

RECORDS OF THE SLUGS *ARIOLIMAX COLUMBIANUS* (ARIOLIMACIDAE) AND *PROPHYSAON FOLIOLATUM* (ARIONIDAE) IMPORTED INTO SWEDEN

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ABSTRACT: Two North American slug species are reported from three locations in southern Sweden: three records (in 2005, 2014 and 2015) of *Ariolimax columbianus* (Gould) and one 2005 record of *Prophysaon foliolatum* (Gould). The record of *P. foliolatum* is the first for Europe. In all cases it is highly probable or proven that the slugs had been accidentally imported with ornamental plants from North America, particularly salal, *Gaultheria shallon* Pursh. Salal is collected on a massive scale from the rainforests of the Pacific Northwest, particularly in Canada and Washington State, and exported as green filler for floral arrangements. The harvest, storage and transport conditions seem perfectly suitable for these slugs, which are not synanthropic but live in natural habitats where salal thrives. We point out that these apparently uncontrolled imports might open the door to the introduction of new, non-synanthropic species.

KEY WORDS: terrestrial slugs, introduced species, salal, North America, Europe, bananaslug, banana slug, taildropper

INTRODUCTION

An unwanted side-effect of our ever increasing mobility and trade is the inadvertent introduction of non-native plants and animals, some of which cause considerable economic or ecological costs in their new range. These include a number of European species of terrestrial slugs that have successfully established populations in North America, where some of them may dominate the synanthropic slug fauna, for example *Arion rufus* (Linnaeus, 1758), *A. intermedius* Normand, 1852, *Limax maximus* Linnaeus, 1758, *Deroceras reticulatum* (O. F. Müller, 1774) and *D. invadens* Reise, Hutchinson, Schunack et Schlitt, 2011 (CHICHESTER & GETZ 1969, ROLLO & WELLINGTON 1975, ROBINSON 1999, REISE et al. 2006, 2011). However, considerably fewer mollusc species have made their way in the opposite direction, from North America to Europe, reflecting a pattern common to

a wide variety of taxa (SIMBERLOFF 2013). Potential causes of this have been discussed, but introduced species are usually those commonly encountered in synanthropic habitats, and there are only few such synanthropic species amongst native North American slugs.

In either direction, there are unsurprisingly few reports of inadvertent introductions of non-synanthropic molluscs restricted to more or less natural woodland. However, here we report the import to Europe of two such slug species native to the temperate rainforests of the Pacific Northwest of America, *Ariolimax columbianus* (Gould, 1851) and *Prophysaon foliolatum* (Gould, 1851). We also point out that these, and possibly other, species might be imported quite regularly with decorative foliage harvested from the wild.



RECORDS

All slugs were found in flower shops in southern Sweden and handed in by shop owners, florists or customers to the Göteborg Natural History Museum in Sweden (GNM) as a result of the project “Molluscs spread by man”, organised by the museum since 1986. This project has invited the public to send in slugs and snails from their gardens for identification. Its main purpose was monitoring the spread and establishment of the “Spanish slug” *Arion vulgaris* Moquin-Tandon, 1855 [= *A. lusitanicus* auctt. non Mabilie, 1868] (cf. VON PROSCHWITZ 2015), but the more than 5,000 samples have also provided much additional information on other species. These were mostly European species, but also a few true exotics, including *Ariolimax* and *Prophysaon* reported here. These individuals were drowned and preserved in 82% ethanol and stored in the collection of the GNM. For morphological determination, we used PILSBRY (1948), FORSYTH (2004) and BURKE (2013).

RECORD 1

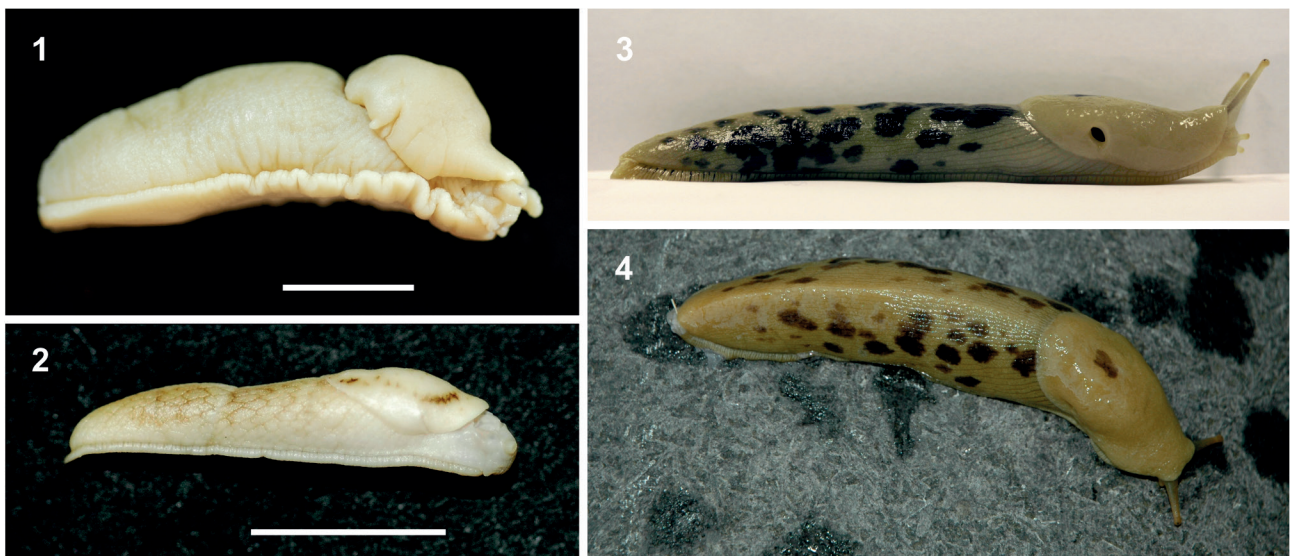
Two slugs were found in a flower shop in Kullavik, province of Halland (on the Swedish west coast, ca. 10 km S of Göteborg, 58°01'05"N 12°27'27"E), at the end of November 2005 and handed over to the GNM on 2nd December 2005 by T. TILIUS-EEK. According to her, the slugs had been imported with ornamental plants, probably from America. They were killed on 19th January 2006 and deposited under the collection numbers 05-21.500-1 (Fig. 1) and 05-21.500-2 (Fig. 2).

Both individuals were still juvenile, but their external appearance and distal genitals allowed us to classify the larger, unicoloured ochre to greenish yellow specimen as a banana slug (*Ariolimax*) of the subgenus *Ariolimax* and the smaller individual as a species of *Prophysaon*.

For further identification, sole tissue was used for sequencing a segment of the mitochondrial COI gene. DNA extraction from foot muscle followed WINNEPENNINCKS et al. (1993). For DNA amplification, we used Taq-polymerase and buffer from Peqlab (Erlangen).

The DNA fragments were gel purified with the QiaQuick gel extraction kit (Qiagen, Hilden, Germany) and then sent to the Laborzentrum Senckenberg BIK-F (Frankfurt) for direct sequencing in both directions. The PCR-primers used for *Ariolimax* were: FOR 5'-GGTCAACAAATCATAAAGATATTGG-3', REV 5'-CGYATRITTAARATAGTAGTAAT-3' ($t_a = 40^\circ\text{C}$, 36 cycles, total volume: 10 μl), and for *Prophysaon*: FOR 5'-GGRACKGGG TGAACWGTRTAYCCYCC-3', REV 5'-TAAACTTCAGGGTGACCAAAAAATCA-3' (for PCR conditions see LERAY 2013).

Comparison with a sequence of *A. columbianus* from South Beach, Oregon, USA (GenBank number MF926240, one base-pair difference out of 443 bp) and unpublished sequences of further *Ariolimax* (see ELEJALDE et al. 2011) allowed us to determine the banana slug as *A. columbianus* (Gould, 1851) sensu stricto. In GenBank are a further three COI sequences (KM612238, KM612174, KM612135), all identical and differing from our sequence in just 2 bp out of 373 bp. These three GenBank se-



Figs 1–4. Slugs imported to Sweden: 1 – alcohol preserved specimen of *Ariolimax columbianus* from Kullavik (record 1); 2 – alcohol preserved specimen of *Prophysaon foliolatum* from Kullavik (record 1); 3 – *Ariolimax columbianus* from Göteborg (record 2); 4 – *Ariolimax columbianus* from Gränna (record 3)



quences are identified only as “*Stylommatophora* sp.” but they were collected within the Pacific Rim National Park, which lies well within the distribution range of *A. columbianus*, and other *Ariolimax* species are not known from there (FORSYTH 2004). Our *Prophysaon* specimen was identified as *P. foliolatum* (Gould, 1851) based on a comparison with sequences of eight *Prophysaon* species available in GenBank (see WILKE & DUNCAN 2004); the difference was only 4 bp out of 303 bp (99% match; the next best match was *P. andersoni* with 90%). In both cases, the COI-based determination is in agreement with the external appearance. Our sequences are deposited in GenBank: *A. columbianus* MG386402 (GNM 05-21.500-1), *P. foliolatum* MG386403 (GNM 05-21.500-2).

RECORD 2

A juvenile slug turned up in the flower shop “Henriksons Blomsterhandel” at Nordhemsgatan 29 in Göteborg (province of Västergötland, 57°41'50"N, 11°57'00"E). The animal had been found on salal foliage imported from the U.S.A. in December 2014.

DISCUSSION

We are not aware of earlier findings of *P. foliolatum* in Europe, but *A. columbianus* has been reported from Cismar in Schleswig-Holstein, Germany (WIESE 2009) and three times from the Netherlands: from Emmen in 2003 (BARON 2005), Bilthoven in 2011 and Uithoorn in 2013 (SOES et al. 2015). The slug in Cismar was found in a garden centre among decorative foliage for adding to flower bouquets and had probably, as in the cases reported above, been introduced with imported salal (WIESE 2009). In the Uithoorn case the origin was clear, as the slug was detected in a box with salal imported from North America. The specimen in Emmen was found in a shop where, amongst other items, cut flowers were sold. In Bilthoven, the slug was found in a residential house but had probably been introduced with flower bouquets bought at the flower market in Utrecht (SOES et al. 2015).

The genus *Ariolimax* (banana slugs) is native to the coniferous rainforests along the Pacific coast of North America, from Alaska to California (MEAD 1943, PILSBRY 1948, FORSYTH 2004, BURKE 2013). It comprises at least eight species (ELEJALDE et al. 2013). The most widely distributed and commonest species is *A. columbianus* (the Pacific banana slug), which has a large range, from Alaska through British Columbia, Washington and Oregon to central California (FORSYTH 2004, BURKE 2013). It is the largest slug of the North American continent,

The shop owner P. EKSTRÖM kept the slug and fed it with vegetables. It grew rapidly and reached roughly adult size by the time it was handed over to the GNM on 24th February 2015. It was photographed and killed on 25th February 2015 and deposited under the collection number 14-22.707.

The individual was determined as *A. columbianus* based on its external appearance (ochre yellow to olive green with black patches, Fig. 3), as this is the only *Ariolimax* species which can have black spotting. The distal genitalia were not yet fully developed but fitted best with this determination.

RECORD 3

An almost adult, spotted banana slug was found by M. SJÖBERG in a flower shop in Gränna, province of Småland and handed over in August 2015. The slug had been discovered on salal imported from Miami, Florida (USA.). The individual was photographed on 24th August 2015 (Fig. 4). It was killed the next day and deposited under 17-22.951. External appearance and genital anatomy revealed an almost mature individual of *A. columbianus*.

reaching a length of 180–260 mm when extended. The ground colour ranges from ochre yellow to olive green but may also be more brownish or whitish, and the slugs are often spotted with irregular black patches of very variable shape and size (FORSYTH 2004, BURKE 2013). Among biologists, it is well known for its peculiar habit of sometimes biting off the partner's or its own penis at the end of copulation (REISE & HUTCHINSON 2002, LEONARD et al. 2002).

The genus *Prophysaon* occurs in the Pacific part of North America with seven to eight species (WILKE & DUNCAN 2004, BURKE 2013). Their ability to self-amputate the tail when attacked has coined their common name taildroppers. In *P. foliolatum* (the yellow-bordered taildropper), the site of potential amputation is particularly prominent, as is visible in the specimen from Kullavik (Fig. 2). This species inhabits the wet coastal forests of the Pacific Northwest from British Columbia (as far north as the Haida Gwaii, formerly Queen Charlotte Islands) to southwestern Oregon.

Both introduced species are not typical synanthropic species but inhabitants of the forest floor and ground vegetation in the rainforests of the Pacific Northwest. All our own and the other published records indicate a more or less clear connection to salal, a plant nowadays commonly used for floral arrangements and as filler in flower bouquets.



Salal (*Gaultheria shallon* Pursh) belongs to the Ericaceae and is native to a zone along the western coastal parts of North America, from northern California to Alaska, with its main distribution in Washington and British Columbia. It is a very common understory shrub thriving on drier to rather wet sites in coniferous or mixed forests up to 800 m altitude. Its height varies, depending on the conditions, from 20 cm to more than man-size (POJAR & MACKINNON 2004). Branches and berries had been used as food by native Americans, but its main commercial value is now in the floral industry. Salal is harvested in the wild by hand between August and April. Pickers sell their harvest daily or, thanks to the plant's robustness, aggregate it first by storing the branches in a cool dark place (HOBBY et al. 2010). Buyers typically repack and store the stems in coolers at 1°C before exporting them in shipping containers or by air freight, mainly to Europe but also to other parts of North America and to Japan (WIESE 2009, HOBBY et al. 2010). Considerable amounts of salal are exported during the harvest season, and this has developed into a significant economic item. From southern Vancouver Island (British Columbia, Canada) alone, 4,000 to 20,000 bunches of stems are exported weekly, yielding a total annual sale average of CAN\$ 6.5–10.5 million which represents 20–30% of the total salal production of British Columbia (HOBBY et al. 2010). Salal is also harvested in the US states of Washington and Oregon. The “floral greens” industry in British Columbia, Washington and Oregon together was valued at over US\$ 128,000,000 in 1989 and has since grown dramatically (BALLARD et al. 2002). There is a whole network of first- and higher-level traders of wild-collected floral greens, and also Canadian salal is often, if not largely, exported via big US-based companies (BALLARD et al. 2002, HOBBY et al. 2010). So, it is not surprising that the slug found in Gränna (record 3) had been on salal imported from Miami, Florida, far away from its natural occurrence.

Considering the amount of salal plants extracted from the forest, it seems not surprising that slugs living in the same habitats are occasionally picked and exported with the plants, as has also been assumed by SOES et al. (2015). Both species can be

found in salal vegetation (R. G. FORSYTH personal communication, REISE unpublished observations), and at least *A. columbianus* has been reported to feed on salal (RICHTER 1979). It seems also plausible that prepared bundles of branches stored on the forest floor or somewhere nearby may attract slugs after picking. The conditions for keeping the branches fresh during shipping appear also to be very slug-friendly.

We do not know of any indications of established populations of banana slugs or any other North American slug species in Europe. This might have to do with unsuitable climate or habitats. There are several examples of successful colonisations in the other direction (see Introduction), but their establishment seems often to have occurred already by the early 20th or even the 19th century (PILSBRY 1948, CHICHESTER & GETZ 1969). In the last decades, the US government has spent much effort and money on preventing introduction of new species (ROBINSON 1999). Europe (and probably also Asia), on the other hand, seems to have no comparable control system, and imports such as salal are not checked for hitchhiking animals or subjected to treatments that might kill off at least the bulk of them. One may also wonder about which other species, smaller and less conspicuous than the comparably big and strikingly coloured banana slugs, are imported regularly with the salal. Particularly, if salal is transported straight to cemeteries for decorating graves, one may imagine a sufficiently high propagule pressure (SIMBERLOFF 2009) to lead to successful introductions of some of them. It seems worthwhile to pay more attention to imports of wild-harvested products such as salal.

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