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Rapid Communication

A new report of *Craspedacusta sowerbii* (Lankester, 1880) in southern Chile

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Abstract

Craspedacusta sowerbii (Lankester, 1880) is a cnidarian thought to originate from the Yangtze River valley in China. However, *C. sowerbii* is now an invasive species in freshwater systems worldwide. In Chile, *C. sowerbii* was first recorded in 1942 by Porter and Schmitt in the Marga-Marga Reservoir, in Valparaíso. Since then, there have been few further Chilean records of this species. Here, we report the presence of *C. sowerbii* medusae in Santa Elena Lake, Bulnes, Región del Bío-Bío, along with limnological parameters.

Key words: jellyfish, freshwater medusa, Chilean lakes

Introduction

Craspedacusta sowerbii (Lankester, 1880), (Cnidaria: Limnomedusae: Olindiidae) is a freshwater species thought to have originated from the Yangtze Valley in China (Kramp 1961). Since then, with the exception of the Antarctic (Dumont 1994; Souza and Ladeira 2011), global occurrence records exist (Jankowski et al. 2008) for what is now considered to be an invasive species in freshwater systems (Gasith et al. 2011; Bekleyen et al. 2011; Figueroa and De los Ríos 2010; Dumont 1994).

Craspedacusta sowerbii was recorded for the first time in Latin America in 1925 (Ringuelet 1950). The first record of *C. sowerbii* in Chile was reported from the Marga-Marga Reservoir, in Valparaíso (Porter and Schmitt 1942) (Figure 1). Subsequently, Quezada (1969) reported the medusa phase in Laguna Grande de San Pedro, Concepción, and later in Lanalhue Lake (Quezada 1973) (Figure 1). Schmid-Araya and Zúñiga (1992) recorded the species in Peñuelas Dam in Región de Valparaíso, while Figueroa and De los Ríos (2010) reported it in Carilafquén Lake in Región de la Araucanía (Figure 1). The most recent report was by Caputo-Galarce et al. (2013) from Illahuapi Lagoon, Región de los Ríos (Figure 1).

The cnidarian *C. sowerbii* is found in diverse sub-tropical and warm-temperate aquatic systems of the world, with medusa most commonly found in warm, stagnant waterbodies such as lakes, dams and ponds (Dumont 1994; Jankowski 2001). The lifecycle is well known, and includes both polyp and medusa phases (DeVries 1992; Lewis et al. 2012; McClary 1959).

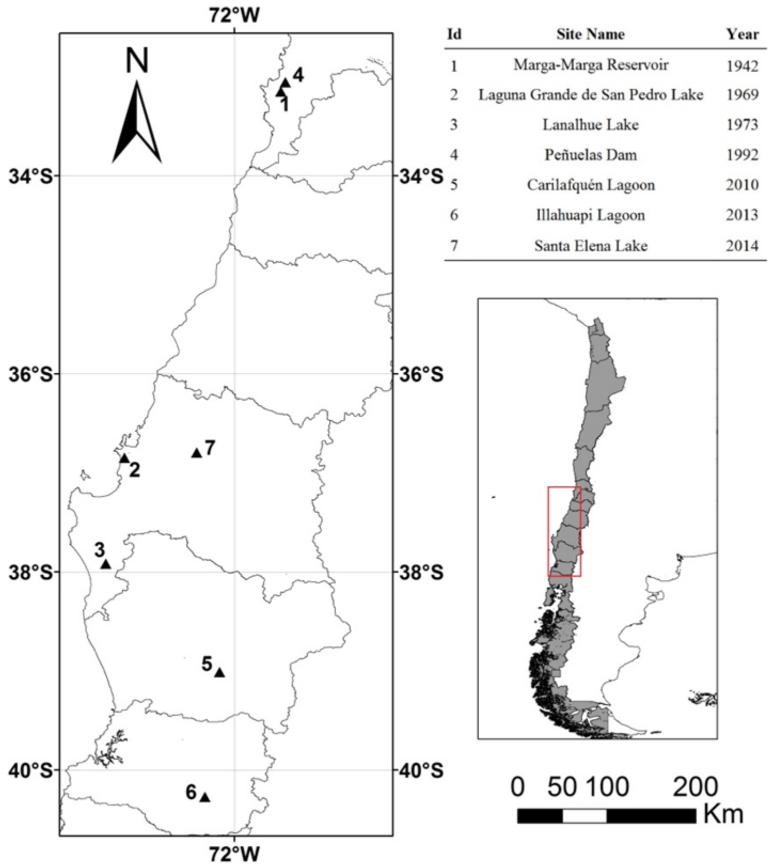

Figure 1. Map of Chile showing sites and years of sighting for *Craspedacusta sowerbii*, including this study (Id 7).

The medusa prey on zooplankton communities ranging in size from 0.2–2.0 mm (Dodson and Cooper 1983), especially copepods (Jankowski et al. 2005; Smith and Alexander 2008; Jankowski and Ratte 2000).

Medusa are usually incidentally detected, and the scarce monitoring for this species is surprising in light of the potential ecological effects on trophic chains in freshwater systems (Jankowski and Ratte 2000). The present work expands knowledge of *Craspedacusta sowerbii* occurrence in Chile to Santa Elena Lake, Región del Bío-Bío, and in addition, provides environmental data associated with its occurrence.

Material and methods

Description of study area

Santa Elena Lake is shallow (Z max: 14 m), with an area of 59 ha and a perimeter of 5,132.92 m, located in Bulnes, Región del Bío-Bío, south-central Chile (36º47′41.01″S; 72º22′56.97″W). The lake is situated 100 km northeast of Laguna Grande de San Pedro where the medusae were reported in 1969 (Quezada 1969) and 228 km north of Lago Lanalhue where the medusae were reported in 1973 (Quezada 1973) (Figure 1). The lake is listed as a conservation and biodiversity priority by the Biodiversity Regional Strategy of Bulnes Municipality (CONAMA 2002). The climate is temperate Mediterranean, with annual average temperatures ranging from 13.5 °C to 14.0 °C, and is warmer in January (28.8 °C monthly average) and colder in July (3.7–5.0 °C). Annual average precipitation is 1,025 mm, with July being the wettest month, and a dry season occurring from December through March (CETSUR 2008). The lake watershed is influenced by human activities such as agriculture, forestry (González-Acuña et al. 2004), and tourism.

Emergent aquatic vegetation dominated by *Juncus* spp. L. occupies the lake perimeter. Upland terrestrial vegetation consists mainly of *Salix babylonica* L. and *Populus* spp. L. (González-Acuña et al. 2004). The vegetation of Santa Elena Lake provides nesting sites for 45 avifauna species (González-Acuña et al. 2004; González et al. 2001), seven of which are migratory (Jaramillo et al. 2005) (Table 1).

Table 1. List of migratory birds at Lake Santa Elena (González-Acuña et al. 2004) with Chilean and Latin American distribution information (Jaramillo et al. 2005).

	Distribution in Chile	Distribution in Latin America
Anas flavirostris flavisrostris (Vieillot, 1816)	Coquimbo to Beagle Channel	Georgia del Sur, Falkland Islands
Anas sibilatrix (Poeppig, 1829)	Vallenar toTierra del Fuego	Southern Chile and Argentina including Falkland Islands
Elaenia albiceps (Hellmayr, 1927)	Atacama toTierra del Fuego	Andes of Bolivia, Brazil, Tierra del Fuego
Lessonia rufa (Gmelin, 1789)	Copiapó River toTierra del Fuego (occasionally in Arica)	Chile and Argentina; SE of Brazil in Winter
Pygochelidon cyanoleuca (Vieillot, 1817)	Atacama to Cabo de Hornos	Southern Chile and Argentina including Tierra del Fuego
Pseudocolopteryx citreola (Landbeck, 1864)	Atacama toValdivia Migrant (with unknown winter distribution)	Chile and Argentina
Troglodytes aedon (Vieillot, 1819)	Atacama toCabo de Hornos	Southern Chile and Argentina including Tierra del Fuego

Sampling

Medusae sampling: Water samples containing medusa visible with the naked eye were collected from Santa Elena Lake on 8 April 2014 at the lake's deepest point. Six medusae were captured and stored in 250 ml hermetic plastic vessels. Taxonomic keys and additional literature (Slobodkin and Bossert 2009; Jankowski 2001) were used to identify *C. sowerbii*. Medusae were photographed using a Stereoscope Olympus SZ6 (Figure 2).

Environmental data: Potential environmental correlates were assessed at the time the medusae were collected at mid-day. Surface UVA-UVB radiation was measured with UVA-UVB meter ST-513. Due to the depletion of the ozone layer in the southern hemisphere, UV radiation was measured as an environmental parameter because it can be harmful to aquatic organisms. These data are provided as a reference for future studies. Water surface temperature was measured with an IR LASER Thermometer, model CHY-110. Subsequently, water samples were taken using a Wildco® water collector to generate temperature, pH, dissolved oxygen (ThermoScientific® Orion3STAR DO portable) and chemical (nitrogen, phosphorous) profiles for the lake. Nitrogen and phosphorous concentrations at 1.0, 5.0 and 10.0 m depths were measured using standard methods for water analyses (APHA 2005).

Phytoplankton and zooplankton sampling for qualitative composition were undertaken using silk plankton nets (mesh size 25 µm). Phytoplankton and zooplankton were identified morphologically using published descriptions (phytoplankton: Graham et al. 2009; zooplankton: Balcer et al. 1984).

Results

Although the density of *C. sowerbii* was not measured, there appeared to be a bloom of medusae on the lake surface. At the time of sampling, the water temperature was around 20.1°C throughout the water column (Table 2; Figure 3), showing that the lake was mixed and, according to Minchin et al. (2016), within the temperature range associated with the occurrence of *Craspedacusta sowerbii* medusae. Secchi disk measurements were 3.31 m (Figure 3), likely indicating the lake was in a clear-water phase, similar to the conditions specified by Lampert et al. (1986) when zooplankton grazing is high in a eutrophic lake. The water pH profile was 7.5, and the nitrogen and phosphorus concentrations were below 1.0 mgL^{-1} and 3.3 mgL^{-1}, respectively. Oxygen levels were above 7 mgL^{-1} up to 2 m deep in the water column and dropped to < 5 mgL^{-1} towards the bottom of the lake (Table 2, Figure 3). UVA-B radiation was 21 $mW*cm^{-2}$ at the water surface. Phytoplankton was scarce (primarily diatoms and green flagellates) and zooplankton was mainly comprised of *Daphnia pulex* Leydig (1860), *Daphnia* sp. (O. F. Müller, 1785), *Macrocyclops albidus* Jurine (1820), *Eucyclops* sp. Claus, 1893 and undetermined species of copepod nauplii (Table 3).

Discussion

Although, *C. sowerbii* has previously been recorded in the central and southern regions of Chile (Figueroa and De los Ríos 2010; Caputo-Galarce et al. 2013; Quezada 1969; Quezada 1973; Porter and Schmitt 1942; Schmid-Araya and Zúñiga 1992) (Figure 1),

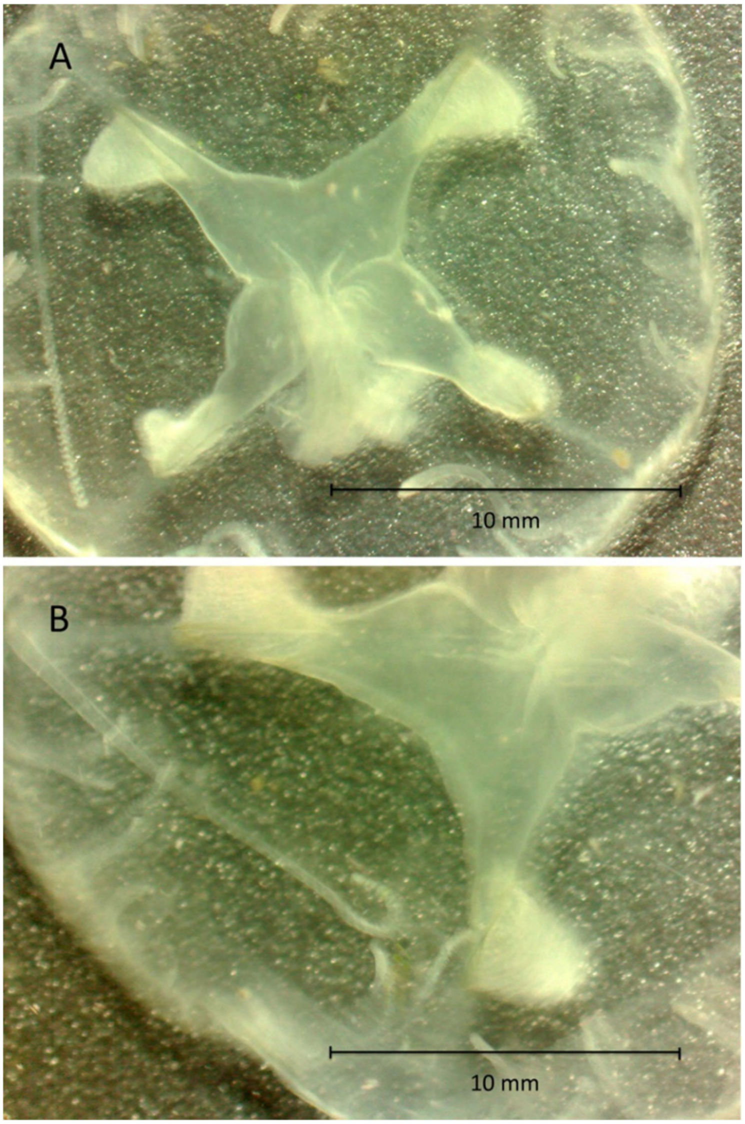

Figure 2. *Craspedacusta sowerbii* (Lankester, 1880). Specimen of 2.3 cm length collected in Santa Elena Lake, Bulnes, Región del Bío-Bío on April 8th 2014. A: gonads, oral arms, mouth, umbrella and tentacles. B: tentacles are seen with better definition. Gonads, oral arms and mouth can also be viewed. Photographs by P. Arancibia-Avila.

more frequent monitoring is required in order to determine any patterns of occurrence and environmental correlates. Figueroa and De los Ríos (2010) suggest that *C. sowerbii* presence could be attributed either to natural phenomena, such as aerial dispersal by migrating birds along the Andes Mountain corridor (Caputo-Galarce et al. 2013), or to human activities, such as commercial use of the medusa as an exotic species (Jakovčev-Todorovič et al. 2010). Ornamental plant transport contributes to the dispersal of *C. sowerbii* (Marsden and Hauser 2009) polyps or resting bodies that are resistant to lower temperatures (Acker and Muscat 1976).

Purcell (2005) and DeVries (1992) suggest that water temperature is an important factor for the growth of medusae populations, since *C. sowerbii* transform from a polyp to medusa at 25 °C (Jakovčev-Todorovič et al. 2010; Silva and Roche 2007; Minchin et al. 2016). In a 50-year study performed in Serbia, *C. sowerbii* medusae densities increased during the summer, when temperatures were between 20–26 °C (Jakovčev-Todorovič et al. 2010). Bekleyen et al. (2011) and Silva and Roche (2007) also reported *C. sowerbii* abundance in the late summer in various lakes when surface water temperatures were 26.9 °C and 25.5 °C, respectively.

Table 2. Limnological profile of a water column at the deepest point in the lake (36º48′048″S; 72º22′95.7″W) in Santa Elena Lake. Data were taken on April 8th 2014.

Depth (m)	Oxygen (mgL^{-1})	pH	Temp (°C)	Nitrogen[1] (mgL^{-1})	Nitrate[2] (mgL^{-1})	Ortho Phosphate[3] (mgL^{-1})	Total Phosphate[4] (mgL^{-1})
0	7,40	7,28	20.3				
1	7,59	7,39	20.4	<1	< 4	1,07	3,27
2	7,69	7,43	20.2				
3	4,64	7,37	20.3				
4	4,54	7,36	20.0				
5	4,60	7,40	20.1	<1	<4	<0,02	<0,06
6	4,60	7,48	20.0				
7	4,52	7,40	20.1				
8	4,48	7,42	19.9				
9	4,41	7,63	20.0				
10	4,36	7,65	20.2	<1	<4	—	—
11	4,25	7,88	20.1				

*Water column for chemicals was sampled at depths of 1; 5 and 10 m.

Table 3. Composition of net plankton from Santa Elena Lake in mid-fall (April 8th).

Phytoplankton	
Class Cyanophyceae	*Microcystis aeruginosa* (Kützing) Kützing, 1846
Class Chlorophyceae	*Coelastrum microporum* Nägeli in A.Braun, 1855
	Pediastrum duplex Meyen, 1829
	Pediastrum tetras (Ehrenberg) Ralfs, 1845
Class Zygnematophyceae	*Staurastrum gracile* Ralfs ex Ralfs, 1848
Class Cryptophyceae	*Cryptomonas* sp. Ehrenberg, 1831
Class Bacillariophyceae	*Navicula* sp. Bory, 1822
	Cymbella sp. C.Agardh, 1830, *nom. et typ. cons*.
	Nitzschia sp. Hassall, 1845
Class Dinophyceae	*Ceratium hirundinella* (O.F.Müller) Dujardin, 1841
Zooplankton	
Class Branchiopoda	
Order Cladocera	*Daphnia pulex* Leydig (1860)
	Daphnia sp. Müller, 1785
Class Maxillopoda	
Sub class Copepoda	
Order Cyclopoida	*Macrocyclops albidus* Jurine (1820)
	Eucyclops sp. Claus, 1893
	Copepod nauplii

Although the medusae reported by this study may be linked to seasonal patterns in the study area, future biomonitoring may indicate that increased medusae abundance could become a permanent problem. Sincethe 19th century, global temperatures have increased by 0.87 °C (NASA 2016), and according to records by the Instituto de Investigaciones Agropecuarias, Chile (Nueva Aldea Station; INIA 2016), average air temperatures from January to April have increased in recent years (22.0 °C in 2011 to 24.9 °C in 2014) in the area around Santa Elena Lake. Since the medusa stage can tolerate water temperatures over 30 °C and the polyp can survive below 25 °C (Acker and Muscat 1976; DeVries 1992), if the water temperature of Santa Elena Lake further increases, environmental conditions could become suitable for medusa growth in winter.

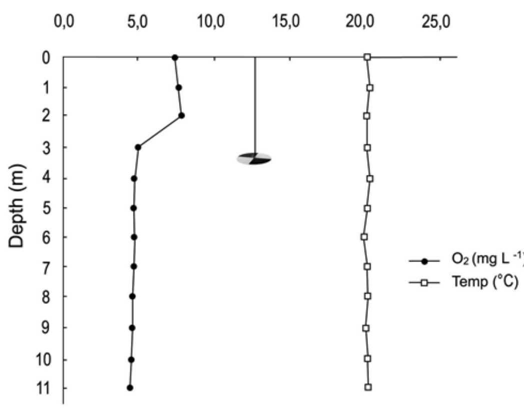

Figure 3. Dissolved oxygen, temperature profiles and Secchi disk measurement of Santa Elena Lake on 8 April 2014.

Although records of low dissolved oxygen affecting *C. sowerbii* blooms are limited, some studies have shown a direct relationship between dissolved oxygen and other medusae populations (Purcell et al. 2001; Purcell et al. 2007). Dissolved oxygen levels in Santa Elena Lake ranged from 7.4 mgL^{-1} to 7.7 mgL^{-1} in the first two meters of the water column, then reduced to <5 mgL^{-1} from 3 m down to the bottom of the lake (Table 2, Figure 3). Low oxygen levels indicate eutrophication (Smith 1998), and can be attributed primarily to decomposition by bacteria and respiration of plants and animals (Cole 1983). The cnidarian is more common in eutrophic lakes (Arai 2001; Jankowski 2001; Raposeiro et al. 2011). As such, the eutrophic Santa Elena is a suitable location for the cnidarian to thrive.

The northernmost (Schmid-Araya and Zúñiga 1992) and southernmost (Caputo-Galarce et al. 2013) reported site of *C. sowerbii* medusa in Chile are located 554 km north and 502 km south of Santa Elena Lake respectively. Hence, Santa Elena Lake is located in the mid-point, almost equidistant, from previous reports of the medusae. Furthermore, Santa Elena Lake is separated by only 100 km to the northeast from Laguna Grande de San Pedro, where medusae were reported by Quezada (1969). The polyp stage of *C. sowerbii* was not observed in this study. However, it may be relevant to take into account for future biomonitoring. For example, Duggan and Eastwood (2012) determined that the *C. sowerbii* polyp stage is more widespread than where medusae are observed, and can include lakes and areas widely separated from where the medusae have been recorded. The appearance and distribution of medusae may be associated with migrating birds (Dumont 1994) and/or human intervention (Marsden and Hauser 2009), but further work is required to establish causal links in this case. Santa Elena Lake hosts a high diversity of migratory birds that might potentially play a long-distance dispersal role as a vector of propagules within the southern cone and across different eco-regions. It is also advisable to identify potential niches and point sources of propagules, especially in the abundant small lakes and shallow ponds of Región del Bío-Bío and other southern regions of Chile. Such ecosystems host a wide diversity of migratory birds (Garay et al. 1991) like Santa Elena Lake. Early detection of both the polyp and medusa stages using molecular tools would be helpful, but little molecular analyses of non-native or native populations have been undertaken to date (Karaouzas et al. 2015). We suggest greater monitoring of this and other lakes in the area, since lakes surrounding Santa Elena Lake might be already colonized by *C. sowerbii* or will be in the future.

Conclusions

The limnological conditions of Santa Elena Lake seem ideal for growth of *C. sowerbii*. The presence of *C. sowerbii* and synergistic environmental elements such as hypoxia, high temperatures and appropriate prey elements such as zooplankton abundance require further investigation. Thus, biomonitoring, including the use of molecular tools, for several years over different seasons, is necessary in order to determine whether the presence of *C. sowerbii* is continuous or irregular throughout the year. It is important to determine the origin of this medusa colonization and the parameters that caused the medusa to thrive.

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