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BRIEF COMMUNICATION

Southernmost distribution limit for endangered Peladillas (*Aplochiton taeniatus*) and non-native coho salmon (*Oncorhynchus kisutch*) coexisting within the Cape Horn biosphere reserve, Chile

Alan Maldonado-Márquez[1,2,3,4] | Tamara Contador[1,2,3,4] | Javier Rendoll-Cárcamo[1,2,3] | Sabrina Moore[1,4,5] | Carolina Pérez-Troncoso[1,2,3,4] | Daniel Gomez-Uchida[4,6] | Chris Harrod[4,7,8]

[1]Wankara Sub-Antarctic and Antarctic Freshwater Ecosystems Laboratory, Universidad de Magallanes, Puerto Williams, Chile

[2]Subantarctic Biocultural Conservation Program, Omora Ethnobotanical Park, Universidad de Magallanes, Puerto Williams, Chile

[3]Institute of Ecology and Biodiversity, Universidad de Chile, Santiago, Chile

[4]Núcleo Milenio INVASAL, Concepción, Chile

[5]Department of Biological Sciences, University of North Texas, Denton, Texas

[6]Genomics in Ecology, Evolution and Conservation Laboratory (GEECLAB), Departamento de Zoología, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Concepción, Chile

[7]Instituto de Ciencias Naturales Alexander von Humboldt, Universidad de Antofagasta, Antofagasta, Chile

[8]Universidad de Antofagasta Stable Isotope Facility, Instituto Antofagasta, Universidad de Antofagasta, Antofagasta, Chile

Correspondence
Alan Maldonado-Márquez, Wankara Sub-Antarctic and Antarctic Freshwater Ecosystems Laboratory, Universidad de Magallanes, Teniente Muñoz 166, Puerto Williams, Magallanes, Chile.
Email: alan.maldonado@umag.cl

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Abstract

The Cape Horn Biosphere Reserve, one of the last wild areas of the planet, is not exempt from the pressures of global change, such as non-native species introductions. During 2018 and 2019 we studied the Róbalo river basin in order to update the diversity and distribution of fishes. Here, we report for the first time the native and endangered "Peladillas" *Aplochiton taeniatus* and the non-native coho salmon *Oncorhynchus kisutch*. The coexistence of native and non-native fishes poses a challenge for the management and conservation of aquatic biota from the Cape Horn Biosphere Reserve.

KEYWORDS

endangered species, freshwater fish, invasive species, salmonids, sub-Antarctic

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Coexistence of native and non-native fishes in freshwaters, introduced through aquaculture, has significantly threatened the structure and functioning of receiving ecosystems (Arthington *et al*., 2016; Habit *et al*., 2015). In particular, the introduction and naturalization of salmonid species in freshwater ecosystems can negatively affect native biota through (a) changes in behaviour at the level of organisms; (b) changes in the abundance and distribution of native fish and invertebrates because of predation; (c) alteration in the nutrient and energy flows of ecosystems (Simon and Townsend 2003); (d) interference of the trophic niche (Elgueta *et al*., 2013); and (e) loss of genetic diversity (Vera-Escalona *et al*., 2019).

Salmonid species have been introduced throughout the whole length of continental Chile either for recreational fisheries or aquaculture (Soto *et al*., 2001), and the remote southernmost forest biomes have not been exempt. In this context, 11 species of salmonids have been introduced and naturalized either by intentional introduction or through salmon farming escapes (Basulto, 2003; Gomez-Uchida *et al*., 2018; Niklitschek *et al*., 2013). At least 50 species of native and endemic freshwater fish have been described through the latitudinal gradient (18–56°S) from the high-Andean ecosystems of Chungara to the Cape Horn Archipelago. Of these, three species of *Aplochiton* have been described for southern Patagonia: *A. taeniatus* (Jenyns 1842), *A. zebra* (Jenyns 1842) and *A. marinus* (Eigenmann, 1928) (Aló *et al*., 2013). According to the IUCN, there is not enough data to classify either of these species (IUCN, 1996). Nonetheless, according to Chile's Ministry of the Environment, through the Regulation for the Classification of Wild Species, these three species have been classified as endangered since 2011. Chile's regulation classifies a species as "Endangered" when the best available evidence indicates that it meets any of the criteria established by the IUCN for such a category and therefore is considered to be facing a very high risk of extinction in its wild state (Ministerio del Medio Ambiente, 2011).

Salmonid impacts in the southernmost region of Chile are not well known, particularly within the South American temperate forest biome, which extends over a narrow strip of land from 35°S to 56°S at Cape Horn (Contador *et al*., 2015; Rozzi *et al*., 2012). Within this biome, the sub-Antarctic Magellanic ecoregion (42–56°S) spans myriad interconnected aquatic ecosystems, comprising fjords, channels, streams, lakes and lagoons (Contador *et al*., 2015; Rozzi *et al*., 2012). This region is unique, and it presents remarkably high levels of endemisms, with 50% of the fish species being endemic to the biome (Armesto *et al*., 1998). The Cape Horn Biosphere Reserve (CHBR) (54–56°S) is located within

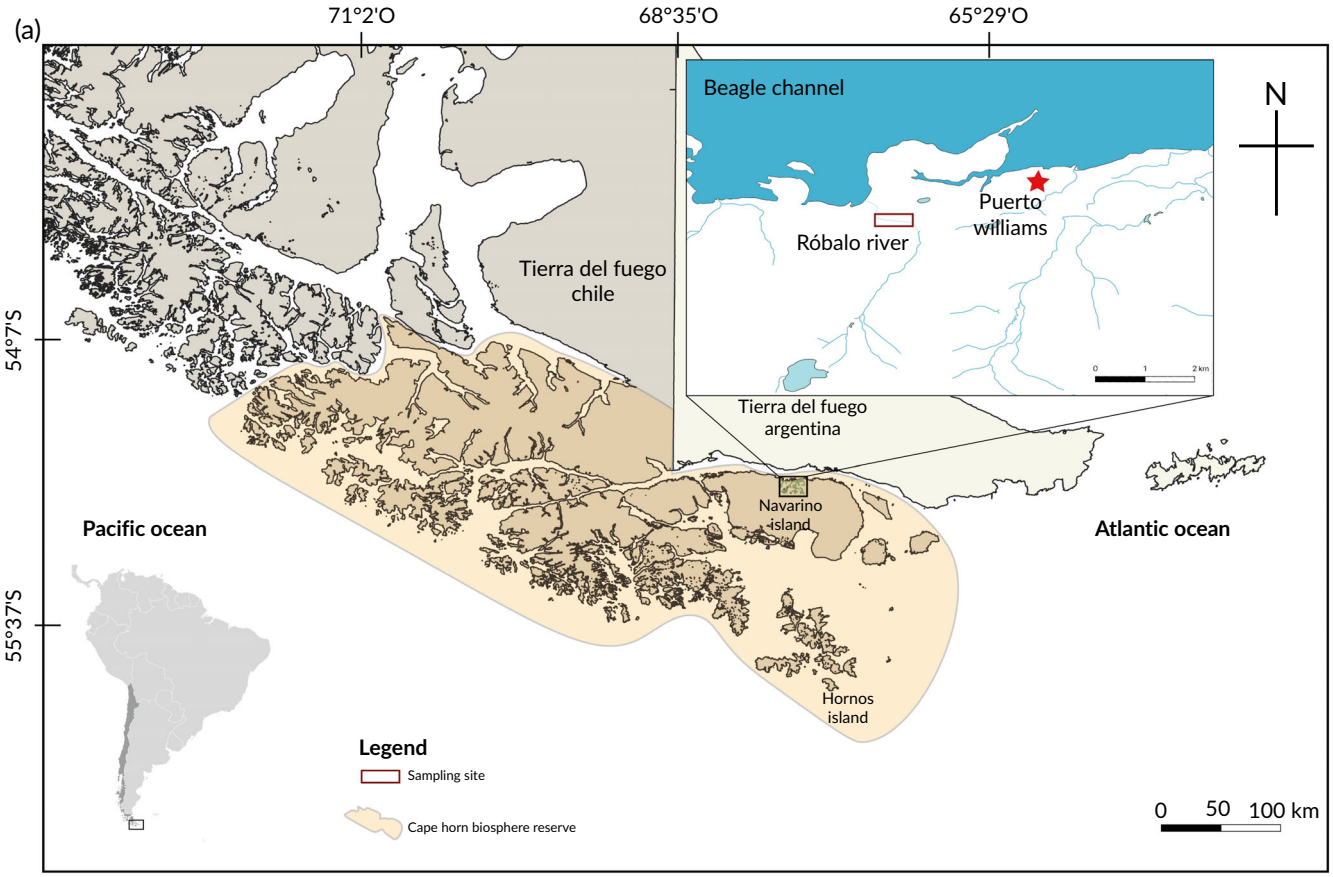

FIGURE 1 (a) Map showing the location of the sampling site within the Robalo River watershed, Navarino Island, Chile, Cape Horn Biosphere Reserve. (b) Ichthyofauna recorded within the sampling site at the Robalo River during the sampling campaigns of autumn 2018 and summer 2019. A, *Aplochiton taeniatus*; B, *Galaxias maculatus*; C, *Oncorhynchus kisutch*; D, *Salmo trutta*; E, *Oncorhynchus mykiss*; F, *Salvelinus fontinalis*. Total length (cm) (TL) is shown for each species registered in the figure

(b) Native freshwater fishes (Róbalo river)

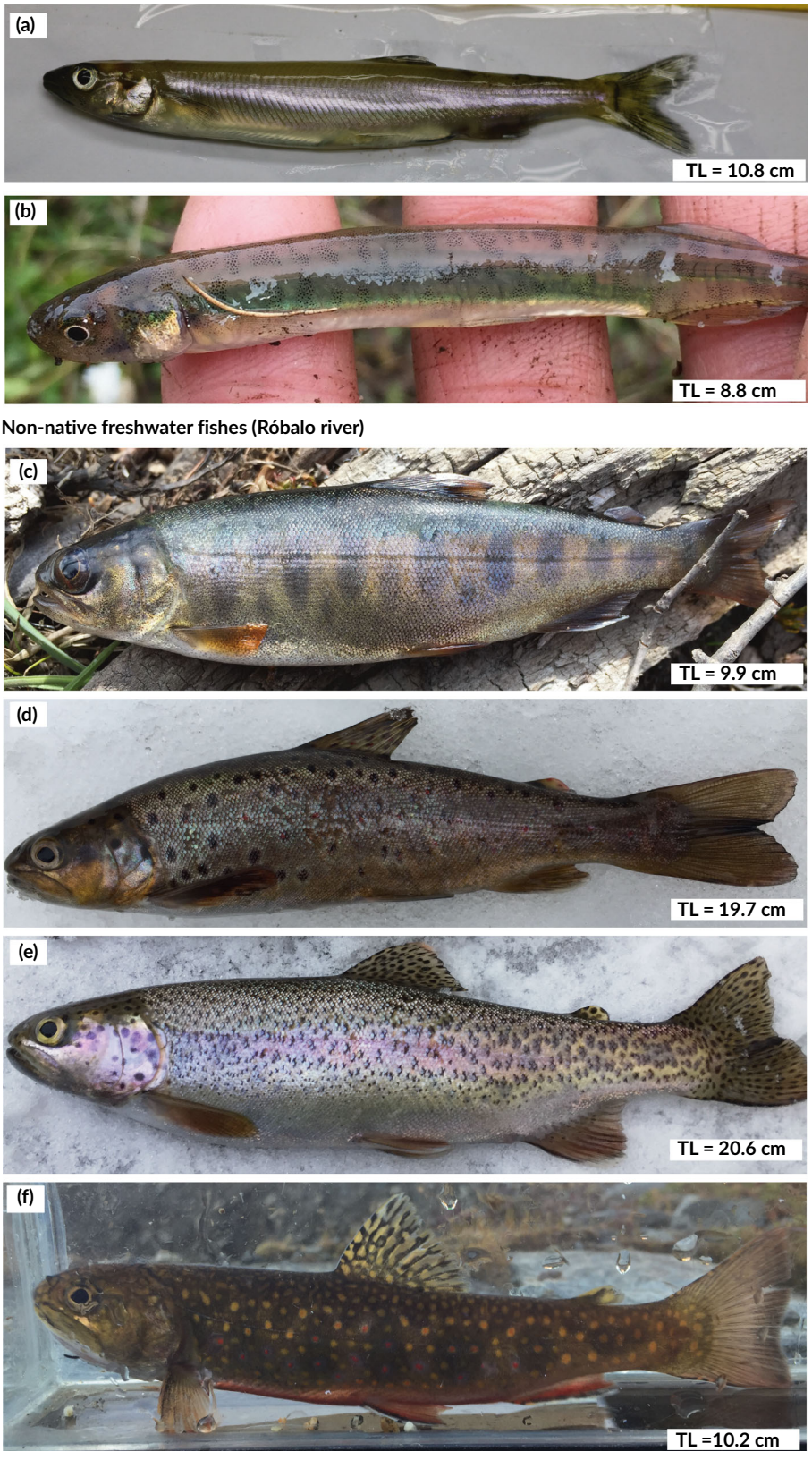

FIGURE 1 (Continued)

the sub-Antarctic Magellanic ecoregion (Magallanes and Antarctic Region of Chile), and it holds the last forested ecosystems of the southern hemisphere before the Antarctic continent. Although the isolation of the CHBR has allowed for its ecosystems to remain pristine, it is not free from the threats posed by global change, particularly from the introduction of potentially invasive species.

This study is framed within the work conducted by INVASAL (Millennium Nucleus of Invasive Salmonids), a Chilean research center that seeks to better understand the effects of salmonids on continental ecosystems of Chile. In this context, we have focused on studying the current status of native and non-native fish species within the CHBR, at 55°S. We provide a report of the fish species found within the Róbalo River watershed, which is located 4 km from the only city on the Island (Figure 1a). This basin is protected by the Omora Ethnobotanical Park, a long-term socio-ecological research site (see https://deims.org/site/ltersam-cl-3) which is considered a priority site for the conservation of biodiversity in Chile (Contador *et al.*, 2015).

To assess fish diversity, we used a backpack electrofisher (Halltech, HT2000B/MK6, Guelph, Ontario, Canada) during two sampling campaigns (austral autumn of 2018 and summer of 2019) within an 85 m sampling area located at approximately 550 m from the mouth of the river (54°56′31.28″S, 67°39′14.87″W). Each sampling event was conducted over a 1200 s timeframe. We measured total length (cm) and weight (g) for each sampled fish, using a standard 30 cm ruler and an OHAUS® (Parsippany, NJ, USA) balance (model Scout II, capacity 1200 × 0.1 *g*). Native fish were measured in the field and returned to the river, while non-native fish were carried to the laboratory in Puerto Williams for further analyses. Fish were identified using McDowall (1971), McConnell and Snyder (1972), and McPhail and Carveth (1993). During each event, we recorded basic physical and chemical parameters (see Table 2). Chemical parameters were recorded using a Yalitech® (Santiago, Chile) Combo 6 multiparameter probe.

We report six species of fishes for the Róbalo River, represented by two families, the native *Galaxiidae* (two species) and the non-native *Salmonidae* (four species). Through all the collection efforts, we collected two individuals of *A. taeniatus* (adults), 15 *G. maculatus* (adults), 319 *S. fontinalis* (alevin, fry, parr, smolt, juveniles, adults and spawn adults), 61 *O. kisutch* (parr and smolt), one *S. trutta* (juvenil) and two *O. mykiss* (smolt and adult) (Figure 1b). The records of *A. taeniatus* and *O. kisutch* are the first confirmed within the Róbalo river watershed. *A. taeniatus* (Table 1) was identified based on the following characteristics: (a) the presence of a high adipose fin with a short base, similar to a trout; (b) the absence of scales; (c) a compressed and elongated trunk; (d) a pointed snout and small eye; (e) a bifurcated caudal fin and low anal fin; (f) the absence of a regular spot pattern, as compared with *A. zebra*; and (g) head depth less than 45.18% of head length. *O. kisutch* (Table 1) was identified based on (a) the presence of a bifurcated caudal fin without the coloured spots; (b) in juvenile parr individuals, lateral spots narrower than intermediate spaces; (c) anal fins having more than 13 rays; (d) anterior rays longer than the rest, forming a sickle with shades of white to black pigmentation in the frontal edge; (e) dorsal punctuation subtle black and thin; and (f) adipose fin completely pigmented.

TABLE 1 Morphological characters of *Aplochiton taeniatus* and *Oncorhynchus kisutch*

Species	Number of individuals	Total length (cm)	Total weight (g)
Aplochiton taeniatus	2	10.5 (0.18)	6.6 (0.76)
Oncorhynchus kisutch	36	6.7 (1.89)	3.9 (3.04)

Note. The number of individuals collected from the Róbalo River watershed is shown, as well as their total length (cm) and weight (cm) ± S.D.

TABLE 2 Physical and chemical parameters recorded for the Róbalo River watershed during the sampling campaigns of 2018 and 2019

	Parameters	Autumn 2018	Summer 2019
Chemical	Temperature (°C)	3.1	10.1
	pH	7.5	7.8
	Conductivity (μS)	138.9	115.5
Physical	Channel distance (m)	558	558
	Depth (cm)	24	23.5
	Width (m)	7	7.1
	Canopy cover (%)	–	50.2
	Boulders (%)	–	20.3
	Cobble (%)	–	54.2
	Gravel (%)	–	23.6
	Sand (%)	–	2.2

The physico-chemical characteristics recorded showed that the instream substrate is mainly composed of cobble and gravel, while the riparian vegetation is dominated by southern beech forests (*Nothofagus* spp.) and shrubs (*Berberis* spp.) (Table 2). The study area is shallow and wide (23.5 cm and 7.1 m, Table 2). Temperature and conductivity change during summer and autumn, while pH does not seem to vary (Table 2).

The native *G. maculatus* (Jenyns 1842) and the non-native *O. mykiss* (Walbaum 1792) were the only two species of freshwater fishes reported for this watershed until this study (Anderson *et al.*, 2006; Moorman *et al.*, 2009). The distribution of *A. taeniatus* extends throughout Patagonia, including aquatic systems in Chile and Argentina (Álo *et al.*, 2013; Cussac *et al.*, 2004). This corresponds southern South America, although its southernmost records correspond to the Beagle Channel (Lopez *et al.*, 1996) and Navarino island, where it is reported from Puerto Toro (Moreno and Jara 1984) and Wulaia Bay (Moorman *et al.*, 2009), with no records being registered for the Róbalo river. Therefore, the presence of *A. taeniatus* in Navarino island is confirmed and we present the first report of this species within the studied watershed.

The native distribution of *O. kisutch* (Walbaum, 1972) is within the North Pacific basin in North America (Sandercock, 1991). In Chile, it has only been reported in naturalized conditions around 51°S in the estuaries of the Coicopihue and Puma rivers, as well as Los Cipreses lake (Gorski *et al.*, 2016). Chalde *et al.* (2019) described its presence through eDNA in Tierra del Fuego, Argentina. Here we report its southernmost distribution point at 55°S.

In 2015, Habit *et al*. proposed that if *O. kisutch* escapes from the salmon industry continued to increase, this species would be able to settle and naturalize in southern Chile due to an increase in propagules and optimal habitats. In this context, and in accordance with Chalde *et al*. (2019), we hypothesize that the establishment of *O. kisutch* at 55°S is due to escapes reported from salmon farms located in the Aysen region at 51°S, the closest region in Chile in which this species is farmed. We report that *O. kisutch* is co-inhabiting with two native and endangered species with significantly lower abundances within the area sampled. We believe that the population of *O. kisutch* is in the process of settling in the basin, as during a field campaign conducted during June of 2019 we found a sexually mature female (68 cm and 3.8 kg in length and weight, respectively) within the same sampling area. Additionally, we have found different cohorts during different seasons throughout monitoring campaigns conducted posteriorly to those informed here.

Our findings generate a warning signal for the conservation of native and endemic fish in the CHBR, the southernmost forested ecosystem in South America. Furthermore, preliminary results from our extended work confirm that *S. fontinalis* and *O. mykiss* actively predate on *G. maculatus*, feed on the same prey and are found within the same habitats. Predation on native fish, as well as competition, may lead to locally imperilled populations of native species. In this context, it is urgent to rethink conservation strategies for native fish in one of the most pristine areas left in the world by developing monitoring and control programs of salmonid populations for this region in the short and long term.

ETHICS STATEMENT

Fishes were sampled under the permits and guidelines of the Subsecretaría de Pesca y Acuicultura de Chile, Resolución Exenta number 3443–2017 and Resolución Exenta number 4231–2017 for Núcleo Milenio de Salmónidos Invasores (INVASAL). Additionally, with the approval of the Subcomité de Bioseguridad del Comité de Ética Científico de la Universidad de Magallanes, certificado number 043/A/2019.

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AUTHORS CONTRIBUTIONS

Alan Maldonado-Marquez contributed to the manuscript preparation, worked in the field, identified the species, prepared figures and approved the final manuscript. Tamara Contador contributed to the manuscript preparation, worked in the field, analysed the data and approved the final manuscript. Javier Rendoll-Cárcamo, Sabrina Moore and Carolina Pérez-Troncoso worked in the field and reviewed drafts of the manuscript and approved the final manuscript. Daniel Gomez-Uchida reviewed drafts of the manuscript and approved the final manuscript. Chris Harrod reviewed drafts of the manuscript and approved the final manuscript.

ORCID

Alan Maldonado-Márquez https://orcid.org/0000-0003-2189-5491
Tamara Contador https://orcid.org/0000-0002-0250-9877
Sabrina Moore https://orcid.org/0000-0001-6237-0355
Daniel Gomez-Uchida https://orcid.org/0000-0002-5150-2030
Chris Harrod https://orcid.org/0000-0002-5353-1556

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