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Arion intermedius (Gastropoda: Stylommatophora); primer registro de esta babosa introducida en Chile, con notas sobre su anatomía e historia natural

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ABSTRACT

Results and conclusions are presented on morphological and field observations made on a collection of land slugs from the Arboretum and Botanical Garden administered by the Universidad Austral de Chile at Valdivia, as well as various records from other collection sites in southern Chile. Based on some anatomical features, the individuals studied were identified as *Arion intermedius* Normand, 1852, endemic to eastern Europe, and known from various locations around the world for its invasive capacity, apparently facilitated by its feeding habits and particularly by its reproductive strategy of strict self fertilization which is unusual in pulmonates. This is the first report of this species, introduced to Chile by human activities, added to previous literature citing the presence of *Limacidae*, *Agriolimacidae*, and *Helicidae*. This slug is a potential threat to agriculture and to native flora and fauna of Chile.

Key words: Arionidae, *Arion intermedius*, species introduction, invasive potential.

RESUMEN

Se entregan los resultados y conclusiones de las observaciones anatómicas y de campo realizadas sobre un grupo de babosas terrestres capturadas principalmente en el parque Arboretum y Jardín Botánico de la Universidad Austral de Chile, en la ciudad de Valdivia, además de sus hallazgos puntuales en otros puntos del sur de Chile. Los ejemplares analizados corresponden a *Arion intermedius* Normand, 1852, especie endémica del este de Europa conocida en diversos lugares del mundo por su alta capacidad de colonización e invasión, ello aparentemente facilitado por su hábito de alimentación y particularmente su inusual estrategia reproductiva dentro de los pulmonados (autofecundación estricta). De esta manera, registramos una nueva especie introducida antrópicamente en Chile, sumándose de esta forma la familia Arionidae a las ya conocidas Limacidae, Agriolimacidae y Helicidae como una potencial amenaza a la agricultura y a la flora y fauna nativas chilenas.

Palabras clave: Arionidae, *Arion intermedius*, introducción antrópica, potencial invasivo.

INTRODUCTION

The phenomenon of introduction of exotic species to new habitats by man has become increasingly serious in recent decades, mainly due to the expansion of world trade. Important agricultural pests are often transferred inadvertently among seeds, harvests, fruits or by machinery. If these species are successful in becoming established within a previously unaffected country, they may be capable of causing serious economic damage (Hausdorf

2002). Some snail species, particularly the carnivores, are known for their deleterious effects on endemic terrestrial snails, in some cases rapidly exterminating local species. The introduction of non-endemic species needs to be prevented to avoid these problems (Robinson 1999). In any case, if an exotic species is able to establish itself in a country, its identification is the first step in evaluation of its potential impact. If necessary, subsequent steps may be required in application of appropriate control measures (Hausdorf 2002).

Live individuals of the terrestrial slug *Arion intermedius* Normand, 1852 were found during field collecting at the Botanical Garden of the Universidad Austral de Chile (UACH) at Valdivia, as well as in informal collections at Arboretum Park of the UACH, the Valdivian Coastal Reserve, the "El Bosque" Urban Park and along the edge of Highway Route S-91 (Loncoche to Villarrica, Cautín Province). *Arion intermedius* is an herbivorous terrestrial gastropod (Bohan et al. 2000), native to eastern Europe (Kerney et al. 1983). Its introduction has been reported in North and South America, as well as to Africa, Australia, and New Zealand (Chichester & Getz 1969, Barker 1982, 1999, Smith 1989, Robinson 1999, Hausdorf 2002). The main diagnostic characters for slugs of the Family Arionidae, within the Stylommatophora, is the absence of a dorsal keel, distal end of the foot rounded from the dorsal aspect, and pneumostome located in the mid-anterior portion of the mantle on the right side of the specimen (Burch 1962).

For consumers such as the herbivores, environmental heterogeneity in quality food resources can structure the population within a determinate space (McLaughlin & Roughgarden 1992, Hambäck et al. 1998). Thus if we are able to learn the spatial structure of a population of herbivores with respect to the availability of food (plants in this case) it may be possible to infer the preferences and feeding range of the species which can elucidate its capacity for invasiveness and thus the ecological implications of its introduction. Based on this concept we made a survey of the Botanical Garden at UACH to determine the plant species with which this species was associated and the origin, whether native of introduced, of the plant involved. The present report documents these findings, supported by identifications based on diagnostic morphology and meristic data from the samples obtained. Based on the results of the present analyses, we discuss the potential impact of successful adaptation and subsequent dispersion that this species may have on native environments.

MATERIAL AND METHODS

Samples of the slug were collected on various occasions between September 2005 and August

2006, searching in mosses, under leaf litter and rotting logs in the Botanical Garden of the UACH at Valdivia (39°48' S; 73°14' W), Arboretum Park UACH (39°48' S; 73°15' W), the Valdivian Coastal Reserve (39°57' S; 73°34' W), the El Bosque Urban Park (39°50' S; 73°14' W) and along the edge of highway route S-91 (39°17'S; 72°24' W).

The slugs were collected and individually identified and weighed and the sample locations were recorded. Subsequent observations were made on details of the internal and external morphology of the specimens, including the reproductive system and color patterns, with aid of a Lavovet FS® stereoscopic microscope. Illustrations were made with the help of digital photographs of specimens taken through this microscope.

The affinities of the slugs for different plant species were studied at the UACH Botanical Garden in August 2006, examining four floristically varied areas, including sites having native vegetation and sites with introduced vegetation (Table 1). Soil samples of 25 x 25 x 10 cm (length x width x depth) (Bohan et al. 2000) were taken to the laboratory, where the absolute density of the slugs was determined. The slugs were extracted from the soil samples by gradual flooding (Symondson et al. 1996), thus forcing them to the soil surface, where they were collected daily. The specimens were recognized and described following the morphotypes described for this species by Backeljau et al. (1992), based on the color patterns evident on different regions of the body. Samples of our specimens are currently deposited in the Malacology Collection of the Institute of Zoology, Universidad Austral de Chile, Valdivia.

TABLE 1

Details of the plant species involved in the sampling carried out in the UACH Botanical Garden

Detalle de las especies vegetales involucradas en los muestreos realizados en el Jardín Botánico UACH

Site	Species	Family	Origin
1	<i>Selaginella apoda</i>	Selaginellaceae	Introduced
2	<i>Nertera granadensis</i>	Rubiaceae	Native
3	<i>Thuidium chilense</i>	Thuidiaceae	Native
4	<i>Trifolium pratense</i>	Fabaceae	Introduced

RESULTS

External observations of the specimens showed characteristics of the family Arionidae (Burch 1962), including rounded terminal portion of the foot in the dorsal perspective, absence of a dorsal keel, and the

pneumostome situated in the mid-anterior region of the mantle, on the right side (Fig. 1 and 2). Further characteristic, detailed below, identified the species to be *Arion intermedius* Normand, 1852 (sensu Pilsbry 1948, Likharev & Wiktor 1980, Kerney et al. 1983, Barker 1999, Wiktor 2000) (Fig. 3).

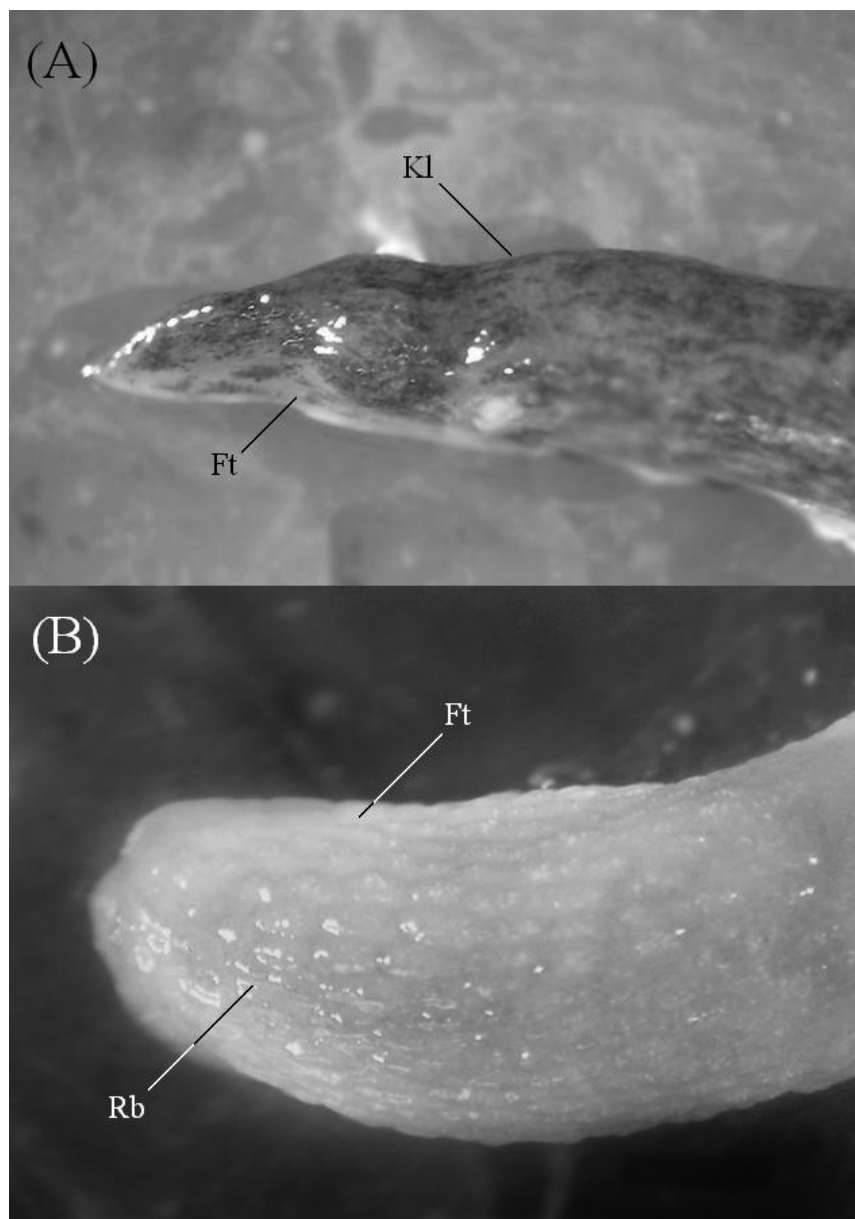


Fig. 1: (A) Extreme distal portion (dorsal view) of *Limax* sp.; (B) same view of *Arion intermedius*. Note the pointed aspect and dorsal keel of (A) compared with the rounded aspect, and absence of dorsal keel of (B). Kl = dorsal keel, Rb = rounded back, Ft = foot.

Extremo posterior (vista dorsal) de *Limax* sp. (A) y de *Arion intermedius* (B). Nótese el extremo aguzado y con una quilla dorsal en *Limax* sp. y el extremo posterior redondeado y carente de quilla dorsal de *A. intermedius*. Kl = quilla dorsal; Rb = dorso redondeado; Ft = pie.

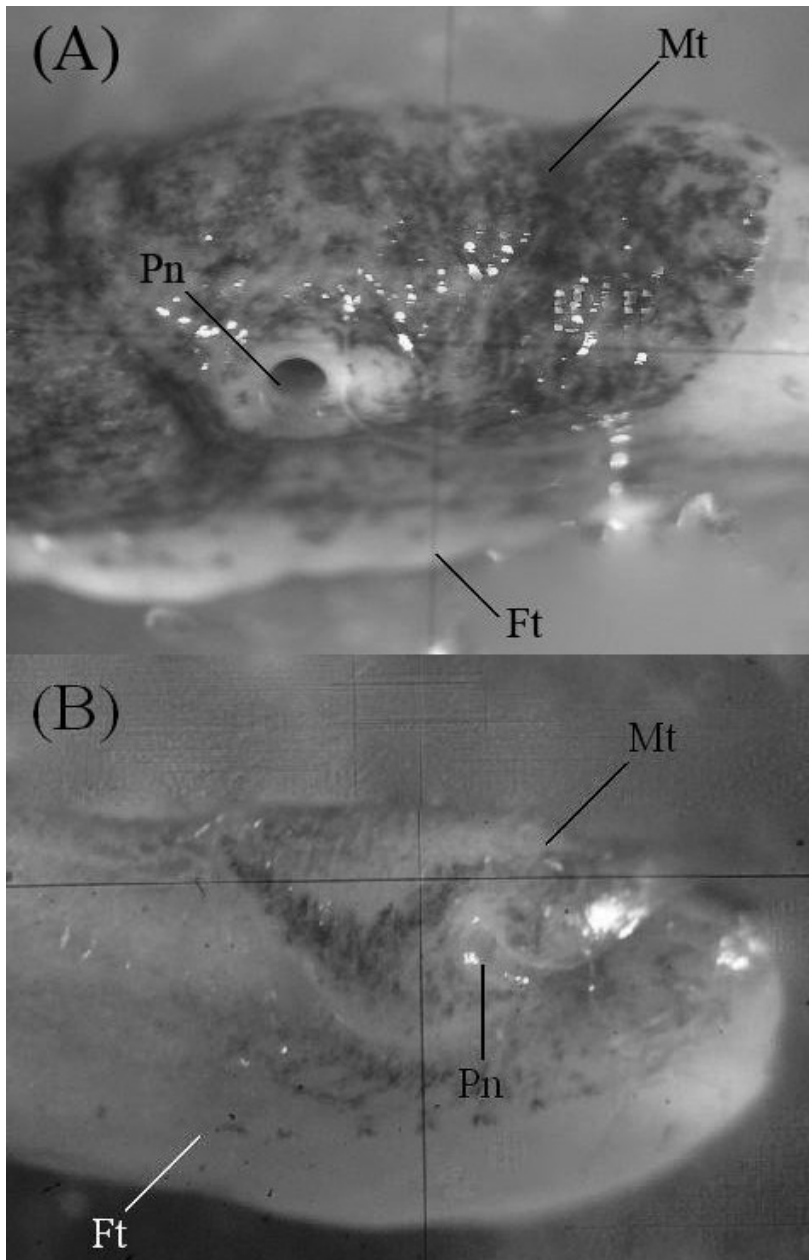


Fig. 2: (A) Extreme anterior right side of *Limax* sp. Location of the pneumostome in *Limax* sp. is in the posterior half of the mantle, whereas in *A. intermedius* (B) this structure is in the anterior half mantle region. Mt = mantle, Pn = pneumostome, Ft = foot.

(A) Extremo anterior (vista lateral derecha) de *Limax* sp.; el pneumostoma en *Limax* sp. está ubicado en la mitad posterior del manto, al contrario de *A. intermedius*, en la cual este se encuentra en la mitad anterior. Mt: manto; Pn: pneumostoma; Ft: pie.

Systematic position of the species

The original classification follows Haszprunar & Huber (1990); to levels of superfamily and to family we followed Hubendick (1978): Class Gastropoda Cuvier, 1795; Subclass

Pulmonata Cuvier, 1814; Order Eupulmonata Haszprunar & Huber, 1990; Suborder Stylommatophora Pilsbry, 1948; Superfamily Arionoidea Gray, 1840; Family Arionidae Gray, 1840; *Arion intermedius* Normand, 1852.

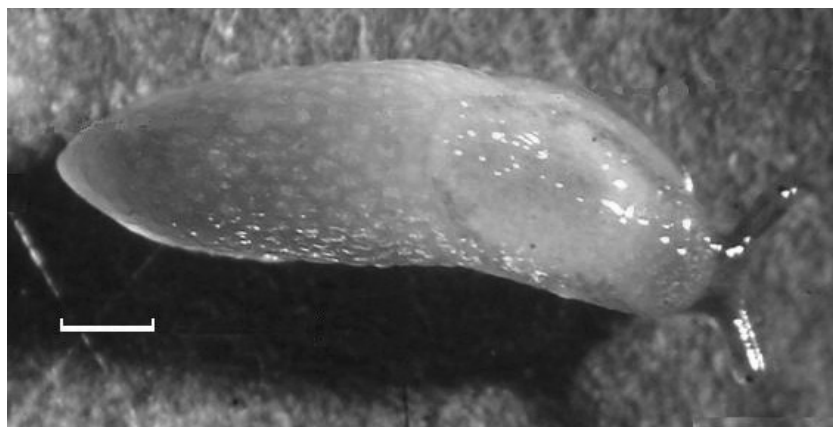


Fig. 3: Juvenile of *Arion intermedius*, dorsal view. Scale bar: 1 mm.

Ejemplar juvenil de *Arion intermedius*, vista dorsal. Escala: 1 mm.

TABLE 2

Results of samplings carried out in the UACH Botanical Garden. In addition to the total number of specimens (n) obtained in each sampling are listed the range in values, mean (\pm SD) both for the lengths and weights of the specimens

Resultados de los muestreos realizados en el Jardín Botánico UACH. Se indica en cada muestreo, además del número de individuos (n), el rango de los valores, su promedio (\pm DE) tanto para la longitud como los pesos de los especímenes

Site	n	Specimen size range (mm)	Mean size (mm)	Specimen weight range (g)	Mean weight (g)
1	7	11.5-15.3	13.3 \pm 1.3	0.025-0.0423	0.0343 \pm 0.0073
2	3	10.5-10.9	11 \pm 0.6	0.0222-0.032	0.046 \pm 0.0059
3	12	5.6-14.5	9.6 \pm 2.9	0.0072-0.0352	0.0162 \pm 0.0089
4	3	8.9-14.1	10.8 \pm 2.9	0.0104-0.0593	0.0279 \pm 0.0272

Morphometric characteristics and structures of taxonomic value

The results obtained with specimens collected at the UACH Botanical Garden are presented in Table 2. The sampled individuals had a minimum size of 5.6 mm (Sample 3) and the maximum was 15.3 mm (Sample 1) as measured from the tips of the upper tentacles to the end of the foot; the overall average (Samples 1 to 4) was 11 \pm 2.7 mm.

External morphology

The *A. intermedius* specimens from the UACH Botanical Garden represented morph "Y" of Backeljau et al. (1992). The same was observed

for all other samples from the different collecting sites. This morphotype was uniformly yellow-ocre in color, with mantle and dorsum lacking a black center and dark spots. The border of the foot was yellowish and weakly lined. The ventral surface of the foot was whitish to yellow.

Reproductive system

Spatial arrangement and identification of the main structures in the reproductive system of *A. intermedius* are presented in Fig. 4. Adult specimens were recognizable from the notably swollen seminal vesicle, indicating storage of mature spermatozoa. No spermatophores were encountered in the bursa copulatrix of the adult specimens examined.

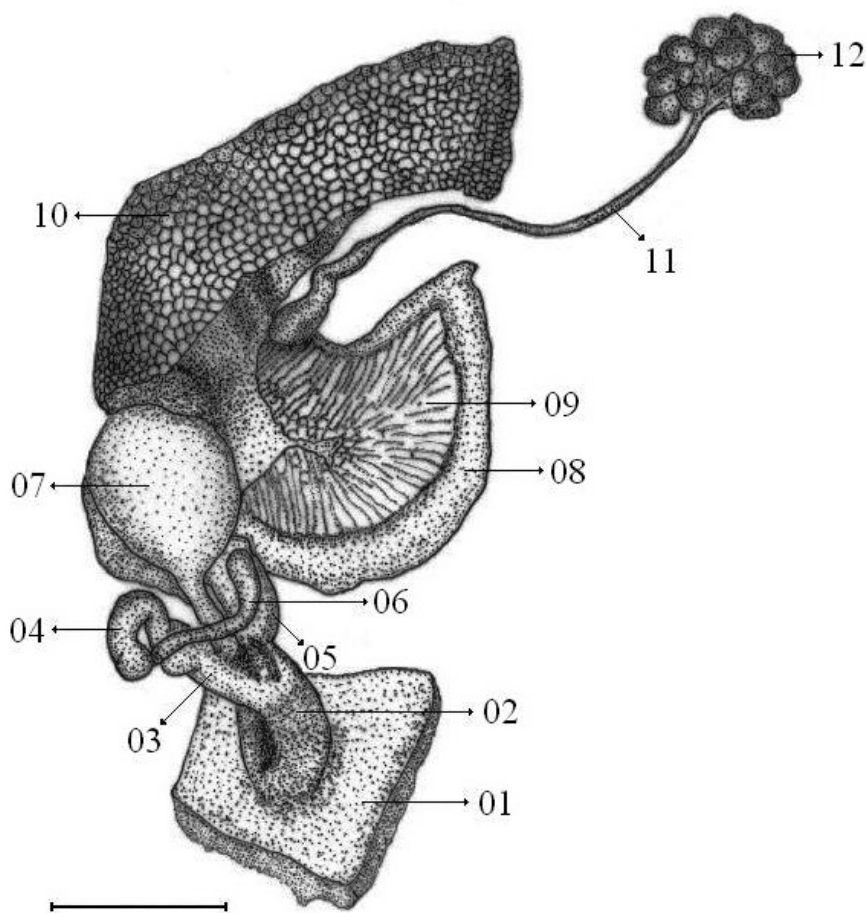


Fig. 4: Reproductive system of *Arion intermedius*. 01, body wall; 02, genital atrium; 03, phallus; 04, epiphallus; 05, vagina; 06, vas deferens; 07, bursa copulatrix; 08, oviduct; 09, prostatic gland; 10, albumin gland; 11, hermaphroditic duct; 12, ovotestis. Scale bar: 2.5 mm.

Sistema reproductor de *Arion intermedius*. 01, pared del cuerpo; 02, atrio genital; 03, falo; 04, epifalo; 05, vagina; 06, vaso deferente; 07, bursa copulatrix; 08, oviducto; 09, glándula prostática; 10, glándula del albumen; 11, ducto hermafrodita; 12, ovotestis. Escala: 2,5 mm.

Radula

The morphology of the radular dentition is shown in Fig. 5. The radula is composed of three types of teeth arranged linearly, including central teeth (CT), lateral teeth (LT), and marginal teeth (MT). The basal plate of the first lateral tooth is observed to be about 1/4 higher than central tooth plate. This arrangement is repeated with the second lateral tooth with respect to the first, with teeth then continuing at the same height until the last marginal tooth. The CT is tricuspid, with a lanceolate, elongated mesocone, with its extreme distal portion reaching the first quarter of the following CT plate. The lateral cuspid are of similar size,

approximately 1/2 the size of the mesocone. The LT are distributed laterally to the CT, are bicuspid, and have an ectocone in regression. The mesocone is lanceolate and perpendicular to its base, and 1/8 larger than its sustaining plate. Its ectocone represents about 1/2 the length of the mesocone. The MT appears as a continuation of the 14-15 LT, with a configuration similar to those of the LT. They are bicuspid, and have an ectocone in regression, but with a marked inclination of the mesocone toward the center of the radula. This inclination becomes increasingly apparent as the MT extend toward the lateral limit of the radula.

Radular formula: C/1 + L14-15/2 + M15-16/2

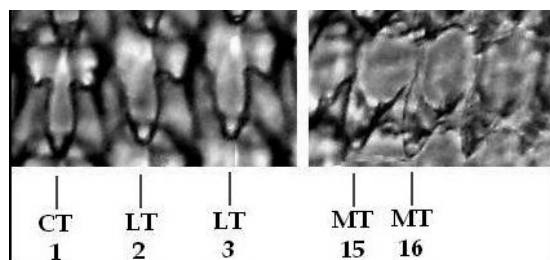


Fig. 5: Scheme of the tooth morphology in *A. intermedius* radula. CT = central tooth ; LT = lateral teeth; MT = marginal teeth. The numbers under the abbreviations indicate the positions of the teeth in the radular scheme (see text).

Esquema de la morfología dentaria en rádula de *Arion intermedius*. CT: diente central; LT: dientes laterales; MT: dientes marginales. Los números bajo las abreviaciones indican la posición de dichos dientes en el esquema radular (ver texto).

Associations with plants

Individuals of this slug were found in all the soil samples examined with no differences related to the origins of the plants on the plots sampled in the Botanical Garden. The frequency, sizes and weights of the specimens found at each site are presented in Table 2.

DISCUSSION

Nine terrestrial gastropods have been reported as introduced species in Chile (Stuardo & Vega 1985, Valdovinos 1999). They include *Milax gagates* (Drapanaurd, 1801); *Deroceras reticulatum* (Müller, 1774); *Deroceras laeve* (Müller, 1774); *Limax valentianus* Férussac, 1821; *Limax maximus* Linnaeus, 1758; *Limax flavus* Linnaeus, 1758; *Oxychilus cellarius* (Müller, 1822); *Oxychilus alliarius* (Müller, 1822); *Helix aspersa* Müller, 1774. Of these, the genera *Milax*, *Deroceras*, *Limax*, and *Helix* are known to be potentially damaging to agriculture (Hausdorf 2002). The family Arionidae, and specifically the genus *Arion* are considered potentially damaging for agriculture according to international organizations concerned with plague control such as CAPS (Eastern Region Cooperative Agricultural Pest Survey) (TUhttp://www.invasive.org)UT.

In general, environments altered by human activities are often areas of invasion by exotic species of snails and slugs (Hausdorf 2002). In this respect, *Arion intermedius* is an exception, since this species has a greater capacity for penetration into unaltered native forests than do other introduced species which have been reported and studied in North America (Chichester & Ges 1969), Australia (Smith 1981), New Zealand (Barker 1982), and Colombia (Hausdorf 2002). In the case of Valdivia, and in accordance with our results of analysis at the UACH Botanical Garden, this species was found strongly associated with mosses such as *Thuidium chilense* (Mitten, 1869), and plants such as *Nertera granadensis* (Mutis ex Lf), which are native species broadly distributed through the south Chilean ecosystem. In the case of the "El Bosque" Urban Park, specimens were found living six meters above ground level on *Laurelia sempervirens* (Monimiaceae), a tree species widely distributed in Chile. When we note that *A. intermedius* has been identified as the slug associated with the highest rate of decomposition of organic leaf litter among several slug species (Jennings & Barkham 1979), its possible impact on systems dependent on the accumulation of thick horizons of leaf litter cannot be ignored. In Arboretum Park, for example, we found *A. intermedius* to be well established in places normally occupied by endemic molluscs such as *Plectostylus* sp., and microgastropods such as *Stephanoda mirabilis* Scott 1968, *Austrodiscus* sp. and *Radiodiscus* sp., which are very small species whose biology is poorly known. It is possible that *A. intermedius* may produce negative effects on the local species of terrestrial gastropods, potentially effecting their ecological displacement.

On the other hand, the reproductive strategy of this slug (self-fertilization, probably strict) (McCracken & Selander 1980, Backeljau & De Bruyn 1990, Reise et al. 2001) allows even one individual to begin colonizing a new habitat, accentuating its invasive capacity.

It would be a difficult, perhaps impossible task to ascertain the history of introduction of this species into Chile. The long distance between specimens collected between Route S-91 and the Valdivian Coastal Reserve (124 km.) indirectly suggests that the introduction

has not been recent. Conversely, if it had been introduced recently, its dispersal has occurred rapidly, probably transported unnoticed in human activities, since the species is highly limited in migrational capacity in comparison with similar species (Bohan et al. 2000). In this case, an effect of propagation promoted by human activity would be accentuated due to the slug's capacity for reproduction by self-fertilization (a rare case among pulmonates) and thus having a high degree of ability to colonize in spite of occurring at low density (Selander & Ochman 1983, Jarne & Charlesworth 1993).

It is of prime importance to monitor the extent of impacts which may be produced by the interaction of this species with native species, and if necessary, take preventive measures for reducing or reversing them. Perhaps more stringent border control needs to be exercised with seeds, harvests, fruits, and machinery, in order to avoid the possibility of similar situations occurring in the future with other exotic species.

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