Northwestern Argentina. Waterbirds 23:121–133. https://doi.org/10.2307/1522157
Carwardine J, Wilson KA, Watts M, Etter A, Klein CJ, Possingham HP (2008) Avoiding costly conservation mistakes: the importance of defining actions and costs in spatial priority setting. PLoS One 3(7):e2586. https://doi.org/10.1371/journal.pone.0002586
Cei JM (1962) Batracios de Chile. Universidad de Chile, Santiago
Cei JM (1969) The patagonian telmatobiid fauna of the Volcanic Somuncura Plateau of Argentina. J Herpetol 3:1–18
Cei JM (1976) Remarks on some Neotropical amphibians of the genus Alsodes from southern Argentina. Atti Soc Ital Sci nat Museo civ nat Milano 117:159–164
Cei JM (1980) Amphibians of Argentina. Monitore Zoologico Italiano, New Series. *Monographs, Milan*
Cei JM (1987) Additional notes to “Amphibians of Argentina”: an update 1980-1986. Monitore Zoologico Italiano 21:209–272
Chebez JC, Bertonatti C (1994) Los que se van: especies argentinas en peligro. Editorial Albatros, Buenos Aires
Cisternas-Medina I, Ortiz JC, Úbeda C, Díaz-Páez H, Vidal M (2019) Distribución geográfica del sapito de rayas o sapo variegado *Nannophryne variegata* Günther, 1870, nuevas localidades y comentarios sobre su hábitat en Chile y Argentina. Gayana 83:33–45. https://doi.org/10.4067/S0717-65382019000100033
Collins JP (2010) Amphibian decline and extinction: what we know and what we need to learn. Dis Aquat Organ 92:93–99. https://doi.org/10.3354/dao02307
Corbalán VE, Debandi G, Martínez F (2010) *Alsodes pehuenche* (Anura: Cycloramphidae): Past, present and future. Cuad herpetol 24:17–23
Cossa NA, Fasola L, Roesler I, Reboreda JC (2018) Incubating Upland Goose (*Chloephaga picta*) differential response to livestock, human, and predator nest disturbance. Wilson J Ornithol 130:739–745. https://doi.org/10.1676/17-105.1
Cossa N, Fasola L, Roesler I, Reboreda JC (2020) Impacts of traditional livestock farming on threatened sheldgeese (*Chloephaga* spp.) in Patagonia. Avian. Conserv Ecol 15:1. https://doi.org/10.5751/ACE-01630-150201

Cuello ME, Perotti MG, Iglesias GJ (2009) Dramatic decline and range contraction of the endangered Patagonian frog *Atelognathus patagonicus* (Anura, Leptodactylidae). Oryx 43:443–446. https://doi.org/10.1017/S0030605308000148

Cuello ME, Bello MT, Úbeda C (2017) Una especie "En peligro". Hacia la conservación de la rana acuÁtica de la Laguna Blanca. Desde la Patagonia Difundiendo Saberes 14:18–27

Cussac VE, Habit E, González J, Battini MA, Barriga JP, Crichigno S (2012) Los peces de agua dulce de la Patagonia: una puesta al día. Informe Técnico. INIBIOMA, Conicet-Universidad Nacional del Comahue, p 13

Darlington PJ (1965) Biogeography of the Southern end of the world. Harvard University Press, Cambridge

Del Hoyo JA, Elliott A, Sargatal J (1992) Handbook of the birds of the world, vol 1. Ostrich to Ducks. Lynx Editions, Barcelona

de Miguel A, Fasola L, Roesler I, Martin L, Cossa N, Giusti E (2019) Ecological requirements and relative impact of threats affecting the Austral Rail *Rallus antarcticus*: monitoring methodology considerations for an imperative conservation status re-evaluation. Bird Conserv Int 29(4):586–597

Di Giacomo AS (2005) Áreas importantes para la conservación de las aves en la Argentina. Sitios prioritarios para la conservación de la biodiversidad. Aves Argentinas/Asociación Ornitológica, Buenos Aires

Dinerstein E, Olson DM, Graham DJ, Webster AL, Primm SA, Bookbinder MP, Ledec G (1995) Una evaluación del estado de conservación de las eco-regiones terrestres de América Latina y el Caribe. Banco Mundial, Washington DC

Duellman WE, Trueb L (1994) Biology of amphibians. The Johns Hopkins University Press, Baltimore

Duffus ALJ, Marschang RE, Waltzek TB, Stöhr A, Allender MC, Gotesman M, Whittington R, Hick P, Hines M (2015) Distribution and host range of ranaviruses. In: Gray MJ, Chinchar VG (eds) Ranaviruses: lethal pathogens of ectothermic vertebrates. Springer, Secaucus, pp 9–57

Eby LA, Roach WJ, Crowder LB, Stanford JA (2006) Effects of stocking-up freshwater food webs. Trends Ecol Evol 21:576–584. https://doi.org/10.1016/j.tree.2006.06.016

Echevarria AL, Chani JM (2000) Estructura de la comunidad de aves acuáticas del embalse El Cadillal, Tucumán, Argentina. Acta zool lilloana 45:219–232

Fasola L, Roesler I (2018) A familiar face with a novel behavior raises challenges for conservation: American mink in arid Patagonia and a critically endangered bird. Biol Conserv 218:217–222. https://doi.org/10.1016/j.biocon.2017.12.031

Fattorini S (2006) A new method to identify important conservation areas applied to the butterflies of the Aegean Islands (Greece). Anim Conserv 9:75–83. https://doi.org/10.1111/j.1469-1795.2005.00009.x

Ferrari S, Imberti S, Albrieu C (2003) Magellanic Plovers Pluvianellus socialis in southern Santa Cruz Province. Argentina WSGB101/102:1–7

Fjeldså J (1984) Three endangered South American grebes (Podiceps): case histories and the ethics of saving species by human intervention. Ann Zool Fennici 21:411–416

Fjeldså J (1985) Origin, evolution and status of the avifauna of Andean Wetlands. Ornith Monogr 36:85–112

Fjeldså J (1986) Feeding ecology and possible life history tactics of the hooded grebe *Podiceps Gallardoi*. Ardea 74:40–58

Fox SF, Yoshioka JH, Cuello ME, Úbeda C (2005) Status, distribution, and ecology of an endangered semi-aquatic frog (*Atelognathus patagonicus*) of north-western Patagonia, Argentina. Copeia 4:921–929. https://doi.org/10.1643/0045-8511(2005)005[0921:SDAEOA]2.0.CO;2

Froneman A, Mangnall MJ, Little RM, Crowe TM (2001) Waterbird assemblages and associated habitat characteristics of farm ponds in the Western Cape, South Africa. Biodivers Conserv 10:251–270

Francisco SJ, Sol P, Julio L, Inés O, Irina I (2019) Both Lake regime and fish introduction shape autotrophic planktonic communities of lakes from the Patagonian Plateau (Argentina). Hydrobiologia 831:133–145

Garay G, Johnson WE, Franklin WL (1991) Relative abundance of aquatic birds and their use of wetlands in the Patagonia of southern Chile. Rev Chil Hist Nat 64:127–137

Gatto A, Quintana F, Yorio P, Lisnizer N (2005) Abundancia y diversidad de aves acuáticas en un humedal marino del golfo de San Jorge, Argentina. Hornero 20:141–152

Ghirardi R, López JA (2017) Anfibios de Santa Fe. Ediciones UNL, Santa Fe

Ghirardi R, Levy MG, López JA, Corbalán V, Steciow MM, Perotti MG (2014) Endangered amphibians infected with the chytrid fungus *Batrachochytrium dendrobatidis* in austral temperate wetlands from Argentina. Herpetol J 24:129–133

Gómez RO, Báez AM, Muzzopappa P (2011) A new helmeted frog (Anura: Calyptocephalellidae) from an Eocene subtropical lake in northwestern Patagonia, Argentina. J Vertebr Paleontol 31:50–59. https://doi.org/10.1080/02724634.2011.539654

González-Gajardo A, Sepúlveda PV, Schlatter R (2009) Waterbird assemblages and habitat characteristics in wetlands: influence of temporal variability on species-habitat relationships. Waterbirds 32:225–233. https://doi.org/10.1675/063.032.0203

González PM (1996) Habitat partitioning and the distribution and seasonal abundances of migratory plovers and sandpipers. in Los Álamos, Río Negro, Argentina. In: Hicklin P (ed) Shorebird ecology and conservation in the Western Hemisphere 8. International Wader Studies, Ottawa, pp 93–102

Green AJ, Elmberg J (2014) Ecosystem services provided by waterbirds. Biol Rev 89:105–122. https://doi.org/10.1111/brv.12045

Hazlitt SL, Martin TG, Sampson L, Arcese P (2010) The effects of including marine ecological values in terrestrial reserve planning for a forest-nesting seabird. Biol Conserv 143:1299–1303. https://doi.org/10.1016/j.biocon.2010.01.026

Heusser CJ (1989) Late Quaternary vegetation and climate of southern Tierra del Fuego. Quatern Res 31:396–406

Hollin JT, Schilling DH (1981) Late WisconsinWeichselian mountain glaciers and small ice caps. In: Dentan G, Hughes TJ (eds) The Last GreatIce Sheets. Wiley, New York

Hudson MS (1983) Waterfowl production on three age classes of stock ponds in Montana. J Wildl Manag 47:112–117

Instituto Nacional de Tecnología Agropecuaria (INTA) (2015) Situación actual y perspectiva de la ganadería en Patagonia (Current situation and perspective of livestock in Patagonia). Technical report. Instituto Nacional de Tecnología Agropecuaria, Buenos Aires, Argentina. [online] URL: https://inta.gob.ar/documentos/situacion-actual-y-perspectivas-de-la-ganaderia-en-patagonia-sur.

Iglesias CG, Pérez AA (1998) Patagonia. In: Canevari P, Blanco DE, Bucher E, Castro G, Davidson I (eds) Los Humedales de la Argentina. Clasificación, situación actual, conservación y legislación. Wetland Internacional 46, Buenos Aires, pp 115–135

Imberti S (2005) Meseta Lago Strobel. In: Di Giacomo AS (ed) Áreas importantes para la conservación de las aves en la Argentina. Sitios prioritarios para la conservación de la biodiversidad. Aves Argentinas/Asociación Ornitológica del Plata, Buenos Aires, pp 415–416

Imberti S, Casañas H (2010) Hooded Grebe *Podiceps gallardoi*: extinct by its 50th birthday? Neot Bird:66–71

Iriondo M (1989) Quaternary lakes of Argentina. Palaeogeogr Palaeoclimatol Palaeoecol 70:81–88

IUCN SSC Amphibian Specialist Group (2016) *Pleurodema somuncurense*. The IUCN Red List of Threatened Species 2016: e.T20372A85948443. https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T20372A85948443.en. Downloaded on 26 May 2021.

IUCN SSC Amphibian Specialist Group (2019a) *Alsodes verrucosus*. The IUCN Red List of Threatened Species 2019: e.T56321A79811666. https://doi.org/10.2305/IUCN.UK.2019-1.RLTS.T56321A79811666.en. Downloaded on 19 November 2021.

IUCN SSC Amphibian Specialist Group (2019b) *Alsodes neuquensis*. The IUCN Red List of Threatened Species 2019: e.T45477280A45477430. https://doi.org/10.2305/IUCN.UK.2019-1.RLTS.T45477280A45477430.en. Downloaded on 21 May 2021.

IUCN SSC Amphibian Specialist Group (2019c) *Atelognathus patagonicus*. The IUCN Red List of Threatened Species 2019: e.T56323A101427111. https://doi.org/10.2305/IUCN.UK.2019-1.RLTS.T56323A101427111.en. Downloaded on 26 May 2021.

IUCN SSC Amphibian Specialist Group (2019d) *Atelognathus praebasalticus*. The IUCN Red List of Threatened Species 2019: e.T56324A96477527. https://doi.org/10.2305/IUCN.UK.2019-1.RLTS.T56324A96477527.en. Downloaded on 19 November 2021.

Izaguirre I, Saad JF (2014) Phytoplankton from natural water bodies of the Patagonian Plateau. Advanc Limnol 65:309–319. https://doi.org/10.1127/1612-166X/2014/0065-0048

Izaguirre I, Lancelotti J, Saad JF, Porcel S, Marinone MC, Roesler I, del Carmen DM (2018) Influence of fish introduction and water level decrease on lakes of the arid Patagonian plateaus with importance for biodiversity conservation. Glob Ecol Conserv 14:e00391. https://doi.org/10.1016/j.gecco.2018.e00391

Kacoliris FP, Velasco MA, Berkunsky I, Celsi CE, Williams JD, Di-Pietro D, Rosset S (2016) How to prioritize allocating conservation efforts: an alternative method tested with imperilled herpetofauna. Anim Conserv 19:46–52. https://doi.org/10.1111/acv.12215

Kacoliris FP, Velasco MA, Arellano ML, Martínez Aguirre T, Zarini O, Calvo R, Berkunsky I, Williams JD (2018) Plan de acción para la conservación de la Ranita del Valcheta (*Pleurodema somuncurense*), Meseta de Somuncura, Río Negro. https://www.iucn-amphibians.org/wp-content/uploads/2018/11/Action-Plan_Valcheta-Frog_-Pleurodema-somuncurense-.pdf

Kacoliris FP, Cuello ME, Úbeda C, Buria L, Pastore H, Rodrigo Calvo, Chazarreta (2020) Plan de acción para la conservación de la Rana de la Laguna Blanca (*Atelognathus patagonicus*) ene l Parque Nacional Laguna Blanca, Neuquén. Documento Inédito. 42 pp

Klein CJ, Tulloch VJ, Halpern BS, Selkoe KA, Watts ME, Steinback C, Scholz A, Possingham HP (2013) Tradeoffs in marine reserve design: habitat condition, representation, and socioeconomic costs. Conserv Lett 6:324–332. https://doi.org/10.1111/conl.12005

Konter A (2008) Decline in the population of Hooded Grebe *Podiceps gallardoi*. Cotinga 29:135–138

Lancelotti J, Pozzi LM, Diéguez MC, Yorio PM, Pascual MA (2009) Fishless shallow lakes of Southern Patagonia as habitat for waterbirds at the onset of trout aquaculture. Aquatic Conserv Mar Freshw Ecosyst 9:497–505. https://doi.org/10.1002/aqc.1018

Lancelotti J, Pessag N, Roesler I, Pascual M (2020) Climate variability and trends in the reproductive habitat of the critically endangered Hooded grebe. Aquatic Conserv Mar Freshw Ecosyst 30:554–564. https://doi.org/10.1002/aqc.3240

Lanctot RB, Blanco DE, Oesterheld M, Balbueno RA, Guerschman JP, Piñeiro G (2004) Assessing habitat availability and use by buff- breasted sandpipers (*Tryngites subruficollis*) wintering in South America. Ornitol Neotrop 15:367–376

Laredo CD (1996) Observations on migratory and resident shorebirds in lakes in the highlands of northwestern Argentina. Int Waders Stud 8:103–111

Lavilla EO, Richard E, Scrocchi GJ (2000) Categorización de los Anfibios y Reptiles de la República Argentina. Edición Especial Asociación Herpetológica Argentina, Argentina

Lavilla EO, Heatwole H (2010) Status of amphibian conservation and decline in Argentina. In: Heatwole H (ed) Amphibian biology. Status of decline of Amphibians: western hemisphere. Chipping Norton, Surrey Beatty & SonsPty Limited, Baulkham Hills, pp 30–78

Lei F, Qu Y, Song G (2014) Species diversification and phylogeographical patterns of birds in response to the uplift of the Qinghai-Tibet Plateau and Quaternary glaciations. Curr Zool 60:149–161. https://doi.org/10.1093/czoolo/60.2.149

León RJC, Bran D, Collantes M, Paruelo JM, Soriano A (1998) Grandes unidades de vegetación de la Patagonia extra andina. Ecol Austral 8:125–144

Lips KR, Burrowes PA, Mendelson JR, Parra-Olea G (2005) Amphibian population declines in Latin America: a synthesis. Biotropica 37:222–226. https://doi.org/10.1111/j.1744-7429.2005.00029.x

Livezey BC (1986) A phylogenetic analysis of recent anseriform genera using morphological characters. Auk 103:737–754

Ma Z, Bo-Li IC, Chen J (2010) Managing Wetland habitats for waterbirds: an international perspective. Wetlands 30:15–27

MAyDS, AA (Ministerio de Ambiente y Desarrollo Sustentable y Aves Argentina) (2017) Categorización de las Aves de la Argentina (2015). Informe del Ministerio de Ambiente y Desarrollo Sustentable de la Nación y de Aves Argentinas. Edición electrónica, Ciudad de Buenos Aires. http://avesargentinas.org.ar/sites/default/files/Categorizacion-de-aves-de-la-Argentina.pdf

Macchi PJ, Vigliano PH (2014) Salmonid introduction in Patagonia: the ghost of past, present and future management. Ecol Austral 24:162–172

Markgraf V (1989) Palaeoclimates in Central and South America since 18,000 BP based on pollen and lake-level records. Quat Sci Rev 8:1–24

Martinazzo LB, Basso NG, Úbeda CA (2011) Geographic distribution record of *Atelognathus reverberii*. Herpetol Rev 42:236–236

Martínez Aguirre T, Calvo R, Velasco MA, Arellano ML, Kacoliris FP (2019) Re-establishment of an extinct local population of the Valcheta Frog (*Pleurodema somuncurense*) in a restored habitat at Patagonia, Argentina. Conserv Evid 16:48–50

Mazzonia E, Vazquez M (2009) Desertification in Patagonia. Dev Earth Surf Proc 13:351–377. https://doi.org/10.1016/S0928-2025(08)10017-7

Montalti D, Arambarri AM, Soave GE, Darrieu CA, Camperi AR (2003) Seeds in the diet of the White-rumped Sandpiper in Argentina. Waterbirds 26:166–168. https://doi.org/10.1675/1524-4695(2003)026[0166:SITDOT]2.0.CO;2

Montesino-Pouzols F, Burgman MA, Moilanen A (2012) Methods for allocation of habitat management, maintenance, restoration and offsetting, when conservation actions have uncertain consequences. Biol Conserv 153:41–50. https://doi.org/10.1016/j.biocon.2012.05.014

Morello J, Matteucci S, Rodríguez AF, Silva M (2012) Ecorregiones y complejos ecosistemicos argentinos. Orientación GrÁfica Editora, Buenos Aires

Muzzopappa P, Martinelli AG, Garderes JP, Rougier GW (2021) Exceptional avian pellet from the paleocene of Patagonia and description of its content: a new species of calyptocephalellid (Neobatrachia) anuran. Pap Palaeontol 7:1133–1146. https://doi.org/10.1002/spp2.1333

Nanni AS, Piquer-Rodríguez M, Rodríguez D, Nuñez-Regueiro M, Periago ME, Aguiar S, Ballari SA, Blundo C, Derlindati E, Di Blanco Y, Eljall A, Grau HR, Herrera L, Huertas Herrera A, Izquierdo AE, Lescano J, Macchi L, Mazzini F, Milkovic M, Montti L, Paviolo A, Pereyra M, Quintana RD, Quiroga V, Renison D, Santos Beade M, Schaaf A, Gasparri NI (2020) Presiones sobre la conservación asociadas al uso de la tierra en las ecorregiones terrestres de Argentina. Ecol Austral 30:304–320

O'Donnell C, Fjeldså J (1997) Grebes: status survey and conservation action plan. IUCN/SSC Grebe Specialist Group, Cambridge, U.K

Ortiz JC (2015) Anfibios de las turberas del extremo austral de Chile. In: Domínguez E, Vega-Valdés D (eds) Funciones y servicios ecosistémicos de las turberas en Magallanes. Colección de libros INIA N° 33. Instituto de Investigaciones Agropecuarias. Centro Regional de Investigación Kampenaike, Punta Arenas, pp 227–238

Ortubay S, Cussac V, Battini M, Barriga J, Aigo J, Alonso M, Macchi P, Ressing M, Yoshioka J, Fox S (2006) Is the decline of birds and amphibians in a steppe lake of northern Patagonia a consequence of limnological changes following fish introduction? Aquat Conserv 16:93–105. https://doi.org/10.1002/aqc.696

Pastore H, Kubisch E, Úbeda C (2013) Informe de Proyecto de Investigación DRP 1232 "Aspectos básicos de la biología y distribución espacial de *Batrachyla fitzroya*, Basso, 1994, rana micro-endémica del Parque Nacional Los Alerces" San Carlos de Bariloche.

Pagnoni G, Garrido J, Marin M (1986) Impacto económico y ambiental del visón. *Mustela vison* (Schreber 1877) en el norte de la Patagonia. Technical report, CENPAT-CONICET, Dirección de Fauna de la Provincia de Chubut.

Peris SJ, Sanguinetti J, Pescador M (2009) Have Patagonian waterfowl been affected by the introduction of the American Mink Mustela vison? Oryx 43:648–654. https://doi.org/10.1017/S0030605309990184

Perotti MG, Diéguez MC, Jara FG (2005) Estado del conocimiento de humedales del norte patagónico (Argentina): aspectos relevantes e importancia para la conservación de la biodiversidad regional. Rev Chil Hist Nat 78:723–737

Roesler I (2015) The status of hooded grebe (*Podiceps gallardoi*) in Chile. Ornitol Neotrop 26:255–263

Roesler I (2016) Conservación del Macá Tobiano (*Podiceps gallardoi*): factores que afectan la viabilidad de sus poblaciones. Universidad de Buenos Aires, Argentina (PhD thesis)

Roesler I, Casañas H, Imberti S (2011) Final countdown for the Hooded Grebe? Neotrop Bird 9:3–7

Roesler I, Imberti S, Casañas HE, Hernández PM, Klavins JM, Pagano LG (2014) Noteworthy records and natural history comments on rare and threatened bird species from Santa Cruz province, Patagonia, Argentina. Rev Bras Ornitol *22*:189–200

Roesler I, Fasola L, Casañas H, Hernández PM, de Miguel A, Giusti ME, Reboreda JC (2016) Colony guardian programme improves recruitment in the critically endangered hooded grebe *Podiceps gallardoi* in austral Patagonia, Argentina. Conserv Evid 13:62–66

Rolando AMA, Agnolin FL, Corsolini J (2019) A new pipoid frog (Anura, Pipimorpha) from the Paleogene of Patagonia. Paleobiogeographical implications. Comptes rendus Palevol 18:725–734. https://doi.org/10.1016/j.crpv.2019.04.003

Romano M, Barberis I, Pagano F, Maidagan J (2005) Seasonal and interannual variation in waterbird abundance and species composition in the Melincue´ saline lake, Argentina. Eur J Wildl Res 51:1–13. https://doi.org/10.1007/s10344-005-0078-z

Romero EJ (1986) Paleogene phytogeography and climatology of South America. Ann Missouri Bot Gard 73:449–461

Soto-Azat C, Valenzuela-Sánchez A, Collen B, Rowcliffe JM, Veloso A, Cunningham AA (2013) The population decline and extinction of Darwin's frogs. PLoS One 8:e66957. https://doi.org/10.1371/journal.pone.0066957

Scott DA, Carbonell M (1986) Inventario de Humedales de la Región Neotropical. IWRB Slimbridge and UICN, Cambridge

Schivo F, Bauni V, Krug P, Quintana RD (2019) Distribution and richness of amphibians under different climate change scenarios in South America humid subtropical region. Appl Geogr 103:70–89. https://doi.org/10.1016/j.apgeog.2019.01.003

Schmutzer C, Gray MJ, Burton EC, Miller DL (2008) Impacts of cattle on amphibian larvae and the aquatic environment. Freshw Biol 53:2613–2625. https://doi.org/10.1111/j.1365-2427.2008.02072.x

Stuart SN, Chanson JS, Cox NA, Young BE, Rodríguez ASL, Fischman DL, Waller W (2004) Status and trends on amphibian declines and extinctions worldwide. Science 306:1783–1786. https://doi.org/10.1126/science.1103538

Úbeda CA (1998) Batracofauna de los bosques templados patagónicos: un enfoque ecobiogeográfico (Doctoral dissertation, Universidad de Buenos Aires. Facultad de Ciencias Exactas y Naturales (PhD Thesis)

Úbeda CA (2000) *Eupsophus calcaratus* (Anura: Leptodactylidae): ampliación de su distribución geográfica y hábitats en Argentina. Cuad herpetol *14*

Úbeda CA, Basso NG (2012) *Rhinella rubropunctata* (Güichénot, 1848). Sapo de puntos rojos. In: Categorización del Estado de Conservación de la Herpetofauna de la República Argentina. Ficha de los Taxones. Anfibios. Cuad herpetol 26: 171

Úbeda CA, Grigera D (2007) El grado de protección de los anfibios patagónicos de Argentina. Ecol Austral 17:269–279

Úbeda C, Veloso A, NÚñez H, Basso B, Blotto B (2010) *Nannophryne variegata.* The IUCN Red List of Threatened Species 2010: e.T54790A11192107. URL: http://www.iucnredlist.org/details/54790/0. Downloaded on 10 November 2021.

Úbeda CA, Basso NG, Blotto B (2012) *Alsodes gargola neuquensis* (Cei, 1976). In: Categorización del Estado de Conservación de la Herpetofauna de la República Argentina. Ficha de los Taxones. Anfibios. Cuad herpetol 26: 187

Vaira M, Akmentins M, Attademo M, Baldo D, Barrasso D, Barrionuevo S, Basso N, Blotto B, Cairo S, Cajade R, Céspedez J, Corbalán V, Chilote P, Duré M, Falcione C, Ferraro D, Gutierrez R, Ingaramo M, Junges C, Lajmanovich R, Lescano JN, Marangoni F, Martinazzo L, Marti R, Moreno L, Natale GS, Pérez Iglesias JM, Peltzer P, Quiroga L, Rosset S, Sanabria E, Sanchez L, Schaefer E, Úbeda CA, Zaracho V (2012) Categorización del estado de conservación de los anfibios de La República argentina. Cuad herpetol 26:131–159

Vaira M, Pereyra LC, Akmentins MS, Bielby J (2017) Conservation status of amphibians of Argentina: An update and evaluation of national assessments. Amphib Reptile Conserv 11:36–44

Vaira M, Akmentins M, Lavilla EO (2018) Plan de Acción para la Conservación de los Anfibios de la República Argentina. Cuad herpetol 32.

Velasco MA (2018) Dinámica poblacional y conservación de la Ranita del Valcheta, *Pleurodema somuncurense* (Cei, 1969), Patagonia, Argentina. Doctoral thesis, Facultad de Ciencias Naturales y Museo. Universidad Nacional de La Plata, Argentina (PhD Thesis)

Velasco MA, Kacoliris FP, Berkunsky I, Quiroga S, Williams JD (2016) Current distributional status of the critically endangered Valcheta Frog: implications for conservation. Neotropical Biol Conserv 11:110–113. https://doi.org/10.4013/nbc.2016.112.08

Velasco MA, Úbeda C, Williams JD, Kacoliris FP (2017) Reproductive biology of the critically endangered Valcheta Frog, *Pleurodema somuncurense* (Anura: Leptodactylidae), from Patagonia, Argentina. South Am J Herpetol 12:205–211. https://doi.org/10.2994/SAJH-D-16-00049.1

Velasco MA, Berkunsky I, Simoy V, Quiroga S, Bucciarelli G, Kats L, Kacoliris FP (2018) The effect of exotic rainbow trout on the occupancy of two native amphibians from the Valcheta Stream (Patagonia, Argentina). Hydrobiologia 817:447–455. https://doi.org/10.1007/s10750-017-3450-6

Velasco MA, Berkunsky I, Akmentins MS, Kass CA, Arellano ML, Martínez Aguirre T, Williams JD, Kacoliris FP (2019) Status and population dynamics of the critically endangered Valcheta frog *Pleurodema somuncurense* on the Patagonian Somuncura Plateau. Endanger Spec Res 40:163–169. https://doi.org/10.3354/esr00988

Vera Candioti MF, Grosso J, MO, Pereyra MB, Haad JN, Lescano K, Siu-Ting C, Aguilar, Baldo D (2020) Larval anatomy of Andean toads of the *Rhinella spinulosa* group (Anura: Bufonidae). Herpetol Monogr 34:116–130. https://doi.org/10.1655/HERPMONOGRAPHS-D-20-00001_hmon-34-01-05_11

Vuilleumier F (1968) Origin of frogs of Patagonian forests. Nature 219:87–89

Vuilleumier F (1972) Bird species diversity in Patagonia (temperate South America). Am Nat 106:266–271

Vuilleumier F (1985) Forest birds of Patagonia: ecological geography, speciation, endemism, and faunal history. Ornithol Monogr:255–304

Vuilleumier F (1991) A quantitative survey of speciation phenomena in Patagonian birds. Ornitol Neotrop 2:5–28

Weller MW (1999) Wetland birds: Habitat resources and conservation implications. Cambridge University Press, Cambridge

Wiens JA (1989) The ecology of bird communities. Cambridge University Press, Cambridge

Wren S, Angulo A, Meredith H, Kielgast J, Dos Santos M, Bishop P (2015) Amphibian conservation action plan. April 2015. IUCN SSC Amphibian Specialist Group. https://www.iucn-amphibians.org/resources/acap/

Young BE, Lips KR, Reaser JK, Ibáñez R, Salas AW, Cedeño JR, Coloma LA, Ron S, La Marca E, Meyer JR, Muñoz A, Bolaños F, Chaves G, Romo D (2001) Population declines and priorities for amphibian conservation in Latin America. Conserv Biol 15:1213–1223. https://doi.org/10.1111/j.1523-1739.2001.00218.x

Young BE, Stuart SN, Chanson JS, Cox NA, Boucher TM (2004) Joyas que están desapareciendo: el estado de los anfibios en el Nuevo Mundo. Nature Serve, Arlington