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Current status of the non-indigenous molluscs in Chile, with the first record of *Otala punctata* (Müller, 1774) (Gastropoda: Helicidae) in the country and new records for *Cornu aspersum* (Müller, 1774) and *Deroceras laeve* (Müller, 1774)

Juan Francisco Araya[a,b]*

[a]*Laboratorio de Invertebrados Acuáticos, Departamento de Ecología, Facultad de Ciencias, Universidad de Chile, Ñuñoa, Chile;* [b]*Laboratorio de Química Inorgánica, Departamento de Química, Facultad de Ciencias, Universidad de Chile, Ñuñoa, Chile*

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A new introduced species, *Otala punctata* (Müller, 1774) and new records in Chile for *Cornu aspersum* (Müller, 1774) and *Deroceras laeve* (Müller, 1774) are documented based on surveys carried out in northern and central areas of the country. The presence and distribution of these alien species are complemented with a comprehensive compilation of all 34 non-indigenous species of marine, freshwater and terrestrial Mollusca in Chile; until 1999, only 16 alien species were known in Chile. Most of these alien species are found exclusively in transformed habitats, few exist in natural environments. The mechanism of introduction for the majority of these non-indigenous species is unknown; however, horticultural development, urban and suburban transformation of original natural habitats, and the aquarium trade are the most likely pathways of introduction. The highest threat of alien species is direct competition and predation of native molluscs, especially the small native land gastropods. Education and continuous field surveys are vital to detect and prevent their propagation as well as to avoid introduction of additional alien taxa.

Keywords: alien species; Chile; land molluscs; *Otala lactea*; *Cornu aspersum*; Mollusca

Introduction

The introduction of non-indigenous species (NIS) of molluscs to Chile almost certainly began with the arrival of the Spanish colonists in the late fifteenth century. However, the oldest confirmed record of introduced molluscs in the country was made by Philippi (1885), who listed three introduced land snail species; *Helix aspersa* (= *Cornu aspersum*), *Helix costata* and *Helix pulchella*, the latter two with no subsequent records in the literature. The last comprehensive review on the distribution of Chilean molluscan species (Valdovinos 1999), listed 13 non-indigenous taxa, with nine terrestrial and four marine species, representing approximately 3% of all the molluscs recorded in the country. Further studies have added 20 new entries to this NIS list, most of them terrestrial gastropods (Kirch

*Email: jfaraya@u.uchile.cl
Present addresses: Programa de Doctorado en Sistemática y Biodiversidad, Departamento de Zoología, Universidad de Concepción, Concepción, Chile; Universidad de Atacama, Copiapó, Chile.

et al. 2009; Cádiz et al. 2013), with a few marine and freshwater species most probably associated with El Niño Southern Oscillation (ENSO) events and with the aquarium trade, respectively (Letelier et al. 2007). Regarding the direct impact of those NIS; it has been established that some alien molluscs, for example species of the genus *Oxychilus* Fitzinger, 1833, can compete with or feed on local native species, especially microgastropods. Alien species can also be invasive or agricultural pests (species of the genera *Deroceras* Rafinesque, 1820; *Otala* Schumacher, 1817 and *Limax* Linnaeus, 1758), and some introduced freshwater mollusc species (species of the genera *Pomacea* Perry, 1811 and *Melanoides* Olivier, 1804) can act as hosts for the parasitic nematode *Angiostrongylus cantonensis* (Chen, 1933) or the parasitic human lung fluke *Paragonimus westermani* Kerbert, 1878. Some introduced molluscan species have indirect impacts on the ecosystem, due to the exploitation of native algae for their aquaculture (species of the genus *Haliotis* Linnaeus, 1758).

Besides documenting for the first time the presence of *Otala punctata* (Müller, 1774) in Chile, and extending the records of *Cornu aspersum* (Müller, 1774) and *Deroceras laeve* (Müller, 1774) for the country, this paper synthesizes all the available records of alien Mollusca recorded so far in the country. This list includes marine, terrestrial and freshwater species that have been introduced into natural environments, species introduced for aquaculture, species whose reports are associated with ENSO events, and species whose introduction was accidental or for which the pathway is unknown. Because little has been published on this group in Chile, information regarding the presence, distribution and possible impacts of these species is crucial for future biodiversity studies.

Methods

A survey of 12 localities in the regions of Iquique, Antofagasta and Atacama, northern Chile, and in the region Metropolitana, central Chile, was made in the southern summer and winter of 2012 and 2013 (Table 1). This information was complemented by an extensive bibliographic compilation on the occurrence of NIS in Chile, compiled from Boyko and Cordeiro (2001), Castilla et al. (2005), Letelier et al. (2007), Ashton et al. (2008), Kirch et al. (2009), Rumi et al. (2010), Landler and Nuñez (2012), Cádiz et al. (2013) and references therein. All the material collected in the field surveys was deposited in the collections of the Museo de Zoología de la Universidad de Concepción (MZUC) and of the Museo Paleontológico de Caldera (MPC).

The systematic affinity, geographical range, ecosystems affected, possible impacts, mode of entry and year of first record are indicated for each species included in this review. The taxonomic status of the 33 species follows the latest published systematic work on each corresponding group; however, no formal taxonomic changes are proposed here. The terminology on bioinvasion follows the definitions proposed by Occhipinti-Ambrogi and Galil (2004), Appendix C. Abbreviations by scale and impact include: EA, Established Alien; IA, Invasive Alien; NA, Noxious Alien; UA, Unestablished Alien. Abbreviations by mode of entry include: I, Introduced Alien; II, Intentional Introduction; SI, Secondary Introduction; SA, Spreading Alien; UI, Unintentional Introduction.

Table 1. New records of *Otala punctata, Cornu aspersum* and *Deroceras laeve* in Chile.

Pulmonata
Limacoidea
Agriolimacidae
Deroceras laeve (Müller, 1774). 2 sppm collected in house gardens, under stones and plant pots, Caldera (27°4′13″ S, 70°49′45″ W), MZUC 39624 (1 spm); 3 sppm collected in house gardens, Tierra Amarilla (27°29′58″ S, 70°16′0″ W), MZUC 39625 (1 spm).
Helicoidea
Helicidae
Cantareus aspersus (Müller, 1774). 18° S to 43° S, EA, I. 4 sppm collected at house gardens, Iquique (20°16′26″ S, 70°7′50″ W), MPC 39626 (1 spm); 6 sppm collected at a public park and in house gardens, Antofagasta (23°40′16″ S, 70°24′22″ W), MPC 39627 (1 spm); 5 sppm collected under shrubs in a public park, Caldera Caldera (2, MZUC 39628 (1 spm), 7°4′13″ S, 70°49′45″ W), 1 spm collected in a public park, Copiapó (27°23′57″ S, 70°18′23″ W), MPC 39629 (1 spm); 3 sppm collected in house gardens, Tierra Amarilla (27°29′58″ S, 70°16′0″ W), MPX 39630 (1 spm), 2 sppm collected in public park, Vallenar (28°34′27″ S, 70°46′11″ W), MPC 39631 (1 spm).
Otala punctata (Müller, 1774), 33° S, UA, I. 2 sppm collected attached to fence-posts in a vineyard, Buin, Santiago (33°44′17″ S, 70°45′06″ W). MZUC 39632 (1 spm).

Abbreviations: MPC, Museo Paleontológico de Caldera; MZUC, Museo de Zoología de la Universidad de Concepción; spm, specimen; sppm, specimens. Abbreviations by scale and impact: EA, Established Alien; UA, Unestablished Alien; by mode of entry: I, Introduced Alien.

Results

Systematic list

Class **BIVALVIA** Linnaeus, 1758
Order **MYTILOIDA** Férussac, 1822
Family **MYTILIDAE** Rafinesque, 1815
Genus **Mytilus** Linnaeus, 1758
Mytilus galloprovincialis Lamarck, 1819

Description

Poppe and Goto (2000).

Distribution

Native to the Mediterranean Sea, this mussel now shows a worldwide distribution (Westfall and Gardner 2010). In Chile, it was recorded for the first time in 2000 (Daguin and Borsa 2000), and it has been recorded from Dichato (36°33′ S, 72°56′ W) to Punta Arenas (53°10′ S, 70°56′ W) (Tarifeño et al. 2012).

Possible mechanism of introduction/Status

Maritime transport or unintentional introduction/established (Daguin and Borsa 2000; Tarifeño et al. 2012).

Remarks

Invasive species, may displace native mytilid species (Branch and Steffani 2004). EA, SA.

Order **OSTREOIDA** Férussac, 1822
Family **OSTREIDAE** Rafinesque, 1815
Genus ***Crassostrea*** Sacco, 1897
Crassostrea gigas (Thunberg, 1793)

Description

Osorio (2002), Coan and Valentich-Scott (2012).

Distribution

Native to Japan and Korea and the North Atlantic Ocean (Coan and Valentich-Scott 2012). This species is usually introduced through aquaculture (Diederich et al. 2005). In Chile this species was introduced in 1978 and has been recorded from latitude 15° S to 40° S (Valdovinos 1999).

Possible mechanism of introduction/Status

Intentional transplantation/unestablished (Valdovinos 1999).

Remarks

Filter feeder, invasive species, species of commercial importance (Diederich et al. 2005). UA, II.

Order **PECTINOIDA** Gray, 1854
Family **PECTINIDAE** Rafinesque, 1815
Genus ***Pecten*** O. F. Müller, 1776
Pecten maximus (Linnaeus, 1758)

Description

Poppe and Goto (2000).

Distribution

Native to Europe, Eastern Atlantic Ocean (Poppe and Goto 2000). The only record for Chile does not give a precise distribution (Valdovinos 1999), although attempts at its aquaculture in Chile were made in La Herradura Bay, Coquimbo (30° S).

Possible mechanism of introduction/Status

Intentional transplantation/unestablished (Valdovinos 1999).

Remarks

Filter feeder, species of commercial importance (Poppe and Goto 2000). UA, II.

Class **GASTROPODA** Cuvier, 1795
Order **CAENOGASTROPODA** Cox, 1960
Family **AMPULLARIIDAE** Gray, 1854
Genus ***Pomacea*** Perry, 1810
Pomacea bridgesii (Reeve, 1856)

Description

Reeve (1856), Coelho et al. (2012).

Distribution

Native to America, Amazon Basin (Brazil, Peru, Bolivia) (Cowie and Thiengo 2003). In Chile, this species was found for the first time in the country in 2000 (Letelier et al. 2007) and has been recorded only in Santiago (33°27′ S, 70°38′ W).

Possible mechanism of introduction/Status

Aquarium trade/established (Letelier et al. 2007).

Remarks

Polyphagous, invasive, they can compete with native freshwater species (Aditya and Raut 2001). EA, I.

Pomacea canaliculata (Lamarck, 1822)

Description

Estebenet and Martín (2003), Rawlings et al. (2007), Jackson and Jackson (2009).

Distribution

Native to America, Uruguay and Argentina (Jackson and Jackson 2009), invasive in the USA (Rawlings et al. 2007) and in South-East Asia (Cowie 2000). In Chile this species has been found only in the Estero Conchalí, Los Vilos (31°55′ S, 71°31′ W), Región de Coquimbo, central Chile (Jackson and Jackson 2009).

Possible mechanism of introduction/Status

Aquarium trade/established (Jackson and Jackson 2009).

Remarks

Omnivorous, invasive, may predate native species (Cazzaniga 1990; Kwong et al. 2009). This species can also act as an intermediate host of the parasitic nematode *Angiostrongylus cantonensis* (Yang et al. 2013). EA, I.

Family **THIARIDAE** Gill, 1871
Genus ***Melanoides*** Olivier, 1804
Melanoides maculata Bruguière, 1789

Description

Moneva et al. (2012).

Distribution

Native to Asia, Philippines. In Chile this species has been found only in the Lluta river (18°24′ S, 70°19′ W), Región de Arica y Parinacota (Letelier et al. 2007).

Possible mechanism of introduction/Status

Aquarium trade/established (Letelier et al. 2007).

Remarks

Detritivore, invasive (parthenogenetic species). This is a common aquarium snail. EA, I.

Melanoides tuberculata (Müller, 1774)

Description

Olivares and Gálvez (2008).

Distribution

Native to southern Asia (China, Taiwan and Philippines) (Letelier et al. 2007). In Chile this species has been found only in Pica (20°29′ S, 69°19′ W), Región de Arica y Parinacota (Olivares and Gálvez 2008).

Possible mechanism of introduction/Status

Aquarium trade/established.

Remarks

Herbivore, detritivore, invasive (parthenogenetic species). This is a common aquarium snail and it has been cited as an intermediate host of the human liver fluke (Dundee and Paine 1977). EA, NA, I.

Order: **LITTORINIMORPHA** Golikov and Starobogatov, 1975
Family **RANELLIDAE** Gray, 1854
Genus ***Monoplex*** Perry, 1810
Monoplex keenae (Beu, 1970)

Description

Keen (1971), Beu (2010).

Distribution

Native to America, from La Paz, Gulf of California (Mexico) to Galápagos Islands (Ecuador) (Beu 2010). In Chile this species has been found only in La Rinconada, Antofagasta Bay (23°28′ S, 70°30′ W), recorded for the first time in the country in 2007 (Ashton et al. 2008).

Possible mechanism of introduction/Status

Associated to ENSO events/established (Ashton et al. 2008).

Remarks

Carnivorous species (Beu 2010). This species is consumed by locals in northern Chile, where it is named *caracol perro* (= dog snail) (Ashton et al. 2008). EA, SA.

Monoplex wiegmanni (Anton, 1838)

Description

Keen (1971), Beu (2010).

Distribution

Native to America, Baja California to Southern Peru (Beu 2010). In Chile this species has been recorded only in Antofagasta Bay (23°28′ S, 70°30′ W), Región de Antofagasta (Castilla et al. 2005).

Possible mechanism of introduction/Status

Associated with ENSO events/unestablished (Castilla et al. 2005).

Remarks

Carnivore (Beu 2010). UA, SA.

Family **TATEIDAE** Thiele, 1925
Genus ***Potamopyrgus*** Stimpson, 1865
Potamopyrgus antipodarum (Gray, 1843)

Description

Collado (2014).

Distribution

Native to New Zealand and its adjacent islands and invasive in North America and Europe (Winterbourn 1970; Kerans et al. 2005). In Chile this species has been recorded in the city of Santiago in the Parque O'Higgins (33°28′ S, 70°39′ W), and Estero La Dehesa (33°22′ S, 70°15′ W), and in the city of Salamanca, central Chile, in the Chalinga River (31°46′ S, 70°59′ W) and in the Estero Consuelo (31°46′ S, 70°37′ W) (Collado 2014).

Possible mechanism of introduction/Status

Unknown/established (Collado 2014).

Remarks

Generalist species, feeding on aquatic plants, green algae and detritus (Haynes and Taylor 1984). Invasive, ovoviviparous species. EA, I.

Order **ANASPIDEA** Fischer, 1883
Family **APLYSIIDAE** Lamarck, 1809
Genus ***Aplysia*** Linnaeus, 1767
Aplysia juliana Quoy and Gaimard, 1832

Description

Marcus (1955).

Distribution

Circumtropical; eastern and western Atlantic (Marcus 1955) as well as the Indian and Pacific Oceans (Kay 1964), in shallow marine habitats. In Chile this species has been recorded in Iquique (20°11′ S, 70°08′ W), Antofagasta (23°38′ S, 70°24′ W) and Taltal (25°24′ S, 70°29′ W) (Castilla et al. 2005). This species was found for the first time in Antofagasta in 1982 (Tomicic 1985), associated with ENSO events.

Possible mechanism of introduction/Status

Associated with ENSO events/unestablished (Castilla et al. 2005).

Remarks

This is a large herbivorous marine slug, feeding almost exclusively on the alga *Ulva lactuca* (Frings and Frings 1965). UA, SA.

Order **STYLOMMATOPHORA** Schmidt, 1855
Family **ACHATINELLIDAE** Gulick, 1873
Genus ***Pacificella*** Odhner *in* Skottsberg, 1922
Pacificella variabilis (Odhner, 1922)

Description

Odhner (1922), Cooke and Kondo (1960).

Distribution

Native to Henderson Island (Preece 1995), widespread in the South Pacific Islands from Western Polynesia (Samoa, Tonga) throughout southeastern Polynesia to Easter Island (Kirch et al. 2009). In Chile this species has been recorded only in Easter Island (39°48′ S, 73°14′ W) (Stuardo and Vega 1985; Stuardo and Vargas-Almonacid 2000), and it was found for the first time in Chile by Odhner (1922).

Possible mechanism of introduction/Status

Human transportation/established (Stuardo and Vargas-Almonacid 2000).

Remarks

Although this species was described as native to Easter Island (Odhner 1922), it is probably native to Henderson Island, where some fossil shells are present in sedimentary deposits pre-dating human settlement (Preece 1995). EA, UI.

Family **SUBULINIDAE** Fischer and Crosse, 1877
Genus ***Allopeas*** Baker, 1935
Allopeas clavulinum (Potiez and Michaud, 1838)

Description

Pilsbry (1906).

Distribution

Native to East Africa (Hayes et al. 2012). In Chile this species has been reported only from Easter Island (39°48′ S, 73°14′ W), with the first record in 1965 (Kirch et al. 2009).

Possible mechanism of introduction/Status

Human transportation/unestablished (Kirch et al. 2009).

Remarks

Detritivore, herbivore (Brodie and Barker 2011). UA, I.

Allopeas gracile (Hutton, 1834)

Description

Pilsbry (1906).

Distribution

Native range uncertain; this species is currently widespread in the tropics (Rowson et al. 2010). In Chile this species has been reported only from Easter Island (39°48′ S, 73°14′ W) (Boyko and Cordeiro 2001).

Possible mechanism of introduction/Status

Human transportation/probably established (Boyko and Cordeiro 2001).

Remarks

Detritivore, herbivore (Brodie and Barker 2011). EA, I.

Genus ***Rumina*** Risso, 1826

Rumina decollata (Linnaeus, 1758)

Description

Paul (1982), De Francesco and Lagiglia (2007).

Distribution

Europe, Mediterranean basin/Cosmopolitan (Cowie 2001), invasive in Far East and South America (Miquel et al. 1995). The first and only record for Chile does not give precise data (Rumi et al. 2010).

Possible mechanism of introduction/Status

Human transportation/unestablished

Remarks

Omnivorous and invasive species, minor plant pest, it may prey on other gastropods (Barker 2004). UA, I.

Family **AGRIOLIMACIDAE** Wagner, 1935
Genus ***Deroceras*** Rafinesque, 1820
Deroceras invadens Reise, Hutchinson, Schunack and Schlitt, 2011

Description

Barker (1999), Reise et al. (2011).

Distribution

Palaeartic/Cosmpolitan (Reise et al. 2011). According to Hutchinson et al. (2014) this species has records in Chile since 1962 (as *Deroceras panormitanum* Lessona and Pollonera, 1882), and it has been recorded in Limache (33°00′ S, 71°23′ W), Santiago (33°24′ S, 70°36′ W), Talagante (33°42′ S, 70°52′ W) and in the Juan Fernández Archipelago.

Possible mechanism of introduction/Status

Human transportation/established.

Remarks

Invasive species (Hutchinson et al. 2014). EA, IA, I.

Deroceras laeve (Müller, 1774)

Description

Thomas et al. (2010).

Distribution

Native to North America and introduced in Europe, New Zealand and South America (Faberi et al. 2006). In Chile this species has been recorded from Caldera (27° S), northern Chile (new records in this work, Table 1), to latitude 46° S, in the Región de Aysén del General Carlos Ibáñez del Campo (Letelier and Ramos 2002). The first record of this species in Chile was by Stuardo and Vega (1985).

Possible mechanism of introduction/Status

Human transportation/established (Landler and Nuñez 2012)

Remarks

This species has been cited as a pest of crops, feeding on seeds and seedlings (Faberi et al. 2006). EA, I.

Deroceras reticulatum (Müller, 1774)

Description

Martín et al. (2009), Thomas et al. (2010).

Distribution

Native to Europe and currently found in most of North America and many temperate and subtropical countries (Boyko and Cordeiro 2001). In Chile this species has been found from Valparaíso to Tierra del Fuego (Valdovinos 1999) and in the Juan Fernández Archipelago and Easter Island (Boyko and Cordeiro 2001.). The first record of this species in Chile was by Stuardo and Vega (1985).

Possible mechanism of introduction/Status

Human transportation/established (Letelier and Ramos 2002)

Remarks

Herbivore, agricultural pest (Hausdorf 2002). This species has also been identified as an intermediate host of nematode parasites *Angiostrongylus costaricensis* Morera and Cespedes, 1971 and *Angiostrongylus cantonensis* (Chen, 1933) (Maurer et al. 2002). EA, NA, I.

Genus ***Lehmannia*** Heynemann, 1862
Lehmannia valentiana (Férussac, 1823)

Description

Barker (1999), Thomas et al. (2010).

Distribution

Native to the Iberian Peninsula, Europe, now Cosmopolitan (Thomas et al. 2010). In Chile this species has been found from Valparaíso to Chiloé and in the Juan Fernández Archipelago and Easter Island (Stuardo and Vega 1985; Boyko and Cordeiro 2001). It was recorded for the first time in the country as *Limax arborum* Bouchard-Chantereaux, 1837 (Odhner 1922).

Possible mechanism of introduction/Status

Human transportation/probably established (Valdovinos 1999).

Remarks

Herbivore, detritivore, greenhouse pest (Thomas et al. 2010). EA, I.

Genus ***Limacus*** Lehmann, 1864
Limacus flavus Linnaeus, 1758

Description

Thomas et al. (2010).

Distribution

Native to Europe; introduced to Australia, New Zealand, and North and South America (Thomas et al. 2010). In Chile this species has been cited from Valdivia (39°48′ S, 73°14′ W) to northern Chile (Landler and Nuñez 2012). The first record of this species for Chile was by Stuardo and Vega (1985).

Possible mechanism of introduction/Status

Human transportation/established (Valdovinos 1999).

Remarks

Highly invasive species, pest of stored agricultural products (Thomas et al. 2010). EA, NA, I.

Genus ***Limax*** Linnaeus, 1758
Limax maximus Linnaeus, 1758

Description

Thomas et al. (2010).

Distribution

Western Palaearctic, introduced into North and South America, South Africa, Pacific Islands, Australia and New Zealand (Gaitán-Espitia et al. 2012). In Chile this species has been cited from 30° to 46° (Valdovinos 1999; Letelier and Ramos 2002).

Possible mechanism of introduction/Status

Human transportation/established (Landler and Nuñez 2012).

Remarks

Synanthropic species, potential carrier of human pathogens (Landler and Nuñez 2012). Nocturnal species, aggressive towards other slugs (Gaitán-Espitia et al. 2012). EA, I.

Family **ARIONIDAE** Gray *in* Turton, 1840
Genus ***Arion*** Férussac, 1819
Arion intermedius (Normand, 1852)

Description

Cádiz and Gallardo (2007).

Distribution

Native to the Holarctic, in Chile this species has been found from Valdivia (39°48′ S, 73°14′ W) to Lago Tarahuin (42°43′ S, 73°47′ W), with the first record in 2007 (Cádiz and Gallardo 2007; Landler and Nuñez 2012).

Possible mechanism of introduction/Status

Human transportation/established (Landler and Nuñez 2012).

Remarks

Herbivorous terrestrial gastropod (Bohan et al. 2000). According to Hausdorf (2002), there are no obvious effects on native land snail fauna after the introduction of this species. EA, I.

Family **HELICIDAE** Rafinesque, 1815
Genus ***Cornu*** Born, 1778
Cornu aspersum (Müller, 1774)

Description

Paul (1982), Barker (1999).

Distribution

Native to Western Europe and Mediterranean region, now cosmopolitan (Cowie 2000). This is the NIS with the oldest occurrence records in Chile (Philippi 1885) and the introduced species with the largest distribution in the country, found in this work (Tables 1, 2) from Iquique (20° S) to Chiloé Island (43° S).

Possible mechanism of introduction/Status

Human transportation/established (Araya and Catalán 2014).

Remarks

Herbivore, agricultural pest, invasive (Barker 1999). This species has a complicated, unresolved, taxonomy (Bank 2012). EA, I.

Table 2. Systematic-taxonomic classification, distribution, Scale/Impact and Mode of Entry of non-indigenous species of Mollusca in Chile.

Bivalvia
Pteriomorpha
Mytiloida
Mytilidae
Mytilus galloprovincialis Lamarck, 1819. 36° S to 53° S, EA, SA.
Ostreoidea
Ostreidae
Crassostrea gigas (Thunberg, 1793). 15° S to 40° S, UA, II.
Pectinoidea
Pectinidae
Pecten maximus (Linnaeus, 1758). Imprecise distribution, UA, II.

Gastropoda
Caenogastropoda
Ampullaroidea
Ampullariidae
Pomacea bridgesii (Reeve, 1856). 33° S, EA, I.
Pomacea canaliculata (Lamarck, 1822). 31° S, EA, I.
Cerithioidea
Thiaridae
Melanoides maculata Bruguière, 1789. 18° S, EA, I.
Melanoides tuberculata (O. F. Müller, 1774). 20° S, EA, NA, I
Tonnoidea
Ranellidae
Monoplex keenae Beu, 1970. 23° S, EA, SA.
Monoplex wiegmanni (Anton, 1838). 23° S, UA, SA.
Truncatelloidea
Tateidae
Potamopyrgus antipodarum (Gray, 1843). 31° S and 32° S, EA, I.
Heterobranchia
Aplysioidea
Aplysiidae
Aplysia (Aplysia) juliana (Quoy & Gaimard, 1832). 23° S to 25° S, UA, SA.
Pulmonata
Achatinelloidea
Achatinellidae
Pacificella variabilis (Odhner, 1922). 39° S, EA, UI.
Achatinoidea
Subulinidae
Allopeas clavulinum (Potiez & Michaud, 1838). 39° S, UA, I.
Allopeas gracile (Hutton, 1834). 39° S, EA, I.
Rumina decollata (Linnaeus, 1758). Imprecise distribution, UA, I.
Helicoidea
Helicidae
Cornu aspersum (Müller, 1774). 18° S to 43° S, EA, I.
Otala lactea (Müller, 1774). Imprecise distribution, UA, I.
Otala punctata (Müller, 1774), 33° S, UA, I.

(*Continued*)

Table 2. (Continued).

Limacoidea
Agriolimacidae
Deroceras invadens Reise, Hutchinson, Schunack and Schlitt, 2011. 33° S, EA, IA, I.
Deroceras laeve (Müller, 1774). 27° S to 46° S, EA, I.
Deroceras reticulatum (Müller, 1774). 32° S to 55° S, EA, NA, I.
Lehmannia valentiana (Férussac, 1823). 32° S to 45° S, EA, I
Limacus flavus Linnaeus, 1758. 18° S to 39° S, EA, NA, I.
Limax maximus Linnaeus, 1758. 30° S to 46° S, EA, I.
Arion intermedius (Normand, 1852). 39° S to 43° S, EA, I.
Lymnaeoidea
Physidae
*Haitia venustula (*Gould, 1847). 29° S to 31° S, EA, UI.
Vitrinoidea
Milacidae
Milax gagates (Draparnaud, 1801). 30° S to 45° S, EA, I.
Zonitidae
Oxychilus alliarius (Miller, 1822). 29° S to 39° S, EA, I.
Oxychilus cellarius Müller (1774). 30° S to 45° S, EA, I.
Punctoidea
Endodontidae
Paralaoma servilis (Shuttleworth, 1852). 39° S, EA, I.
Pupilloidea
Vertiginidae
Gastrocopta pediculus (Shuttlerworth, 1852). 39° S, UA, I.
Gastrocopta servilis (Gould, 1843). 39° S, UA, I.
Vetigastropoda
Haliotoidea
Haliotidae
Haliotis discus hannai Ino, 1953. 27° S, UA. II.
Haliotis rufescens Swainson, 1822. 27° S, 41° S to 46° S, UA, II.

Abbreviations: EA, Established Alien; IA, Invasive Alien; I, Introduced Alien; II, Intentional Introduction; NA, Noxious Alien; SA, Spreading Alien; UA, Unestablished Alien; UI, Unintentional Introduction.

Genus ***Otala*** Schumacher, 1817
Otala lactea (Müller, 1774)

Description

Abbott (1989).

Distribution

Native to countries bordering the western Mediterranean Sea (Iberian Peninsula and northwest Africa) (Herbert and Sirgel 2001). The first and only record for Chile did not give precise data (Rumi et al. 2010).

Possible mechanism of introduction/Status

Human transportation/unestablished.

Remarks

Generalist herbivore, possibly invasive, garden and horticultural pest (La Pierre et al. 2010). UA. I.

Otala punctata (Müller, 1774)

Description

De Mattia and Mascia (2011).

Distribution

Western Mediterranean: northwest Algeria, eastern Spain and the Balearic Islands (De Mattia and Mascia 2011). This is the first record for this species in the country: Buin, Santiago (33°43′59″ S; 70°45′00″ W) (Tables 1, 2).

Possible mechanism of introduction/Status

Human transportation/unestablished.

Remarks

Herbivore, invasive. This species is widely raised in heliciculture (De Mattia and Mascia 2011). UA, I.

Family **MILACIDAE** Ellis, 1926

Genus ***Milax*** Gray, 1855

Milax gagates (Draparnaud, 1801)

Description

Barker (1999), Thomas et al. (2010).

Distribution

Native to Europe, Mediterranean basin. Introduced in North America, Australia, New Zealand, Japan, South America, and numerous Atlantic and Pacific Islands (Thomas et al. 2010). In Chile this species has been cited from latitude 30° S to 45° S and in the Juan Fernández Archipelago and Easter Island (Valdovinos 1999). The first record of this species for Chile was by Stuardo and Vega (1985).

Possible mechanism of introduction/Status

Human transportation/established (Valdovinos 1999).

Remarks

Herbivore, invasive and common in areas associated with humans; it is predominantly a subterranean species and a pest of root crops (Barker 1999). EA, I.

Family **OXYCHILIDAE** Hesse, 1926 (1879)
Genus ***Oxychilus*** Fitzinger, 1833
Oxychilus alliarius (Miller, 1822)

Description

Cádiz et al. (2013).

Distribution

Native to Western Europe/Cosmopolitan (Horácková and Juricková 2009). In Chile this species has been recorded in Las Rojas, Coquimbo region (29°54′ S, 71°10′ W), in the Arboretum Park, Isla Teja, Valdivia (39°50′ S, 73°14′ W) and in the Juan Fernández Archipelago (Cádiz et al. 2013). The first record of this species for Chile was by Odhner (1922).

Possible mechanism of introduction/Status

Human transportation/established (Cádiz et al. 2013).

Remarks

Carnivore, facultative predator of other small snails (Meyer and Cowie 2010). This species is known as the "garlic snail" because of its ability to emit a strong smell of garlic when irritated (Hayes et al. 2012). EA, I.

Oxychilus cellarius Müller (1774)

Description

Rigby (1963), Barker (1999).

Distribution

Native to western and central Europe and the western Mediterranean, introduced to Scandinavia, North and South America, the Philippines, South Africa, St Helena, Australia and New Zealand (Barker 1999). In Chile this species has been recorded between 30° S and 45° S (Letelier and Ramos 2002), and in the Juan Fernandez Archipelago (Stuardo and Vega 1985). The first record of this species for Chile was by Stuardo and Vega (1985).

Possible mechanism of introduction/Status

Human transportation/established (Cádiz et al. 2013).

Remarks

Carnivorous species (Cádiz et al. 2013). EA, I.

Family **PUNCTIDAE** Morse, 1864
Genus ***Paralaoma*** Iredale, 1913
Paralaoma servilis (Shuttleworth, 1852)

Description

Christensen et al. (2012).

Distribution

Native to New Zealand, widespread worldwide (Christensen et al. 2012). In Chile this species has been found only on Easter Island (39°48′ S, 73°14′ W), Región de Valparaiso (Kirch et al. 2009).

Possible mechanism of introduction/Status

Human transportation/established (Kirch et al. 2009).

Remarks

Detritivore, invasive. This species has a historically complex taxonomy (Falkner et al. 2002). EA, I.

Family **GASTROCOPTIDAE** Pilsbry, 1918
Genus ***Gastrocopta*** Wollaston, 1878
Gastrocopta pediculus (Shuttleworth, 1852)

Description

Pilsbry 1916–1918.

Distribution

Widely distributed among tropical Pacific islands, probably native to Indonesia and the tropical western Pacific (Brook et al. 2010). In Chile, this species has been reported only from Easter Island (39°48′ S, 73°14′ W), Región de Valparaiso (Boyko and Cordeiro 2001).

Possible mechanism of introduction/Status

Human transportation/unestablished (Boyko and Cordeiro 2001).

Remarks

Detritivore (Brodie and Barker 2011). UA, I.

Gastrocopta servilis (Gould, 1843)

Description

Pilsbry 1916–1918; Whisson and Köhler (2013).

Distribution

Probably native to the Caribbean, Central America and Brazil (Brook et al. 2010). In Chile this species has been reported only from Easter Island (39°48′ S, 73°14′ W), Región de Valparaiso (Kirch et al. 2009).

Possible mechanism of introduction/Status

Human transportation/unestablished (Kirch et al. 2009).

Remarks

Detritivore, could compete with native species (Brodie and Barker 2011). UA, I.

Family **PHYSIDAE** Fitzinger, 1833
Genus ***Haitia*** Clench and Aguayo, 1932
Haitia venustula (Gould 1847)

Description

Gould (1847), Biese (1949) (as *Physa nodulosa* Biese, 1949).

Distribution

Native to South America, from northern Peru to central Chile (Núñez and Pelichotti 2003), introduced in Argentina (Miquel 1985). In Chile this species has been cited (as *Physa nodulosa*) for the Limari, Illapel and Elqui (29° S to 31° S) (Miquel 1985).

Possible mechanism of introduction/Status

Cryptogenic/record dubious (Taylor 2003).

Remarks

Cryptogenic freshwater gastropod species, it may represent a native species. EA, UI.

Subclass **VETIGASTROPODA**
Family **HALIOTIDAE** Rafinesque, 1815
Genus ***Haliotis*** Linnaeus, 1758
Haliotis discus hannai Ino, 1953

Description

Geiger and Owen (2012).

Distribution

Native to coastal waters of East Asia (Geiger and Owen 2012). In Chile this species is commercially harvested, with aquaculture farms in Caldera (27° S), northern Chile (Valdovinos 1999). It was first introduced to the country in 1982 (Flores-Aguilar et al. 2007).

Possible mechanism of introduction/Status

Imported to Chile for aquaculture (Castilla et al. 2005; Flores-Aguilar et al. 2007).

Remarks

Herbivorous species, this species has an indirect impact on the communities of the native rocky kelp *Lessonia nigrescens* and *Lessonia trabeculata*, which are used as abalone food in Chilean aquaculture facilities (Castilla et al. 2005; Flores-Aguilar et al. 2007). This species is also a primary introduction vector for the non-indigenous boring polychaete species *Polydora uncinata* Sato-Okoshi, 1998 (Radashevsky and Olivares 2005). UA, II.

Haliotis rufescens Swainson, 1822

Description

Geiger and Owen (2012).

Distribution

East coast of the Pacific Ocean from Sunset Bay, Oregon, USA, to El Rosario, Baja California, Mexico (Mardones et al. 2013). In Chile this species is found around Caldera (27° S) and in the Región de Los Lagos (41° S to 46° S), only in aquaculture farms (Valdovinos 1999), with the first introduction to the country in 1977 (Flores-Aguilar et al. 2007).

Possible mechanism of introduction/Status

Imported to Chile for aquaculture (Flores-Aguilar et al. 2007).

Remarks

Herbivorous species, this species has an indirect impact on the communities of the native rocky kelp *Lessonia nigrescens* and *Lessonia trabeculata*, which are used as abalone food in the local aquaculture facilities (Castilla et al. 2005; Flores-Aguilar et al. 2007). This species is also a primary and secondary introduction vector in Chile for the non-indigenous boring polychaete species *Dipolydora huelma* Sato-Okoshi and Takatsuka, 2001*; Dodecaceria cf. opulens* Gravier, 1908; *Polydora rickettsi* Woodwick, 1961 and *Terebrasabella heterouncinata* Fitzhugh and Rouse, 1999 (Moreno et al. 2006). UA, II.

Discussion

A total of 34 introduced species in 19 families are documented, including 20 terrestrial gastropods, eight marine species (gastropods and bivalves) and six freshwater gastropods (Table 2). Taxa in the families Haliotidae, Ostreidae and Pectinidae include species that are cultivated for export, with no records in natural environments in Chile (Castilla et al. 2005; Castilla and Neill 2009). *Mytilus galloprovincialis*, the only marine NIS in Bivalvia, is found in natural environments associated with banks of the native species *Mytilus edulis* in the Bay of Concepción, central Chile (Tarifeño et al. 2012). Other marine species include the gastropods *Aplysia juliana, Monoplex keenae* and *Monoplex wiegmanni*, all of which are associated with ENSO events (Castilla et al. 2005) and whose records may represent natural southern range extensions of their corresponding natural tropical distributions.

All of the 20 recorded introduced terrestrial Gastropoda species are ground-dwellers, and they are all associated (together with freshwater species) with human-disturbed habitats (Table 2). Ten of these terrestrial species have been recorded in Easter Island alone (Boyko and Cordeiro 2001; Kirch et al. 2009) which, however, has a single species of native land mollusc: the subfossil snail species *Hotumatua anakenana* Kirch, Christensen and Steadman, 2009; now extinct (Kirch et al. 2009). The remaining invasive species are distributed in continental Chile, mostly in specific locations along the southern part of the country (Cádiz and Gallardo 2007; Rumi et al. 2010; Landler and Nuñez 2012). Among these, species of the genus *Oxychilus* have been cited as particularly dangerous to native micromolluscs, preying selectively on them (Cádiz et al. 2013). Freshwater species include six gastropods, five of them widely known as invasive molluscs (Olivares and Gálvez 2008; Jackson and Jackson 2009; Collado 2014) and a cryptogenic species of Physidae, *Haitia venustula*, recently transferred from genus *Physa* Draparnaud, 1801, and which may possibly constitute a native species (Miquel 1985; Taylor 2003). Dubious records include the species *Otala lactea* – a species easily misidentified with the congeneric *Otala punctata* – and *Rumina decollata*, both species listed from Chile but without any geographic reference or further information (Rumi et al. 2010).

The first record of *Otala punctata* is made here from two locations near agricultural land in the commune of Buin, Region Metropolitana, in central Chile (Table 1). The species is widespread worldwide and is a minor plant pest. Even when only a pair of specimens was collected, the potential proliferation of this species may approach that of *Cornu aspersum* in Chile. *Cornu aspersum* and *Deroceras laeve* were found in gardens, greenhouses, and monoculture plantations in the cities of Vallenar, Tierra

Amarilla, Copiapó, Caldera, Antofagasta and Iquique, in northern Chile (Table 2). *Cornu aspersum* was previously recorded in Chile only from Caldera (27° S) to Chiloé Island (42° S), including Easter Island and the Juan Fernández Archipelago (Araya and Catalán 2014), whereas *Deroceras laeve* had been recorded from latitudes 30° S to 40° S (Valdovinos 1999). The northern distribution in Chile for *C. aspersum* and *D. laeve* is therefore extended here by about 1084 km. Fortunately, both of these species (*C. aspersum* and *D. laeve*) have never been recorded in natural environments and it seems that they are restricted to transformed habitats in general.

Regarding impacts by NIS, apart from the obvious invasive threats, the aquaculture of *Haliotis* species in particular has an indirect negative impact on communities of indigenous algae (*Lessonia trabeculata*, *Macrocystis pyrifera* and *Gracilaria chilensis*) which are collected and processed to feed these abalone species (Flores-Aguilar et al. 2007). These haliotid species also constitute introduction vectors for non-indigenous boring polychaete species (Radashevsky and Olivares 2005; Moreno et al. 2006). Regarding freshwater NIS, the introduction of the snails *Pomacea canaliculata* and *Melanoides tuberculata* poses a risk as both of these species have been documented as potential vectors for trematode parasites (Letelier et al. 2007) and *P. canaliculata* in particular has been listed as a predator of amphibian eggs (Karraker and Dudgeon 2014). The only positive impact of non-indigenous molluscan species relies on the primary production and commercialization of *Crassostrea gigas, Haliotis discus* and *Haliotis rufescens* (2138 tons in 2012) (Servicio Nacional de Pesca 2012).

As a result of this revision, a new record for a molluscan NIS – *Otala punctata* – and new distribution records for the species *Cornu aspersum* and *Deroceras laeve* are given for the Chilean territory, resulting in a total at present of 34 invasive molluscan species recorded in the country. Most (61%) of the molluscan NIS constitute terrestrial taxa, and most (about 45%) of the new arrivals have a European origin. More than half (52%) of all these molluscan NIS were first recorded after the year 2000, doubling the 13 species recorded by Valdovinos (1999), indicating a large increase in the introduction (or recognition) of these species in Chile. Results indicate that the majority of the molluscan NIS in the country are associated with human-dominated/disturbed habitats, with comparatively few species found in natural environments. Among these, the gastropods *Pomacea, Melanoides* and *Oxychilus* have the largest potential negative impact as invasive species and could greatly affect native biota. Taking into account that this is the first comprehensive study compiling all the records of freshwater, marine and terrestrial non-indigenous molluscs in Chile – and that the results indicate a rapid increase in this group in the country – an in-depth study of the distribution, ecological characteristics and impacts of these alien species is of utmost importance. Particularly, it is necessary to study and test their direct effects on the native freshwater and terrestrial species, to eradicate alien species already established in the country, and to prevent further NIS from establishing in the Chilean territory.

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ORCID

Juan Francisco Araya http://orcid.org/0000-0002-4087-9641

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