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Current situation of the fish fauna in the Mediterranean region of Andean river systems in Chile

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SUMMARY

The low number of native fish species of the Chilean Mediterranean region (27º S to 36º S) is a consequence of its geographic and hydrological characteristics. The area has marked precipitation gradients as a result of both latitudinal differences in precipitation and the higher precipitation at high altitudes in the Andes. The seasonal hydrologic variability characteristic of Mediterranean climatic zones occurs in the area together with inter-annual variations due to El Niño Southern Oscillation (ENSO), a significant oceanic climatic influence which determines lower daily and seasonal temperature gradients compared to similar northern latitudes. River catchment areas above 3000 elevation generate short and torrential channels with high velocity, a snow–pluvial regime without riparian vegetation and high total salinity composition.

Only 21 native species have been described in this region. They are important due to their high endemism and primitiveness, along with their biogeographical relations, especially the Siluriforms with the northern tropical fauna and the Galaxiidae with Gondwana fish. Currently 75% of the fish species of this region are classified as endangered or vulnerable according to Chilean regulations.

Knowledge of the biology and ecology of these species is still incomplete. The information available is mostly classical morphological descriptions, although recently there have been studies of genetics and speciation. This review describes the current distribution and knowledge of the biology and ecology of the native fauna of the Chilean Mediterranean zone and the main threats for their conservation.

Keywords: Freshwater fish, distribution, conservation, Siluriforms, Galaxiidae

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INTRODUCTION

Between 27º and 36º south latitude Chile has a Mediterranean climate, with important latitudinal differences in precipitation among seasons and years due to the effects of El Niño Southern Oscillation [ENSO, (Niemeyer & Cereceda, 1982)]. These natural fluctuations are currently influenced by the effects of climate change on Mediterranean zones, which have serious repercussions on biodiversity (Cowling et al, 1996; Elosegui & Sabater 2009). This is particularly serious for the Mediterranean zone of Chile, which is one of the world hotspots of biodiversity (Myers et al 2000). Terrestrial and freshwater fauna in Chile have high endemism as a result of geological history. The geographic isolation of Chile due to the uplift of the Andes since the Cenozoic Era, the presence of the Pacific Ocean on the west, the desert in the north and glaciers in the south, together with the high natural salt content of the soils of the western mountain slopes, have been the main forcing variables in the structuring of the aquatic communities, which are characterized by low species number and high endemism, with some species restricted to two or three small river basins (Vila et al 1999; Dyer 2000; Habit et al 2006a). A total of 46 fish species have been described for the whole Chilean territory. River hydrology and geology may have influenced the rather small size of the majority of the native species and the capacity of the fish to ascend torrents above 1000 m altitude (Fig. 1), with the exception of those found in systems of the high Andean lands (Vila et al 1999). The geographical relationships of the fish fauna of the Chilean Mediterranean have both a Pacific coast origin in the case of galaxiids and atherinids (Dyer 2000), and a very old relic tropical origin for catfish and characids (Arratia 1997).

In this review, we update the knowledge of the native fish fauna of the Chilean Mediterranean region, describing their current distribution and addressing the main conservation issues and needs for research.

STUDY AREA

Mediterranean river watersheds between 27º S and 36º S in Chile are short, torrential, with steep slopes, no intercommunication, few tributaries and thus of low order. The Mediterranean climate in this region is characterized by a strong latitudinal gradient in precipitation, which together with the altitude generates rivers with a snowmelt-rain regime with significant differences among seasons (Table 1). Precipitations determine winter (June to August) floods and summer (January to March) low flows; snowmelt runoff during spring and the beginning of summer (October to November) produces a second but usually smaller high flow peak. The latitudinal gradient determines increased flows from north to south, varying from 0.10 to 34.8 m^3/s in the northern Mediterranean region up to 11.20 to 585.1 m^3/s (Niemeyer & Cereceda 1984; DGA 2013; Table 1). Together with flow, other dependent variables change along the latitudinal gradient, such as an increase in water velocity, lower water temperature and lower conductivity to the South (Leopold 1994; Pizarro et al 2014). pH tends to be basic (from 7.6 to 8.0) in the northern rivers, varying to neutral to the South. The average annual air temperature ranges from 6° C during winter at higher altitudes to 29° C in the lowlands during summer. Table 1 details hydrological and temperature characteristics of the main Chilean rivers.

Here we summarize information collected during the last 30 years based on our own fish collecting using a variety of sampling gear (e.g. electrofishing, gill nets, seines, traps), and relevant literature for the main Andean drainage systems (from North to South): Huasco, Elqui, Limarí, Petorca, Choapa, Aconcagua, Maipo, Rapel, Mataquito, Maule, Itata and Biobío Rivers (Fig. 1).

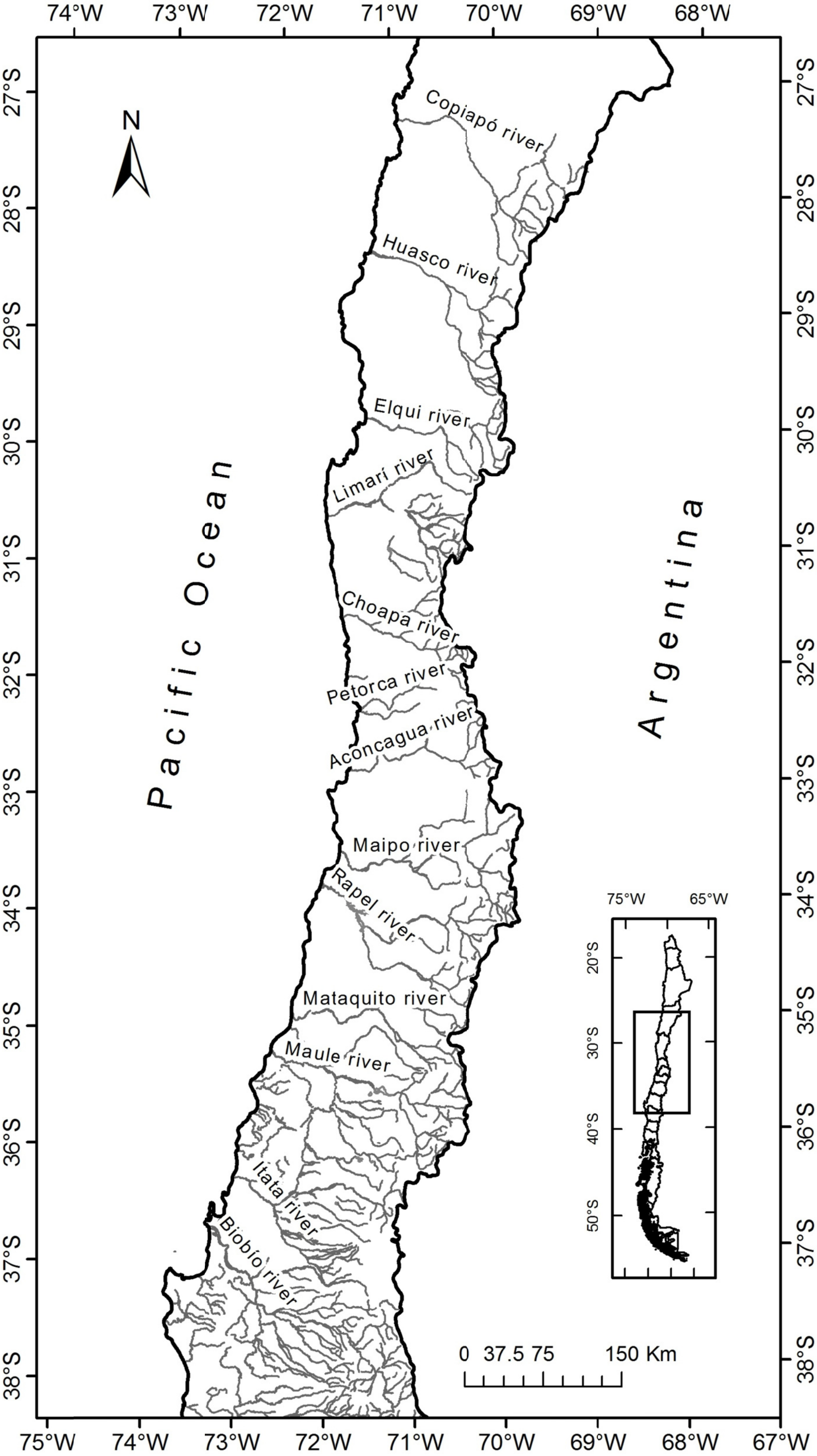

FIGURE 1. Main Andean river basins of the Mediterranean zone in Chile

TABLE 1. Minimum and maximum temperatures and flows of main Mediterranean rivers of Chile. Data from the Chilean Dirección General de Agua (DGA) http://snia.dga.cl/BNAConsultas/reportes

	Monthly temperature (ºC)		Flow ($m^3 s^{-1}$)	
	Min.	Max.	Min.	Max.
Huasco	12.3	29.7	0.38	32.2
Limarí	14.2	24.8	0.24	34.8
Petorca	2.8	25.6	0.4	162.8
Aconcagua	3.9	26.1	1.6	457.6
Cachapoal (Rapel)	5.1	23.9	11.2	149.5
Mataquito	9.9	23.8	6.6	585.1
Maule	8.2	26.5	0.60	2021.1
Itata	6.4	27.3	2.2	1309.3
Biobio	4.1	26.7	49.9	3363.3

CHARACTERIZATION OF THE FISH FAUNA

We recognize a total of 21 native fish species from the Chilean Mediterranean region, including two species of Agnatha and 19 Teleosts (Tables 2 & 3).

Agnatha is represented by two species, *Geotria australis* with a broad distribution in the Southern Hemisphere and *Mordacia lapicida*, endemic to Chile. Both species are anadromous and parasitic when adults.

Teleostei is represented by different orders; Siluriforms are the richest group in the region. Arratia (1990) cited 32 families of Siluroidei for South America, but only three of them are present in the Mediterranean region of Chile. Catfish of the family Trichomycteridae are species with strongly compressed body, three pairs of maxillary barbells reaching the tip of the interopercular spines and small body size (seldom reaching 30 cm total length). *Trichomycterus* inhabits the dead zone of rhithronic river areas with high oxygenation and coarse substrate of boulders or gravel (Arratia, 1983a,b). *Trichomycterus areolatus* Valenciennes (Figure 2) is the species of this family with the broadest distribution in Chile, inhabiting along the entire Mediterranean zone. It spawns during the austral spring (Manríquez et al 1988; Chiang et al 2011a, b). The maximum total length of mature fish is 56.7 mm for males and 51.1 for females. During spawning the mature oocytes are bright yellow and their diameters range from 1.5 to 2.1 mm (Manríquez et al 1988).

Their feeding habits are benthic, consuming preferentially aquatic insects such as chironomid Diptera, Trichoptera and Ephemeroptera (Scott et al 2007). *Trichomycterus chiltoni* has only been described in the Biobío River basin. Its reproductive behavior is unknown; however, mature females have been observed in spring. It has benthonic feeding, consuming especially aquatic insects and juveniles of the crustacean *Aegla* (Arratia 1983b); it has a wide trophic superposition with *T. areolatus* (Scott et al 2007). The last species of this family is *Bullockia maldonadoi*, which is found in the potamon zone of rivers; it is characteristic of the Coast Range, particularly the Cordillera de Nahuelbuta (Oliver, 1949; Habit & Victoriano 2005). *Bullockia maldonadoi* (Figure 2) changes its habitat during development from a sandy substrate to one composed mainly of gravel and small rocks. It is also found in riparian ponds with macrophyte vegetation (Arratia, 1983a). It is a small fish which usually does not exceed 70 mm total length and most aspects of its biology are unknown.

TABLE 2. Historical distribution of the native fish species in Chile. Whether or not they are endemic to the country is indicated (END), along with their distribution in the ichthyographic provinces recognized by Dyer (2000)- TIT, Titicaca; CHI- Chilean; PAT- Patagonia. The Chilean Province corresponds in part to the Chilean Mediterranean region

ORDER	FAMILY	SPECIES	END	TIT	CHI	PAT
Petromyzontiformes	Petromyzontidae "lampreys"	*Geotria australis* Gray, 1851	No		×	×
		Mordacia lapicida Gray, 1851	Yes		×	×
Characiformes	Characidae "pochas"	*Cheirodon pisciculus* Girard, 1855	Yes		×	
		Cheirodon australe Eigenmann, 1928	Yes		×	
		Cheirodon kiliani Campos, 1982	Yes		×	
		Cheirodon galusdae Eigenmann, 1928	Yes		×	
Siluriformes	Nematogenyidae	*Nematogenys inermis* (Guichenot, 1848)	Yes		×	
	Trichomycteridae "catfishes"	*Bullockia maldonadoi* (Eigenmann, 1928).	Yes		×	
		Trichomycterus areolaus (Valenciennes, 1840) "	No		×	
		Trichomycterus chiltoni (Eigenmann, 1928)	Yes		×	
		Trichomycterus rivulatus (Valenciennes, 1840)	Yes	×		
		Trichomycterus chungaraensis Arratia, 1983	Yes	×		
		Trichomycterus laucaensis Arratia, 1983	Yes	×		
		Hatcheria macraei (Girard, 1855)	No		×	×
	Diplomystidae	*Diplomystes chilensis* Molina, 1782	Yes		×	
		Diplomystes nahuelbutaensis Arratia, 1987	Yes		×	
		Diplomystes camposensis Arratia, 1987	Yes		×	
		Diplomystes sp	*			×
Galaxiformes	Galaxiidae "whitefishes"	*Galaxias maculatus* (Jenyns, 1842)	No		×	×
		Galaxias globiceps Eigenmann, 1928	Yes		×	
		Galaxias alpinus ? (Jenyns, 1842)	Yes		×	
		Galaxias platei Steindachner, 1898	Yes		×	×
		Brachygalaxias bullocki (Regan, 1908)	Yes		×	
		Brachygalaxias gothei Busse, 1982	Yes		×	
		Aplochiton zebra Jenyns, 1842	Yes		×	×
		Aplochiton marinus Eigenmann, 1928	Yes		×	×
		Aplochiton taeniatus Jenyns, 1842	Yes		×	×
Mugiliformes	Mugilidae	*Mugil cephalus* Linnaeus, 1758	No		×	
Cyprinodontiformes	Cyprinodontidae "karachi"	*Orestias agassii* Valenciennes, 1846	No	×		
		Orestias chungarensis Vila & Pinto, 1986	Yes	×		
		Orestias laucaensis Arratia, 1982	Yes	×		
		Orestias ascotanensis Parenti, 1984	Yes	×		
		Orestias parinacotensis Arratia, 1982	Yes	×		
		Orestias piacotensis Vila, 2006	Yes	×		
		Orestias gloriae Vila 2011	Yes	×		
Atheriniformes	Atherinopsidae "silversides"	*Basilichthys microlepidotus* (Jenyns, 1841)	Yes		×	
		Basilichthys cf. semotilus (Cope, 1874)	Yes	×		
		Odontesthes hatcheri (Eigenmann, 1909)	No			×
		Odontesthes (Cauque) mauleanum (Steindachner, 1896)	Yes		×	
		Odontesthes (Cauque) brevianalis (Günther, 1880)	Yes		×	
		Odontesthes (Cauque) itatanum ? (Steindachner, 1896)	Yes		×	
Perciformes	Percichthyidae "trout perch"	*Percichthys trucha* (Valenciennes, 1833)	No		×	×
		Percichthys melanops Girard, 1855	Yes		×	
	Perciliidae "darter"	*Percilia irwini* Eigenmann, 1928	Yes		×	
		Percilia gillissi Girard, 1855	Yes		×	

TABLE 3. Current presence of native fish species in the main Andean watersheds of the Mediterranean zone of Chile (from north to south). EX- possibly extinct in the watershed; **Diplomystes* cf *chilensis*. Codes for watersheds: 1- Huasco; 2- Elqui; 3- Limari; 4- Choapa; 5- Petorca; 6- Aconcagua; 7- Maipo; 8- Rapel; 9- Mataquito; 10- Maule; 11- Itata; 12- Biobio

	WATERSHEDS											
	1	2	3	4	5	6	7	8	9	10	11	12
Geotria australis						×	×	×	×	×	×	×
Mordacia lapicida												×
Cheirodon pisciculus		×	×	×	×	×	×	×	×			
Cheirodon galusdae										×	×	×
Nematogenys inermis							×	×	×	×	×	×
Bullockia maldonadoi										×	×	×
Trichomycterus areolaus		×	×	×	×	×	×	×	×	×	×	×
Trichomycterus chiltoni												×
Diplomystes chilensis						**	×	*	*			
Diplomystes nahuelbutaensis										×	×	×
Galaxias maculatus	**	**	×	×	×	×	×	×	×	×	×	×
Brachygalaxias bullocki											×	×
Brachygalaxias gothei										×		
Aplochiton zebra												×
Basilichthys microlepidotus	×	×	×	×	×	×	×	×	×	×	×	×
Odontesthes mauleanum										×	×	×
Odontesthes brevianalis				×	×	×	×	×	×	×	×	×
Percichthys trucha						×	×	×	×	×	×	×
Percichthys melanops						×	×	×	×	×	×	×
Percilia irwini												×
Percilia gillissi						×	×	×	×	×	×	×

Siluriforms are also represented by the family Diplomystidae, which is considered by most ichthyologists to be the most primitive among the Siluriforms and shares characters with primitive teleosts (Lundberg & Baskin 1969; 1970; De Pinna 1998). The family is endemic to southern South America and is distributed on both sides of the Andes in rivers and lakes in Chile and Argentina between 34°S and 47°S (Arratia 1983). Three of the six described species are endemic to Chile (Pacific drainages), while the other three are endemic to Argentina (Atlantic drainages), (Muñoz-Ramirez et al, 2010). Species of this genus inhabit well-oxygenated water and move throughout river systems, and thus they are much affected by contamination and construction of dams. Two of the three species present in Chile are found in the Mediterranean region. *Diplomystes chilensis* has a maximum recorded total length of 25 cm. It was originally reported that juveniles inhabit lateral rhithronic zones and adults of more than 12 cm total length move to more potamic flat areas. Feeding is benthonic, changing from aquatic insects in juveniles to *Aegla* crustaceans in adults. Its reproduction is unknown, but should be very similar to that described for *Diplomystes nahuelbutaensis* (Vila et al 2006). This species has been classified as endangered, and it has practically disappeared from the region. *Diplomystes nahuelbutaensis* is morphologically very similar to *D. chilensis* (Arratia 1987). Some aspects of its biology and habitat were described by Vila et al (1996) and Habit (2005), and its distribution has been discussed by Muñoz-Ramirez et al (2010). It inhabits the rithron of rivers; juveniles prefer shallow rapids and shallow margins, while adults prefer deeper areas with faster current. Adults reach 30 cm total length (Habit 2005) and the maximum age is 5+ years. Lundberg et al (2004) described free-living juveniles of 13 mm total length. Food varies from aquatic insects and small mollusks to adult crustaceans *Aegla* (Arratia 1983b, 1987, Beltrán-Concha et al 2012). Gonads united in an unpaired sac indicate the primitiveness of the family. Reproduction begins in the second year of life in summer-autumn, coinciding with the lowest flows and highest temperatures in the rivers. Eggs are large and demersal (2.5-3.0 mm diameter). Low fecundity, along with slow growth, explains the low population density of the species. As a management measure for the preservation of this species, Habit et al (2002) translocated individuals from deteriorated areas. The last family among siluriforms is Nematogenidae, a monotypic family with a restricted distribution, endemic to Chile. The species *Nematogenys inermis* is considered to be the most primitive of the Loricariodea (Arratia 1992; de Pinna 1998). As with most Siluriforms, it requires highly oxygenated waters and it has been described as inhabiting fluvial potamic and rithronic areas (Campos et al 1993; Ruiz 1993; Habit & Victoriano 2005). Similar to *D. nahuelbutaensis*, *N. inermis* has very large eggs (4-4.5 mm) which mature synchronically, indicating a single spawning (Huaquín et al, 2002; Manríquez et al. 1984). *Nematogenys inermis* feeds on benthic fauna such as crustaceans, snails, and insects. No more information on the biology of this species is available. Originally indicated as reaching up to 40 cm of total length, it is the largest body size cat fish in Chile. It is currently classified as “Vulnerable” (Table 4), although it has disappeared from the majority of the river systems in its distribution area. Currently only remnant populations in the Coast Range still exist.

Characiforms are represented by the family Characidae. This family of tropical origin is represented in Chile only by the genus *Cheirodon*, with five native species (Campos 1982); *C. pisciculus*, *C. galusdae* (Figure 2), *C. austral* and *C. killiani* and one introduced from Argentina (*C. interruptus*). The species are morphologically similar; however, recently Salas et al (2012) reported morphological landmarks which allow rapid field identification: They are small fish, usually not exceeding 10 cm total length. Their typical habitats are potamal river zones with aquatic vegetation where they feed on the “auwfuchs” community. There is no information available about their reproduction (Campos 1982; Habit et al 2006a).

Galaxiforms are represented by the suborder Osmeroidei, and the families Galaxiidae and Aplochitonidae. Galaxiidae is the most species-rich family of freshwater fish in Chile, comprising over 50 species distributed throughout the Southern Hemisphere (South America, South Africa, Australia and New Zealand; (McDowall 1971, 2006). Eight species belonging to three genera (*Galaxias*, *Brachygalaxias* and *Aplochiton*) are found in Chile, five of which are endemic (Habit et al 2010). Two of the endemics, *Brachygalaxias bullocki* and *B. gothei*, the widespread *Galaxias maculatus* and *Aplochiton zebra* are present in the Mediterranean zone. *Brachygalaxias bullocki* and *B. gothei* are the smallest galaxiids in Chile, found especially abundant in weedy habitats (Eigenmann 1927). *Brachygalaxias gothei* has very restricted distributions in the Maule River basin (McDowall 1971; Dyer 2000). *Brachygalaxias bullocki* used to have a larger distribution range, from the Itata River basin to Chiloé Island. However, currently it seems to be extinct in the Biobío and Imperial Rivers (Habit et al 2010), and is a scarce species in the Mediterranean zone. *Brachygalaxias bullocki* typically inhabits streams and rivers with high levels of humic acids, lowland rivers with native riparian forest and large floodplains. It is found in riverine habitats with little or no current, and is completely absent from rapids or riffles (Habit et al 2010).

FIGURE 2. Representative fish species from the Chilean Mediterranean region

Galaxias maculatus is generally found close to the coastal zones. It is one of the smallest species of the genus, not exceeding 160 mm total length. Its reproductive period is related to the dynamics of estuaries, since it spawns in coastal zones and juveniles enter the rivers; this process extends from spring to autumn, with temperatures which fluctuate from 6 ºC to 21 ºC, although landlocked lacustrine reproduction has also been reported (Barriga et al 2006). Mature oocytes measure on average 0.9 mm diameter. It feeds on insects, small crustaceans, fish eggs and plankton. In rivers, *G. maculatus* is found in shallow, slow current zones along river edges, on substrates ranging from mud to boulders, with or without aquatic vegetation. Larger individuals (> 12 cm standard length (SL)) tend to inhabit slightly deeper (> 50 cm) zones (Habit et al 2010).

The family Aplochitonidae is represented by three species in Chile (Aló et al 2013), but only one inhabits the southern zone of the Mediterranean region: *Aplochiton zebra*. This species has an elongated, flattened body and a small adipose fin. It moves between rivers and lakes, probably for reproduction. In the Chilean Mediterranean zone it only occurs in one lake of the Biobío River basin (Galletué Lake. Campos et al 1993), being more abundant to the south and Patagonia (Habit et al 2010), where it has strong trophic interference from the introduced *Salmo trutta* (Elgueta et al 2012).

Perciforms are represented by the endemic family Perciliidae with two species, and two species of the family Percichthyidae. The endemic genus *Percilia* is represented by small darters not exceeding 10 cm total length. *Percilia gillissi* (Figure 2) is widespread in the Chilean Province (sensu Dyer 2000), found in rithronic and potamal zones of rivers with well-oxygenated water. Its feeding and reproduction are associated with the benthonic fauna (Habit 1998; Aedo et al 2009; Chiang et al 2011b). The other species, *P. irwini* has a restricted distribution and is considered highly threatened (Habit et al 2009). It can be found in high abundance in riffles and rapids in the middle Biobío River (García et al 2011a) and it has been described as a good swimmer over short distances after (Ruiz 1993).

The genus *Percichthys* is endemic to South America; the other genera of the family Percichthyidae are found only in Australia (Ruzzante et al 2006). *Percichthys trucha* occurs both west of the Andes in Pacific drainages and east of the Andes in Atlantic and Pacific drainages, but *P. melanops* is restricted to western drainages of the Andes (Ruzzante et al 2006). *Percichthys trucha* is a carnivorous predator beginning at a young age; it may reach 50 cm total length it is found both in fluvial and lacustrine systems. Guerrero (1991) estimated that the species may live for 9 years in Patagonian lakes. It reproduces in spring with demersal eggs.

Percichthys melanops is endemic to the Chilean Province and morphologically similar to *P. trucha*, although with dark, mottled flanks and smaller size, which usually reaches 30 cm total length. It is found preferentially in river systems of the Coastal Range. Its reproductive period and specific feeding habits are unknown.

Atheriniforms are represented in the region by the family Atherinopsidae. Two genera of this family are found in Chile, *Basilichthys* without a protractile mouth, which separates it clearly from the other genus, *Odontesthes*, which has protractile maxillaries (Dyer 2006). Both are widely distributed in the region and associated with a marine origin due to their high salt tolerance. Species of Atherinopsidae have rapid growth and high fecundity (Vila et al 1981b). *Basilichthys* is a genus of fresh water silversides exclusively distributed in the western slopes of the Andes Range. They have been divided into two groups (Dyer 2006), corresponding to *B. semotilus* and *B. microlepidotus*, which have disjunct distributions. *Basilichthys microlepidotus* included two species of the genus with southern distributions, *B. microlepid*otus from the Huasco River to the Maipo River and *B. australis* between the Aconcagua River and Chiloé Island. Recently two parallel studies, Véliz et al. (2012) and Cifuentes (2012) demonstrated that these two are only one species with wide distribution. According to the rules of nomenclature, this species must be called *B. microlepidotus*. As with most Atherinids it has fast growth, reaching around 12 cm total length in the first year of life, and starts reproducing in the first year (Comte & Vila 1987; 1992). It reaches a maximum total length of 30 cm at this latitude; in Rapel Reservoir the study of Vila & Soto (1981b) found a three-year age cohort reaching 28 cm total length, but farther south it reaches greater lengths. Spawning begins in spring when water temperature reaches 15 °C and extends during the spring and summer months. Maturation begins at age one year. The absolute fecundity ranges from 2000 to 9000 oocytes in females from 49 to 170 mm of total length. Mature oocytes measure 1.7 to 2.0 mm diameter (Moreno et al 1977). They spawn in clusters that are stuck to riverine macrophytes. It is a benthic feeder, predating on aquatic macroinvertebrates (Bahamondes et al 1979; Montoya et al 2012).

The genus *Odontesthes* is also represented by two species in the Mediterranean zone of Chile. *Odontesthes mauleanum* moves extensively among lakes, rivers and estuaries. It has been reported that juveniles and adults in lakes feed mainly on zooplankton. It usually moves up and down rivers feeding on benthic macroinvertebrates (Klink & Eckmann 1985). In Rapel Reservoir it has been reported feeding extensively on small *B. microlepidotus* and carp (Bahamondes et al 1979). As other Atherinids it has fast growth, reaching 60-100 mm in the first year of life; growth predictions show total length of 30 to 40 cm at eight years; it starts reproducing in the first year of life during spring (Klink & Eckmann 1985). *Odontesthes brevianalis* is a silverside that inhabits exclusively saline coastal systems where it feeds and reproduces. As most Atherinids it grows rapidly and has been reported to attain up to 40 cm total length at four years. Its food has been reported to be small mollusks and zooplankton. Mature specimens have been found in spring, but detailed information on its reproduction is still lacking (Vargas et al 2002).

The freshwater systems of the Mediterranean region of Chile correspond in part to the Chilean Ichthyographic Province (Arratia 1997; Dyer 2000; see Table 2), including river basins from the Huasco to the Biobío Rivers (Fig.1). The headwaters of these rivers correspond to crenons or high Andean zone, characterized by high current velocity and turbulence, and large-sized substrate (rocks and boulders). The only native fish found there are Siluriforms of the genera *Trichomycterus* and *Diplomystes*, which inhabit lateral pools or shallow water with low current velocity. In the middle area or hyporhithron rivers have sequences of rapids and pools, a substrate of rocks and gravel and riparian sectors colonized by macrophytes. In this area, as well as catfish there are Atheriniforms (silversides) and Perciforms (perch); while in the low potamal zone there are also catfish of the genera *Nematogenys* and *Bullockia* and Characiforms of the genus *Cheirodon*. River mouths are inhabited by more salt-tolerant species such as *Galaxias maculatus*, *Odontesthes mauleanum* and *O. brevianalis*.

In the northern Mediterranean zone between 27º and 31º S, near one of the most arid deserts of the world (Atacama Desert), the rivers are separated by up to 1000 km. The Huasco, Choapa, Petorca and Limarí Rivers have low-medium flows (0.24-83.9 m3/s), with one rainy month and a prolonged dry period, with high hydrological fluctuations between years, mainly due to the scarcity of precipitation. The development of these rivers in semi-arid zones does not allow mountain snow melt to increase their flow. Only five fish species are known from these rivers: *T. areolatus*, *C. pisciculus*, *B. microlepidotus*, *O. brevianalis* and *G. maculatus*. Farther south in the Mediterranean Region rivers increase their flow; their flows reach above 3000 m3/s, typical of torrential rivers with snow melt runoff (Maule, Itata and Biobío Rivers; Table 1). In these rivers with greater flows additional species are found, typical of the Chilean Ichthyographic Province: *D. chilensis*, *N. inermis*, *P.*

trucha, *P.melanops*, *P. gillissi* and *O. mauleanum* (Dyer 2000, Vila & Pardo 2008; Habit 1994a; Habit et al 1994b; Habit et al 2006a). The ichthyofauna reaches its maximum diversity at 36º S latitude; with 18 native species in the Biobío River. This is the southernmost river of the Mediterranean Region and that of greatest order and flow; other species in this river are *D. nahuelbutaensis*, *T. chiltoni* and *B. maldonadoi*.

MAIN THREATS AND MANAGEMENT ISSUES

The fish fauna of the Mediterranean watersheds of Chile has a high conservation value because of high endemism and primitiveness, along with their biogeographic relations; Siluriforms with the tropical fauna and the Galaxiidae with Gondwana fauna. Currently 75% of the fish species in the Mediterranean zone of Chile are classified as endangered and vulnerable species (Table 4).

TABLE 4. Conservation status of the native fish species of the Mediterranean zone of Chile according to the official classification of the Ministerio del Medio Ambiente (http://www.mma.gob.cl/clasificacionespecies/index2.htm).

	CATEGORY
Geotria australis	Vulnerable
Mordacia lapicida	Endangered
Cheirodon pisciculus	Vulnerable
Cheirodon galusdae	Vulnerable
Nematogenys inermis	Vulnerable
Bullockia maldonadoi	Endangered
Trichomycterus areolaus	Vulnerable
Trichomycterus chiltoni	Endangered and Rare
Diplomystes chilensis	Endangered and Rare
Diplomystes nahuelbutaensis	Endangered
Galaxias maculatus	Vulnerable (Maule to the north) Less Concern (Biobío to the south)
Brachygalaxias bullocki	Less Concern
Brachygalaxias gothei	Unclassified
Aplochiton zebra	Endangered
Basilichthys microlepidotus	Vulnerable
Odontesthes mauleanum	Vulnerable
Odontesthes brevianalis	Vulnerable
Percichthys trucha	Near Threatened (Maule to the north) Less Concern (Biobío to the south)
Percichthys melanops	Vulnerable
Percilia irwini	Endangered
Percilia gillissi	Endangered

According to the literature and the detailed information on the species richness of the most important Mediterranean river basins compiled 40 years ago, their presence and abundance has declined significantly in recent years. This is particularly true for the Aconcagua (Dazarola 1972) and Maipo Rivers (Duarte et al 1971), both located in the more populated areas of the country (cities of Valparaíso and Santiago). For both river systems 10 native species were reported, but currently less than 50% of these can be found. Siluriforms are considered to be in the process of extinction due to their elimination from locations cited in their original descriptions. This is the case of *D. chilensis* in the Aconcagua basin (Muñoz-Ramirez et al 2010), and of *N. inermis* in the Biobío basin (Habit et al 2006b). Something similar is occurring with Percichthyidae and Atherinopsidae, mainly in the northern part of their distribution range. In the case of the galaxiids, the latitudinal range of *G. maculatus* has declined by 26%, and most of this reduction has occurred in the northern part of its range. *Brachygalaxias bullocki* has experienced reductions (8–17% loss) in the total drainage area occupied, and it has disappeared from, or is now extremely difficult to find, in latitudes 36° to 41° S, coincident with areas of urban growth and intense economic activities (Habit et al 2010). These authors also suggested that negative interactions between introduced and native fish are responsible for some of the range reductions among the Galaxiidae in Chile.

The generalized decrease in the abundances and distribution ranges of the species native to the Mediterranean area of Chile appears to be the synergic result of multiple stressors in the river basins, the most important of which are: 1) the negative effect of introducing as many exotic species as the native species present (Table 5), (Arratia 1981; 1997; Basulto 2003; Habit et al 2006b; Vila et al 2006; Habit et al 2010). Recently, Marr et al (2013) reviewed freshwater fish introductions across Mediterranean regions in the world to evaluate the influences of non-native fish on the biogeography of taxonomic and functional diversity, and found that faunal homogenization was greatest in Chile; 2) Changes in soil use in the river basins, mainly replacement of the native forests by pine and *Eucalyptus* plantations; 3) Extraction of water, with dams in the majority of the rivers; the high water demand has generated negative water balances; together with water extraction for various agricultural crops in the central and southern areas with irrigation channels which in some cases cross drainage systems (e.g. Habit & Parra 2001); 4) Dredging and channeling of river systems (e.g. Ortiz-Sandoval et al 2009); 5) Construction of diversion or hydropower plants (e.g. Habit et al 2007) which generate changes in the flow regime downstream from the dam (e.g. García et al 2011 b); 6) Entrance of multiple industrial and domestic effluents which generate contamination in the majority of these river basins (Vila et al 2000;. Habit et al 2005, 2006b, Habit & Ortiz 2009; Orrego et al 2009; Chiang et al 2011a, b); and 7) Fishing; although intensive fishing has not been one of the principal stressors of the native fish fauna as it has been in other areas, mainly due to the small body size of the majority of the species (adults <15 of total length), a few species are caught by recreational and local fishermen such as silversides and perch, and other small fish are used as bait (e.g. catfish).

To all the above must be added natural causes, which probably generate synergic effects with human activities, such as: 1) Lithological characteristics of the area, with significant presence of mineral salts and consequent development of mining; 2) Low growth rates and fecundity of the Siluriforms (e.g. *D. nahuelbutaensis*, Vila et al 1996); 3) Low genetic variability of some species (Victoriano et al 2012) and their limited swimming capacity (Piedra et al 2012; García et al 2012; Sobenes et al 2013). Another key aspect in the poor conservation state of this fish fauna is that, due to their small size and little use of the native species, these are unknown to the majority of the population and thus there is no social conscience of the need for their protection. In spite of this, in recent years a few management measures have been implemented. Thus for example currently 30 of the 46 species native to Chile are under a prohibition of extraction for 15 years (Resolution 878/2011 Subsecretaría de Pesca). Also, the System of Environmental Impact Assessment of Chile establishes that, according to Article 168 of the fishing law (Ley de Pesca y Acuicultura), all projects constructed in continental waters which imply the interruption of the free movement of fish must propose mitigation measures (e.g. fish channels) or undertake restocking. A few programs of translocation of individuals of native species have been undertaken (e.g. Habit et al 2002), but there has been little or no long term monitoring of the efficacy of these programs. Recently there has been a beginning of the basic studies on how to maintain native species in captivity (Sobenes et al 2012), as a measure of *ex situ* conservation.

FUTURE DIRECTIONS IN SCIENCE AND MANAGEMENT

Knowledge of the biology and ecology of the fish native to the Mediterranean region of Chile is still incomplete. The information available is mostly classical morphological descriptions, although recently there have been studies of genetics and speciation (Ruzzante et al 2006, 2008; Unmack et al 2009, 2012, Zemlak et al 2009, 2010; Quezada-Romegialli et al 2010; Véliz et al 2012). We lack specific information about the current distribution and population abundance among river systems, reproductive periods, fecundities and growth rates for the majority of the species. We also need to advance in our understanding of the processes involved in the decrease of their population sizes using ecosystem approaches.

TABLE 5. List of species reported as introduced in continental waters of the Mediterranean zone of Chile. The question mark for *Salvelinus namycush* indicates that there are no recent records and thus it is not clear if they were successfully established. ** Previously described as *Cichlassoma facetum* for Chile.

FAMILY	SPECIES	WATERSHEDS
Acipenseridae	*Acipenser baeri* Brandt, 1869	Río Maipo
	Acipenser transmontanus Richardson, 1836	Río Maipo
Salmonidae	*Oncorhynchus mykiss* (Walbaum, 1792)	All Chile
	Salmo trutta Linnaeus, 1758	All Chile
	Salvelinus fontinalis (Mitchill, 1815)	Río Aconcagua
	Salvelinus namycush (Walbaum, 1792)	Lagunas de San Pedro, Concepción (?)
Cyprinidae	*Carassiuss carassius* (Linnaeus, 1758)	Río La Ligua, Aconcagua to the Biobío.
	Ctenopharyngodon idella (Valenciennes, 1844)	Laguna Redonda Concepción
	Cyprinus carpio Linnaeus, 1758	Río Quilimarí to Río Biobio.
	Tinca tinca (Linnaeus, 1758)	Lago Peñuelas, L. Vichuquén,
Characidae	*Cheirodon interruptus* (Jenyns, 1842)	Central zone of Chile
Icatluridae	*Ameiurus melas* (Rafinesque, 1820)	Central zone of Chile
	Ameiurus nebulosus (Lesueur, 1819)	Río Maipo, Angostura, Itata
	Ictalurus punctatus (Rafinesque, 1818)	Maule
Atherinopsidae	*Odontesthes bonariensis* (Valencienes, 1835)	Río Limarí to Río Lleulleu
Poecilidae	*Cnesterodon decenmmaculatus* (Jenyns, 1842)	Río Petorca to Río Maipo
	Gambusia holbrooki (Girard, 1859) *Gambusia affinis*	Río Huasco to Río Biobio Río Huasco to Río Biobio
Cichlidae	*Australoherus sp***	Río Aconcagua to Biobío
Anablepidae	*Jenynsia multidentata* (Jenyns 1842)	Estero Puangue to Río Maipo

There are multiple management needs for the future; the most relevant are the following: 1) it is urgent to implement measures of integrated management of the watersheds, which does not exist formally in Chile, since the productive activities with effects on the aquatic ecosystems are assessed case by case separately; 2) introduce the concept of ecosystem services in water resource management, emphasizing the value of the conservation of biodiversity; 3) generate more information on measures to insure reproduction of the different native species in captivity; 4) continue with the identification of priority conservation sites for native fish fauna and achieve their management.

In summary, we conclude that 75% of the 21 native species of fish present in the Mediterranean river basins of Chile are severely threatened and these threats are not simple, but rather the result of a combination of human activities and natural conditions which are difficult to manage and require more scientific and public attention.

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CITED REFERENCES

AEDO, J., BELK, M. & HABIT, E. 2009 Geographic variation in age, growth and size structure of *Percilia irwini* from south-central Chile. *Journal of Fish Biology* **74**: 278-84.

ALO D., CORREA, C., ARIAS, C., & CÁRDENAS, L. 2013. Diversity of *Aplochiton* fishes (Galaxiidea) and the taxonomic resurrection of *A. marinus*. *Plos One* **8**: e71577.

ARRATIA, G. 1981. Géneros de peces de aguas continentales de Chile. Mus. Nac. Hist. Natur. Chile. Publ. Ocasional 34: 3-108.

ARRATIA, G. 1983a. The caudal skeleton of ostariophysan fishes (Teleostei): Intraspecific variation in Trichomycteridae (Siluriformes). *Journal of Morphology*. **177**: 213-229.

ARRATIA, G. 1983c. Preferencias de hábitat de peces siluriformes de aguas continentales de Chile (Fam. Diplomystidae y Trichomycteridae). *Studies on Neotropical Fauna and Environment* **18**: 217-237.

ARRATIA, G. 1987. Description of the primitive Family Diplomystidae (Siluriformes, Teleostei, Pisces): Morphology, Taxonomy and Phylogenetic implications. *Bonner Zoologische Monographien* **24**: 5-120.

ARRATIA. G. 1990. The South American Trichomycterinae (Teleostei: Siluriformes), a problematic group. Pp 395-403 in: Peters, G. & R. Hutterer, eds. Vertebrates in the tropics. Proceedings of the International Symposium on Vertebrate Biogeography and Systematics in the Tropics (Bonn, 1989).

ARRATIA, G. 1992. Development and variation of the suspensorium of primitive Catfishes (Teleostei:Ostariophysi) and their phylogenetic relationships. *Bonner Zoologishe Monographien* **32**: 1- 49.

ARRATIA, G. 1997. Brazilian and Austral freshwater fish faunas of South America. A contrast. Pp. 179-186 in: Ulrich, H., ed. Tropical Biodiversity and Systematics. Proceedings of the International Symposium on Biodiversity and Sistematics in Tropical Ecosystem. Museum Alexander Koenig, Bonn.

BAHAMONDES, I., D. SOTO & I. VILA. 1979. Hábitos alimentarios de las especies de Atherinidae del Embalse Rapel. *Medio Ambiente* **4**: 3-18.

BARRIGA J.P, M.A., BATTTINI, P.J., MACCHI, D. MILANO & D. CUSSAC 2002. Spatial and temporal distribution of landlocked *Galaxias maculatus* (Pisces: Galaxiidae) in a lake in the South American Andes. *New Zealand Journal Marine and Freshwater Research* **36**: 345-359.

BASULTO, S. 2003. El largo viaje de los salmones: una crónica olvidada, propagación y cultivo de especies acuáticas en Chile. Editorial Maval, Santiago de Chile. 299 pp.

BELTRÁN-CONCHA M., MUÑOZ RAMÍREZ C., IBARRA J. & HABIT E. 2012. Análisis de la dieta de *Diplomystes* (Siluriformes: Diplomystidae) de Chile. *Gayana* **76**: 102-111.

CAMPOS, H. 1982. Sistemática del género *Cheirodon* (Pisces: Characidae) en Chile con descripción de una nueva especies. Análisis de multivarianza. *Studies on Neotropical Fauna and Environment* **17**: 129-162.

CAMPOS, H., F. ALAY, V.H. RUÍZ & J.F. GAVILÁN. 1993. Antecedentes biológicos de la fauna íctica presente en la hoya hidrográfica del río Bío-Bío. Pp. 70-72 in: O. Parra & F. Faranda, eds. Seminario Limnología y Evaluación de Impacto Ambiental. pp. 70-72. Ediciones Centro EULA-Chile, Universidad de Concepción, Chile.

CHIANG, G., M. MCMASTER, R. URRUTIA, M.F. SAAVEDRA, J.F. GAVILÁN, F. TUCCA, R. BARRA & K.R. MUNKITTRICK. 2011a. Health status of native fish (*Percilia gillissi* and *Trichomycterus areolatus*) downstream of the discharge of effluent from a tertiary-treated elemental chlorine-free pulp mill in Chile. *Environmental Toxicology and Chemistry* **30**: 1793–1809.

CHIANG, G., K.R. MUNKITTRICK, F. TUCCA, M. MCMASTER, R.URRUTIA, G. TETREAULT & R. BARRA. 2011b. Seasonal changes in reproductive endpoints in *Trichomycterus areolatus* (Siluriformes: Trichomycteridae) and *Percilia gillissi* (Perciformes, Perciliidae), and the consequences for environmental monitoring. *Studies on Neotropical Fauna and Environment* **46**: 185-196

CIFUENTES, R. 2012. Evaluación del estatus taxonómico de las especies de *Basilichthys* del grupo microlepidotus (Atheriniformes, Atherinopsidae) basado en genética y morfología. Tesis Magíster. Universidad de Concepción. 85 pp.

COMTE, S. & I. VILA. 1987. Modalidad reproductiva de *Basilichthys microlepidotus* (Jenyns) en el río Choapa. (Pisces: Atherinidae). *Anales del Museo Historia Natural de Valparaíso* **18**: 85-94.

COMTE, S. & I. VILA. 1992. Spawning of *Basilichthys microlepidotus* (Jenyns). *Journal of Fish Biology* **41**: 971-981.

COWLING, R. M., P. W. RUNDEL, B. B. LAMONT, M. K. ARROYO & M. ARIANOUTSOU. 1996. Plant diversity in Mediterraneanclimate regions. *Trends in Ecology and Evolution* **11**: 362–366.

DAZAROLA, G. 1972. Contribution a l' ètude de la faune ichtyologique de la region Valparaíso Aconcagua(Chili*). Annals de Limnologie, Paris* **8**: 87- 100.

DE PINNA, M. 1998. Phylogenetic relationships of neotropical siluriformes (Teleostei: Ostariophysi): historial overview and synthesis of hypotheses. Pp. 279-330 in: L.R. Malabarba, R.E. Reis, R.P. Vari, Z.M. Lucena & C.A. Lucena, eds. Phylogeny and Classification of Neotropical Fishes. Edipucrs, Porto Alegre, Brasil.

DUARTE, W., R. FEITO, C. JARA, C. MORENO & A.E. ORELLANA. 1971. Ictiofauna del sistema hidrográfico del río Maipo. *Boletín Museo Nacional de Historia Natural (Chile)* **32**: 227-268.

DYER, B. 2000. Systematic review and biogeography of the freshwater fishes of

Chile. *Estudios Oceanológicos, Chile* **19**: 77-98.

DYER, B. 2006. Systematic revision of the South American silversides (Teleostei, Atheriniformes). Symposium: Biology and Culture of Silversides (Pejerreyes). *Biocell* 30: 69-88

EIGENMANN, C. & R. EIGENMANN, 1890. A revision of the South American Nematognathi. *Occasional papers of the California Academy of Sciences* **1**: 1-509.

EIGENMANN, C.H. 1927. Fresh-water fishes from Chile. *Memories of the National Academy of Sciences* **22**: 1-63.

ELGUETA, A., GONZÁLEZ, J., RUZZANTE, D., WALDE, S. & HABIT, E. 2012. Trophic interference by *Salmo trutta* on *Aplochiton zebra* and *Aplochiton taeniatus* in southern Patagonian lakes. *Journal of Fish Biology* **82**: 430-43.

ELOSEGI, A. & S. SABATER. 2009. Conceptos y técnicas en ecología fluvial. Publicaciones de la Fundación BBVA. 444 pp.

GARCÍA, A., C. JORDE, E. HABIT, D. CAAMAÑO & O. PARRA. 2011. Downstream environmental effects of dam operations: changes in habitat quality for native fish species. *River Research and Applications* **27**: 312-327.

GARCÍA A., C. SOBENES, O. LINK & E. HABIT. Bioenergetic models of the threatened darter *Percilia irwini*. *Marine and Freshwater Behaviour and Physiology* **45**:17-25.

GUERRERO, C.A. 1991. Crecimiento de la perca boca chica (*Percichthys trucha*) en cuatro ambientes leníticos patagónicos. Segundo Taller Internacional sobre Ecología y manejo de peces en lagos y embalses (Vila, I, Ed.). FAO.COPESCAL Doc. Téc. 9:47-71.

HABIT, E. 1994a. Contribución al conocimiento de la fauna íctica del río Itata. *Boletín de la Sociedad de Biología de Concepción Chile* **65**: 143-147.

HABIT, E. 1994b. Ictiofauna en canales de riego de la cuenca del río Itata durante la época de otoño-invierno. *Comunicaciones del Museo de Historia Natural de Concepción, Chile* **8**: 7-12.

HABIT, E. 1998. Análisis de la dieta de *Percilia gillissi* en ambientes de río y canales de riego (cuenca del río Itata, Chile). *Teoría* **7**: 33-46.

HABIT, E. & O. PARRA. 2001. Impacto ambiental de los canales de riego sobre la fauna de peces fluviales. *Ambiente y Desarrollo* **17**: 50-56.

HABIT, E., P. VICTORIANO & O. PARRA. 2002. Translocación de peces nativos en la cuenca del río Laja (Región del Bío-Bío, Chile). *Gayana* **66**: 181-190.

HABIT, E. 2005. Aspectos de la biología y hábitat de un pez endémico de Chile en peligro de extinción (*Diplomystes nahuelbutaensis* Arratia, 1987). *Interciencia* **30**: 8-11.

HABIT, E. & P. VICTORIANO. 2005. Peces de agua dulce de la Cordillera de la Costa. Pp. 392-406 in: C. Smith-Ramírez, J. Armesto & C. Valdovinos, eds. Historia, Biodiversidad y Ecología de la Cordillera de la Costa de Chile. Editorial Universitaria, Santiago, Chile.

HABIT, E., B. DYER & I. VILA. 2006a. Estado de conocimiento de los peces dulceacuícolas de Chile. *Gayana* **70**: 100-112.

HABIT, E., M. BELK, C. TUCKFIELD & O. PARRA. 2006b. Response of the fish community to human-induced changes in of the Biobío River in Chile. *Freshwater Biology* **51**: 1-11.

HABIT, E. M. BELK & O. PARRA. 2007. Response of the riverine fish community to the construction and operation of a diversion hydropower plant in central Chile. *Aquatic Conservation: Marine and Freshwater Ecosystems* **17**: 37-49.

HABIT, E. & ORTIZ, N. 2009. Composición, distribución y conservación de los peces de agua dulce de la cuenca del río Itata.

Pp. 127-142 in: Parra, O., Castilla, J.C., Romero, H., Quiónes, R., Camaño, A, eds. La Cuenca Hidrográfica del Río Itata. Aportes Científicos para su Gestión Sustentable. Universidad de Concepción, Concepción, Chile.

HABIT, E., P. PIEDRA, D. RUZZANTE, S. WALDE, M. BELK, V.CUSSAC, J. GONZÁLEZ, & N. COLIN. 2010. Changes in the distribution of native fishes in response to introduced species and other anthropogenic effects. *Global Ecology and Biogeography* **19**: 697-710

HUAQUÍN, L.G., D. VELIZ & G. ARRATIA. 2002. Estudio comparativo de ovarios y cubiertas ovocitarias en peces siluriformes de aguas continentales de Chile. *Gayana Zoología* **66**: 269-274.

KLINK, A. & R. ECKMANN. 1985. Age and growth, feeding habits, and reproduction of *Cauque mauleanum* (Steindachner 1896) (Pisces: Atherinidae) in southern Chile. *Studies Neotropical Fauna Environment* **20**: 239-249.

LEOPOLD, L. B., 1994. A View of the River, Harvard University Press, Cambridge, Mass. 298pp

LUNDBERG, J.G. & J. N. BASKIN. 1969. The caudal skeleton of the catfishes, order Siluriformes. *American Museum Novitates* **2398**:1-49.

LUNDBERG, J. G. & G. R. CASE. 1970. A new catfish from the Eocene Green River Formation, Wyoming. *Journal of Paleontology* **44**: 451–457.

LUNDBERG, J., T. BERRA & J. FRIEL. 2004. First description of small juvenile of the primitive catfish *Diplomystes* (Siluriformes: Diplomystidae). *Ichthyological Exploration of Freshwaters* **15**: 71-82.

MANRÍQUEZ, A., L. HUAQUÍN, M. ARELLANO & G. ARRATIA. 1988. Aspectos reproductivos de *Trichomycterus areolatus* Valenciennes, 1846 (Pisces: Teleostei: Siluriformes) en río Angostura, Chile. *Studies on Neotropical Fauna and Environment* **23**: 89-102.

MANRÍQUEZ, A., M. ARELLANO & L. HUAQUIN. 1984. Antecedentes ecológicos y biológicos de *Nematogenys inermis* (Guichenot, 1848) una especie en extinción. Memorias *Asociación Latinoamericana de Acuicultura* **5**: 609-614.

MARR, S.M., J.D. OLDEN, F. LEPRIEUR, I. ARISMENDI, M. CALETA, D.L. MORGAN, A. NOCITA, R. ŠANDA, A.S. TARKAN, E. GARCÍA-BERTHOU. 2013. A global assessment of freshwater fish introductions in mediterranean-climate regions. *Hydrobiologia* **719**: 317-329

MCDOWALL, R.M. 1971. The galaxiid fishes of South America. *Zoological journal of the Linnean Society, London* **50**: 33-73.

MCDOWALL, R.M. 2006 Crying wolf, crying foul, or crying shame: alien salmonids and a biodiversity crisis in the southern cool-temperate galaxioid fishes? *Reviews in Fish Biology and Fisheries* **16**: 233-422.

MORENO, C., R. URZUA & N. BAHAMONDE. 1977. Breading season, sexual rate and fecundity of *Basilichthys australis* Eigenmann 1927, from Maipo river, Chile (Atherinidae, Pisces). *Studies on Neotropical Fauna and Environment* **12**: 217-223.

MUÑOZ-RAMÍREZ, C., JARA, A., BELTRÁN-CONCHA, M., ZÚÑIGA-REINOSO, A., VICTORIANO, P. & HABIT, E. 2010. Distribución de la família Diplomystidae (Pisces: Siluriformes) en Chile: nuevos registros. *Boletín de Biodiversidad de Chile* **4**: 6-17.

MYERS N, MITTERMEIER RA, MITTERMEIER CG, FONSECAGAB & KENT J. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403**: 853–858.

NIEMEYER, H. & P. CERECEDA. 1984. Hidrografía. Tomo VIII. Instituto Geográfico Militar. Santiago. Chile.

OLIVER, F.1949. Catálogo de los peces marinos de la zona litoral de Concepción y Arauco. *Boletín de la Sociedad de Biología de Concepción* **17**:75-126.

ORREGO, R.,S. M. ADAMS, R. BARRA, G. CHIANG & J.F. GAVILAN. 2009. Patterns of fish community composition along a river affected by agricultural and urban disturbance in south-central Chile. *Hydrobiología* **620**: 35-46

ORTIZ-SANDOVAL, J., N. ORTIZ, R. CIFUENTES, J. GONZALEZ & E. HABIT. 2009. Respuesta de la comunidad de peces al dragado de ríos costeros de la región del Biobío (Chile). *Gayana* **73**: 64-75.

PIEDRA, P., E. HABIT, A. OYANEDEL, N. COLIN, K. SOLIS-LUFI, J. GONZÁLEZ, A. JARA, N. ORTIZ & R. CIFUENTES. 2012. Patrones de desplazamiento de peces nativos en el Río San Pedro (cuenca del Río Valdivia, Chile). *Gayana* **76**: 59-70.

PIZARRO, J., M. VERGARA, J. MORALES, J. RODRÍGUEZ & I. VILA. 2014. Influence of land use and climate onthe load of suspended solids in catchments of Andean rivers. Environmental monitoring and assessment 186: 835-843

QUEZADA-ROMEGIALLI, C., FUENTES, M. & D. VELIZ. 2010 Comparative population genetics of *Basilicthys microlepidotus* (Atherinifromes: Atherinopsidae) and *Trichomycterus areolatus* (Siluriformes: Trhichomycteridae) in north central Chile. *Environmental Biology of Fishes* **89**: 173-186

REGAN, C. T. 1911. The classification of the teleostean fishes of the order Synentognathi. *The Annals and Magazine of Natural History* **8:** 7327-335.

RUIZ, V. 1993. Ictiofauna del río Andalién. *Gayana Zoología* **57**:109-284.

RUZZANTE, D., S.J. WALDE, V.E. CUSSAC, M.L. DALEBOUT, J. SEIBERT, S. ORTUBAY & E. HABIT. 2006. Phylogeography of the Percichthyidae (Pisces) in Patagonia: roles of orogeny, glaciation, and volcanism. *Molecular Ecology* **15**: 2949-2968.

RUZZANTE, D., S. WALDE, J. GOSSE, V. CUSSAC, E. HABIT, T. ZEMLAK & E. ADAMS 2008. Climate control on ancestral population dynamics: insight from patagonian fish phylogeography. *Molecular Ecology* **17**: 2234-2244.

SALAS, D., D. VELIZ & S. SCOTT. 2012. Diferenciación morfológica en especies del género *Cheirodon* (Ostariophysi: Characidae) mediante morfometría tradicional y geométrica. *Gayana* **76**:142-152.

SCOTT, S., R. PARDO & I. VILA. 2007. Trophic niche overlap between two Chilean endemic species of *Trichomycterus* (Teleostei: Siluriformes). *Revista Chilena de Historia Natural* **80**: 431-437

SOBENES, C., A. GARCÍA, E. HABIT & O. LINK. 2012. Mantención de peces nativos dulceacuícolas de Chile en cautiverio: un aporte a su conservación ex situ. *Boletín de Biodiversidad de Chile* **7**: 27-41

SOBENES, C., LINK, O. & E. HABIT. 2013. Evaluación de velocidades críticas en juveniles de puye grande (*Galaxias platei*) y contraste con la especie invasora trucha café (*Salmo trutta*). XXI Congreso Chileno de Ingeniería Hidráulica. Concepción. 9 págs.

UNMACK, P., A. BENNIN, E. HABIT, P. VICTORIANO & J. JOHNSON. 2009. Impact of ocean barriers, topography and glaciation on phylogeography of the catfish *Trichomycterus areolatus* (Teleostei: Trichomycteridae) in Chile. *Biological Journal of the Linnean Society* **97**: 876-892.

UNMACK, P., J. BARRIGA, M. BATTINI, E. HABIT & J. JOHNSON. 2012. Phylogeography of the catfish *Hatcheria macraei* reveals a negligible role of drainage divides in structuring populations. *Molecular Ecology* **21**: 942-959.

VARGAS, C., M. CONTRERAS & I. VILA. 2002. Edad y crecimiento de *Odontesthes brevianalis* (Gunter 1880) en la laguna Conchalí (31°53'; 71°32'), Chile. *Gayana* **66**: 199-202.

VELIZ, D., L. CATALAN, L. PARDO, P. ACUÑA, A. DIAZ, E. POULIN & I. VILA. 2012. The genus *Basilichthys* (Teleostei:

Atherinopsidae) revisited along its Chilean distribution range (21º to 40º S) using variation in morphology and mtDNA. *Revista Chilena de Historia Natural* **85**: 49-59.

VICTORIANO, P., I. VERA, V. OLMOS, M. DIB, B. INSUNZA, C. MUÑOZ- RAMÍREZ, R. MONTOYA, A. JARA & E. HABIT. 2012. Patrones de diversidad genética de los peces nativos del río San Pedro. *Gayana* **76** (Número Especial): 71-85.

VILA, I. & D. SOTO. 1981a. Age and growth of *Basilichthys australis* (Eigenmann 1927) in Rapel reservoir, Chile. *Studies on Neotropical Fauna and Environment* **16**: 9-22.

VILA, I., SOTO D. & I. BAHAMONDES 1981b. Atherinidae (Pisces) of Rapel Reservoir, Chile. *Internacional Verein Limnologie* **21**: 1334-1338.

VILA, I., M. CONTRERAS & L. FUENTES. 1996. Reproducción de *Diplomystes nahuelbutaensis* Arratia 1987 (Pisces: Diplomystidae). *Gayana Oceanol*. **4**: 129-137.

VILA, I., L. FUENTES & M. CONTRERAS.1999. Peces límnicos de Chile. *Boletín Mueso Nacional de Historia Natural, Chile* **48**:61-75.

VILA, I., M. CONTRERAS, V. MONTECINO, J. PIZARRO & D. ADAMS. 2000. Rapel: A 30 years temperate reservoir. Eutrophication or Contamination? *Ergebnisse der Limnologie* **55**: 31-44.

VILA, I., A. VELOSO., R. SCHLATTER & C. RAMIREZ. 2006. Macrófitas y vertebrados de los sistemas límnicos de Chile.Editorial Universitaria. Santiago Chile. 187 p.

VILA, I. & R. PARDO. 2008. Peces límnicos. Biodiversidad de Chile. Patrimonio y desafíos. Comisión Nacional del Medio Ambiente. Ocho Libros Ed. Santiago Chile.

ZEMLAK T., HABIT, E., WALDE, S., BATTINI, M., ADAMS, E. & RUZZANTE, D. 2009. Across the southern Andes on fin: glacial refugia, drainage reversals and a secondary contact zone revealed by the phylogeographical signal of *Galaxias platei* in Patagonia. *Molecular Ecology*. **17**: 5049-5061.

ZEMLAK T., E. HABIT, S. WALDE, C. CARREA & D. RUZZANTE. 2010. Surviving historical Patagonian landscapes and climate: molecular insights from *Galaxias maculatus*. *BMC Evolutionary Biology* **10**: 67