

Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention

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Final Report

Annex 4: Risk Assessment for *Lampropeltis getula* (Linnaeus, 1766)

Risk assessment template developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention" Contract No 07.0202/2016/740982/ETU/ENV.D2

Based on the Risk Assessment Scheme developed by the GB Non-Native Species Secretariat (GB Non-Native Risk Assessment - GBNNRA)

Name of organism: Common kingsnake *Lampropeltis getula* (Linnaeus, 1766)

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Risk Assessment Area: The geographical coverage of the risk assessment is the territory of the European Union (excluding the outermost regions)

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This risk assessment has been peer-reviewed by two independent experts and discussed during a joint expert workshop. Specific sections have been mini-reviewed by two other reviewers. Details on the review and how comments were addressed are available in the final report of the study.

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RISK SUMMARIES			
	RESPONSE	CONFIDENCE	COMMENT
Summarise Entry	likely	high	<i>Lampropeltis getula</i> is a regularly introduced, popular pet species. Casual records in several EU member states illustrate the species is widely kept as a pet in the EU and that escapes occur regularly. Common kingsnake is especially popular among beginner pet amateurs as they generally require little specific care, have a low purchase price and are easy to handle.
Summarise Establishment	likely	high	The species is already established in Macaronesia (Canary Islands). Similar climatic conditions occur in the EU in parts of Iberia. Excluding outermost territories, under current climate, species distribution modelling predicts establishment in the EU is possible through southern Iberia and Greece as well as in small areas of Italy. Depending on the subspecies introduced, <i>L. getula</i> could establish in several EU member states. Member states potentially suitable for establishment include Portugal, Spain, Italy, Greece, Malta and Cyprus. In terms of Biogeographical Regions the Mediterranean and Steppic bioregions are suitable for establishment.
Summarise Spread	slowly	low	<i>Lampropeltis</i> species generally exhibit small home ranges and small spatial movement patterns which is one of the reasons why they easily persist in fragmented landscapes. They are generally low perceptible range species i.e. do not easily cross dispersal barriers to disperse into an unsuitable matrix. The detection threshold of snakes is known to be low, and this is expected to be the case for a fossorial species like <i>L. getula</i> as well. Human assistance may however easily complement natural spread. Snakes can be introduced or released deliberately or may be accidentally transported on ornamental trees. On the Canary islands, the species has spread to at least three disparate locations on Gran Canaria and to other islands despite concerted management action (pers. comm. Miguel Ángel Cabrera). A newly established population could already be quite large before it reaches a

			detection threshold, given the secretive nature of <i>L. getula</i> and the fact that it is a fossorial (underground) species.
Summarise Impact	major	medium	The species may have a major impact on biodiversity, particularly through predation, to a lesser extent also through competition and the spread of diseases. <i>Lampropeltis getula</i> is a generalist predator of rodents and other small mammals, lizards and their eggs, snakes (including poisonous viper species) and their eggs, turtle eggs and hatchlings, frogs, salamanders, birds, bird eggs and chicks, and large invertebrates. Because of its generalist diet, the snake can pose a threat to many native European species (including snakes, turtles, small mammals and birds), given that <i>L. getula</i> occur in sufficiently large numbers or when the available prey is rare or threatened. Several studies have shown introduced snakes have had devastating effects on native (often endemic) herpetofauna of mediterranean islands, thus also impacting upon the natural and cultural heritage of isolated island ecosystems. As an illustration, on the Canary islands, where <i>L. getula</i> is established, it preys on several endemic reptile species which have experienced population declines. Especially on Iberia and the Mediterranean island faunas, where the degree of endemism is high e.g. in reptiles and small mammals, the risk of impact through predation on such species is high. Due to their generalist diet and their habits of roaming in wet environments, it is also possible <i>L. getula</i> will prey on amphibians, which could pose a threat to species that are already in decline, especially in the Mediterranean bioregion. As omnivorous lizards on islands can act as important seed dispersers for plant species with fleshy fruits, this predation could also alter plant-animal mutualism and impact on native plant species or vegetation structure. Furthermore, <i>L. getula</i> is a possible carrier of snake fungal disease, which could cause damage to native reptile species, but this remains currently largely undocumented.
Conclusion of the risk assessment	high	medium	

Distribution Summary (for explanations see EU chapeau and Annex IV):

Member States

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Austria	-	-	-	-
Belgium	YES	-	-	-
Bulgaria	-	-	-	-
Croatia	-	-	-	-
Cyprus	-	-	YES	-
Czech Republic	-	-	-	-
Denmark	-	-	-	-
Estonia	-	-	-	-
Finland	-	-	-	-
France	-	-	YES	-
Germany	YES	-	-	-
Greece	-	-	YES	-
Hungary	-	-	YES	-
Ireland	-	-	-	-
Italy	YES	-	YES	-
Latvia	-	-	-	-
Lithuania	-	-	-	-
Luxembourg	-	-	-	-
Malta	-	-	YES	-
Netherlands	YES	-	-	-
Poland	-	-	-	-
Portugal	-	-	YES	-
Romania	-	-	YES	-
Slovakia	-	-	-	-
Slovenia	-	-	-	-
Spain	-	-	YES	-
Sweden	-	-	-	-
United Kingdom	YES	-	-	-

EU biogeographical regions

	Recorded	Established (currently)	Established (future)
Alpine	-	-	?
Atlantic	YES	-	YES
Black Sea	-	-	YES
Boreal	-	-	-
Continental	YES	-	YES
Mediterranean	YES	-	YES
Pannonian	-	-	YES
Steppic	-	-	YES

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EU CHAPEAU		
QUESTION	RESPONSE	COMMENT
Ch1. In which EU biogeographical region(s) or marine subregion(s) has the species been recorded and where is it established?	<p>Recorded (but not established) in the following EU biogeographical regions:</p> <ul style="list-style-type: none"> • Atlantic region (BE, NL, DE, UK) • Continental region (DE) • Mediterranean region (IT) <p>Currently not established in any EU biogeographical region, except for the Macaronesian region (Canary Islands), which is in the Outermost Territories outside the risk assessment area.</p>	More detail is provided in Ch3.
Ch2. In which EU biogeographical region(s) or marine subregion(s) could the species establish in the future under current climate and under foreseeable climate change?	<p>Under current climate:</p> <ul style="list-style-type: none"> • Already established in the Macaronesian bioregion; however, this is only relevant for Outermost Territories which are not part of the risk assessment area. • Biogeographical regions suitable for establishment include the Mediterranean and Steppic bioregion. Environmental conditions in more temperate EU bioregions and member states are currently less suited for the species. <p>Under foreseeable climate change conditions such as the future climate scenarios rcp4.5 and rcp8.5 (EEA 2016) the number of biogeographical regions suitable for establishment is expected to increase with the Atlantic, Black Sea, Continental, Alpine and Pannonian bioregions becoming suitable for establishment.</p>	Climatic requirements of the species are discussed in Ch5.
Ch3. In which EU member states has the species been recorded? List them with an indication of the timeline of observations.	<p>Recorded, but not established, in five EU MS:</p> <ul style="list-style-type: none"> • De Panne, Belgium – an escape from captivity in 2014. • Netherlands - escapes from captivity in 2008 	These casual records illustrate the species is probably widely kept as a pet in the EU and escapes occur regularly. Presumably there are many more casual records in other member states.

	<p>and 2011 (Bugter et al 2014).</p> <ul style="list-style-type: none"> • Germany - escapes reported in local newspapers e.g. 2009, 2011, 2012 (Nehring & Rabitsch 2015) and 2014 (PETA 2014), although identity of the species is not always unambiguous. • Italy - there is at least one occasional record, near Florence at the locality Ponte a Ema (Vanni and Nistri 2006). • UK - one record by Kraus (2009) relating to an introduction event which was not successful, and some generic records for <i>Lampropeltis</i> sp. (Inskipp 2003). However, introductions regarding this genus date back to 200 years ago in the UK, according to Fitter (1959) who actually refers to <i>L. triangulum</i> (syn <i>Coronella doliata</i>). On GBIF, a (presumably old) museum specimen originating from a wild caught individual in London area is mentioned under the name <i>Ophibolus getulus</i> Yarrow, 1882 but without a collecting date. <p>In addition, three separate populations have established on Gran Canaria (Telde, Gáldar, San Bartolomé de Tirajana), following introduction in c. 1998 (Pether & Mateo 2007, Mateo et al. 2011, Cabrera-Pérez et al. 2012, Monzón-Argüello et al., 2015). Gran Canaria is within the EU (part of Spain) but is an Outermost Region and therefore outside of the scope of this risk assessment.</p>	<p>So far, there have been no reported records of <i>L. getula</i> in other EU member states (www.inaturalist.org, www.observation.org, www.gbif.org).</p> <p>As a remark, the subspecies introduced in the Canary islands is <i>L. getula californiae</i>.</p>
<p>Ch4. In which EU member states has this species established populations? List them with an indication of the timeline of establishment and spread.</p>	<p>This species is not established in the EU, except in Gran Canaria which is an Outermost Territory (i.e. not within the risk assessment area).</p>	<p>The naturalization of <i>L. getula</i> was confirmed in 2007 in the east of Gran Canaria (Cabrera-Pérez et al., 2012). Monzón-Argüello et al. (2015) reported two <i>L. getula</i> populations on Gran Canaria (Canary Islands, Spain). These originate from two separate introduction events. Both established populations have remained isolated from each other, with one population established in the north of the island (Gáldar) and the</p>

		<p>other in the east (Telde). From 2007 to 2011, the <i>L. getula</i> range has increased to around 55km² (3.52% of Gran Canaria). This area is divided into a 45 km² range in the east of the island, where the species was introduced around 1998, and a 10 km² range in the northwest, where the introduction event likely took place around 2009-2010.2015). Meanwhile, a third population was discovered in the south of the island (www.lifelampropeltis.com). The populations are currently subject to a control campaign aimed at preventing the spread of the species to other islands of the Canary archipelago (Juan Luis Rodríguez Luengo, pers. comm., 2017). As a result, between 2011 and 2017 an increasing number of snakes were caught, totalling nearly 4524 individuals (on average 646 snakes/year). This was possible thanks to the implementation of a project co-funded by the EU through the LIFE programme, until 2015. However, this is considered not sufficient to achieve the eradication of the species (Juan Luis Rodríguez Luengo, pers. comm., 2017).</p>
<p>Ch5. In which EU member states could the species establish in the future under current climate and under foreseeable climate change?</p>	<p>Under current climate conditions establishment is possible through southern Iberia and Greece as well as in small areas of Italy. Member states potentially suitable for establishment include: Portugal, Spain, Italy, Greece, Malta and Cyprus.</p> <p>By the 2070s, climate change is predicted to increase the area suitable for establishment in Europe to expand northwards as far north as southern France, Italy, Hungary and Romania.</p>	<p><i>Lampropeltis getula</i> is one of the commonest and most widely distributed snake species in North America. The species occurs from the Atlantic to the Pacific coast, and can be found anywhere in its distribution area, from 0 to 2130 meters altitude (Cabrera-Pérez et al., 2012; Steen et al., 2010). It is however more prevalent under 900 meters (Cabrera-Pérez et al., 2012). The native range of <i>Lampropeltis getula</i> spans several warm temperate and arid climate zones with a range of precipitation regimes (e.g. desert, fully humid) (Hubbs, 2009). This matches the following Köppen-Geiger climate classifications: csa, csb, bsk, bsh, dsb, bwk, cfa, dfa, am, af, aw. Some of these climatic conditions (csa, csb, bsk, bsh and cfa) also occur in the risk assessment area, notably in the Mediterranean and Steppic bioregion. Outside this area, suitable climates also occur in Macaronesia where <i>L. getula</i> is established.</p>

		<p>The optimum temperature range for <i>L. getula</i> activity ranges from 15.1°C-31.3°C and the critical minimum and maximum for activity are 2°C and 42°C, respectively (Brattstrom, 1965; Cabrera-Pérez et al., 2012). <i>Lampropeltis getula</i> can escape cold winter conditions and survive in hibernacula such as caves, rock crevices, clay and gravel banks, mammal burrows, hollow logs and stumps, root systems of shrubs and trees, old sawdust mounds and abandoned buildings (Linehan et al., 2010; Wund et al., 2007). Even though the species will not be active in freezing temperatures, <i>L. getula</i> can survive moderately harsh winters by hibernating. It occurs throughout the state of Missouri (U.S.A.), where winter temperatures average 0.2 °C. Common kingsnake also occurs in more northern states with even lower temperatures in winter (e.g. Illinois, Indiana and south of Iowa). These average winter temperatures are colder than those in some temperate European regions (Paris: 5°C, Brussels: 3.3 °C in January).</p> <p>Currently, according to the SDM (Annex IV), potential evapotranspiration (mm/yr) is the most determining variable (50%) for the suitability, followed by mean temperature of the warmest quarter (33%) and minimum temperature of the coldest month (12%), precipitation seasonality (4%) and moisture index (2%). The most important variables are all temperature-related, and are most likely linked to egg incubation temperature. Outside the mediterranean, low potential evapotranspiration was identified as the main limiting factor for establishment.</p>
<p>Ch6. In which EU member states has this species shown signs of invasiveness?</p>	<p><i>L. getula</i> has shown signs of invasiveness on the Canary Islands (Spain). This is Outermost Territories which are not part of the risk assessment area.</p>	<p>The species has spread on Gran Canaria and is reported to predate on endemic lizards (Gran Canaria giant lizard <i>Gallotia stehlini</i>, Gran Canaria Skink <i>Chalcides sexlineatus</i>, Boettger's Wall Gecko <i>Tarentola boettgeri</i>), small rodents and birds (Cabrera-Pérez et al., 2012). This resulted in a EU co-funded LIFE</p>

<p>Ch7. In which EU member states could this species become invasive in the future under current climate and under foreseeable climate change?</p>	<p>Under current climate:</p> <ul style="list-style-type: none"> • It might be possible for <i>L. getula</i> to become invasive in the 10 Mediterranean member states (Portugal, Spain, France, southern Italy, Croatia, Malta, Greece, Bulgaria, Romania, Cyprus). • Climatic conditions in central and northern European member states are currently less suitable for successful recruitment of juvenile snakes. • Additionally, the species is expected to spread and establish in the other islands of the Canary archipelago (Juan Luis Rodríguez Luengo, pers. comm., 2017). <p>Under foreseeable climate change conditions as described above:</p> <ul style="list-style-type: none"> • <i>L. getula</i> could also become invasive in France, northern Italy, Hungary and Romania. 	<p>project aimed at management of <i>L. getula</i>.</p> <p>In central and northern EU member states, winter conditions are expected to represent a constraint on the life history of <i>L. getula</i> (Gregory, 2009). Additionally, short and cool summers will restrict their foraging and reproductive opportunities (Gregory, 2009). <i>Lampropeltis getula</i> is oviparous (i.e. lays eggs), while most higher-latitude snake species are viviparous. This might prevent <i>L. getula</i> to become established in colder, temperate regions of Europe. However, <i>L. getula</i> could escape these limiting conditions by behavioural adaptations and niche selection at micro scale. To illustrate this, the species occurs at high altitudes (up to 2130m) in North America, where it is notably cooler.</p>
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SECTION A – Organism Information and Screening		
Organism Information	RESPONSE	COMMENT
A1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	<p>Scientific name: <i>Lampropeltis getula</i> (Linnaeus 1766) Class: Reptilia Order: Squamata Family: Colubridae Genus: <i>Lampropeltis</i> (kingsnakes) Common names: common kingsnake, Ketten-Königsnatter (Ge), La Culebra Real (Sp), Serpent roi de californie (Fr), Serpente reale (It)</p> <p>At least seventeen different subspecies of <i>Lampropeltis getula</i> have been described over the last 75 years (Pyron & Burbrink, 2009). More recently, based on mitochondrial DNA-evidence, ecological niche modeling, morphology, and historical precedence, Pyron & Burbrink (2009) promoted five subspecies to species level. This division is however debated (B. Hubbs pers. comm.).</p> <p>This risk assessment refers to the originally described <i>L. getula</i> Linnaeus 1766 sensu lato, with a native range covering all of the United States and northwestern Mexico, thus including the subspecies <i>L. getula californiae</i> which is considered a valid species by Pyron & Burbrink (2009) and is reported to have a different ecology than <i>L. getula getula</i> which is more bound to water (pers. comm. R. Fisher). On Gran Canaria, different colour varieties were reported: a typical striped form, and striped or banded albino morph types. The individuals used for albino breeding originate from southern California (pers. comm. R. Fisher).</p>	<p>The systematics of the species are to this day not entirely clear. Pyron & Burbrink (2009) recognise <i>L. getula</i>, <i>L. californiae</i>, <i>L. holbrooki</i>, <i>L. niger</i> and <i>L. splendida</i> as different species. The authors argue, in favour of splitting, that recognizing five distinct species better reflects evolutionary history and provides a phylogenetically robust description of the common kingsnake group, while retaining the historical connection to the original descriptions of those taxa extending back over 250 years. They hypothesize that color pattern evolution in common kingsnakes was driven by phenotypic responses to ecological or environmental variables, or clinal variation rather than gene flow (Pyron & Burbrink 2009). These authors consider the subspecies <i>L. getula getula</i>, <i>L. getula floridana</i>, <i>L. getula meansi</i>, <i>L. getula goini</i> and <i>L. getula sticticeps</i> as belonging to <i>L. getula</i>, and the subspecies <i>nigrita</i> and <i>californiae</i> as a part of <i>L. californiae</i>.</p>

	<p>Reptile Database reports hybrids between California kingsnake <i>L. getulus californiae</i> and corn snake <i>Pantherophis guttatus</i> (in captivity), which despite belonging to different genera, are sexually viable (Fisher & Csurhes, 2009). Such hybrids, however, are excluded from this risk assessment. A risk assessment for <i>Pantherophis guttatus</i> is available for Queensland, Australia (Queensland Government 2016).</p> <p>Bartz (2012) (Animal Diversity Web http://animaldiversity.org/) reports seven subspecies, including <i>L. getula getula</i> (eastern kingsnake), <i>L. getula floridana</i> (Florida kingsnake), <i>L. getula californiae</i> (California kingsnake), <i>L. getula holbrooki</i> (speckled kingsnake), <i>L. getula nigra</i> (black kingsnake), <i>L. getula sticticeps</i> (Outer Banks kingsnake) and <i>L. getula nigrita</i> (black desert kingsnake). The Integrated Taxonomic Information System (ITIS), which is based on the latest scientific consensus available, largely adds one subspecies and considers the following 8 subspecies for <i>L. getula</i> as valid:</p> <p><i>L. getula californiae</i> (Blainville, 1835) –California Kingsnake <i>L. getula floridana</i> Blanchard, 1919– Florida Kingsnake <i>L. getula getula</i> (Linnaeus, 1766) – Eastern Kingsnake <i>L. getula holbrooki</i> Stejneger, 1902– Speckled Kingsnake <i>L. getula nigra</i> (Yarrow, 1882) – Black Kingsnake <i>L. getula nigrita</i> Zweifel and Norris, 1955 – Black Desert Kingsnake <i>L. getula splendida</i> (Baird and Girard, 1853) – Desert Kingsnake <i>L. getula sticticeps</i> Barbour and Engels, 1942 – Outer Banks Kingsnake</p> <p>Subspecies overlap and interbreed in several different regions across North America (Bartlett & Bartlett,</p>	
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	<p>2005; Bartz, 2012; Wund et al., 2007).</p> <p>Many synonyms of <i>L. getula</i> have been used in the past, e.g.:</p> <p><i>Coluber getulus</i> Linnaeus, 1766 <i>Lampropeltis getulus</i> (Linnaeus, 1766) <i>Herpetodryas getulus</i> — SCHLEGEL <i>Ophibolus getulus</i> — BAIRD & GIRARD 1853: 85 <i>Ophibolus boylii</i> Baird & Girard, 1853 <i>Coronella Getulus</i> — DUMÉRIL, BIBRON & DUMÉRIL 1854: 616 <i>Coronella getulus</i> var. <i>pseudogetulus</i> – JAN 1865 <i>Ophibolus getulus</i> — COPE 1875: 11 <i>Ophibolus getulus</i> — GARMAN 1884: 68 <i>Ophilobus</i> [sic] <i>getulus</i> — COPE 1892: 335 <i>Triaeniopholis arenarius</i> WERNER 1924 <i>Triaenopholis</i> [sic] <i>arenarius</i> WERNER 1924 (fide SMITH 1928) <i>Lampropeltis getulus goini</i> NEILL & ALLEN 1949: 101 <i>Lampropeltis getulus brooksi</i> BARBOUR 1919 <i>Lampropeltis getula getula</i> — TENNANT & BARTLETT 2000: 413 <i>Lampropeltis getula meansi</i> KRYSKO & JUDD 2006 <i>Lampropeltis getula meansi</i> — SKUBOWIUS 2009 <i>Lampropeltis getula goini</i> — RENNER in BERG 2013</p> <p>The species distribution model that provides the evidence base to assess establishment potential used the following taxonomic denominations of species, subspecies and hybrids to look for occurrences on the Global Biodiversity Information Facility (GBIF) and other sources of occurrences:</p> <p><i>L. boylii</i> Stejneger, 1893; <i>L. californiae</i>; <i>L. californiae</i> (Blainville, 1835); <i>L. californiae californiae</i>; <i>L. catalinensis</i> Van Denburgh & Slevin, 1921; <i>L. degranvilli getulus</i>; <i>L. getula</i>; <i>L. getula brooksi</i>; <i>L.</i></p>	
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	<p><i>getula californiae</i>; <i>L. getula californiae</i> (Blainville, 1835); <i>L. getula conjuncta</i>; <i>L. getula floridana</i>; <i>L. getula floridans</i>; <i>L. getula getula</i>; <i>L. getula getula</i> x <i>L. getula floridana</i>; <i>L. getula getulus</i>; <i>L. getula holbrookii</i>; <i>L. getula holbrookia</i>; <i>L. getula</i> Linnaeus, 1766; <i>L. getula niger</i>; <i>L. getula nigra</i>; <i>L. getula nigrita</i>; <i>L. getula splendida</i>; <i>L. getula sticticeps</i>; <i>L. getula</i> subsp. <i>californiae</i> (Blainville, 1835); <i>L. getula</i> subsp. <i>conjuncta</i>; <i>L. getula</i> subsp. <i>floridana</i> Blanchard, 1919; <i>L. getula</i> subsp. <i>getula</i>; <i>L. getula</i> subsp. <i>holbrookii</i> Stejneger, 1902; <i>L. getula</i> subsp. <i>niger</i>; <i>L. getula</i> subsp. <i>nigra</i> (Yarrow, 1882); <i>L. getula</i> subsp. <i>nigrita</i> Zweifel & Norris, 1955; <i>L. getula</i> subsp. <i>splendida</i> (Baird & Girard, 1853); <i>L. getula</i> subsp. <i>sticticeps</i> Barbour & Engels, 1942; <i>L. getula yumensis</i>; <i>L. getulus</i>; <i>L. getulus boyliei</i>; <i>L. getulus brooksi</i>; <i>L. getulus californiae</i>; <i>L. getulus californiae</i> x <i>L. getulus nigritus</i>; <i>L. getulus conjuncta</i>; <i>L. getulus floridana</i>; <i>L. getulus floridana</i> x <i>L. getulus brooksi</i>; <i>L. getulus floridanae</i>; <i>L. getulus floridanus</i>; <i>L. getulus getulus</i>; <i>L. getulus getulus</i> x <i>L. getulus sticticeps</i>; <i>L. getulus getulus</i> x <i>L. getulus stricticeps</i>; <i>L. getulus getulus</i> x <i>Lampropeltis getulus stricticeps</i>; <i>L. getulus holbrookii</i>; <i>L. getulus holbrookii</i>; <i>L. getulus niger</i>; <i>L. getulus nigra</i>; <i>L. getulus nigritus</i>; <i>L. getulus nijer</i>; <i>L. getulus sayi</i>; <i>L. getulus splendida</i>; <i>L. getulus sticticeps</i>; <i>L. getulus stricticeps</i>; <i>L. getulus</i> subsp. <i>brooksi</i>; <i>L. getulus</i> subsp. <i>californiae</i>; <i>L. getulus</i> subsp. <i>getulus</i>; <i>L. getulus</i> subsp. <i>nigritus</i>; <i>L. getulus</i> subsp. <i>sticticeps</i>; <i>L. getulus</i> subsp. <i>yumensis</i>; <i>L. nigra</i>; <i>Ophibolus boyliei</i> Baird & Girard, 1853.</p>	
<p>A2. Provide information on the existence of other species that look very similar</p>	<p><i>Lampropeltis getula</i> have a glossy black, blue-black or dark brown ground color overlaid with a series of 23-52 white chain-like rings. The species exhibits substantial color pattern variation which resulted in the numerous subspecies described. On Gran Canaria, four distinct morph types are present: a banded colour morph, a lined colour morph and the albino morphs of both the lined and banded types. Young individuals of native</p>	<p>Within the species, there are substantial color pattern variations, ranging from a dark brown to black ground color punctuated by 17–36 narrow cross-bands of white, yellow, or reddish yellow (Blaney, 1971; Pyron & Burbrink, 2009). In peninsular Florida, the bands increase in number (22–54) and width, and the ground color lightens to a light brown color with yellow stippling (Blaney, 1971; Pyron & Burbrink, 2009).</p>

	<p>Ladder snake <i>Rhinechis scalaris</i>, leopard snake <i>Elaphe situla</i> or the striped phase of Aesculapian snake <i>Zamenis longissima</i> can superficially resemble the lined morphotype.</p> <p>The genus includes up to 21 species, depending on the taxonomic concepts, with several confusing species that look very similar morphologically. For example, <i>L. triangulum</i> (Lacépède, 1789) (Eastern Milksnake) is a North American species that is also commonly kept as a pet and in collections.</p>	<p>Isolated populations of other aberrant color pattern variants can be found in Florida (Krysko & Judd, 2006; Pyron & Burbrink, 2009). Black Kingsnakes all have a black ground color, typically with a black-and-white checkered venter, sometimes with faint traces of dorsal crossbands (Blaney, 1971; Conant & Collins, 1991; Pyron & Burbrink, 2009). Each dorsal scale has a yellow or white speckle near the center; most clear in the southern portion of their range, fades considerably in the north, where many adults may be almost completely black (Conant & Collins, 1991; Pyron & Burbrink, 2009). The majority of the range of <i>L. getula holbrooki</i> is characterized by the ‘speckled’ pattern, which consists of a black ground color, with a white or yellow speckle in the center of each scale, and very occasionally a faint trace of dorsal cross-banding (Pyron & Burbrink, 2009). The pattern of the Desert Kingsnake (<i>L. getula splendida</i>) is characterized by a black or dark brown ground color with heavy yellow lateral and dorsolateral stippling. The remnant cross-bands formed by this stippling yield a row of black or brown dorsal blotches or saddles, numbering 42–97. The head is typically black or dark brown, and the onset of the yellow dorsal patterning sometimes gives the appearance of a collar (Blaney, 1971; Conant & Collins, 1991; Pyron & Burbrink, 2009). The California Kingsnake (<i>L. getula californiae</i>) can be distinguished from other subspecies on the basis of color pattern, possibly the most distinct of the group. Throughout the majority of their range, California Kingsnakes exhibit a black or dark brown ground color, with 21–44 broad cross-bands of white or light yellow, which typically widen laterally. Along the Pacific coast from Los Angeles to San Diego counties, individuals can be found possessing a black or dark brown ground color and a single thin, white dorsal stripe beginning at the neck and continuing to the tail. Finally, populations in the Mexican states of Sonora and Sinaloa may exhibit considerable ontogenetic darkening, with adults, and</p>
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		occasionally subadults and even juveniles turning jet black, with almost no trace of pattern (Blaney, 1971; Pyron & Burbrink, 2009; Stebbins, 2003).
A3. Does a relevant earlier risk assessment exist? (give details of any previous risk assessment and its validity in relation to the EU)	No.	There is no risk assessment for <i>L. getula</i> or any of its subspecies available. A dutch risk analysis of non-native snakes (Bugter et al. 2014) mentions <i>L. getula</i> as a common species in trade, but does not assess the risk associated with its introduction.
A4. Where is the organism native?	<p>The native range of <i>L. getula</i> extends from the Pacific to the Atlantic coast of North America (Cabrera-Pérez et al., 2012; Steen et al., 2010), from southwestern Oregon, Nevada, southern Utah, southern Colorado, southeastern Nebraska, southern Iowa, Illinois, southern Indiana, southern Ohio, West Virginia, and New Jersey in the United States, south to southern Baja California, northern Sinaloa, San Luis Potosi, Tamaulipas, Texas, the U.S. Gulf Coast, and southern Florida, at elevations from sea level to around 2,130 m asl (Conant & Collins, 1991; Hammerson et al., 2007; Stebbins, 2003) The species also occurs in northwest Mexico (Behler & King 1979).</p> <p>The species occurs in a variety of habitats, from open coniferous forest and woodland, swamps, coastal marshes and river bottoms, to farmland, prairie and chaparral, and even in desert habitats (Hammerson et al., 2007). <i>L. getula</i> is a primarily terrestrial snake, although it often occurs in the vicinity of water which allows them to burrow (Enge, 1997; Krysko, 2001; Plummer, 2010). They prefer sites with thick leaf litter and dense shrub layer foliage (Wund et al., 2007). Periods of inactivity are spent under rocks, logs, stumps, vegetation, in crevices or burrows, or in other types of cover (Hammerson et al., 2007). <i>L. getula</i> is regarded as a habitat generalist (Wund et al., 2007). However, an important factor in microhabitat selection by <i>L. getula</i> is the presence of sufficient ground vegetation, leaf litter, or other ground cover (Jenkins et al., 2001; Plummer, 2010; Wund et al., 2007). This type</p>	<p><i>Lampropeltis getula getula</i> (eastern kingsnake) is found on the east coast of North America from southern New Jersey and southeast Pennsylvania to the eastern parts of West Virginia, southwest to Mobile Bay, Alabama, and east through northern Florida. <i>Lampropeltis getula floridana</i> (Florida kingsnake) is found on the peninsula of Florida south to Dade County. <i>Lampropeltis getula californiae</i> (California kingsnake) is restricted to southwestern California and Baja California. <i>Lampropeltis getula holbrooki</i> (speckled kingsnake) is found in southwestern Illinois, eastern Iowa, and south central Alabama. <i>Lampropeltis getula nigra</i> (black kingsnake) is found west of the Appalachian mountains and east of the Mississippi River; this includes the region from West Virginia to southern Ohio, southeastern Illinois, and northern Alabama. <i>Lampropeltis getula sticticeps</i> (Outer Banks kingsnake) is found only in North Carolina from Cape Hatteras to Cape Lookout. <i>Lampropeltis getula nigrita</i> (black desert kingsnake) can be found in southern Arizona and northwestern Mexico.</p> <p>On the Florida peninsula, the species is found in or near tropical hardwood hammocks, cypress strands (<i>Taxodium ascendens</i> and <i>T. distichum</i>), freshwater and sawgrass prairies (<i>Cladium jamaicense</i>), salt marshes, estuaries with black (<i>Avicennia germinans</i>), red (<i>Rhizophora mangle</i>), and white (<i>Laguncularia racemosa</i>) mangroves, clay hills, pitcher plant, sphagnum bogs, Australian pine (<i>Casuarina equisetifolia</i>), mesic pine flatwoods (<i>Pinus elliottii</i>) melaleuca forests (<i>Melaleuca quinquenervia</i>), along</p>

	of microhabitat may occur where the canopy is sufficiently open to permit growth of ground vegetation, in forests where leaf litter and fallen logs accumulate, and at habitat edges (Plummer, 2010). The diet of <i>L. getula</i> includes a wide variety of animals, including reptiles, birds, rodents, small mammals, amphibians and eggs (Jenkins et al., 2001; Linehan et al., 2010; Seigel et al., 1987; Winne et al., 2007). The species can also be cannibalistic.	drainage canals in sugarcane fields, and where excavated oolitic limestone is piled up alongside man-made canals (Krysko, 2001). Stumpholes (holes in tree stumps) have been identified as important refugia for <i>L. getula</i> , although this relationship has rarely been quantified for individual snakes (Steen et al., 2010). Lastly, <i>L. getula</i> is typically not found in xeric sandhill habitats (Enge, 1997; Krysko, 2001).
A5. What is the global non-native distribution of the organism (excluding the Union, but including neighbouring European (non-Union) countries)?	There are no documented non-native distribution ranges nor invasion histories outside the European Union apart from the population on the Canary Islands which is part of the Outermost Territories and outside the risk assessment area (Cabrera-Pérez et al., 2012; Monzón-Argüello et al., 2015).	
A6. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world?	<i>Lampropeltis getula</i> is considered invasive on Gran Canaria (Canary Islands, Macaronesia), causing damage to endemic lizard, skinks and geckos (Cabrera-Pérez et al., 2012; Monzón-Argüello et al., 2015).	Further details on invasiveness are in the Impact section.
A7. Describe any known socio-economic benefits of the organism in the risk assessment area.	The species is a popular pet snake and as such may provide cultural service as a pet/zoo animal. On this regard, it may be assumed that it also represents an economic value.	<i>Lampropeltis getula</i> and its subspecies are especially popular among beginner pet amateurs as they generally require little specific care and are relatively easy to handle. They also have a relatively low purchase price.

SECTION B – Detailed assessment

Important instructions:

- In the case of lack of information the assessors are requested to use a standardized answer: “No information has been found.”
- For detailed explanations of the CBD pathway classification scheme consult the IUCN/CEH guidance document.
- With regard to the scoring of the likelihood of events or the magnitude of impacts see Annex.
- With regard to the confidence levels, see Annex.

PROBABILITY OF INTRODUCTION and ENTRY

Important instructions:

- Introduction is the movement of the species into the EU.
- Entry is the release/escape/arrival in the environment, i.e. occurrence in the wild. Not to be confused with spread, the movement of an organism within Europe.
- For organisms which are already present in Europe, only complete this section for current active or if relevant potential future pathways. This section need not be completed for organisms which have entered in the past and have no current pathway of introduction and entry.

QUESTION	RESPONSE [chose one entry, delete all others]	CONFIDENCE [chose one entry, delete all others]	COMMENT
<p>1.1. How many active pathways are relevant to the potential entry of this organism?</p> <p>(If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)</p>	<p>moderate number</p>	<p>medium</p>	<p>The following pathways are potentially relevant for snake introductions:</p> <ul style="list-style-type: none"> • Escape and/or release from confinement (zoos, terraria, private collections) • Landscape/flora/fauna “improvement” in the wild • Transport–stowaway (hitchhikers on ships/boats or in containers) • Snakes are frequently accidentally introduced as

			<p>contaminants on live plant material such as ornamental trees (e.g. De Urioste & Mateo 2011);</p> <ul style="list-style-type: none"> • Releases of snakes as an act of compassion by religious practitioners (“fang sheng” or “animal release”, an East Asian Buddhist ritual cf. Liu et al. 2012): there are no indications of this happening in the EU therefore this pathway is not dealt with
<p>1.2. List relevant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways as well as a description of the associated commodities.</p> <p>For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 1.3a, 1.4a, etc. and then 1.3b, 1.4b etc. for the next pathway.</p>			<ul style="list-style-type: none"> • The following pathways are discussed together under the ‘pet’ pathway as the mechanism may be release, escape, or both and there are no data on their relative importance: <ul style="list-style-type: none"> ○ Escape from confinement (pet/aquarium/terrarium species) = accidental escapes of snakes from collections; ○ Release in nature (other intentional release) = people dumping pets that they grew tired off or will/can no longer support; • Release in nature (Landscape/flora/fauna “improvement in the wild”) = intentional release of snakes; • Zoo pathway: escape from confinement (Botanical garden/zoo/aquaria (excluding domestic aquaria)) = accidental escapes of snakes from collections; • Transport – stowaway (hitchhikers in or on airplane) = unintentionally transported snakes on airplanes. This pathway is considered very unlikely and is therefore not discussed; • Transport – stowaway (hitchhikers on ships/boats) = unintentionally transported snakes on cargo boats; • Contaminant on plants (except parasites, species transported by host/vector) = accidental introductions of snakes on live plant material (potted

			plants or old ornamental trees e.g. citrus and olive trees e.g. Mateo et al. 2011, Silva-Rocha et al. 2015);
Pathway name:	<i>Pet</i> pathway which includes [Escape from confinement (pet/aquarium/terrarium species)] [Release in nature (other intentional release)]		
1.3a. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)? (If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)	intentional	very high	This pathway includes accidental escapes of snakes from terraria and private collections. According to CBD pathway classification, this is an intentional pathway as it is the result of deliberate keeping of snakes. Furthermore, the pathway also involves people dumping pet snakes they grew tired off or will/can no longer support into the natural environment.
1.4a. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.	likely	medium	The pet pathway (release, escape or a combination) is a likely pathway of introduction. It is nearly impossible to give an indication of the propagule pressure for this pathway as casual records are hardly ever reported in literature or databased. Data from Germany, however, indicate that individuals escape/are released regularly with almost yearly records, published in local newspapers (Nehring & Rabitsch 2015, PETA 2014). This is consistent with the data documenting that <i>L. getula</i> was introduced through the pet trade in the US, Brazil and Europe, particularly in the Canary islands and the UK, but in the latter without succeeding (Kraus 2009, Krysko et al. 2011). Also, there are many other records of introductions of similar kingsnakes (other than <i>Lampropeltis getula</i>) introduced through the pet trade, among which <i>Lampropeltis</i> sp., <i>Lampropeltis alterna</i> , <i>Lampropeltis calligaster</i> and <i>Lampropeltis triangulum</i> , particularly in the US, Brazil and the UK (Kraus 2009, Krysko et al. 2011). <i>Lampropeltis getula</i> is commonly and widely kept as a pet in terraria and is popular with beginners, therefore propagule pressure is likely to be high. The species is used as a <i>learning species</i> for private people wanting to keep and rear snakes in terraria. Due to their lack of experience, it can be assumed that <i>L. getula</i> could escape from captivity more easily e.g. whilst handling or feeding. The species is denominated on some popular websites as an <i>escape king</i> .

			<p>The pet pathway was also the pathway of introduction of the invasive Gran Canaria population that likely originated from a few captive bred escaped animals (Monzón-Argüello et al., 2015). <i>Lampropeltis getula</i> is reproducing and expanding here despite the population likely descended from just a few individuals (Monzón-Argüello et al., 2015), therefore there is no need of large numbers to be released to have some populations successfully established in the wild.</p> <p>Although precise data on the extent of animals in trade are not available for the EU, there are clues that <i>L. getula</i> may be very popular in the global market. For example, <i>L. getula</i> is among the ten most popular alien pet reptiles in Taiwan (Shiau et al. 2006). The pet trade is a significant economic actor in the EU with member states officially reporting the import of 20,788,747 live reptiles (CITES and non-CITES species) between 2004 and 2014 (Aulyia et al. 2016, Duffy, 2016). <i>Lampropeltis getula</i> is a popular pet species and is on sale on several European websites. The majority of animals are produced in captivity (Fitzgerald et al., 2004), with one US reptile captive breeding centre reporting a production of 5000 <i>L. getula</i> in 2001 (UNEP-WCMC, 2009). Between 1995 and 2000, on average 2000 live specimens were exported out of the US each year (Fitzgerald et al., 2004).</p> <p>The risk of reinvasion after eradication is high as long as animals are available in the pet trade.</p>
1.9a. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	likely	medium	Transfer from this pathway to a suitable habitat is more likely than for escaped <i>L. getula</i> , since owners will probably bring snakes to an area they feel resembles its habitat. <i>L. getula</i> is a generalist snake species and can survive in nature given the temperatures are high enough (minimum temperature required for activity is 2°C). If released in a colder climate, the species could survive by hibernating in burrows or caves.
1.10a. Estimate the overall likelihood of entry into Europe based on this pathway?	likely	high	<i>L. getula</i> is a popular pet, and described on many online platforms as a <i>beginner snake</i> . So it is not unlikely that a relatively high number of owners are indeed, beginners. Due to their lack of experience, it can be assumed that they may

			release <i>L. getula</i> when care becomes too much of a burden or is higher than expected. The populations on Gran Canaria most likely result from a release or escape in the wild. There are numerous albino specimens on Gran Canaria, which are very rare in the natural native range (Life+ Lampropeltis EU project). Therefore, populations likely originated from captive bred animals and are probably the result of released or escaped specimens.
Pathway name:	[Release in nature: Landscape/flora/fauna improvement in the wild]		
1.3b. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)? (If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)	intentional	very high	This intentional release pathway involves the intentional release of snakes as a means of “completing the ecosystem”, e.g. to introduce a generalist rat or mice predator or just because a snake is missing from the ecosystem. In this sense, it can be treated like the pathway <i>introduction for biological control</i> . It is distinct from the pet pathway as it aims at establishing a viable population. Such introductions are sometimes performed with prior knowledge of the species biology and ecology.
1.4b. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.	unlikely	low	It is likely that releases would include a moderate number of animals, since the aim is to establish the species. It is known that success of establishment increases with number of released organisms. There are good indications <i>L. getula</i> was introduced this way in its invasive range on Gran Canaria (pers. comm. B. Hubbs). Reinvasion through this pathway can occur after eradication.
1.9b. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	likely	high	If <i>L. getula</i> would be released as landscape improvement, it is likely that this will be done in a suitable habitat for the species since the aim is to establish the species.
1.10b. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	unlikely	medium	Although there are good indications <i>L. getula</i> was introduced this way in its invasive range on Gran Canaria (pers. comm. B. Hubbs) the chances of this happening are probably low.
Pathway name:	[Escape from confinement (Botanical garden/zoo/aquaria (excluding domestic aquaria))]		
1.3c. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)? (If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)	intentional	very high	This pathway includes accidental escapes of snakes from zoological gardens. According to CBD pathway classification, this is an intentional pathway as it is the result of deliberate keeping of snakes.

<p>1.4c. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?</p> <p>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.</p>	<p>moderately likely</p>	<p>low</p>	<p><i>Lampropeltis getula</i> occurs in great numbers in zoological gardens throughout Europe (www.zootierliste.de). <i>L. getula</i> is denominated on some popular websites as an <i>escape king</i>.</p> <p>It is nearly impossible to give an indication of the propagule pressure for this pathway as casual records, including indications on the origin of the animals, are hardly ever reported in literature or databased. It can be assumed that less individuals will escape from zoological gardens than from private collections, since anti-escape mechanisms in the former are generally better.</p> <p>In Gran Canaria, where <i>L. getula</i> is reproducing and expanding (Monzón-Argüello et al., 2015), populations likely descend from just a few individuals, therefore there is no need for large numbers to escape to have some populations successfully established in the wild.</p> <p>The risk of reinvasion after eradication is high as long as animals are present in zoological gardens.</p>
<p>1.9c. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?</p>	<p>moderately likely</p>	<p>medium</p>	<p>It is more likely that released <i>L. getula</i> rather than escaped specimens will reach suitable habitat, because owners will probably release their pet in an area they feel is more suitable for them to survive.</p> <p><i>L. getula</i> is a generalist species and could probably survive in nature given that the temperatures are high enough (minimum 2°C). If released in a colder climate, the species could survive by hibernating in burrows or caves.</p>
<p>1.10c. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?</p>	<p>likely</p>	<p>medium</p>	<p>Since <i>L. getula</i> is present in zoological gardens throughout Europe, the species is likely to enter the risk assessment area by escape from these facilities.</p>
<p>Pathway name:</p>		<p>[Transport – stowaway (hitchhikers on ship/boat)]</p>	
<p>1.3d. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?</p>	<p>unintentional</p>	<p>very high</p>	<p>This pathway involves unintentionally transported snakes on ships and cargo boats.</p>

(If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)			
<p>1.4d. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?</p> <p>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.</p>	unlikely	high	<p>Even though the world's cargo carrying fleet was 55,138 ships in 2011 (IMO, 2012), it is rather unlikely that large numbers of stowaway <i>L. getula</i> will travel along this pathway over the course of one year. However, on the Canary islands <i>L. getula</i> has been transported to other islands through this pathway. For example, in 2017 a California kingsnake was detected on Lanzarote, which arrived as a stowaway from Gran Canaria on a pallet of pumpkins (pers. comm. R. Gallo Barneto). As populations likely descend from just a few individuals large numbers are not a prerequisite for successful establishment.</p> <p>There is a record of an introduction of a closely related species, <i>L. triangulum</i>, in the US, Indiana, as cargo stowaway (Kraus 2009).</p> <p>Reinvasion through this pathway can occur after eradication.</p>
<p>1.5d. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?</p> <p>Subnote: In your comment consider whether the organism could multiply along the pathway.</p>	likely	medium	<p>Snakes are known to sustain themselves for longer periods of time with very little food. Therefore it is moderately likely that <i>L. getula</i> could survive the long journey between North-America and Europe feeding on rats and mice on ships.</p> <p>For surface cargo, the main factor contributing to snake mortality is time on the dock (Perry & Vice, 2007).</p> <p>In order to reproduce along the pathway, a <i>L. getula</i> female must have mated successfully before the journey and lay eggs in a suitable place on board, which is unlikely to happen. The other option is that one male and one female snake would be present on board and mate, which is also unlikely to happen.</p>
<p>1.6d. How likely is the organism to survive existing management practices during passage along the pathway?</p>	moderately likely	low	<p>Active rat/mice control on the ship might impact snake survival during the journey.</p>
<p>1.7d. How likely is the organism to enter the risk assessment area undetected?</p>	moderately likely	high	<p><i>L. getula</i> is a fossorial species, spending most of its time underground and known for being rather inconspicuous (Wund et al., 2007). As a consequence, when accidentally</p>

			transported, this characteristic could lead to them not being detected without specific surveillance programmes (e.g. camera, traps or visual inspections). For example, it is believed that brown tree snakes (<i>Boiga irregularis</i>) were accidentally introduced to Guam with military equipment transported to the island shortly after World War II (Chapple et al., 2012) and there is still movement of that species through this vector.
1.8d. How likely is the organism to arrive during the months of the year most appropriate for establishment?	moderately likely	medium	The time of the year most appropriate for establishment is probably late spring-summer-early autumn, when snakes do not need to hide from the cold and can adapt to the new environment. It is also the time when certain prey (other snakes, turtle eggs) is more abundant.
1.9d. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	moderately likely	low	<p>There are (at least) two possible ways that <i>L. getula</i> could transfer from the pathway to a suitable habitat. Firstly, the specimen could escape from the ship through the passenger/crew exit, however these are often small and detection would be relatively high. Second, if <i>L. getula</i> would be on or between the cargo of the ship, it could simply be transported out of the ship whenever the cargo is loaded off.</p> <p>Sea ports are often in the vicinity of wetlands or estuaries. These are not per se suitable habitats for <i>L. getula</i> even though they could establish in some of the drier, warmer spots inside wetlands and are known to live in the vicinity of water. Sea ports can be very large and thus far away from suitable habitats, and there is no suitable <i>L. getula</i> habitat in harbours itself. Therefore, it is less likely that specimens will transfer from the pathway to a suitable habitat than it is for airports. On mediterranean islands, ports are often smaller and do have suitable habitat nearby.</p>
1.10d. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	unlikely	low	
Pathway name:	[Contaminant on plants (except parasites, species transported by host/vector)]		
1.3e. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	unintentional	medium	This pathway involves accidental introductions of snakes on live plant material (potted plants e.g. citrus and olive trees)

(If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)			
<p>1.4e. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?</p> <p>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.</p>	moderately likely	medium	<p><i>L. getula</i> is a fossorial, ground dwelling species (see above), and is not known to climb in trees or other large plants. As such, the species could be moved along with plants whilst hiding near the stem, in leaf litter or roots. However, there are no quantitative studies available to judge on the frequency of this happening.</p> <p>There is a record of an introduction of a closely related species, <i>Lampropeltis triangulum</i>, in the US, Massachusetts, through the nursery trade (Kraus 2009). Other species of reptiles have been successfully introduced through this pathway, including the Italian wall lizard (<i>Podarcis sicula</i>) that was introduced in the Iberian Peninsula (Silva-Rocha, 2015) through the olive tree trade. In addition, most of the records of <i>Hemorrhoids hippocrepis</i>, <i>Malpolon monspessulanus</i> and <i>Rhinechis scalaris</i>, and significantly their first appearance in the Balearic Islands, have been recorded by environmental authorities inside trunks or root balls of olive trees deposited in the nursery centres (Silva-Rocha et al. 2015). In this context olive tree trade is considered as a powerful vector for biological invasions across the Mediterranean (Silva-Rocha et al. 2015).</p> <p>In Gran Canaria, where <i>L. getula</i> is reproducing and expanding (Monzón-Argüello et al., 2015) populations likely descend from just a few individuals. So large numbers are not needed for successful introduction.</p> <p>Reinvasion through this pathway can definitely occur after eradication.</p>
<p>1.5e. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?</p> <p>Subnote: In your comment consider whether the organism could multiply along the pathway.</p>	likely	high	<p>If <i>L. getula</i> would be present as a plant contaminant, it is very likely that it would survive. Based on other documented cases of snakes introductions in Europe, we can infer the likelihood to be very high.</p>
1.6e. How likely is the organism to survive existing management	N/A	N/A	

practices during passage along the pathway?			
1.7e. How likely is the organism to enter the risk assessment area undetected?	moderately likely	low	<i>L. getula</i> is a rather large snake but is known not to be conspicuous, is not easily detected. See 1.4, there have been successful introductions of snakes and other reptiles through this pathway.
1.8e. How likely is the organism to arrive during the months of the year most appropriate for establishment?	moderately likely	high	The time of the year most appropriate for establishment is probably late spring-summer-early autumn, when snakes do not need to hide from the cold and can slowly adapt to the new environment. It is also the time when certain prey (other snakes, turtle eggs) is more abundant.
1.9e. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	likely	high	It is possible that the specimen is able to enter the plant transport undetected and stay undetected throughout its journey. However, when individual plants are sold at their destination, the <i>L. getula</i> specimen may be detected. The specimen could have transferred to a suitable habitat along the transport route by then.
1.10e. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	unlikely	low	
<i>End of pathway assessment.</i>			
1.11. Estimate the overall likelihood of entry into the risk assessment area based on all pathways in relevant biogeographical regions in current conditions (comment on the key issues that lead to this conclusion).	very likely	high	<i>L. getula</i> is a popular pet species and is kept in numerous zoological gardens and terraria throughout Europe. Escape/release from these facilities has already happened in the past (Gran Canaria) and is likely to happen again in the future. We therefore consider release/escape to be the most important and plausible pathway of introduction/entry of the species in the European Union. Similarly, the contaminant pathway may also deserve greater attention in the future, particularly in the light of the episodes involving the alien populations established in the Canary islands.
1.12. Estimate the overall likelihood of entry into the risk assessment area based on all pathways in relevant biogeographical regions in foreseeable climate change conditions?	likely	medium	Climate change will most likely have no specific effect on the possibility of entry of <i>L. getula</i> in the European Union.

PROBABILITY OF ESTABLISHMENT			
<p>Important instructions:</p> <ul style="list-style-type: none"> For organisms which are already established in parts of the Union, answer the questions with regard to those areas, where the species is not yet established. If the species is established in all Member States, continue with Question 1.16. 			
QUESTION	RESPONSE	CONFIDENCE	COMMENT
1.13. How likely is it that the organism will be able to establish in the EU based on the similarity between climatic conditions in Europe and the organism's current distribution?	likely	high	<p>The native range of <i>Lampropeltis getula</i> spans several warm temperate and arid climate zones with a range of precipitation regimes (e.g. desert, fully humid) (Hubbs, 2009). This matches the following Köppen-Geiger climate classifications: csa, csb, bsk, bsh, dsb, bwk, cfa, dfa, am, af, aw. Some of these climatic conditions (csa, csb, bsk, bsh and cfa) also occur in the Union, more notably in the Mediterranean region, Macaronesian and to a lesser extent the Steppic bioregion. According to the SDM (Annex IV), a very small part (the warmest) of the Alpine bioregion could also be suitable.</p> <p>In central and northern member states, winter conditions are expected to represent a constraint on the survival of <i>L. getula</i> (Gregory, 2009). Additionally, short and cool summers will restrict their foraging and reproductive opportunities (Gregory, 2009). <i>Lampropeltis getula</i> is oviparous (i.e. lays eggs), while most higher-latitude snake species are viviparous. This will prevent <i>L. getula</i> to become established in colder, temperate regions of Europe. However, <i>L. getula</i> could escape these limiting conditions in some southern parts of the possible range by behavioural adaptations and niche selection at micro scale.</p>
1.14. How likely is it that the organism will be able to establish in the EU based on the similarity between other abiotic conditions in Europe and the organism's current distribution?	likely	medium	<p>The species is a generalist and occurs in a variety of habitats in its native range (Wund et al., 2007), from open coniferous forest and woodland, swamps, coastal marshes and river bottoms, to farmland, prairie and chaparral, and even in desert habitats (Hammerson et</p>

			<p>al., 2007).</p> <p>Several studies (Jenkins et al., 2001; Plummer, 2010; Wund et al., 2007) indicate that <i>L. getula</i> prefers certain microhabitats within its broad range with sufficient ground vegetation, leaf litter, or other ground cover (Jenkins et al., 2001; Plummer, 2010; Wund et al., 2007). This type of microhabitat may occur where the canopy is sufficiently open to permit growth of ground vegetation, in forests where leaf litter and fallen logs accumulate, and at habitat edges (Plummer, 2010). A number of studies point out that <i>L. getula</i> is usually found in the vicinity of water-containing microhabitats that allow for them to burrow (Enge, 1997; K. L. Krysko, 2001; Plummer, 2010). In the Eastern United States, <i>L. getula</i> has shown a population decline which could be linked to extreme droughts (Seigel et al., 2007).</p> <p>On Gran Canaria, <i>L. getula</i> is also present in urbanized areas. Another study on <i>L. getula</i> points out that the species is known to use urban edge habitat (Anguiano & Diffendorfer, 2015). Additionally, one study indicates that California Kingsnakes (<i>L. getula californiae</i>) are more capable of persisting in small fragments than other snake species (Anguiano & Diffendorfer, 2015). Given the highly fragmented nature of the European landscape, this may benefit the establishment of <i>L. getula</i> in the EU.</p> <p>Neither one of these habitat (components) is in short supply in the EU.</p>
<p>1.15. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, terraria, zoological gardens) in Europe?</p> <p>Subnote: gardens are not considered protected conditions</p>	<p>very likely</p>	<p>very high</p>	<p><i>L. getula</i> occurs in a great number of zoological gardens and terraria throughout Europe (www.zootierliste.de). It is very likely that, given the artificially maintained environment, <i>L. getula</i> will be able to survive and establish in protected conditions even in northern regions.</p>

<p>1.16. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Europe?</p>	<p>moderately widespread</p>	<p>medium</p>	<p>see 1.14. The species is a generalist and all the abiotic components of its preferred habitat are plenty in the Union. Besides suitable habitat, potential prey are widespread as well. <i>Lampropeltis getula</i> feeds on a wide array of prey such as snakes (including conspecifics), lizards and other reptiles, small mammals (e.g. rats, shrews, rodents, rabbits), birds and eggs of various bird and reptile species (Jenkins et al., 2001; Linehan et al., 2010; Winne et al., 2007).</p> <p>Cabrera-Pérez et al. (2012) note that on average, captured <i>L. getula</i> on Gran Canaria were in good physiological condition, indicating they have no problem finding food throughout the year. Of two populations studied on Gran Canaria, one had a higher proportion of skinks in its diet, whereas rodents made up a higher proportion of the other population's diet.</p> <p>The breeding season for <i>L. getula</i> generally runs from spring to early summer. In warmer regions (e.g. Florida), the breeding season can start as early as February. Females lay 3–29 eggs in June or July, approximately 45–60 days after mating (Krysko et al., 2008) and hatching occurs from late July through mid-October. A study by Burger (1990) found that eggs of <i>L. getula</i> incubated at 22 °C failed to hatch; eggs incubated at 28 °C hatched in 52–54 days, compared to 39–40 days for eggs incubated at 32 °C.</p> <p>Combining the results of the previous study and a SAGE (1998) map of the average temperature in June, July and August in Europe, only the southernmost regions (Mediterranean, Macaronesia, Bulgaria, Romania) have average summer temperatures high enough for the incubation of <i>L. getula</i> eggs.</p>
<p>1.17. If the organism requires another species for critical stages in its life cycle then how likely is the organism to become associated with such species in Europe?</p>	<p>N/A</p>	<p>N/A</p>	<p>There are no indications <i>L. getula</i> needs another species for critical stages in its life cycle.</p>

1.18. How likely is it that establishment will occur despite competition from existing species in Europe?	moderately likely	low	Even though there are snakes with similar diets (e.g. reptile-eating) and habitat in Europe (e.g. <i>Malpolon monspessulanus</i> , <i>Hierophis viridiflavus</i> , <i>Coronella austriaca</i>) that could potentially compete with <i>L. getula</i> , they could probably easily adapt their lifestyle to escape competitive interactions, or exploit alternative food sources to escape competition for food. It is therefore moderately likely competitive interactions will not prevent <i>L. getula</i> from establishing populations in the Union.
1.19. How likely is it that establishment will occur despite predators, parasites or pathogens already present in Europe?	moderately likely	medium	<p>The short-toed snake eagle (<i>Circaetus gallicus</i>) in particular is a potential predator for <i>L. getula</i>. Also, a number of other large snake species are reported to display ophiophagy (the eating of snakes), more specifically viperophagy or cannibalism, such as green whip snake (<i>Hierophis viridiflavus</i>) or Aesculapian snake (<i>Zamenis longissimus</i>). Potentially, also four-lined snake (<i>Elaphe quatuorlineata</i>) or Montpellier snake (<i>Malpolon monspessulanus</i>) could do so. Yet, other snake species usually do not represent an important part a snake's diet that mostly comprises rodents and lizards. Capula et al., (2014) conclude that ophiophagy mostly occurs in response to low level of normal prey availability (lizards and rodents) and a high abundance of snakes.</p> <p>Small Asian mongoose (<i>Herpestes javanicus</i>), introduced to several Croatian islands early 1900s for biological control of horned viper (Barun et al., 2010; Ćirović et al., 2011), could hinder effective establishment in the eastern part of the Mediterranean bioregion where this invasive species of EU concern is established. Likewise, the presumably native Egyptian mongoose (<i>Herpestes ichneumon</i>) could do the same on Iberia, as reptiles, including snakes, represent a significant part of the diet of this generalist predator (Delibes et al., 1984; Palomares, 1993; Rosalino et al., 2009).</p>

			Other potential kingsnake predators include (introduced) striped skunk (<i>Mephitis mephitis</i>) and raccoon (<i>Procyon lotor</i>) (e.g. Urban (1970)), but these are either rare or omnivorous and mostly not present in bioregions predicted currently suitable for establishment of <i>L. getula</i> .
1.20. How likely is the organism to establish despite existing management practices in Europe?	N/A	N/A	There are currently no known existing management practices for <i>L. getula</i> in the EU, with the exclusion of the recurring control operations in the Canary islands and the activities aimed at controlling/eradicating alien snakes in the Balearics (Joan Mayol Serra, pers. comm., 2017), which indeed may prevent further establishment of species in the archipelago. It is unknown to what extent the snakes present on Gran Canaria represent a risk of introductions to the EU mainland.
1.21. How likely are existing management practices in Europe to facilitate establishment?	N/A	N/A	
1.22. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in Europe?	very likely	high	<i>L. getula</i> is a fossorial species, spending most of its time underground in burrows (Steen et al., 2010). It is therefore very likely that animals would survive eradication campaigns in Europe. This is well documented in the case of the eradication project in the Canary islands (www.lifelampropeltis.com). Actually, despite the use of a combination of classic (trapping, hand capture, hunting with raptors) and more advanced management methods (e.g. pheromone traps), the control operators on Gran Canaria recognised that the species will be impossible to eradicate (Miguel Ángel Cabrera and Juan Luis Rodríguez Luengo, pers. comm. 2017). However, this kind of management practices are highly context dependent, and some positive results seem being achieved with the eradication of alien snakes in the Balearic islands (Joan Mayol Serra, pers. comm., 2017).
1.23. How likely are the biological characteristics of the organism to facilitate its establishment?	likely	high	Since the majority of <i>L. getula</i> that could establish in the EU will be escapees/releases of captive-bred origin, it must be taken into account that such captive-bred

		<p>specimens are known to reproduce in great numbers, achieve sexual maturity earlier and produce multiple clutches per year (Seigel et al., 1987). Interestingly, <i>L. getula californiae</i> populations on Gran Canaria are 23% heavier, have greater mean and maximum clutch sizes (10.02 vs 6.67 and 29 vs 11 respectively) and have more gravid females (57.24% vs 10.38%) compared to populations in the native range. Females also become gravid earlier in the year. It is hypothesized this increase in mass and reproductive output is due to the lack of predation and higher food availability on the Canaries (Fisher et al. 2017).</p> <p>Reproductive activity in the native range is mostly confined to late spring-early summer (Knepton, 1951; Seigel et al., 1987; Krysko, 2001, 2002; Hubbs 2009). Eastern kingsnakes mate from spring to early summer and eggs are laid during summer months (Howze & Smith, 2012; Krysko et al., 2008). On Gran Canaria, pregnant snakes are found from March onward (Cabrera-Pérez et al. 2012).</p> <p>The Gran Canaria population of kingsnakes successfully recruits juveniles (Cabrera-Pérez et al., 2012; Monzón-Argüello et al., 2015). As already mentioned above, <i>L. getula</i> is known to occur in highly fragmented areas, meaning it could spread along small fragments of suitable habitat throughout Europe.</p> <p>The breeding season for <i>L. getula</i> generally runs from spring to early summer. In warmer regions (e.g. Florida), the breeding season can start as early as February. Females lay 3–29 eggs in June or July, approximately 45–60 days after mating (Krysko et al., 2008) and hatching occurs from late July through mid-October. A study by Burger (1990) found that eggs of <i>L. getula</i> incubated at 22 °C failed to hatch; eggs incubated at 28 °C hatched in 52–54 days, compared to 39–40 days for eggs incubated at 32 °C. On Gran</p>
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			Canaria, the species lays between 3-24 eggs with an average number of eggs per female of 16.8 (Cabrera-Pérez et al. 2012). These are laid 45 to 65 days post-copula. Sexual maturity is reached after 2 years (www.lifelampropeltis.com).
1.24. How likely is the capacity to spread of the organism to facilitate its establishment?	moderately likely	medium	
1.25. How likely is the adaptability of the organism to facilitate its establishment?	likely	medium	<p>According to Detwiler & Criscione (2014), recently established invasive reptiles profit from life history characteristics such as high growth rate and generation overlap, and low predation and competition pressure, which allows them to recover from bottlenecks. <i>Lampropeltis getula</i> is a generalist, ubiquitous species in its native range, has a flexible life history and fits that description.</p> <p>Even though the Gran Canaria populations of <i>L. getula</i> likely descend from just a few individuals, they are reproducing and expanding (Monzón-Argüello et al., 2015). One of two studied populations feeds more on reptiles, the other more on rodents (Monzón-Argüello et al., 2015). These populations are situated in fairly different habitats (cliffs in combination with agriculture, providing humidity for reptiles, vs. open habitat with chicken farm, respectively), indicating that this snake will likely be able to adapt to a variety of habitats (Monzón-Argüello et al., 2015).</p>
1.26. How likely is it that the organism could establish despite low genetic diversity in the founder population?	very likely	high	Despite low genetic diversity in the founder population, the species has successfully established on the Canary islands (Monzón-Argüello et al., 2015).
1.27. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Europe? (If possible, specify the instances in the comments box.)	very likely	high	The species has established in Macaronesia (Monzón-Argüello et al., 2015) and similar conditions occur in the Mediterranean bioregion so the likelihood is considered high.
1.28. If the organism does not establish, then how likely is it that casual populations will continue to occur?	very likely	medium	<i>Lampropeltis getula</i> is a popular pet snake, therefore future escapes are practically inevitable. Similarly, the spread of the species through accidental introductions

<p>Subnote: Red-eared Terrapin, a species which cannot reproduce in GB but is present because of continual release, is an example of a transient species.</p>			<p>(as a contaminant or as a stowaway) is always possible. Therefore it is very likely that casual populations will continue to occur in the future, but will not reproduce in most parts of the Union due to insufficiently high temperatures for egg-incubation (see above).</p>
<p>1.29. Estimate the overall likelihood of establishment in relevant biogeographical regions in current conditions (mention any key issues in the comment box).</p>	<p>very likely</p>	<p>high</p>	<p>The native range of <i>Lampropeltis getula</i> spans several warm temperate and arid climate zones with a range of precipitation regimes (e.g. desert, fully humid) (Hubbs, 2009). This matches the following Köppen-Geiger climate classifications: csa, csb, bsk, bsh, dsb, bwk, cfa, dfa, am, af, aw. Some of these climatic conditions (csa, csb, bsk, bsh and cfa) also occur in the Union, more notably in the Mediterranean region.</p> <p>Hence, it is likely that <i>L. getula</i> will be able to establish in the EU under current climatic conditions. Under current climate, establishment of <i>L. getula</i> is a fact for the Macaronesian bioregion. Similar conditions and suitable habitat are currently present in the Mediterranean and to a lesser extent steppic bioregions (also a very small part of the alpine bioregion). These contain areas with the same Köppen-Geiger climate classification as the Canary islands (csa), where the species has established. Therefore, depending on the subspecies introduced, <i>L. getula</i>, under current climatic conditions, could establish in several EU member states in the Mediterranean, Steppic and a very small part (the warmest) of the Alpine bioregion.</p> <p>Currently, critical minimum winter temperature is probably the most limiting factor for establishment of <i>L. getula</i> in the EU. In more central and northern areas, establishment is less likely, since incubation temperature for eggs are likely too low.</p> <p>Although environmental conditions in more temperate EU bioregions and member states are currently less suited for the species, it is possible <i>L. getula</i>, like other snake species in northwest Europe (e.g. <i>Elaphe schrenkii</i> (Bugter et al., 2014); <i>Orthriophis taeniurus</i> in</p>

			Belgium), can escape these limiting conditions by behavioural adaptations and niche selection at micro scale (e.g. warm hay stacks could provide suitable refuges and breeding conditions). The species could escape cold winters conditions and survive in hibernacula such as caves, rock crevices, clay and gravel banks, mammal burrows, hollow logs and stumps, root systems of shrubs and trees, old sawdust mounds and abandoned buildings (Linehan et al., 2010; Wund et al., 2007).
1.30. Estimate the overall likelihood of establishment in relevant biogeographical regions in foreseeable climate change conditions	very likely	high	As temperatures will rise in Europe, more areas will be suitable for egg incubation, therefore the possible establishment area will increase. Under foreseeable climate change conditions the number of biogeographical regions suitable for establishment is expected to increase, with the Atlantic, Black Sea, Continental, Alpine and Pannonian bioregions becoming suitable for establishment. Consequently, it can be expected that, under foreseeable climate change, there will be a higher probability of establishment in more northern EU member states. In regions neighbouring to the EU, the species could establish in the Anatolian biogeographical region, North Africa and the Middle East.

PROBABILITY OF SPREAD			
<p>Important notes:</p> <ul style="list-style-type: none"> • Spread is defined as the expansion of the geographical distribution of an alien species within the assessment area. • Repeated releases at separate locations do not represent spread and should be considered in the probability of introduction and entry section. 			
QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How important is the expected spread of this organism in Europe by natural means? (Please list and comment on each of the mechanisms for natural spread.)	minimal	medium	<p>Natural spread is movement by slithering. Anguiano & Diffendorfer (2015) indicate <i>L. getula</i> only shows small spatial movement patterns.</p> <p><i>Lampropeltis</i> species have small home ranges (1-50 ha minimum convex polygons) (Anguiano & Diffendorfer, 2015; Hansen, 1982; Jenkins et al., 2001; Linehan et al., 2010; Plummer, 2010; Wund et al., 2007) and can therefore persist in fragmented landscapes (e.g. Case et al., 2001). Small spatial movement patterns, home-range overlap, and ability to use urban edge habitat may further contribute to persistence in fragmented landscapes (Anguiano & Diffendorfer, 2015). As a consequence, it is expected that <i>L. getula</i> will spread naturally across the island of Gran Canaria, although the rate of this spread will likely be slow.</p> <p>Anguiano & Diffendorfer (2015) conducted a study on <i>L. getula</i> and found that, of 18 snakes studied, 17 did not cross streets or move into the urban matrix. Indeed, Hansen (1982) also noted that pavement, railroad beds and open expanses of soil act as physical barriers to <i>L. getula californiae</i> movement. The study by Anguiano & Diffendorfer (2015) further hypothesized that open areas in urban habitats, such as manicured lawns, as well as human activity likely prevent movement into the urban matrix and subsequently onto roads.</p> <p><i>L. getula</i> reproduction, as well as environmental and</p>

			climatic requirements have been described above. <i>L. getula</i> is known to effectively recruit juveniles in both studied Gran Canaria populations.
2.2. How important is the expected spread of this organism in Europe by human assistance? (Please list and comment on each of the mechanisms for human-assisted spread) and provide a description of the associated commodities.	moderate	medium	<i>Lampropeltis getula</i> is spread on several islands of the canaries, and may thus further spread across the Canary Islands and the rest of Europe by human assistance. The snakes can be inadvertently transported by boat/plane as stowaways (see introduction part) and, more importantly, can be (un)intentionally introduced into the environment (see introduction part for an account on the pathways).
2.2a. List and describe relevant pathways of spread. Where possible give detail about the specific origins and end points of the pathways. For each pathway answer questions 2.3 to 2.9 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 2.3a, 2.4a, etc. and then 2.3b, 2.4b etc. for the next pathway.	[insert text]		Unaided - Natural dispersal across borders of invasive alien species that have been introduced through other pathways.
<i>Pathway name:</i>	[Unaided - Natural dispersal across borders of invasive alien species that have been introduced through other pathways]		
2.3. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)?	N/A	N/A	
2.4. How likely is it that large numbers of the organism will spread along this pathway from the point(s) of origin over the course of one year?	moderately likely	medium	At least one population on Gran Canaria is successfully recruiting juveniles into the population (Monzón-Argüello et al., 2015). It can be assumed that this population is more likely to expand its range, consistent with the observation that the area in which snakes of that population were being caught has increased in size between 2007 and 2011 (Cabrera-Pérez et al., 2012).
2.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	very likely	high	

2.6. How likely is the organism to survive existing management practices during spread?	moderately likely	medium	Efforts to control <i>L. getula</i> have been implemented on Gran Canaria since 2007. Initial management practices were visual searching and hand capture of snakes. Passive capture with cages has been tested with a variety of traps including funnel traps and pitfall traps, all baited with mice (Cabrera-Pérez et al., 2012). In some cases, artificial barriers were also used (Cabrera-Pérez et al., 2012). Additionally, since 2010, artificial cover objects (wooden boards) have been used (Cabrera-Pérez et al., 2012).
2.7. How likely is the organism to spread in Europe undetected?	moderately likely	high	A newly established population could already be quite large before it reaches a detection threshold, given the secretive nature of <i>L. getula</i> and the fact that it is a fossorial species.
2.8. How likely is the organism to be able to transfer to a suitable habitat or host during spread?	very likely	high	<p><i>Lampropeltis getula</i> has already spread in Gran Canaria, proving the islands habitat is suitable for the species. The Canary islands fall into the BWh and Csa categories of the Köppen-Geiger categories, both of which are also present in the native range of <i>L. getula</i>.</p> <p><i>Lampropeltis</i> species have small home ranges (1-50 ha minimum convex polygons) (Anguiano & Diffendorfer, 2015; Hansen, 1982; Jenkins et al., 2001; Linehan et al., 2010; Plummer, 2010; Wund et al., 2007) and can therefore persist in fragmented landscapes (e.g. Case et al., 2001). Small spatial movement patterns, home-range overlap, and ability to use urban edge habitat may further contribute to persistence in fragmented landscapes (Anguiano & Diffendorfer, 2015). As a consequence, it is expected that <i>L. getula</i> will spread naturally across the island of Gran Canaria, although the rate of this spread will likely be slow.</p> <p>Anguiano & Diffendorfer (2015) conducted a study on <i>L. getula</i> and found that, of 18 snakes studied, 17 did not cross streets or move into the urban matrix. Indeed, Hansen (1982) also noted that pavement, railroad beds and open expanses of soil act as physical barriers to <i>L. getula californiae</i> movement. The study by Anguiano & Diffendorfer (2015) further hypothesized that open areas in</p>

			urban habitats, such as manicured lawns, as well as human activity likely prevent movement into the urban matrix and subsequently onto roads.
2.9. Estimate the overall likelihood of spread into or within the Union based on this pathway?	very likely	high	
<i>End of pathway assessment, repeat as necessary.</i>			
2.10. Within Europe, how difficult would it be to contain the organism?	difficult	medium	Given the secretive nature of <i>L. getula</i> and the fact that it is a fossorial species, it would be difficult to contain this organism. Large areas would have to be surveyed and monitored. The ongoing presence and spread of <i>L. getula</i> on Gran Canaria despite management practices is a good example of how much effort it takes to find, catch and remove individuals.
2.11. Based on the answers to questions on the potential for establishment and spread in Europe, define the area endangered by the organism.	The area endangered by <i>L. getula</i> include the Mediterranean and Steppic bioregion. Climate change could increase the area at risk with parts of the Atlantic, Continental and Alpine bioregion becoming suitable.	high	See Questions 3, 4 of the Chapeau.
2.12. What proportion (%) of the area/habitat suitable for establishment (i.e. those parts of Europe where the species could establish), if any, has already been colonised by the organism?	0-10	high	This species has not colonized other parts of Europe apart from Gran Canaria, however snakes are inconspicuous creatures and can easily be overlooked (e.g. Kery 2002).
2.13. What proportion (%) of the area/habitat suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)?	0-10	high	Unintentional transport of the species in sufficient numbers for establishment into the EU is unlikely. The most likely pathway of introduction will thus be escape from pet keepers or zoos. Even though high numbers of <i>L. getula</i> are present as pets or in zoological gardens within the EU that could possibly escape or be released, its limited movements in the wild and small home ranges will likely slow its spread and invasion.
2.14. What other timeframe (in years) would be appropriate to estimate any significant further spread of the organism in	80	medium	Because <i>L. getula</i> generally occurs in warmer areas, a temperature increase due to global warming will inherently

Europe? (Please comment on why this timeframe is chosen.)			increase the percentage of suitable habitat for the species in the European Union. Consistent with the SDM (Annex IV) which models <i>L. getula</i> under greenhouse gas emission scenarios up to in 2100, we consider 80 years a valuable timeframe to estimate any further spread of <i>L. getula</i> in the Union.
2.15. In this timeframe what proportion (%) of the endangered area/habitat (including any currently occupied areas/habitats) is likely to have been invaded by this organism?	10-33	low	The most likely pathway of introduction is escape from pet keepers or zoological gardens. Since <i>L. getula</i> is present in captivity throughout the EU, it is likely that there will be many escapes/releases in the future. Combined with the fact that suitable habitat surface area will have increased 80 years from now, it is likely that <i>L. getula</i> will be present in several EU member states within the endangered area. However, since <i>L. getula</i> has small home and activity ranges, the species will probably spread rather slow. Only few studies have been performed on this subject, and none of them took climate change into account.
2.16. Estimate the overall potential for spread in relevant biogeographical regions under current conditions for this organism in Europe (using the comment box to indicate any key issues).	slowly	medium	This is discussed under 2.15
2.17. Estimate the overall potential for spread in relevant biogeographical regions in foreseeable climate change conditions	moderately likely	medium	This is discussed under 2.15

MAGNITUDE OF IMPACT

Important instructions:

- Questions 2.18-2.22 relate to environmental impact, 2.23-2.25 to impacts on ecosystem services, 2.26-2.30 to economic impact, 2.31-2.32 to social and human health impact, and 2.33-2.36 to other impacts. These impacts can be interlinked, for example a disease may cause impacts on biodiversity and/or ecosystem functioning that leads to impacts on ecosystem services and finally economic impacts. In such cases the assessor should try to note the different impacts where most appropriate, cross-referencing between questions when needed.
- Each set of questions above starts with the impact elsewhere in the world, then considers impacts in Europe separating known impacts to date (i.e. past and current impacts) from potential future impacts (including foreseeable climate change).
- Assessors are requested to use and cite original, primary references as far as possible.

QUESTION	RESPONSE	CONFIDENCE	COMMENTS
Biodiversity and ecosystem impacts			
2.18. How important is impact of the organism on biodiversity at all levels of organisation caused by the organism in its non-native range excluding the Union?	major	medium	<p>On Gran Canaria, various endemic reptiles are impacted upon by predation. Following analysis of the stomach contents of <i>L. getula</i> in Gran Canaria the diet of the species appeared to include the giant lizard (<i>Gallotia stehlini</i>), Gran Canaria skink (<i>Chalcides sexlineatus</i>) and Boettger's wall gecko (<i>Tarentola boettgeri</i>). Gran Canaria giant lizard makes up most of the diet of <i>L. getula</i>. This endemic species is currently of least concern (IUCN Red List), but could become threatened in the near future. Gran Canaria giant lizard is also known to be an important seed dispersers of plant species with fleshy fruits, and some plants germinate better after passage through their gut (Valido and Nogales 1994). Therefore, predation on the lizard could also have effects on the relative abundance of these plants and on vegetation structure (in this case xerophytic scrub).</p> <p>On Gran Canaria, densities of the endemic giant lizard <i>G. stehlini</i>, which represents the most important food source of <i>L. getula</i> (Cabrera-Pérez et al. 2012), were compared between an invaded and an uninvaded site using capture-mark-recapture. Densities were about 10% in the invaded site.</p>

			<p>Also, biometric data indicated lizards in invaded sites were 30% taller which could indicate the snakes preferentially predate on younger lizard and impact on the demography of the population (Life+ Lampropeltis 2013).</p> <p>Currently, we could not find any evidence of documented, quantified decline in the conservation status of other native species caused by <i>L. getula</i>. Impacts on endemic reptiles on Gran Canaria have had no effect on ecosystem functions so far but this remains largely undocumented.</p>
2.19. How important is the impact of the organism on biodiversity at all levels of organisation (e.g. decline in native species, changes in native species communities, hybridisation) currently in the different biogeographical regions or marine sub-regions where the species has established in Europe (include any past impact in your response)?	N/A		The species is only established in Macaronesia, which is outside the RA area.
2.20. How important is the impact of the organism on biodiversity at all levels of organisation likely to be in the future in the different biogeographical regions or marine sub-regions where the species can establish in Europe?	major	medium	<p>The species may have a major impact on biodiversity and ecosystem services, by interacting with other species through a number of ways, particularly through predation and competition, alteration of plant-animal interactions (e.g. seed-dispersal mutualistic interactions, pollination), but also through the spread of diseases and parasites.</p> <p>In its native range, <i>L. getula</i> is considered as a generalist predator with a preference for aquatic snakes and turtle eggs (Winne et al., 2007). A diet analysis of <i>L. getula</i> in South Carolina between 1975 and 2005 identified several food items, including <i>Thamnophis sirtalis</i>, several species of watersnakes, <i>Crotalus horridus</i>, <i>Blarina carolinensis</i> (a kind of shrew) and eggs from <i>Chelydra serpentina</i> and <i>Trachemys scripta</i> (Winne et al., 2007). Another source reports predatory activities on rodents and other small mammals, lizards and their eggs, snakes (including poisonous viper species) and their eggs, turtle eggs and hatchlings, frogs, salamanders, birds, bird eggs and chicks, and large invertebrates (Weldon & Schell, 1984). Additionally, in the Canary islands, <i>L. getula</i> preys on several endemic reptile species (Fritts & Rodda, 1998; Guicking, Griffiths, Moore, Joger, & Wink,</p>

			<p>2006; Martínez-Morales & Cuarón, 1999; Monzón-Argüello et al., 2015).</p> <p>Because of its generalist diet, the snake can pose a threat to many native European species (including snakes, turtles, small mammals and birds), given that <i>L. getula</i> occur in sufficiently large numbers. Indeed, snakes introduced to other islands have had devastating effects on native fauna. Other examples include snakes introduced to Mediterranean islands, such as horseshoe whip snake <i>Hemorrhhois hippocrepis</i>, introduced on the Balearics with potted plants, which is causing declines in native endemic Ibiza wall lizard <i>Podarcis pityusensis</i> populations through predation (Hinckley et al. 2016). The historical introduction of the snake <i>Macroprotodon cucullatus</i>, together with some introduced mammals, have been considered responsible for the extinction of native Lilford's wall lizard <i>Podarcis lilfordi</i> in Mallorca and Menorca (Pinya and Carretero 2011, Silva-Rocha 2015) and of the native Mallorcan midwife toad <i>Alytes muletensis</i> and an undescribed Discoglossid (Pleguezuelos 2004). The restricted contemporary range of Mallorcan midwife toad <i>A. muletensis</i> may also be the result of predation by introduced Viperine Snake <i>Natrix maura</i>. These examples illustrate introduced snakes on Mediterranean islands can have profound effects on native, often endemic herpetofauna through predation.</p> <p>The potential impact of snake predation on lizards impacting on plant-animal mutualism is illustrated by a case on the Balearic islands. The frugivorous lizard <i>P. lilfordi</i> went extinct due to snake and rat predation on Menorca causing declines in the endemic perennial shrub <i>Daphne rodriguezii</i> due to lowered seedling recruitment and reduced levels of dispersal (Traveset and Riera 2005, Traveset and Richardson 2006). Similar effects are possible on pollination services (e.g. Traveset and Saez 1997).</p> <p>Especially in areas under threat, such as Iberia and the Mediterranean islands, the degree of endemism is high e.g. in</p>
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		<p>reptiles and small mammals, hence the risk of impact through predation on such species is high. Due to their generalist diet and their habits of roaming in wet environments, it is quite possible <i>L. getula</i> will also prey on amphibians, which could pose a major threat to many species that are already in decline, especially in the Mediterranean bioregion (Winne et al., 2007). Species under threat may include the ocellated skink (<i>Chalcides ocellatus</i>) in Sicily, Sardinia, Greece and Malta, the Cyprus whip snake (<i>Hierophis cypriensis</i>) in Cyprus, the Cretan wall lizard (<i>Podarcis cretensis</i>) in Crete and the North-African white-toothed shrew (<i>Crocidura pachyura</i>) in Ibiza, Sardinia and Pantelleria (Italy). Of course, this list is not complete and many other species could become threatened by introduced <i>L. getula</i> in the future.</p> <p><i>L. getula</i> may also have an impact as a vector of diseases and parasites. For example, three new species of <i>Hepatozoon</i> infecting the Florida kingsnake, <i>Lampropeltis getula floridana</i> were recently described (Telford 2010). The genus is particularly prevalent in amphibians and reptiles and is well known in veterinary circles for causing a tick-borne disease called hepatozoonosis in some mammals (e.g. dogs). However, such blood parasites mostly occur on wild snakes, and are less prevalent in captive (and escaped) snakes. The probability of transmission of such parasites, which have complex life cycles and require vectors or intermediate hosts, is therefore limited (pers. comm. F. Pasmans).</p> <p><i>L. getula</i> is a possible carrier of Chrysosporium-related fungi, which could cause damage to native reptile species (Cabañes et al., 2014; Lorch et al. 2016; Franklinos et al. 2017). Snakes have been known to carry several of these Chrysosporium-related fungi, such as <i>Nannizziopsis guarroi</i>, <i>Paranannizziopsis australiensis</i>, <i>P. californiensis</i>, <i>P. crustacean</i>, <i>P. longispora</i> and <i>Ophidiomyces ophiodiicola</i> (Cabañes et al., 2014). Snake Fungal disease (SFD), caused by the agent <i>Ophidiomyces ophiodiicola</i>, has the potential to cause lethal infections and contribute to extinction of wild snake populations. Both wild and captive <i>Lampropeltis</i> are</p>
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		<p>known hosts (Lorch et al. 2016). Mortality rates, transmission patterns and population-level effects may be difficult to assess with the cryptic nature of snakes, they can be substantial and SFD was identified as a major conservation concern (Sutherland et al. 2014). Skin infections by SFD have been documented increasingly throughout most of the eastern USA (Sleeman 2013) and were also reported from wild caught grass snakes (<i>Natrix natrix</i>) in the UK and dice snake (<i>Natrix tessellata</i>) in the Czech Republic (Franklinos et al. 2017). Genetic and phenotypic differences indicate that the European isolates represent novel strains of <i>O. ophioidicola</i> (Franklinos et al. 2017). The individual and population level impacts of SFD in Europe remain currently unknown due to the challenges of reptile health surveillance and a paucity of long-term monitoring data (Böhm et al. 2013).</p> <p>Furthermore, some reptiles can potentially carry ticks that spread the bacterium <i>Cowdria ruminantium</i> that, although not lethal to reptiles, can cause heartwater disease and kill grazing ruminants (Fisher & Csurhes, 2009). There are no known records of this bacterium on <i>L. getula</i> however and this phenomenon is more relevant to African reptiles (Burrige 2001). So far, there is no evidence that the importation of reptiles or amphibians into Europe has had any negative ramifications for livestock production (Pasmans et al. in press.).</p> <p>However, it should be noted that, in general, the knowledge of infectious diseases of snakes is relatively limited. Knowledge of the impact of most of the diseases described in wild populations is even more rare. Despite these gaps, potentially, the situation is that spill-over from unknown pathogens to wildlife could be an issue and represents an inherent risk associated with snake introductions.</p> <p><i>Lampropeltis getula</i> is not aggressive nor poisonous, but like other reptiles, is a potential carrier/reservoir for <i>Salmonella</i> which are well known to pose a significant health risk to humans (Damborg et al. 2016). However, this risk needs to be</p>
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			<p>placed in context, as the vast majority of infections in humans are caused by foodborne <i>Salmonella</i> (see review by Pasmans et al. in press.). Also, <i>Salmonella</i> is common in reptiles and is not specific to <i>Lampropeltis</i>.</p> <p><i>Lampropeltis getula</i> might reduce biodiversity and disturb trophic interactions in areas where it would establish in the future in Europe due to its predatory activities on rodents and other small mammals, lizards and their eggs, snakes (including poisonous viper species) and their eggs, turtle eggs and hatchlings, frogs, salamanders, birds, bird eggs and chicks, and large invertebrates. However, due to its generalist diet, it is impossible to make clear assumptions on this matter.</p>
2.21. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism currently in Europe?	minimal	high	<p>The species is not yet established in the risk assessment area.</p> <p>On Gran Canaria, various endemic reptiles are used as prey. Following the analysis of the stomach contents of <i>L. getula</i> in Gran Canaria the diet of the species appeared to include the giant lizard (<i>Gallotia stehlini</i>), Gran Canaria skink (<i>Chalcides sexlineatus</i>) and Boettger's wall gecko (<i>Tarentola boettgeri</i>). These endemic reptiles, although listed as Least Concern in the IUCN Red List, are vital components of the native fauna, and do not only have major ecological value as top-level predators (Barahona et al., 2000; Carranza et al., 2002; López-Jurado, 1991), but are also of socio-economic importance for the island, as charismatic endemic species (Barahona et al., 2000; Monzón-Argüello et al., 2015). Population declines of species preyed upon in Gran Canaria have not been quantified so far. Gran Canaria giant lizard makes up most of the diet of <i>L. getula</i>. This endemic species is currently of least concern (IUCN Red List), but could become threatened in the near future. Currently, there is no documented, quantified decline in the conservation status of native species caused by <i>L. getula</i>.</p>
2.22. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism likely to be in the future in Europe?	major	medium	<p>Since <i>L. getula</i> preys on reptiles, amphibians, birds and small mammals, the species could cause a threat to many native European species, including red list species, protected species and species listed in the Birds and Habitats Directives. An</p>

			<p>already vulnerable species that could be impacted by <i>L. getula</i>, for example, is <i>Arvicola sapidus</i>, an endemic to France, Spain and Portugal, but there are more examples of endemic rodents, amphibians and lizards with restricted ranges, specifically on Mediterranean islands: the ocellated skink (<i>Chalcides ocellatus</i>) in Sicily, Sardinia, Greece and Malta, the Cyprus whip snake (<i>Hierophis cypriensis</i>) in Cyprus, the Cretan wall lizard (<i>Podarcis cretensis</i>) in Crete and the North-African white-toothed shrew (<i>Crocidura pachyura</i>) in Ibiza, Sardinia and Pantelleria (Italy).</p> <p>Other examples include snakes introduced to Mediterranean islands, such as horseshoe whip snake <i>Hemorrhhois hippocrepsis</i>, introduced on the Balearics with potted plants, which is causing declines in native endemic Ibiza wall lizard <i>Podarcis pityusensis</i> populations through predation (Hinckley et al. 2016). The historical introduction of the snake <i>Macroprotodon mauritanicus</i>, together with some introduced mammals, have been considered responsible for the extinction of native Lilford's wall lizard <i>Podarcis lilfordi</i> in Mallorca and Menorca (Pinya and Carretero 2011, Silva-Rocha 2015) and of the native Menorcan midwife toad <i>Alytes muletensis</i> and an undescribed Discoglossid (Pleguezuelos 2004).</p> <p>There are concerns that the endemic Gran Canaria giant lizard might become threatened in the future, as it made up the largest proportion of prey for <i>L. getula</i> (Monzón-Argüello et al., 2015). Other endemic species susceptible to predation from <i>L. getula</i> include <i>Gallotia stehlini</i>, Gran Canaria skink, <i>Chalcides sexlineatus</i>, Boettger's wall gecko and <i>Tarentola boettgeri</i>, in addition to rodents and birds (Monzón-Argüello et al., 2015). Other instances of snakes threatening native fauna have been recorded several times (Fritts & Rodda, 1998; Guicking et al., 2006; Monzón-Argüello et al., 2015).</p>
Ecosystem Services impacts			
2.23 How important is the impact of the organism on provisioning, regulating, and cultural services in its non-native	minor	low	No information has been found on the issue. <i>L. getula</i> has no known impact on provisioning and regulating ecosystem

range excluding the Union?			services (e.g. crops, game animals, drinking water, erosion, climate regulation). Impact on cultural ecosystem services are probably small, but may include disturbance of outdoor activities and cultural heritage of isolated island ecosystems.
2.24. How important is the impact of the organism on provisioning, regulating, and cultural services currently in the different biogeographical regions or marine sub-regions where the species has established in Europe (include any past impact in your response)?	N/A		No information has been found on the issue.
2.25. How important is the impact of the organism on provisioning, regulating, and cultural services likely to be in the different biogeographical regions or marine sub-regions where the species can establish in Europe in the future?	N/A		No information has been found on the issue.
Economic impacts			
2.26. How great is the overall economic cost caused by the organism within its current area of distribution, including both costs of damage and the cost of current management	moderate	medium	No quantitative information on direct economic damage by <i>L. getula</i> is available. The EU finances the Life+ Biodiversity project <i>Lampropeltis</i> (LIFE10 NAT/ES/000565, 2011-2015, http://www.lifelampropeltis.com/), with a total budget of 1.025.863 € (512,931 € EU contribution). Currently the post-LIFE projects have total budget of 640.000 € (2016-2020). Apart from control, part of which is performed with the help of volunteers, this cost also covers research into the snakes biology and reliable detection and capture techniques. Between 2011 and 2017 an increasing number of snakes were caught, totalling nearly 4524 individuals (on average 646 snakes/year).
2.27. How great is the economic cost of damage* of the organism currently in the Union (include any past costs in your response)? *i.e. excluding costs of management	N/A		The species is not yet established in the risk assessment area.
2.28. How great is the economic cost of damage* of the organism likely to be in the future in the Union? *i.e. excluding costs of management	minor	low	No information has been found on the issue. Future cost of damage are difficult to assess. The species is not aggressive nor poisonous, therefore any future medical costs incurred if <i>L. getula</i> were to establish and spread in all suitable areas in the EU are probably not significant. Like other reptiles, it is a

			potential carrier/reservoir for <i>Salmonella</i> which are well known to pose a significant health risk to humans but potential costs are difficult to assess due to lack of data (Damborg et al. 2016). As the species does pose a threat to native (endemic) reptiles and potentially also bird species, this could indirectly impact on the natural, aesthetic values of islands and other natural areas, which can cause loss of revenue and income through reduced levels of tourism and recreation.
2.29. How great are the economic costs associated with managing this organism currently in the Union (include any past costs in your response)?	N/A		The species is not yet established in the risk assessment area. See 2.18
2.30. How great are the economic costs associated with managing this organism likely to be in the future in the Union?	major	low	If <i>L. getula</i> were to establish and spread in all suitable areas in the EU, the economic costs associated with managing the species could be very high. The EU co-financed project LIFE10 NAT/ES/000565 <i>Lampropeltis</i> (www.lifelampropeltis.com/), covered a total budget of 1.025.863€ (512,931€ EU contribution) for control (part of which performed by volunteers), monitoring and research in the years 2011-2015. Currently the post-LIFE projects have total budget of 640.000 € (2016-2020). Despite considerable effort and resources, the number of snakes caught per year is still on the rise and the population is still spreading, with no concrete chance to achieve any eradication. Given that island populations are generally easier to manage than mainland ones, including preventive strategies at a more limited number of entry points and the absence of any native snakes on Gran Canaria, it can be assumed that management costs would be much higher on the mainland. Additionally, the presence of native (often protected) snakes could seriously complicate the management and increase the costs.
Social and human health impacts			
2.31. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism for the Union and for third countries, if relevant (e.g. with similar eco-climatic conditions).	minimal	high	<i>Lampropeltis getula</i> is a non-venomous colubrid, although it has a painful bite (Ernst & Barbour, 1989; Mattison, 1995). They are considered harmless to humans, but if handled it is common for this species to bite as well as excrete musk and faecal contents from their cloaca, as does almost any snake

			<p>species. As such, there is no direct threat to human health apart from the social harm or nuisance that comes with people's general fear of snakes.</p> <p>The species could cause social harm in countries or regions that have no native snakes. For example, since snakes naturally do not occur on Gran Canaria, sightings of <i>L. getula</i> caused enormous social alarm (Cabrera-Pérez et al., 2012).</p>
2.32. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism in the future for the Union.	minimal	medium	See 2.31
Other impacts			
2.33. How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	minor	low	<p><i>L. getula</i> is a possible carrier of Chrysosporium-related fungi, which could cause damage to native reptile species (Cabañes et al., 2014). Snakes have been known to carry several of these Chrysosporium-related fungi, such as <i>Nannizziopsis guarroi</i>, <i>Paranannizziopsis australiensis</i>, <i>P. californiensis</i>, <i>P. crustacean</i>, <i>P. longispora</i> and <i>Ophidiomyces ophiodiicola</i> (Cabañes et al., 2014). Although in recent years there has been a noticeable increase in mycoses caused by some Chrysosporium-related fungi in reptiles (Cabañes et al., 2014) the impact of these fungi on native reptile populations is not documented.</p> <p>Furthermore, some reptiles can potentially carry ticks that spread the bacterium <i>Cowdria ruminantium</i> that, although not lethal to reptiles, can kill grazing animals (Fisher & Csurhes, 2009). There are no documented records of this bacterium on <i>L. getula</i> however.</p>
2.34. How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (specify in the comment box)	minimal	medium	See 2.33
2.35. How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in Europe?	minimal	low	Natural predators (e.g. eagles) or parasites are not considered to play an important role in the expected impacts of <i>L. getula</i> in the risk assessment area.

2.36. Indicate any parts of Europe where any of the above impacts are particularly likely to occur (provide as much detail as possible).	N/A		
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ADDITIONAL QUESTIONS - CLIMATE CHANGE			
3.1. What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?	temperature increase potential evapotranspiration	high	By the 2070s, climate change is predicted to increase the suitable region in Europe to expand northwards as far north as southern France, Italy, Hungary and Romania. In terms of Biogeographical Regions, climate change is predicted to increase suitability in all of these regions, as well as Black Sea, Pannonian and Steppic.
3.2. What is the likely timeframe for such changes?	100 years	medium	Species distribution modeling estimating the effect of climate change on the potential distribution showed additional bioregions suitable for establishment under modelled future climate conditions for the 2070s, both under medium and high emissions scenarios respectively.
3.3. What aspects of the risk assessment are most likely to change as a result of climate change?	establishment, spread	high	A summer temperature increase will have most effect on the successful reproduction and establishment of <i>L. getula</i> , since the eggs of this species need sufficiently high average summer temperatures for incubation. Higher reproduction rates may translate into higher spread rates and larger distribution ranges. Common kingsnake is able to survive winter frost such as it occurs in the mideastern parts of the US.
ADDITIONAL QUESTIONS - RESEARCH			
4.1. If there is any research that would significantly strengthen confidence in the risk assessment please summarise this here.	reproduction physiology, prey selection and parasites	high	There are several gaps in the scientific knowledge that would improve the risk assessment, including data on thermal requirements and adaptive capacity of reproduction under European climate conditions, preferred prey choices and possible impact on native species at the population level, as well as data on the transmission and possible consequences of parasites and pathogens.

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ANNEX I - Scoring of Likelihoods of Events

(taken from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	Description	Frequency
Very unlikely	This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur	1 in 10,000 years
Unlikely	This sort of event has not occurred anywhere in living memory	1 in 1,000 years
Possible	This sort of event has occurred somewhere at least once in recent years, but not locally	1 in 100 years
Likely	This sort of event has happened on several occasions elsewhere, or on at least one occasion locally in recent years	1 in 10 years
Very likely	This sort of event happens continually and would be expected to occur	Once a year

ANNEX II - Scoring of Magnitude of Impacts

(modified from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	Biodiversity and ecosystem impact	Ecosystem Services impact	Economic impact (Monetary loss and response costs per year)	Social and human health impact
	<i>Question 2.18-22</i>	<i>Question 2.23-25</i>	<i>Question 2.26-30</i>	<i>Question 2.31-32</i>
Minimal	Local, short-term population loss, no significant ecosystem effect	No services affected ¹	Up to 10,000 Euro	No social disruption. Local, mild, short-term reversible effects to individuals.
Minor	Some ecosystem impact, reversible changes, localised	Local and temporary, reversible effects to one or few services	10,000-100,000 Euro	Significant concern expressed at local level. Mild short-term reversible effects to identifiable groups, localised.
Moderate	Measureable long-term damage to populations and ecosystem, but little spread, no extinction	Measureable, temporary, local and reversible effects on one or several services	100,000-1,000,000 Euro	Temporary changes to normal activities at local level. Minor irreversible effects and/or larger numbers covered by reversible effects, localised.
Major	Long-term irreversible ecosystem change, spreading beyond local area	Local and irreversible or widespread and reversible effects on one / several services	1,000,000-10,000,000 Euro	Some permanent change of activity locally, concern expressed over wider area. Significant irreversible effects locally or reversible effects over large area.
Massive	Widespread, long-term population loss or extinction, affecting several species with serious ecosystem effects	Widespread and irreversible effects on one / several services	Above 10,000,000 Euro	Long-term social change, significant loss of employment, migration from affected area. Widespread, severe, long-term, irreversible health effects.

¹ Not to be confused with „no impact“.

ANNEX III - Scoring of Confidence Levels

(modified from Bacher et al. 2017)

Confidence level	Description
Low	There is no direct observational evidence to support the assessment, e.g. only inferred data have been used as supporting evidence <i>and/or</i> Impacts are recorded at a spatial scale which is unlikely to be relevant to the assessment area <i>and/or</i> Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous <i>and/or</i> The information sources are considered to be of low quality or contain information that is unreliable.
Medium	There is some direct observational evidence to support the assessment, but some information is inferred <i>and/or</i> Impacts are recorded at a small spatial scale, but rescaling of the data to relevant scales of the assessment area is considered reliable, or to embrace little uncertainty <i>and/or</i> The interpretation of the data is to some extent ambiguous or contradictory.
High	There is direct relevant observational evidence to support the assessment (including causality) <i>and</i> Impacts are recorded at a comparable scale <i>and/or</i> There are reliable/good quality data sources on impacts of the taxa <i>and</i> The interpretation of data/information is straightforward <i>and/or</i> Data/information are not controversial or contradictory.
Very high	There is direct relevant observational evidence to support the assessment (including causality) from the risk assessment area <i>and</i> Impacts are recorded at a comparable scale <i>and</i> There are reliable/good quality data sources on impacts of the taxa <i>and</i> The interpretation of data/information is straightforward <i>and</i> Data/information are not controversial or contradictory.

ANNEX IV – Species Distribution Model

(Projection of climatic suitability for *Lampropeltis getula* establishment)

Aim

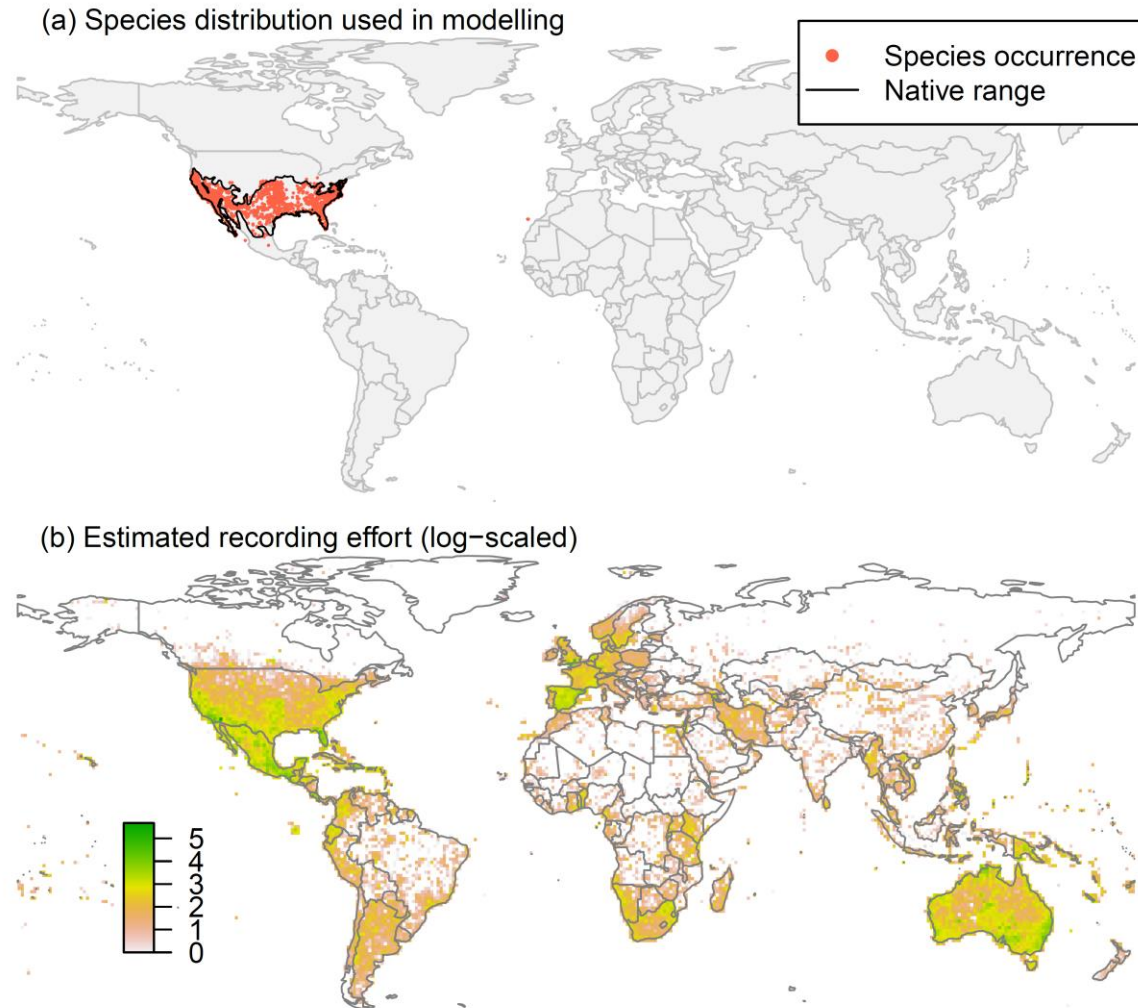
To project the suitability for potential establishment of *Lampropeltis getula* in Europe, under current and predicted future climatic conditions.

Data for modelling

Species occurrence data were obtained from the Global Biodiversity Information Facility (GBIF), iNaturalist, VertNet and the Berkeley Ecoinformatics Engine. Because of taxonomic uncertainty among *Lampropeltis*, we decided to model the distribution of the *Lampropeltis getula* and *Lampropeltis californiae* complex. Within this group a range of synonyms were searched for and records for the following taxa were retrieved: *Lampropeltis boylii*, *Lampropeltis californiae*, *Lampropeltis californiae californiae*, *Lampropeltis catalinensis*, *Lampropeltis degranvilli getulus*, *Lampropeltis getula*, *Lampropeltis getula brooksi*, *Lampropeltis getula californiae*, *Lampropeltis getula conjuncta*, *Lampropeltis getula floridana*, *Lampropeltis getula floridans*, *Lampropeltis getula getula*, *Lampropeltis getula getula x Lampropeltis getula floridana*, *Lampropeltis getula getulus*, *Lampropeltis getula holbrookii*, *Lampropeltis getula holbrookia*, *Lampropeltis getula niger*, *Lampropeltis getula nigra*, *Lampropeltis getula nigrita*, *Lampropeltis getula splendida*, *Lampropeltis getula sticticeps*, *Lampropeltis getula yumensis*, *Lampropeltis getulus*, *Lampropeltis getulus boylii*, *Lampropeltis getulus brooksi*, *Lampropeltis getulus californiae*, *Lampropeltis getulus californiae x Lampropeltis getulus nigritus*, *Lampropeltis getulus conjuncta*, *Lampropeltis getulus floridana*, *Lampropeltis getulus floridana x Lampropeltis getulus brooksi*, *Lampropeltis getulus floridanae*, *Lampropeltis getulus floridanus*, *Lampropeltis getulus gelutus*, *Lampropeltis getulus getulus*, *Lampropeltis getulus getulus x Lampropeltis getulus sticticeps*, *Lampropeltis getulus getulus x Lampropeltis getulus stricticeps*, *Lampropeltis getulus getulus x Lampropeltis getulus stricticeps*, *Lampropeltis getulus holbrookii*, *Lampropeltis getulus holbrookii*, *Lampropeltis getulus niger*, *Lampropeltis getulus nigra*, *Lampropeltis getulus nigritus*, *Lampropeltis getulus nijer*, *Lampropeltis getulus sayi*, *Lampropeltis getulus splendida*, *Lampropeltis getulus sticticeps*, *Lampropeltis getulus stricticeps*, *Lampropeltis nigra*, *Ophibolus boylii*, *Ophibolus getulus*, *Ophibolus getulus boylii*, *Ophibolus getulus getulus*.

We scrutinised occurrence records from regions where the species is not known to be established and removed any dubious records (e.g. fossils, captive records) or where the georeferencing was too imprecise (e.g. records referenced to a country or island centroid) or outside of the coverage of the predictor layers (e.g. small island or coastal occurrences). The remaining records were gridded at a 0.25 x 0.25 degree resolution for modelling, yielding 1506 grid cells with occurrence (Figure 1a). As a proxy for recording effort, the density of Reptilia records held by GBIF was also compiled on the same grid (Figure 1b).

Figure 1. (a) Occurrence records obtained for *Lampropeltis getula* and used in the modelling. The native range polygon was obtained from the IUCN (Hammerson *et al.*, 2007). (b) The recording density of Reptilia on GBIF, which was used as a proxy for recording effort.



Climate data were selected from the 'Bioclim' variables contained within the WorldClim database (Hijmans et al., 2005) originally at 5 arcminute resolution (0.083 x 0.083 degrees of longitude/latitude) and aggregated to a 0.25 x 0.25 degree grid for use in the model. Based on the biology of the focal species, the following climate variables were used in the modelling:

- Mean minimum temperature of the coldest month (Bio6 °C) reflecting exposure to winter cold and frost, which may be a trigger for hibernation behaviour.
- Mean temperature of the warmest quarter (Bio10 °C) reflecting the thermal regime of the active season.
- Mean annual potential evapotranspiration (PET, mm) reflecting available solar and thermal energy. For its calculation, monthly PETs were estimated from the WorldClim monthly temperature data and solar radiation using the simple method of Zomer et al. (2008) which is based on the Hargreaves evapotranspiration equation (Hargreaves, 1994).
- Climatic moisture index (CMI, ratio of mean annual precipitation to PET, log+1 transformed) reflecting moisture regime.
- Precipitation seasonality (Bio15, coefficient of variation for monthly precipitations, log+1 transformed), which was considered potentially important for *L. getula* by the risk assessment expert working group.

To estimate the effect of climate change on the potential distribution, equivalent modelled future climate conditions for the 2070s under the Representative Concentration Pathways (RCP) 4.5 and 8.5 were also obtained. These represent medium and high emissions scenarios, respectively:

- rcp4.5: stabilization scenario with greenhouse gas emissions falling below current levels by 2070 and atmospheric CO2 concentrations stabilizing by 2100
- rcp8.5: worst case scenario with atmospheric concentrations 3-4 times higher than pre-industrial levels by 2100

The above variables were obtained as averages of outputs of eight Global Climate Models (BCC-CSM1-1, CCSM4, GISS-E2-R, HadGEM2-AO, IPSL-CM5A-LR, MIROC-ESM, MRI-CGCM3, NorESM1-M), downscaled and calibrated against the WorldClim baseline (see http://www.worldclim.org/cmip5_5m).

Species distribution model

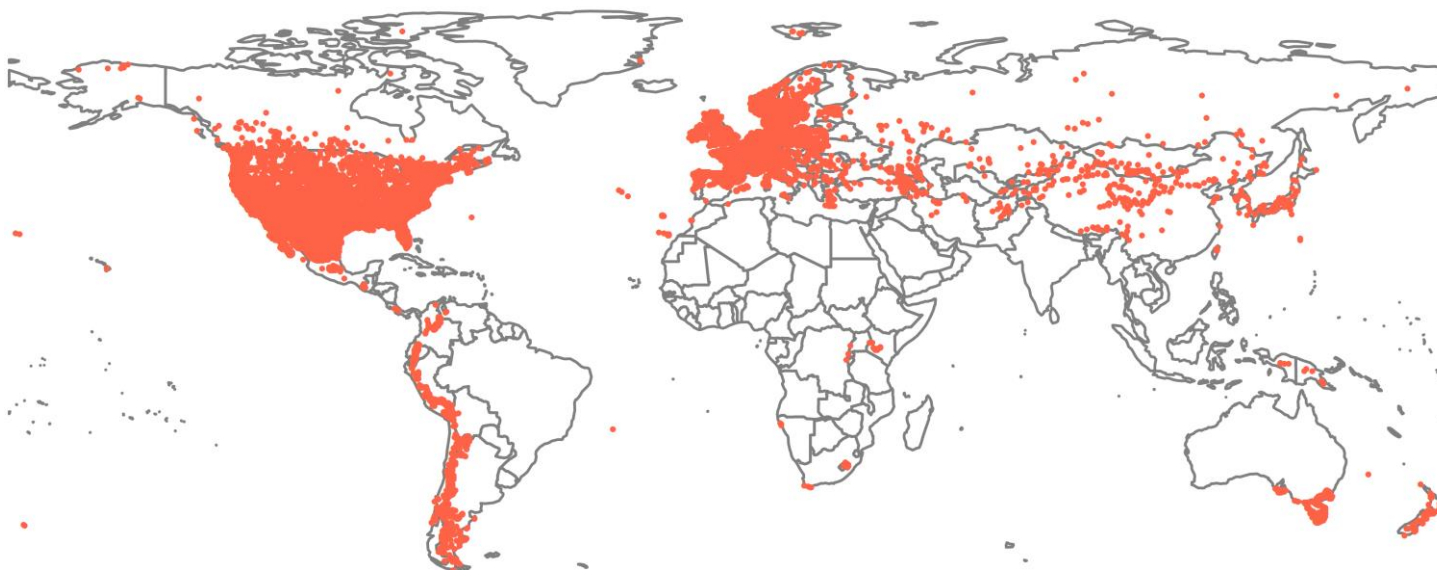
A presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package v3.3-7 (Thuiller et al., 2014, Thuiller et al., 2009). These models contrast the environment at the species' occurrence locations against a random sample of the global background environmental conditions (often termed 'pseudo-absences') in order to characterise and project suitability for occurrence. This approach has been developed for distributions that are in equilibrium with the environment. Because invasive species' distributions are not at equilibrium and subject to dispersal constraints at a global scale, we took care to minimise the inclusion of locations suitable for the species but where it has not been able to disperse to. Therefore the background sampling region included:

- The area accessible by native *L. getula* populations, in which the species is likely to have had sufficient time to disperse to all locations. The accessible region was defined as a 100 km buffer around the IUCN's native range polygon (Hammerson et al., 2007); AND

- A 30 km buffer around the non-native occurrences, encompassing regions likely to have had high propagule pressure for introduction by humans and/or dispersal of the species; AND
- Regions where we have an *a priori* expectation of high unsuitability for the species so that absence is considered to be irrespective of dispersal constraints (see Figure 2). As we expected low temperature to be the key limiting factor for Europe, the following rules were applied to define a region expected to be highly unsuitable for *L. getula* at the spatial scale of the model:
 - Potential evapotranspiration < 1000 mm. Only 0.5% of occurrence grid cells were in colder locations.
 - Mean temperature of the warmest quarter (Bio10) < 16 °C. Only 1 % of occurrence grid cells were colder than this.
 - Mean minimum temperature of the coldest month (Bio6) < -10 °C. Only 0.9% of occurrence grid cells were colder than this.

Within this background region, 10 samples of 5000 randomly sampled grid cells were obtained, weighting the sampling by recording effort (Figure 2).

Figure 2. Randomly selected background grid cells used in the modelling of *Lampropeltis getula*, mapped as red points. Points are sampled from the native range, a small buffer around non-native occurrences and from areas expected to be highly unsuitable for the species (grey background region), and weighted by a proxy for recording effort.



Each dataset (i.e. combination of the presences and the individual background samples) was randomly split into 80% for model training and 20% for model evaluation. With each training dataset, ten statistical algorithms were fitted with the default BIOMOD2 settings and rescaled using logistic regression, except where specified below:

- Generalised linear model (GLM)
- Generalised boosting model (GBM)
- Generalised additive model (GAM) with a maximum of four degrees of freedom per smoothing spline.
- Classification tree algorithm (CTA)
- Artificial neural network (ANN)
- Flexible discriminant analysis (FDA)
- Multivariate adaptive regression splines (MARS)
- Random forest (RF)
- Maxent
- Maximum entropy multinomial logistic regression (MEMLR)

Since the background sample was much larger than the number of occurrences, prevalence fitting weights were applied to give equal overall importance to the occurrences and the background. Normalised variable importance was assessed and variable response functions were produced using BIOMOD2's default procedure. Model predictive performance was assessed by calculating the Area Under the Receiver-Operator Curve (AUC) for model predictions on the evaluation data, that were reserved from model fitting. AUC is the probability that a randomly selected presence has a higher model-predicted suitability than a randomly selected absence.

An ensemble model was created by first rejecting poorly performing algorithms with relatively extreme low AUC values and then averaging the predictions of the remaining algorithms, weighted by their AUC. To identify poorly performing algorithms, AUC values were converted into modified z-scores based on their difference to the median and the median absolute deviation across all algorithms (Iglewicz & Hoaglin, 1993). Algorithms with $z < -2$ were rejected. In this way, ensemble projections were made for each dataset and then averaged to give an overall suitability. These were then thresholded into suitable and unsuitable regions using the 'minROCDist' method.

We also produced limiting factor maps for Europe following Elith et al. (2010). For this, projections were made separately with each individual variable fixed at a near-optimal value. These were chosen as the median values at the occurrence grid cells. Then, the most strongly limiting factors were identified as the one resulting in the highest increase in suitability in each grid cell.

Results

The ensemble model suggested that suitability for *L. getula* was most strongly determined by temperature, with strong effects of potential evapotranspiration, mean temperature of the warmest quarter and minimum temperature of the coldest month. (Table 1, Figure 3). By contrast precipitation related variables contributed little to model fit.

Global projection of the model in current climatic conditions indicates that the native and known invaded records generally fell within regions predicted to have high suitability (Figure 4). The model predicts potential for further expansion of the non-native range of the species in warm temperate regions of the northern and southern hemispheres (Figure 4). In Europe, the model suggested establishment may be possible through southern Iberia and Greece as well as in small areas of Italy (Figure 5). Outside of these regions, low potential evapotranspiration was identified as the main limiting factor (Figure 6).

By the 2070s, climate change is predicted to increase the suitable region in Europe to expand northwards as far north as southern France, Italy, Hungary and Romania (Figures 7 and 8).

In terms of Biogeographical Regions (Bundesamt für Naturschutz (BfN), 2003), those predicted to be most suitable for *L. getula* establishment in the current climate are Mediterranean, Macaronesia, and Anatolian (Figure 9). Climate change is predicted to increase suitability in all of these regions, as well as Black Sea, Pannonian and Steppic.

Table 1. Summary of the cross-validation predictive performance (AUC) and variable importances of the fitted model algorithms and the ensemble (AUC-weighted average of the best performing algorithms). Results are the average from models fitted to ten different background samples of the data.

Algorithm	AUC	Used in the ensemble	Variable importance				
			Minimum temperature of coldest month	Mean temperature of warmest quarter	Precipitation seasonality	Potential evapotranspiration	Climatic moisture index
GAM	0.7893	yes	16%	31%	4%	48%	1%
MARS	0.7871	yes	11%	34%	4%	51%	0%
GBM	0.7858	yes	13%	32%	1%	52%	1%
Maxent	0.7830	yes	17%	25%	2%	55%	1%
FDA	0.7808	yes	8%	43%	5%	43%	0%
ANN	0.7769	yes	11%	33%	3%	50%	3%
GLM	0.7712	yes	11%	39%	6%	44%	0%
CTA	0.7580	yes	12%	26%	3%	54%	5%
RF	0.6488	no	16%	24%	14%	34%	12%
MEMLR	0.6199	no	17%	9%	24%	0%	50%
Ensemble	0.7900		12%	33%	4%	50%	2%

Figure 3. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the algorithms in the ensemble, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data. Some of the divergence among algorithms is because of their different treatment of interactions among variables.

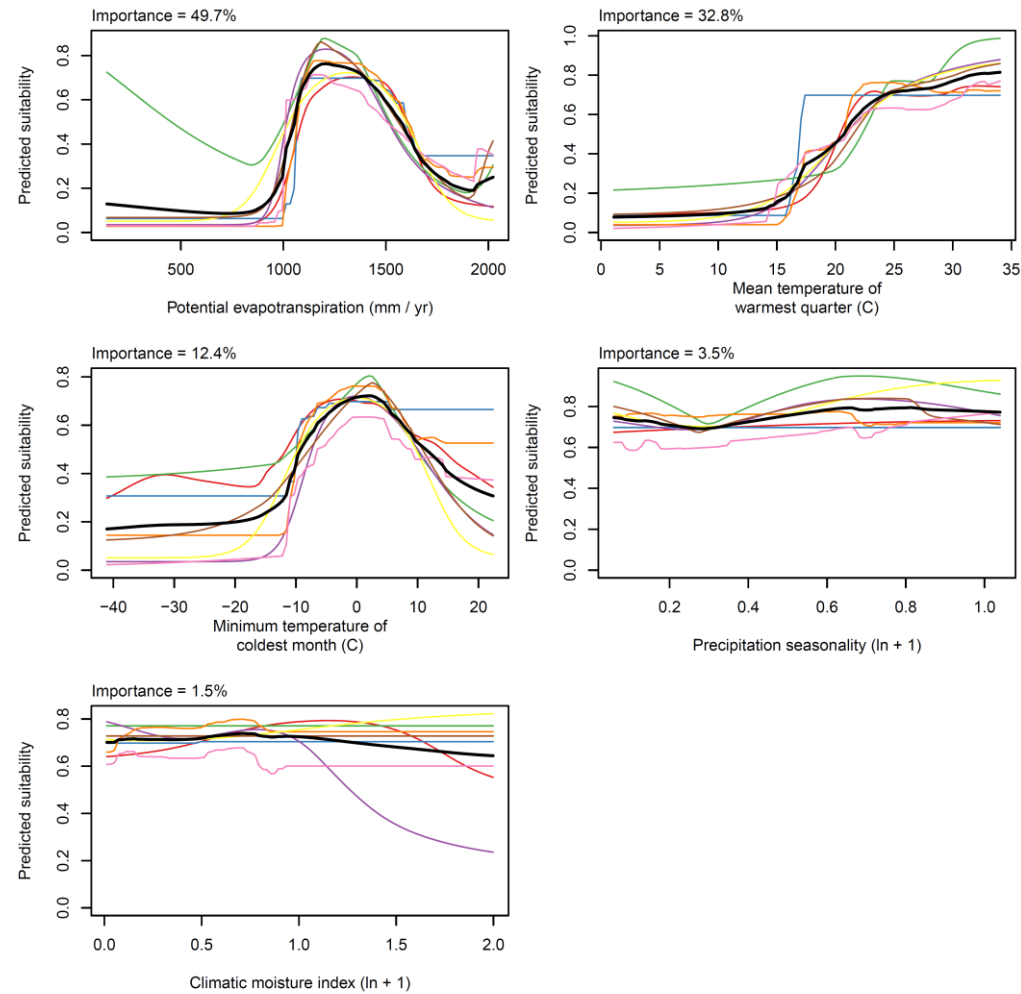


Figure 4. (a) Projected global suitability for *Lampropeltis getula* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Values > 0.5 may be suitable for the species. White land areas have climatic conditions outside the range of the training data so were excluded from the projection. (b) Uncertainty in the ensemble projections, expressed as the among-algorithm standard deviation in predicted suitability, averaged across the ten datasets.

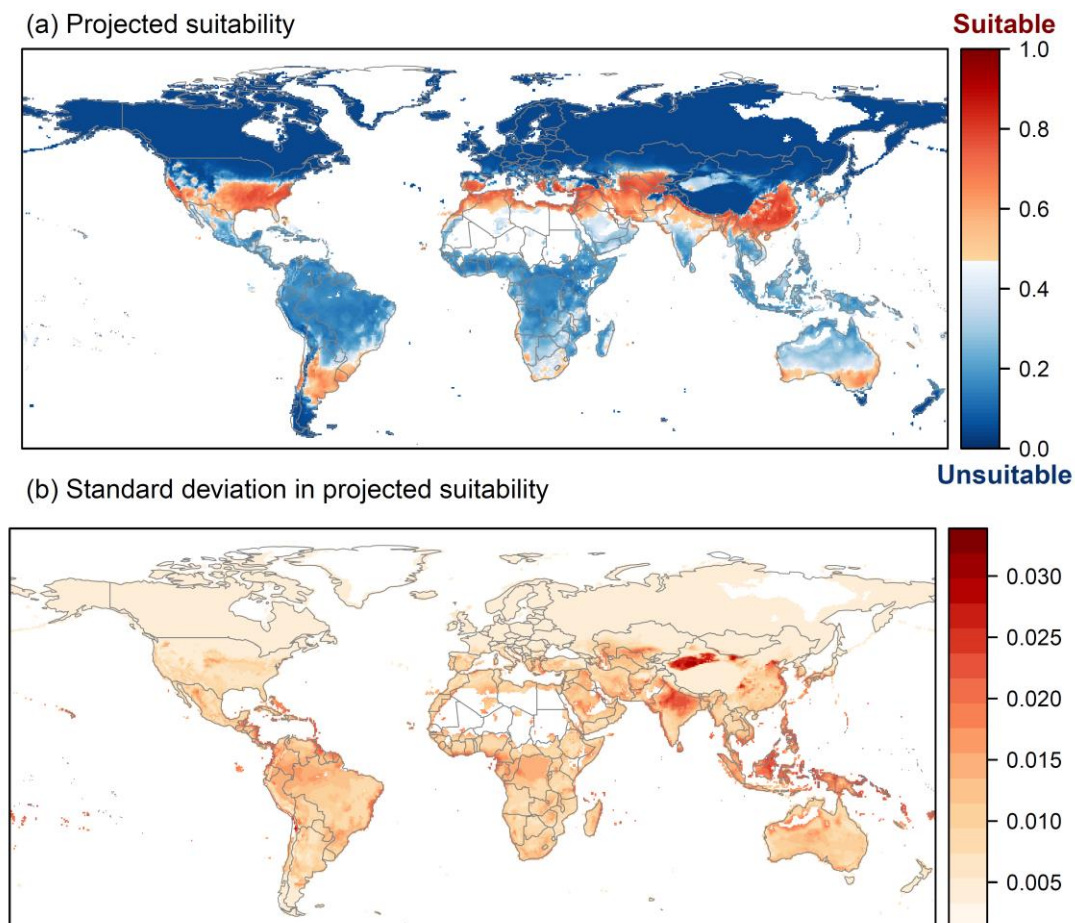


Figure 5. Projected current suitability for *Lampropeltis getula* establishment in Europe and the Mediterranean region. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

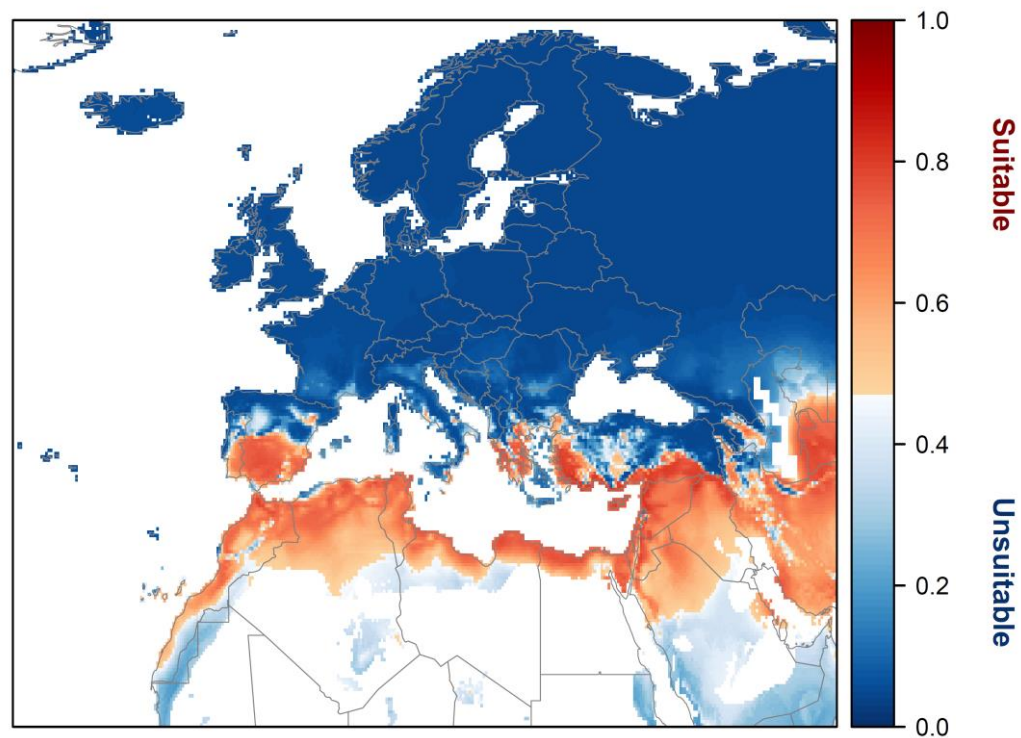


Figure 6. The most strongly limiting factor estimated by the model in Europe and the Mediterranean region in current climatic conditions.

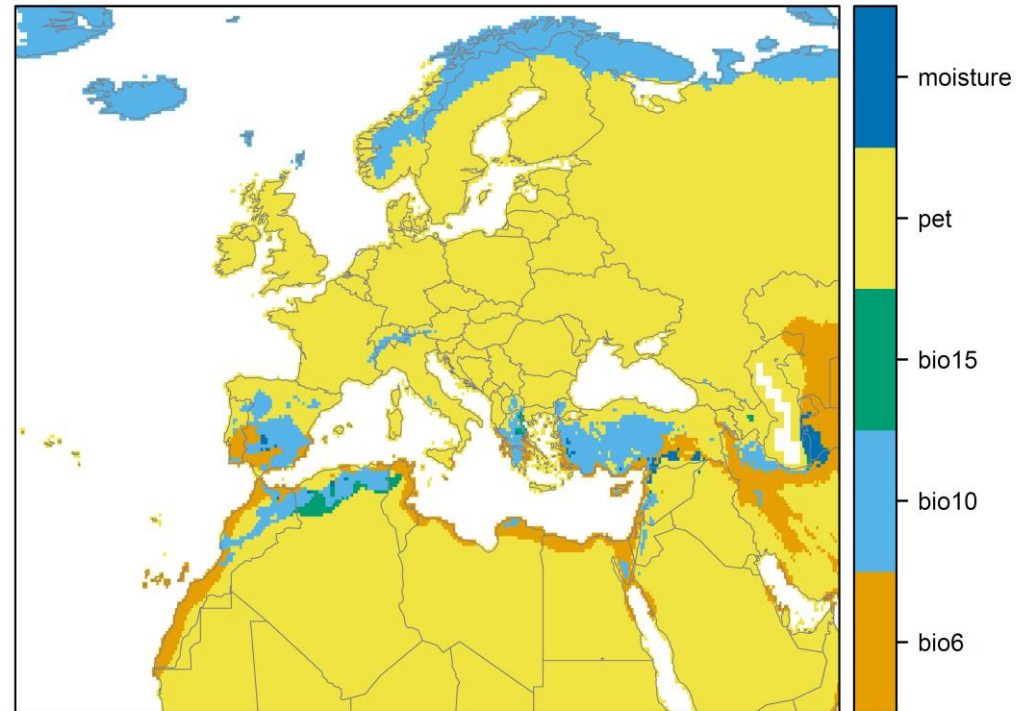


Figure 7. Projected suitability for *Lampropeltis getula* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP4.5, equivalent to Figure 5.

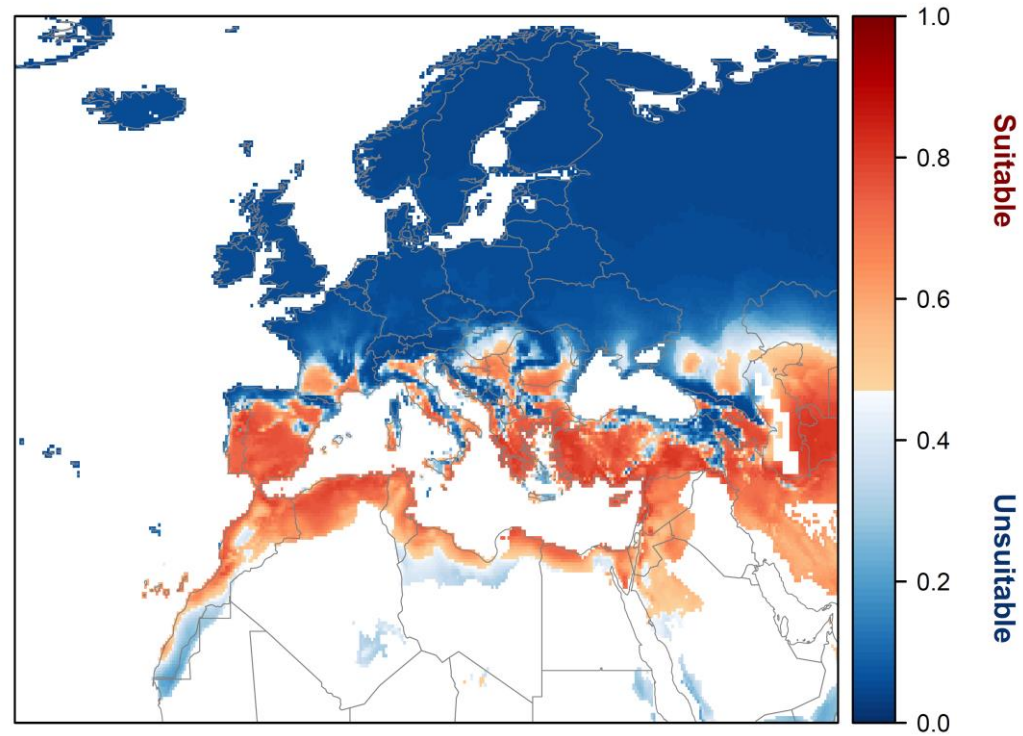


Figure 8. Projected suitability for *Lampropeltis getula* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Figure 5.

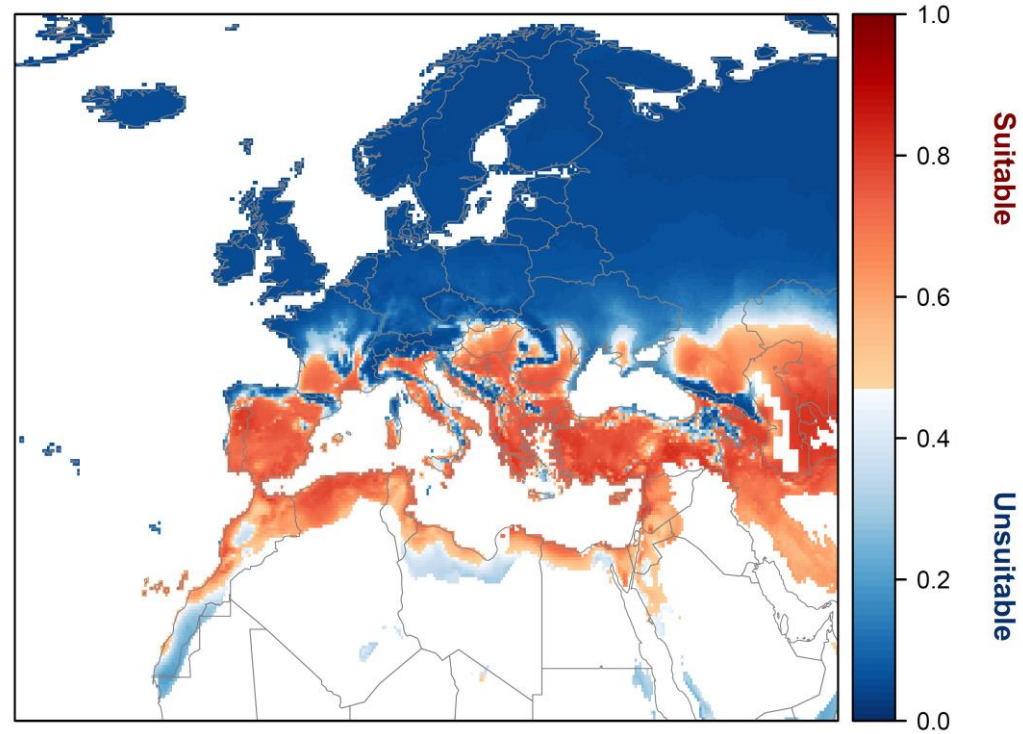
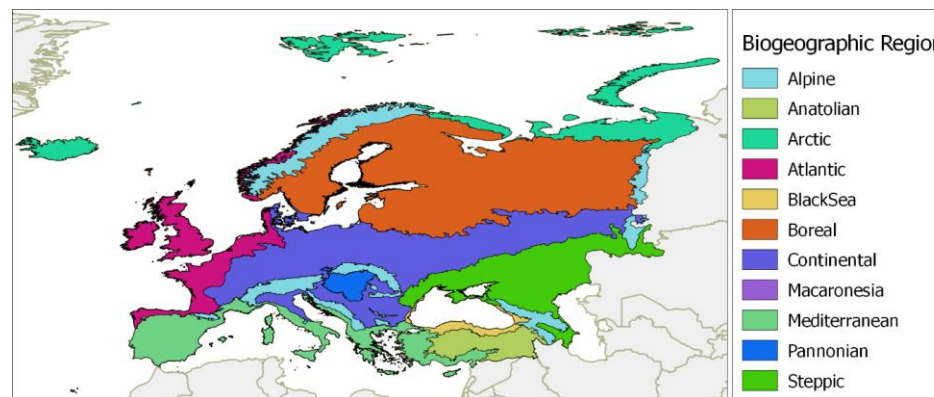
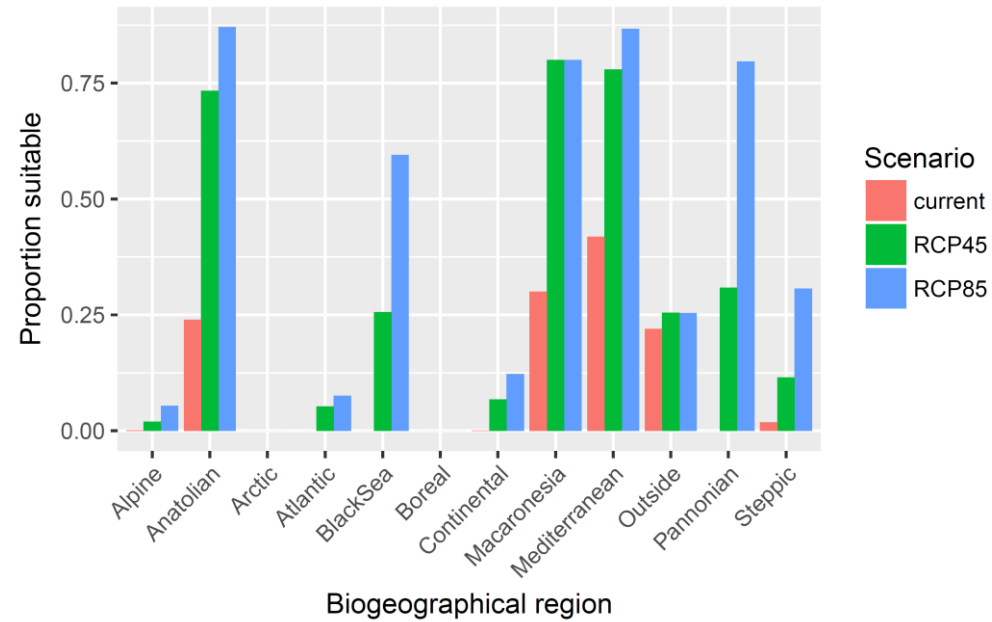


Figure 9. Variation in projected suitability among Biogeographical regions of Europe (Bundesamt für Naturschutz (BfN), 2003). The bar plots show the proportion of grid cells in each region classified as suitable in the current climate and projected climate for the 2070s under two RCP emissions scenarios. The location of each region is also shown.



Caveats to the modelling

To remove spatial recording biases, the selection of the background sample was weighted by the density of Reptilia records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, it may not provide the perfect measure of recording bias. There was substantial variation among modelling algorithms in the partial response plots (Figure 3). In part this will reflect their different treatment of interactions among variables. Since partial plots are made with other variables held at their median, there may be values of a particular variable at which this does not provide a realistic combination of variables to predict from. Other variables potentially affecting the distribution of the species, such as land cover or prey abundance were not included in the model.

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ANNEX V - Evidence on measures and their implementation cost

Species (common name)	Common Kingsnake
Species (scientific name)	<i>Lampropeltis getula</i>
Date Completed	25 April 2017
Authors	Peter Robertson, Tim Adriaens, Riccardo Scalera
Version	1.1

	Description of measure	Assessment of implementation cost and cost-effectiveness (per measure)	Level of confidence
Methods to achieve prevention	Managing pathways: <i>Lampropeltis</i> have been introduced to new areas through a variety of pathways, including the pet trade and deliberate introductions. The adoption and enforcement of appropriate legislation and codes of best practice to reduce the risks posed by these pathways should reduce the probability of further introductions		
	Effective surveillance and reporting: <i>Lampropeltis</i> are a readily identifiable species often found in association with human activity. The discovery of new snakes in an area is likely to attract public attention. Encouraging rapid reporting of new incursions increases the likely success of rapid response before the species can become established.	In its native range, the following methods were used to monitor the population of the species, which in fact may be suitable for surveillance and monitoring in the EU as well: terrestrial drift fences with funnel and pitfall traps, artificial coverboard arrays (constructed of metal, wood, or roofing material and placed in both upland and aquatic habitats to serve as artificial refugia for snakes), and aquatic funnel traps (Winne 2007). Citizen-science species occurrence datasets are increasingly recognized as a valid tool for monitoring the occurrence and spread of invasive species across large spatial and temporal scales (Roy <i>et al.</i> , 2015). They are dependent on citizen-scientists who collect and upload data, typically from ‘opportunistic sampling’ with no underlying scientific survey design (Boakes <i>et al.</i> , 2010) which can limit the conclusions that can be drawn from these data (Isaac <i>et al.</i> , 2014) and may lead to a delay in detecting a new presence of the species. Smartphone applications can be a helpful tool to support recording and speed up record submission (Adriaens <i>et al.</i> 2015), such as the dedicated app for reporting <i>Lampropeltis</i> occurrences on Gran Canaria (<i>Lampropeltis</i> , Gobierno de	

		Canarias). Most parts of north-west Europe have an extensive network of volunteer observers although this is less true of southern and especially eastern Europe (Boakes <i>et al.</i> , 2010). Unstructured citizen-science data do not reliably allow to estimate species abundance or population trends (Kamp <i>et al.</i> , 2016), yet in an early-warning scenario it is likely sufficient to know where a species is establishing, and these data limitations are thus of a lesser concern.	
	Raising awareness: Raising public awareness of the risks posed by invasive alien species in general and <i>Lampropeltis</i> in particular. The production of targeted publicity and identification material.	Identification and publicity material has been produced as part of the LIFE10 NAT/ES/565AG11---003 project Control of the invasive alien species <i>Lampropeltis getula californiae</i> on the island of Gran Canaria. http://www.lifelampropeltis.com/ . This also includes a smartphone application <i>Lampropeltis</i> for citizens to report on snake occurrences.	
Methods to achieve eradication	Hand capture: during searches. <i>Lampropeltis</i> can be located and captured by hand during searches of suitable habitats. Snake tongs can assist capture from vegetation.	<p>Significant numbers of snakes can be captured using this method if using experienced personnel, although it is labour intensive. Over a four-year period, 1064 <i>Lampropeltis</i> have been caught in Gran Canaria. Most of these snakes have been caught by hand after visual searching (Cabrera-Pérez et al 2012). Hand capture is an important component of invasive snake control operations in other areas (Vice and Pitzler 2000, brown tree snakes on Guam)</p> <p>Studies of <i>Lampropeltis</i> in its native range suggests animals spend over 70% of their time inactive in holes and crevices (Richardson et al 2006, Wund et al 2007). Studies of search efficiency to detect brown tree snakes suggest only 7% of the snakes present in an area are located per search (Christie et al 2010). Multiple repeated searches will be required to give confidence that an area has been cleared if eradication is the objective. While this is an effective method to capture individuals, it may not be an effective method to completely remove snakes from an area if used in isolation. Its efficiency will decline as a population is reduced, and more targeted approaches are likely to be required to ensure the removal of all animals in an area.</p> <p>A knowledge of <i>Lampropeltis</i> ecology and behaviour can improve efficiency by identifying productive times of day, season, habitats and microhabitats to target. For example, control in the Canaries (Cabrera-Pérez et al 2012) has found catch rates to be affected by temperature and</p>	High – Hand capture has been documented as an effective method to capture significant numbers of snakes, although other methods may be needed to ensure the complete removal of snakes from an area.

		<p>humidity as seen with other species (Hubbs 2009). Capture rates are highest between April and June reflecting increased snake activity and the mating season.</p> <p>Any control of a vertebrate is likely to attract some opposition, but hand capture has been widely used in <i>Lampropeltis</i> and other snake species control programmes (Cabrera-Pérez et al 2012, Vice and Pitzler 2000).</p> <p>This method requires minimal equipment costs, causes no non-target impacts aside from minimal disturbance, but is time-consuming. It poses few risks to health and safety beyond those associated with handling snakes, and is unlikely to raise significant environmental, social or environmental concerns.</p> <p>Snake control for eradication poses particular problems. Brown tree snakes have been successfully eradicated from small (1ha) fenced plots on Guam using a variety of methods including hand-capture. However, attempts to eradicate snakes from larger areas have not proved successful (Rodda et al 2002). The eradication of well-established snake populations remains challenging.</p>	
	<p>Refugia: made by placing wooden boards or metal sheets on the ground. These can form attractive areas for resting snakes. These can be regularly checked to remove any snakes from underneath.</p>	<p>This method has been widely used to catch a range of snake species (eg Hofer et al, 2002; Caron et al, 2010).</p> <p>Artificial refuges have been used on Gran Canaria with some success. In 2011, 33 snakes (7.12%) were caught in the primary fieldwork area by using this method; 27 in less than two weeks and 8 in just one day (Cabrera-Pérez et al 2012.) Success rates were higher following rain and on days with increased cloud cover as has also been observed by other authors (Joppa <i>et al.</i> 2009).</p> <p>This method is a useful addition to hand searching, but has similar shortcomings.</p>	<p>High – Refugia have been documented as an effective method to capture significant numbers of snakes, although other methods may be needed to ensure the complete removal of snakes from an area.</p>
	<p>Traps: These include funnel entrance designs such as minnow traps and pitfalls, where animals fall into a pit from which they cannot escape.</p>	<p>A variety of trap designs have been successfully used to capture snakes. (Fitch, 1987; Bennett, 1999; Das, 2012; Fitzgerald & Yantis, 2012; Picó et al. 2017). Cabrera-Pérez et al (2012) provide photographs of designs trialed on Gran Canaria, against <i>Lampropeltis</i>, based on those used to capture brown tree snakes on Guam. A wide variety of snake traps are available commercially and designs are freely available on-line. The</p>	<p>High – Traps have been documented to be an effective method to catch snakes. To date there are no accounts of this method being used to</p>

		<p>materials are cheap and likely to be locally available.</p> <p>Traps can be baited with food items, or used with lures to increase their attractiveness to snakes. Some programmes have used live bait to attract snakes. The use of live bait may be restricted by welfare and wildlife regulations and advice from local authorities should be sought before considering this approach. A variety of lures to attract snakes are commercially available (web search ‘snake lure’), although the advantages of these products remains largely untested. The efficiency of trapping can be increased by the use of artificial barriers to guide moving snakes towards the trap.</p> <p>On Gran Canaria a variety of different kinds of traps have been trialed for use with <i>Lampropeltis</i> but with limited success, catching only two snakes. The failure of the traps may be the limited number of traps and the low snake density, the size selectivity of the traps or the seasonal cessation of feeding activity (Rodda <i>et al.</i> 2002), but the low interest of the snakes for the food in the traps and the high prey abundance in the area is thought to be the main causes for the lack of success (Cabrera-Pérez et al (2012).</p> <p>Traps are likely to also catch other vertebrates. Regular checking and the release of non-target species can reduce the risks posed.</p> <p>Traps are a relatively safe and benign method of capture if used correctly. They do not pose particular health and safety, environmental, economic or social risks.</p>	<p>eradicate an established snake population</p>
	<p>Net traps: fine nylon netting held upright on a frame. Snakes moving through the netting can become entangled. Electrical netting can also be used.</p>	<p>The use of net-traps to catch Habu (<i>Trimeresurus flavoviridis</i>) on Okinawa is described by Nishimura (2011). For this species they used a 25mm mesh and captured >1 snake per 10m of netting per year. In this study, nets were mainly set around residential properties to be checked and maintained by the residents. They describe the non-target capture of other snake species, crabs and giant land snails. This method preferentially captured larger animals, those carrying a recent meal or gravid females. Nishimura (2011) describe checking nets infrequently and most animals were found dead in the nets. The welfare of the captured animals was not recorded and snakes may be injured during capture as well as dying in the nets. Daily checking would be required to</p>	<p>Medium – These methods have been used on a local scale against other snake species. Their effectiveness, welfare and non-target impacts remain poorly quantified.</p>

		<p>use this method for live-capture. Neal et al (1993) used net traps to protect woodpecker nests from predatory snakes.</p> <p>Hayashi et al (1983, 1984) describe an electric net variant of this approach, where an electric filament was included to kill any captured snakes. This was trialed on a small scale to keep individual fields free of Habu in Okinawa.</p> <p>These methods use cheap and freely available materials. Their use has been limited to specific circumstances and they have not been assessed as a method for wider control. The welfare of animals captured in this way remains poorly quantified, and non-target risks are likely to be situation dependent, but would need to be carefully assessed before use.</p>	
	<p>Glue Traps: Various boxes, tunnels or tubes coated with a sticky resin. Snakes are caught on the sticky surface.</p>	<p>A wide variety of glue trap designs are available commercially and on-line, together with instructions for their manufacture (web search ‘snake glue trap’). These are primarily used to remove small numbers of snakes from in or around dwellings (Knight 1986). This author describes the release of captured animals by the use of cooking oil to break down the glue. Released animals appeared to suffer no long-term effects if released quickly after capture, although in many applications snakes are left to die in the trap.</p> <p>These traps are likely to capture a wide range of other wildlife including small mammals and other reptiles and are primarily used indoors for this reason.</p>	<p>High. This method is widely used and available, although most appropriate for use in or close to dwellings.</p>
	<p>Dogs: Specially trained dogs can be used to locate snakes or areas where they are active</p>	<p>Specially trained dogs are used to detect brown tree snakes around ports and in cargo handling areas in Guam to reduce the risks of dispersal to other islands.</p> <p>Dogs have also been trialed to detect free-living brown tree snakes. Studies based on marked snakes suggests dogs located 26-44% of snakes to within 5m but that other methods were then needed to help humans find and extract snakes from their refuges (Savidge et al 2011). Trained dogs have also been used to identify holes used by snakes of other species. (Stevenson et al 2010).</p> <p>Dogs are likely to increase the effectiveness of searches, particularly when snakes may only be present at a low density. They offer a method to improve the likelihood of complete removal from areas where other methods have been used to reduce snake numbers. However, other methods are likely to be needed to capture snakes once dogs have identified the general area of interest.</p>	<p>Medium. Dogs can be used to improve search efficiency, but have yet to be used effectively as part of a snake eradication programme</p>

		The current control of <i>Lampropeltis</i> on Gran Canaria is considering the use of dogs to supplement their other activities.	
	Raptors/falconry: Hawks have been used on Gran Canaria to detect and remove <i>Lampropeltis</i> snakes.	No information has been found on the effectiveness of this measure.	
	Toxins: A variety of toxins have been tested for use against snakes (Brooks et al 1998). Field trials of Acetaminophen have been undertaken for brown tree snakes (Clarke et al 2012) and to risk assess the use of this compound (Johnston et al 2002).	No toxins are currently approved for use against <i>Lampropeltis</i> in the EU. Nicotine in water has been used for the control of gartersnakes during drought conditions (Stickel 1953). The use of Acetaminophen is proposed as a control method for use against brown tree snakes on Guam	Medium. The evidence for the use of this approach is based on field trials. As yet they have not been used for wide-scale snake control.
Methods to achieve management	All of the methods described to support eradication can also be used to manage existing <i>Lampropeltis</i> populations.	See above	See above
	Reducing risks of further dispersal	The presence of <i>Lampropeltis</i> on islands such as Gran Canaria increases the risk of further transportation to neighbouring snake free islands, as illustrated by a 2017 stowaway introduction on Lanzarote. A similar situation exists with the brown tree snake on Guam. In this case particular efforts are made to prevent its further dispersal through cargo traffic to other locations (Engeman and Vice 2001). These include intensive inspection, control and trapping around ports together with the use of snake proof fencing and sniffer dogs.	
	Maintaining snake free areas	Areas of high conservation value may be targeted for intensive snake control to reduce their impacts. The coordinated use of the methods described above together with fencing to reduce rates of recolonization may reduce levels of damage	
	The removal of problem snakes from buildings.	Snakes are perceived as a pest by many members of the public. A variety of methods, such as glue traps, are widely used in other areas to remove problem snakes from buildings. Snake removal is offered as a service by pest control companies in affected regions	