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ECOLOGY

Habitat and abundance of *Aegla papudo* (Decapoda: Anomura: Aeglidae) at two new record sites

Hábitat y abundancia de *Aegla papudo* (Decapoda: Anomura: Aeglidae) en dos nuevos sitios de registro

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ABSTRACT

Aegla papudo is a freshwater crab endemic to Chile. Although known to inhabit turbid watercourses with gravel, sand, filamentous algae, leaf litter, and no tree cover; however, is scarce the information on the proportions of these components, physical-chemical aspects of the water, population abundance, and reproductive season. Its presence in the Cordillera El Melon led us to describe the habitat. Between 2018 and 2019, the species was searched for in seven streams. Its habitat was described, the density calculated, the water's physical-chemical parameters recorded. The variable that explained the abundance was analyzed with a model of Poisson. The species was recorded in the Los Coiles and El Gallo streams (62 and 24 individuals respectively) with a mean density of 1 individual/m^2. The abundance was explained by the volume of the mud with gravel and pebble. This investigation is the first to determine the abundance of adults and juveniles, as well as the variable that explained it. Environments with transparent water and tree cover are new aspects of the habitat. Fecal coliforms varied remarkably. Juvenile individuals present in August suggest that reproduction takes place between summer and fall. The International Union for Conservation of Nature does not register the species; however, we agree with other researchers who propose that the species be classified as Endangered due to known threats.

Keywords: Chilean pancoras, endemic decapodans, freshwater invertebrates, habitat selection, threatened species.

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RESUMEN

Aegla papudo es un cangrejo de agua dulce endémico de Chile. Aunque se sabe que habita en cursos de agua turbios con grava, arena, algas filamentosas, hojarasca y sin cobertura arbórea, la información sobre las proporciones de estos componentes, los aspectos físico-químicos del agua, la abundancia de la población y la época de reproducción, es escasa. Su presencia en la Cordillera El Melón motivó a describir el hábitat. Entre 2018 y 2019 se buscó la especie en siete quebradas. Se describió su hábitat, se calculó la densidad y se registraron los parámetros físico-químicos del agua. Se analizó la variable que explicaba la abundancia con un modelo de Poisson. La especie se registró en las quebradas Los Coiles y El Gallo (62 y 24 individuos respectivamente) con una densidad media de 1 individuo/m^2. La abundancia fue explicada por el volumen del lodo con grava y guijarros. Esta investigación es la primera en determinar la abundancia de adultos y juveniles, así como la variable que las explica. Los ambientes con agua transparente y la cobertura arbórea son aspectos nuevos del hábitat. Los coliformes fecales variaron notablemente. Los individuos juveniles en agosto sugieren que la reproducción tiene lugar entre el verano y el otoño. La Unión Internacional para la Conservación de la Naturaleza no registra la especie, pero estamos de acuerdo con otros investigadores quienes proponen que la especie se clasifique como En Peligro debido a las amenazas conocidas.

Palabras clave: Decápodos endémicos, especies amenazadas, invertebrados de agua dulce, pancoras de Chile, selección de hábitat.

INTRODUCTION

Aegla papudo (Schmitt, 1942) is a freshwater decapod endemic to Chile (Jara *et al.* 1995, Bahamonde *et al.* 1998) that is distributed, according to records between 1925 and 1991, from the Choapa River in the Coquimbo Region to the Mapocho River in the Metropolitan Region of Santiago, 30 - 800 meters above sea level (Jara *et al.* 1995). Tudge (2003) reported in 2000 that the species inhabits the Rabuco River in the Quillota Province, Valparaíso Region. Later, Ortíz (2018) found the species in the La Cortadera and El Arenal streams in La Campana National Park, Palmas de Ocoa sector (also located in the Valparaíso Region), but did not report location coordinates or abundance data. In this area, there is no other species of *Aegla* living in sympatry with *A. papudo*.

It is known that the species inhabits turbid watercourses with flows 1.5-2.0 m^3/s, on coarse gravel and sand bottoms, with filamentous algae, rotting organic matter and without riparian tree cover (Jara *et al.* 1995). Ortíz (2018) indicated that the species inhabits river bottoms composed of sand, mud, and a high leaf litter accumulation. However, there is little other knowledge about the habitat, population sizes, and reproduction (Jara *et al.* 1995, Ministerio del Medio Ambiente 2015).

The Ministry of the Environment of Chile classified the species as Endangered (Supreme Decree No. 52/2014 MMA). The criteria applied by the authority to categorize the species in this rank include: i) the disappearance of their populations from several of the known sites; ii) reduction in the quality of the habitat due to contamination of the water with pesticides and waste from the cities; iii) the prolonged drought in the region, and iv) decrease in water flow. These three criteria will make any new site of occurrence of the species a high priority site for its conservation. The International Union for Conservation of Nature does not register the species (IUCN 2018).

The limited knowledge of the ecology of the species, its conservation status, and the references, by local people, of its presence in the Cordillera El Melon Priority Site for Conservation (CEMPSC) led to a review of the streams in this site, located in the center of its geographic distribution range, in order to determine its presence, describe the habitat, and contribute to the knowledge of its population abundance.

MATERIAL AND METHODS

The CEMPSC is located in the northwest of the Valparaiso Region, Chile. It has elevations above 2000 m above sea level with vegetation named "Coastal Sclerophyllous Forest" (Ministerio del Medio Ambiente c2018). Between April 2018 and March 2019, seven streams running from east to west were visited. From north to south, the streams are named Talanquen, Los Maquis, La Madera, Infiernillo, Los Mayos, Los Coiles and El Gallo (Fig. 1). The water regime of these streams follows the rainy season; however, it is common to observe within their channels pools connected by running water.

Each stream was visited once in its entirety. It was examined by gently and slowly moving the bottom with a wooden stick and manually using rubber gloves in the places of possible presence of the crab. When the species was found, coordinates were recorded, and the habitat was described considering the surrounding flora, rocks, canopy cover (Jennings *et al.* 1999). Water flow was measured with the section-velocity or float method (ICC 2017). The area occupied by each stream sector was estimated multiplying the mean length and width measured at four equidistant points. The mean depth of the water column, mud, and gravel were calculated at four random points. The volume of the site (mud, gravel and pebbles) was calculated by multiplying the means of both the surface area and the depth. Water's physical-chemical parameters were obtained from a company that undertakes these measurements in area. The stream sectors were visited on four occasions every two hours, between 9:00 and 19:00 h; in each visit, the number of individuals was counted. The mean population density was calculated with the largest number of individuals counted by the occupied surface. Additionally, when the species' presence was recorded, camera traps (Bushnell Trophy Cam) were placed for the duration of this study, to record possible predators.

A Poisson regression model was run to determine which habitat component better explained the abundance of the species. The model was fed with the estimates of the volume of mud, water, gravel, pebbles and the combination of these variables. The models were run with the R v3.4.4 program (R Core Team 2018); the best model was selected with the Akaike Information Criterion for small samples. Finally, the coordinates of the records of this study were located on a map next to the historical records of Jara *et al.* (1995) to visualize them within the framework of their geographic distribution area, concerning the National System

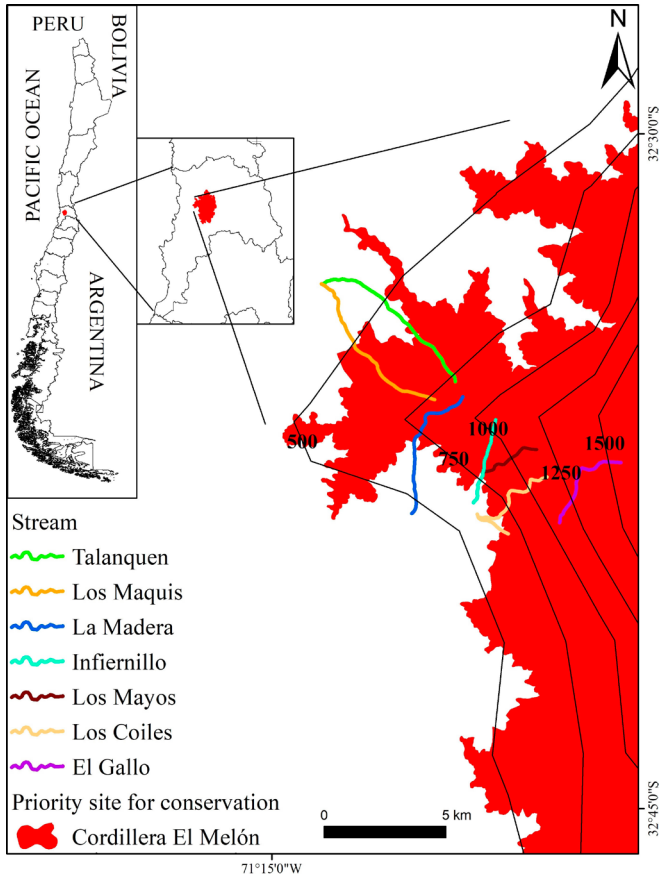

Figure 1. Location of the streams evaluated in the Priority Conservation Site Cordillera El Melon, Valparaiso - Chile.

of Protected Areas by the State (NSPAS) and Priority Areas for the Conservation of Biodiversity of Chile (Biblioteca del Congreso Nacional de Chile 2010).

RESULTS

The species was recorded in two of the seven streams evaluated. The first population was found on 4 Apr 2018, in Los Coiles stream, 420 -450 m above sea level (32°38' South, 71°9' West), in a section of 200 m with permanent water, which discharged in a mine tailings reservoir. This stream was interrupted in the upper part by a water division channel, leaving the population isolated in the absence of rain. The second population was found on 16 Feb 2019, in El Gallo stream, 675-685 m above sea level (32°38' South, 71°7' West), in a section of 70 m with permanent water, 3 km east of Los Coiles stream, with connection to a larger stream named El Sauce. Both streams are within a private property where mining activity takes place. However, these streams are not in areas subject to exploitation.

The population of the Los Coiles stream was the best-studied due to the access provided by the owners. Fifty adult individuals and twelve juveniles were recorded in 13 sectors shaped like ponds, in water with a mean flow of 0.009 m^3/s (CI95% 0.005-0.014). Juveniles were less than one centimeter long and had a whitish to pinkish coloration (Fig. 2).

The mean density of adults in the Los Coiles stream was 1.0 individuals/m^2 (CI95% 0.3 - 1.8), while the mean density of juveniles was 0.1 individuals/m^2 (CI95% 0.0 - 0.3) (Table 1). The mean depths varied from 5.1 - 31.8 cm. The water column ranged from 1.3 - 8.8 cm, always allowing visibility of the bottom. The mean length of the ponds varied from 85 - 465 cm, while the mean width varied from 90.3 - 309.3 cm, always with rocks on the edges (Fig. 2. Table 1). The ponds consisted of a bottom with a small amount of gravel (size: 0.2 - 1.6 cm), small pebbles (size: 1.6 - 3.2 cm), and very few large pebbles (size: 3.3 - 6.4 cm), mixed with mud, which was soft, dark brown to black, sulfur odor, and with litter (Table 2). The riverbanks were populated by *Cryptocarya alba* ((Molina) Looser) trees, 20 and 30 m high with a canopy that covered 90 % of the ponds (Fig. 2), some individuals of *Lithraea caustica* ((Molina) Hook and Arn) and next to the rocks, the herbaceous *Tropaeolum ciliatum* (Ruiz and Pavon). The camera traps placed in this stream did not register any predation event. However, *Accipiter bicolor* (Vieillot, 1817) was recorded over a pond and *Lycalopex culpaeus* (Molina, 1782), around the riverbanks.

Figure 2. Habitat and views of specimens of *A. papudo*. **a**. View of the water body of a pond, **b**. View of the canopy cover of *Cryptocarya alba* (Molina) Looser, at the registration site. Los Coiles stream (Valparaiso – Chile), **c**. White arrows show three juveniles, all smaller than one centimeter, **d**. A specimen of *Aegla papudo* in a pond, **e**. Juvenile specimen of *Aegla papudo*. **f**. Ventral view. **G**. Dorsal view.

The model that better explained the abundance of the species in the Los Coiles stream considered the volume of mud with gravel and pebbles (AICc = 87.26. ΔAICc = 0.0. Weight = 0.82). According to this model, the slope had a value of 0.47 (CI95% 0.24 - 0.70. $P < 0.00$). The exponential value of the slope was 1.60 (CI95 % 1.27 - 2.01), which means that for each cubic meter that the volume of mud with gravel and pebbles increases in the ponds of the Los Coiles stream abundance increased by 60 %.

The population of El Gallo creek was little evaluated because it was visited only once. Seven small ponds were found with 18 adult individuals and six juveniles smaller than one centimeter and whitish in color. The water was transparent, and the bottom had gravel on the mud and some leaf litter.

The physicochemical analysis of the water from both streams was provided by a mining company working in the area. Los Coiles stream showed higher values of Conductivity to 20°C (us/cm), Dissolved chlorides (mgCl/l), Total fluorine (mgF/l), Total aluminum (mgAl/l), Total arsenic (mgAs/l), Total iron (mgFe/l) and Total dissolved solids (mg/l) than El Gallo stream, while the values of Dissolved sulfates (mgSO4/l) and Fecal coliforms (NMP/100 ml) were lower (Table 3). Finally, both Los Coiles and El Gallo streams constituted two new sites for the species within its historical distribution range (Fig. 3). Both streams had their origin within the CEMPSC and ran outside the limits.

DISCUSSION

The components and vertical structure of the habitat between Los Coiles, El Gallo stream and those described by Jara *et al.* (1995) and Ortíz (2018) were different in terms of those related to water depth, substrate type and arrangement, flow, turbidity, presence of leaf litter, and tree cover. Mud on the bottom mixed with gravel and pebbles, trans-

Table 1. Location coordinates of ponds with *Aegla papudo* in Los Coiles Stream, habitat, and abundance variables. Valparaiso - Chile. XY=UTM. Datum WGS84. 19H. L=Mean Length. W=Mean Width. WaD=Mean Water Depth. M+G D= Mean Mud+Gravel Depth. WaV= Water Volume. M+G V= Mud+Gravel Volume. TV=Total Volume. Ad= Adults Individuals. Juv=Juvenile Individuals. D=Density.

Pond	X	Y	L (cm)	W (cm)	WaD (cm)	M+G D (cm)	WaV (m^3)	M+G V (m^3)	TV (m^3)	Ad	Juv	D Ad (ind/m^2)	D Juv (ind/ m^2)
1	6386485	298309	450.0	117.0	7.4	15.4	0.4	0.8	1.2	2	0	0.4	0.0
2	6386482	298303	465.0	148.4	5.6	5.1	0.4	0.4	0.8	2	0	0.3	0.0
3	6386480	298300	170.0	90.3	7.0	9.3	0.1	0.1	0.2	5	0	3.3	0.0
4	6386478	298297	360.0	132.7	8.8	7.7	0.4	0.4	0.8	3	0	0.6	0.0
5	6386479	298294	520.0	200.0	3.0	27.0	0.3	2.8	3.1	10	11	1.0	1.1
6	6386462	298241	420.0	309.3	2.5	14.2	0.3	1.8	2.1	6	1	0.5	0.1
7	6386456	298218	350.0	120.0	3.5	7.5	0.1	0.3	0.4	2	0	0.5	0.0
8	6386455	298220	380.0	203.3	1.3	13.8	0.1	1.1	1.2	4	0	0.5	0.0
9	6386451	298191	360.0	240.0	1.3	31.8	0.1	2.8	2.9	1	0	0.1	0.0
10	6386450	298181	395.0	219.7	2.0	9.0	0.2	0.8	1.0	1	0	0.1	0.0
11	6386466	298138	85.0	107.0	3.0	5.5	0.0	0.1	0.1	2	0	2.2	0.0
12	6386471	298133	300.0	98.3	3.7	5.2	0.1	0.2	0.3	11	0	3.7	0.0
13	6386474	298130	420.0	175.0	3.5	5.6	0.3	0.4	0.7	1	0	0.1	0.0
	Mean (CI95%)		360 (288-431)	166 (127-206)	4.1 (2.6-5.5)	12 (7-17)	0.2 (0.1-0.3)	1.0(0.3-2.0)	1.1 (0.5-1.7)	4 (2-6)	1 (1-3)	1.0 (0.3-1.8)	0.1(0.0-0.3)

Table 2. Habitat components of *Aegla papudo* as compared to the components described previously.

Habitat Component	Jara *et al.* (1995)	Ortíz (2018)	This study
Mud	No	Yes	Yes
Mud + Gravel	No	No	Yes
Mud + Pebbles	No	No	Yes
Sand	No	Yes	No
Sand + Gravel	Yes	No	No
Filamentous Algae	Yes	No	No
Rotting organic matter	Yes	No	Yes
Appearance of water	Turbid	?	Transparent
Leaf litter	No	Yes	Yes
Flow	1.5-2.0 m^3/s	?	0.009 m^3/s
Riparian tree cover	No	?	Yes

parent water, tree cover and its arrangement in the water column were new components described for the species' habitat (Table 2). In Los Coiles and El gallo streams, the water did not show any movement appearance, although Los Coiles had a very low flow (0.009 m3/s), unlike that reported by Jara *et al.* (1995) (Table 2). However, El Retiro reservoir (Viña del Mar, Valparaíso) is the only lentic water body where the species was recorded (Jara *et al.* 1995), which contrasts with the results of this study.

Another novel aspect of this work, which constitutes a contribution to the ecology of *A. papudo*, is the physicochemical parameters of the water, at least in two streams. The values recorded (Table 3) will serve as a baseline for future comparisons of studies involving the relationship between the species and water as a component of its habitat. It is important to note that this is the first study to determine the abundance of the species and the variables that explain it, in addition to having determined the density, data considered practically unknown (Jara *et al.* 1995).

Some species of the genus *Aegla* present reproductive periods restricted to a particular season. *A. laevis laevis* (Latreille, 1818) does it from March to October, *Aegla paulensis* (Schmitt, 1942) from May/June to October. *Aegla rostrata* (Jara, 1977) begins in April and *Aegla leptodactyla* (Buckup and Rossi, 1977) does it from April to September (Bahamonde and López 1961, López 1965, Jara 1977, Noro and Buckup 2002). *A. franciscana* (Buckup and Rossi, 1977) does so in spring/summer (Gonçalves *et al.* 2006), while *A. platensis* (Schmitt, 1942) reproduces all year round (Sokolowicz *et al.* 2006). Although the reproductive cycle of *A. papudo* is unknown, the presence of individuals smaller than one centimeter at the end of August suggests that this species probably reproduces between summer and autumn, although it could occur throughout the year similarly to *A. platensis* (Sokolowicz *et al.* 2006).

Another unknown aspect of the species was related to the hours of activity. However, the Ministerio del Medio Ambiente (c2013) indicated that the species was hidden under gravel during the day. In this work, adult and juvenile individuals less than one centimeter were recorded between 12:00 h and 19:00 h, which allowed establishing that this species is observed during the day and at twilight times too.

A. papudo is not registered on the Red List of the International Union for Conservation of Nature (IUCN 2018); however, the environmental authority of Chile classified it as Endangered (Ministerio del Medio Ambiente c2013). Santos *et al.* (2017) supported this classification based on their studies and the threats and considerations proposed by Jara *et al.* (1995). It should be added that this species is only present in one protected area of the National System of Wild Areas Protected by the State (NSWAPS) and the best studied population, located in the CEMPSC, which is not a strict conservation figure according to the laws of Chile, is isolated. Here we propose that the species should be classified as Endangered.

Under these considerations, it is necessary to review the historical sites where the species was registered to determine if they are still present or extinct, search in the areas of the NSWAPS and Priority Sites for Conservation within their geographic distribution range, bodies of water with the presence of the species, increase studies of its ecology within La Campana National Park and in the CEMPSC.

AUTHOR'S CONTRIBUTION

CCV, ETV, and SAV planned and designed the study, participated in the field sampling, conducted data analysis, wrote, and discussed the manuscript. SAV died in June 2020.

CONFLICT OF INTEREST

The authors declare that they have not conflict of interest.

Table 3. Physical-chemical parameters of the water in Los Coiles (2018 September) and El Gallo (2017 July) streams. Valparaiso, Chile.

Parameter	Los Coiles	El Gallo
pH a 25°C	7.7	8.4
Conductivity to 20°C (us/cm)	469	268
Dissolved chlorides (mgCl/l)	4.55	<5
Dissolved sulfates (mgSO4/l)	38.55	51
Total fluorine (mgF/l)	0.14	<0.5
Sodium Percent (%Na)	9.8	10.1
Cyanide (mgCN/l)	< 0.02	< 0.02
Total silver (mgAg/l)	< 0.01	< 0.01
Total aluminum (mgAl/l)	0.11	< 0.05
Total arsenic (mgAs/l)	0.003	< 0.001
Total boron (mgB/l)	0.05	0.05
Total barium (mgBa/l)	< 0.01	< 0.01
Total beryllium (mgBe/l)	< 0.01	< 0.01
Total cadmium (mgCd/l)	< 0.005	< 0.005
Total cobalt (mgCo/l)	< 0.01	< 0.01
Total chrome (mgCr/l)	< 0.01	< 0.01
Total copper (mgCu/l)	0.02	0.01
Total iron (mgFe/l)	0.46	< 0.01
Total mercury (mgHg/l)	< 0.0005	< 0.0005
Total lithium (mgLi/l)	< 0.01	< 0.01
Total manganese (mgMn/l)	0.02	< 0.01
Total molybdenum (mgMo/l)	< 0.01	0.002
Total nickel (mgNi/l)	< 0.01	< 0.01
Total lead (mgPb/l)	< 0.01	< 0.005
Total selenium (mgSe/l)	< 0.001	< 0.001
Total vanadium (mgV7l)	< 0.005	< 0.001
Total zinc (mgZn/l)	< 0.01	< 0.01
Fecal coliforms (NMP/100 ml)	< 1.8	4.5
Total dissolved solids (mg/l)	303	179
Total solids (mg/l)	210	----
Total Suspended Solids (mg/l)	< 5	----
Ratio Sodium Adsorption	0.30	0.30
pH	7.64	8.39
Oxide-Reduction Potential (mV)	114	----
Temperature (°C)	14.1	10.5
Conductivity (us/cm)	381	268
Dissolved oxygen (mg/l)	6.16	----
Saturation (%)	62.9	----

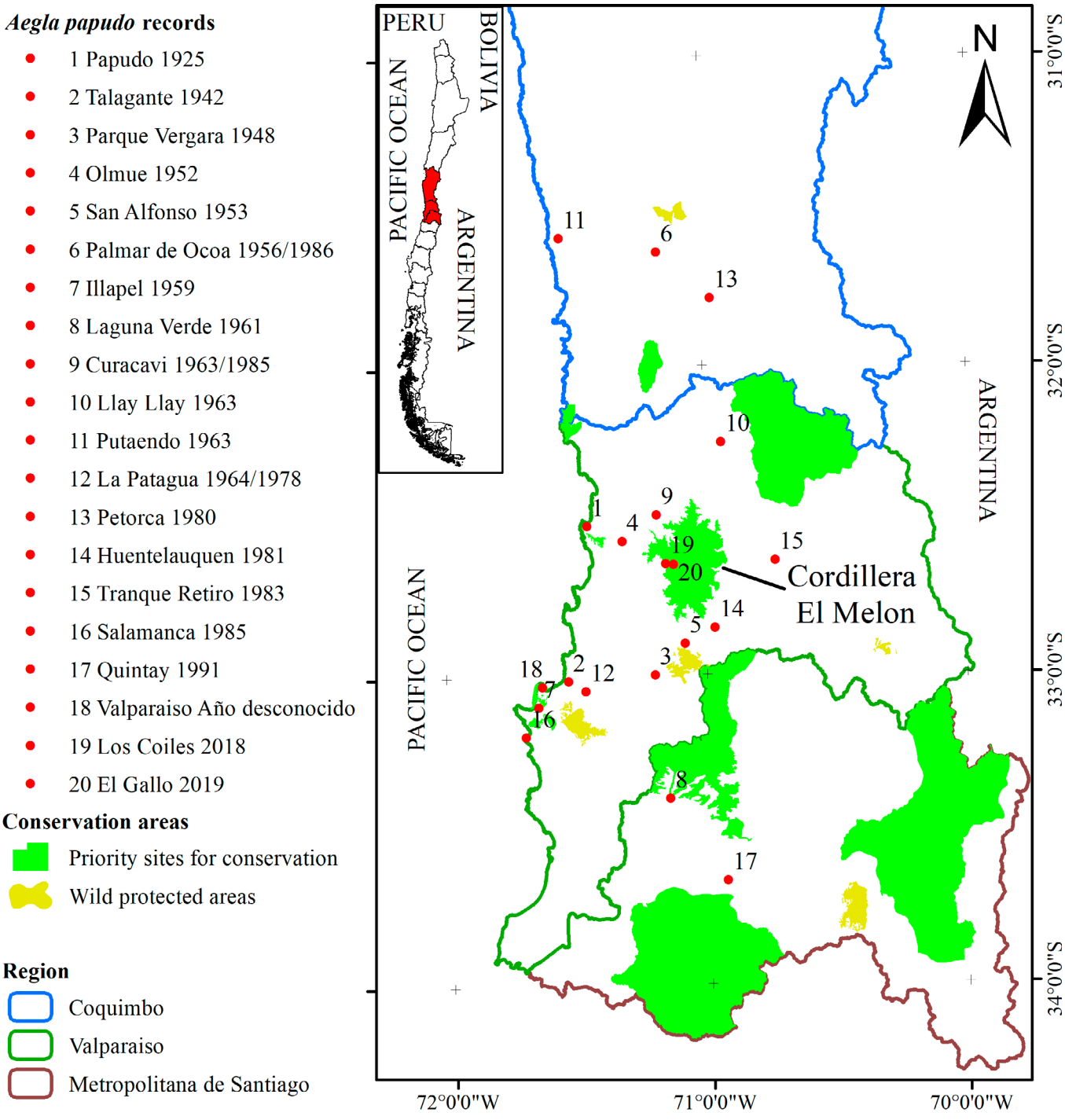

Figure 3. Historical records of *Aegla papudo* and the new records (Los Coiles 2018 y El Gallo 2019) in the context of the State Protected Wild Areas and Priority Conservation Sites in Chile.

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