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

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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Contents

RISK SUMMARIES

	RESPONSE	CONFIDENCE	COMMENT
Summarise Entry	**likely**	**high**	*Lampropeltis getula* is a sporadically 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 sporadically. 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, which is considered an Outermost Region). Similar climatic conditions occur in the EU in parts of Iberia. Excluding Outermost Regions, 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. *L. getula* could establish in several EU member states. Member states potentially suitable for establishment include Portugal, Spain, Italy, Greece, Croatia, Malta and Cyprus. In terms of Biogeographical Regions the Mediterranean and Steppic bioregions are suitable for establishment.
Summarise Spread	**slowly**	**low**	*Lampropeltis* species generally have 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 perceptive 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 *L. getula* 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 *L. getula* 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. *Lampropeltis getula* is a generalist predator of rodents and other small mammals, lizards and their eggs, snakes (including venomous 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 *L. getula* occurs 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, negatively affecting the natural and cultural heritage of isolated island ecosystems. As an illustration, on the Canary islands, where *L. getula* 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 *L. getula* 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 are important seed dispersers of plant species with fleshy fruits, their decline due to *L. getula* predation could also alter plant-animal mutualism and impact on native plant species or vegetation structure. Furthermore, *L. getula* 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	-	-	YES	-
Croatia	-	-	YES	-
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

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?	Recorded (but not established) in the following EU biogeographical regions: ● Atlantic region (BE, NL, DE, UK) ● Continental region (DE) ● Mediterranean region (IT) Currently not established in any EU biogeographical region, except for the Macaronesian region (Canary Islands), which is in the Outermost Regions outside the risk assessment area.	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?	Under current climate: ● Already established in the Macaronesian bioregion; however, this is only relevant for Outermost Regions 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. 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.	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.	Recorded, but not established, in five EU MS: ● De Panne, Belgium – an escape from captivity in 2014. ● Netherlands - escapes from captivity in 2008 and 2011 (Bugter et al 2014). ● Germany - escapes reported in local newspapers	These casual records illustrate the species is probably widely kept as a pet in the EU and escapes may occur sporadically. So far, there are no known records of *L. getula* in other EU member states (www.inaturalist.org, www.observation.org, www.gbif.org).

	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 *Lampropeltis* sp. (Inskipp 2003). However, introductions regarding this genus date back to 200 years ago in the UK, according to Fitter (1959) who reports *L. triangulum* (syn *Coronella doliata*). On GBIF, a (presumably old) museum specimen originating from a wild caught individual in London area is mentioned under the name *Ophibolus getulus (Baird & Girard, 1853)*. In addition, three separate populations have established in Spain, 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.	The subspecies introduced in the Canary islands is *L. getula californiae*.
Ch4. In which EU member states has this species established populations? List them with an indication of the timeline of establishment and spread.	This species is not established in the EU, except in Gran Canaria which is an Outermost Region (i.e. not within the risk assessment area).	The naturalization of *L. getula* was confirmed in 2007 in the east of Gran Canaria (Cabrera-Pérez et al., 2012). Monzón-Argüello et al. (2015) reported two *L. getula* 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 other in the east (Telde). From 2007 to 2011, the *L.*

		getula 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). 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 that ended in 2015. However, this was not sufficient to achieve the eradication of the species (Juan Luis Rodríguez Luengo, pers. comm., 2017).
Ch5. In which EU member states could the species establish in the future under current climate and under foreseeable climate change?	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 (Annex IV). 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 (Annex IV).	*Lampropeltis getula* 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 *Lampropeltis getula* 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 *L. getula* is established.

		The optimum temperature range for *L. getula* activity ranges from 15.1ºC-31.3ºC and the critical minimum and maximum for activity are 2ºC and 42ºC, respectively (Brattstrom, 1965; Cabrera-Pérez et al., 2012). *Lampropeltis getula* 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, *L. getula* can survive moderately harsh winters by hibernating. It occurs throughout the state of Missouri (USA), 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). Currently, according to the species distribution model (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.
Ch6. In which EU member states has this species shown signs of invasiveness?	*L. getula* has shown signs of invasiveness on the Canary Islands (Spain). This is not part of the risk assessment area.	The species has spread on Gran Canaria and is reported to predate on endemic lizards (Gran Canaria giant lizard *Gallotia stehlini*, Gran Canaria Skink *Chalcides sexlineatus*, Boettger's Wall Gecko *Tarentola boettgeri*), small rodents and birds (Cabrera-Pérez et al., 2012). This resulted in an EU co-funded LIFE

		project aimed at management of *L. getula*.
Ch7. In which EU member states could this species become invasive in the future under current climate and under foreseeable climate change?	Under current climate: ● It might be possible for *L. getula* to become invasive in 6 Mediterranean member states (Portugal, Spain, southern Italy, Malta, Greece, 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). These islands are however not part of the risk assessment area. Under foreseeable climate change conditions as described above: ● *L. getula* could also become invasive in France, northern Italy, Hungary, Croatia and Romania.	In central and northern EU member states, winter conditions are expected to represent a constraint on the life history of *L. getula* (Gregory, 2009). Additionally, short and cool summers will restrict their foraging and reproductive opportunities (Gregory, 2009). *Lampropeltis getula* is oviparous (i.e. lays eggs), while most higher-latitude snake species are viviparous. This might prevent *L. getula* to become established in colder, temperate regions of Europe. However, *L. getula* 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 as well as in northern states such as Illinois, Indiana and south of Iowa, with low temperatures in winter, thus more resembling the climatological situation in Europe.

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?	Scientific name: *Lampropeltis getula* (Linnaeus 1766) Class: Reptilia Order: Squamata Family: Colubridae Genus: *Lampropeltis* (kingsnakes) Common names: common kingsnake, Ketten-Königsnatter (Ge), La Culebra Real (Sp), Serpent roi de californie (Fr), Serpente reale (It) At least seventeen different subspecies of *Lampropeltis getula* 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. 2017). In the light of the unclear and unstable taxonomy (hence the risk of uncertain attribution of the subspecies of the reported records of *L. getula* found in the wild and in trade), this risk assessment refers to the originally described *L. getula* Linnaeus 1766 sensu lato, with a native range covering all of the United States and northwestern Mexico, thus including the subspecies *L. getula californiae* which is considered a valid species by Pyron & Burbrink (2009) and is reported to have a different ecology than *L. getula getula* which is more bound to water (R. Fisher pers. comm. 2017). This is consistent with the approach followed also in the risk	The systematics of the species is not entirely clear. Pyron & Burbrink (2009) recognise *L. getula*, *L. californiae, L. holbrooki*, *L. niger and L. splendida* 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 *L. getula getula*, *L. getula floridana*, *L. getula meansi*, *L. getula goini* and *L. getula sticticeps* as belonging to *L. getula,* and the subspecies *nigrita* and *californiae* as a part of *L. californiae*.

	evaluation by Fonseca et al. (2017). On Gran Canaria, where the subspecies *L. getula californiae* was introduced, 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 (R. Fisher pers. comm. 2017). Reptile Database reports hybrids between California kingsnake *L. getulus californiae* and corn snake *Pantherophis guttatus* (in captivity), which despite the parental species belonging to different genera, are sexually viable (Fisher & Csurhes, 2009). Such hybrids, however, are excluded from this risk assessment. A risk assessment for *Pantherophis guttata* is available for Queensland, Australia (Queensland Government 2016). Bartz (2012) (Animal Diversity Web http://animaldiversity.org/) reports seven subspecies, including *L. getula getula* (eastern kingsnake), *L. getula floridana* (Florida kingsnake), *L. getula californiae* (California kingsnake), *L. getula holbrooki* (speckled kingsnake), *L. getula nigra* (black kingsnake), *L. getula sticticeps* (Outer Banks kingsnake) and *L. getula nigrita* (black desert kingsnake). The Integrated Taxonomic Information System (ITIS), which is based on the latest scientific consensus available, adds one subspecies and considers the following 8 subspecies for *L. getula* as valid: *L. getula californiae* (Blainville, 1835) – California Kingsnake *L. getula floridana* Blanchard, 1919– Florida Kingsnake *L. getula getula* (Linnaeus, 1766) – Eastern Kingsnake *L. getula holbrooki* Stejneger, 1902– Speckled Kingsnake *L. getula nigra* (Yarrow, 1882) – Black Kingsnake	

	L. getula nigrita Zweifel and Norris, 1955 – Black Desert Kingsnake *L. getula splendida* (Baird and Girard, 1853) – Desert Kingsnake *L. getula sticticeps* Barbour and Engels, 1942 – Outer Banks Kingsnake All of these subspecies are present in trade (e.g. www.undergroundreptiles.com, www.reptmart.com). Subspecies overlap and interbreed in several different regions across North America (Bartlett & Bartlett, 2005; Bartz, 2012; Wund et al., 2007). Many synonyms of *L. getula* have been used in the past, e.g.: *Coluber getulus* Linnaeus, 1766 *Lampropeltis getulus* (Linnaeus, 1766) *Herpetodryas getulus* — SCHLEGEL *Ophibolus getulus* — BAIRD & GIRARD 1853: 85 *Ophibolus boylii* Baird & Girard, 1853 *Coronella Getulus* — DUMÉRIL, BIBRON & DUMÉRIL 1854: 616 *Coronella getulus* var. *pseudogetulus* – JAN 1865 *Ophibolus getulus* — COPE 1875: 11 *Ophibolus getulus* — GARMAN 1884: 68 *Ophilobus* [sic] *getulus* — COPE 1892: 335 *Triaeniopholis arenarius* WERNER 1924 *Triaenopholis* [sic] *arenarius* WERNER 1924 (fide SMITH 1928) *Lampropeltis getulus goini* NEILL & ALLEN 1949: 101 *Lampropeltis getulus brooksi* BARBOUR 1919 *Lampropeltis getula getula* — TENNANT & BARTLETT 2000: 413 *Lampropeltis getula meansi* KRYSKO & JUDD 2006 *Lampropeltis getula meansi* — SKUBOWIUS 2009 *Lampropeltis getula goini* — RENNER in BERG 2013 The species distribution model (Annex IV) 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: *L. boylii* Stejneger, 1893; *L. californiae*; *L. californiae* (Blainville, 1835); *L. californiae californiae*; *L. catalinensis* Van Denburgh & Slevin, 1921; *L. degranvilli getulus*; *L. getula; L. getula brooksi; L. getula californiae; L. getula californiae* (Blainville, 1835); *L. getula conjuncta*; *L. getula floridana*; *L. getula floridans*; *L. getula getula*; *L. getula getula* x *L. getula floridana*; *L. getula getulus*; *L. getula holbrooki*; *L. getula holbrookia*; *L. getula* Linnaeus, 1766; *L. getula niger*; *L. getula nigra*; *L. getula nigrita*; *L. getula splendida*; *L. getula sticticeps*; *L. getula* subsp. *californiae* (Blainville, 1835); *L. getula* subsp. *conjuncta*; *L. getula* subsp. *floridana* Blanchard, 1919; *L. getula* subsp. *getula*; *L. getula* subsp. *holbrooki* Stejneger, 1902; *L. getula* subsp. *niger*; *L. getula* subsp. *nigra* (Yarrow, 1882); *L. getula* subsp. *nigrita* Zweifel & Norris, 1955; *L. getula* subsp. *splendida* (Baird & Girard, 1853); *L. getula* subsp. *sticticeps* Barbour & Engels, 1942; *L. getula yumensis*; *L. getulus*; *L. getulus boylii*; *L. getulus brooksi*; *L. getulus californiae*; *L. getulus californiae* x *L. getulus nigritus*; *L. getulus conjuncta*; *L. getulus floridana*; *L. getulus floridana* x *L. getulus brooksi*; *L. getulus floridanae*; *L. getulus floridanus*; *L. getulus gelutus; L. getulus getulus; L. getulus getulus* x *L. getulus sticticeps*; *L. getulus getulus* x *L. getulus stricticeps*; *L. getulus getulus* x *Lampropeltus getulus stricticeps*; *L. getulus holbrooki; L. getulus holbrookii; L. getulus niger; L. getulus nigra; L. getulus nigritus; L. getulus nijer; L. getulus sayi; L. getulus splendida; L. getulus sticticeps; L. getulus stricticeps; L. getulus* subsp. *brooksi*; *L. getulus* subsp. *californiae*; *L. getulus* subsp. *getulus*; *L. getulus* subsp. *nigritus*; *L. getulus* subsp. *sticticeps; L. getulus* subsp. *yumensis; L. nigra; Ophibolus boylii* Baird & Girard,	

	1853.	
A2. Provide information on the existence of other species that look very similar	*Lampropeltis getula* 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 Ladder snake *Rhinechis scalaris*, leopard snake *Elaphe situla* or the striped phase of Aesculapian snake *Zamenis longissima* can superficially resemble the lined morphotype. The genus includes up to 21 species, depending on the taxonomic concepts, with several confusing species that look very similar morphologically. For example, *L. triangulum* (Lacépède, 1789) (Eastern Milksnake) is a North American species that is also commonly kept as a pet and in collections. Fertile hybrids between *L. getula californiae* and *L. triangulum*, called “jungle corn snakes”, are common in captivity and appreciated for their aesthetic qualities (Piett et al. 2015).	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). 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 *L. getula holbrooki* is characterized by the ‘speckled’ pattern, which consists of a black ground color, with a white or yellow speckle in the centre of each scale, and very occasionally a faint trace of dorsal cross-banding (Pyron & Burbrink, 2009). The pattern of the Desert Kingsnake (*L. getula splendida*) 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 (*L. getula californiae*) 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 is black

		or dark brown, 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 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 *L. getula* or any of its subspecies available. The Netherlands risk analysis of non-native snakes (Bugter et al. 2014) mentions *L. getula* as a common species in trade, but does not assess the risk associated with its introduction.
A4. Where is the organism native?	The native range of *L. getula* 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 USA 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). 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). *Lampropeltis getula* is a primarily terrestrial snake, although it often occurs in the vicinity of water (Enge, 1997; Krysko, 2001; Plummer, 2010). They prefer sites with thick leaf litter and dense shrub layer	*Lampropeltis getula getula* (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. *Lampropeltis getula floridana* (Florida kingsnake) is found on the peninsula of Florida south to Dade County. *Lampropeltis getula californiae* (California kingsnake) is restricted to southwestern California and Baja California. *Lampropeltis getula holbrooki* (speckled kingsnake) is found in southwestern Illinois, eastern Iowa, and south central Alabama. *Lampropeltis getula nigra* (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. *Lampropeltis getula sticticeps* (Outer Banks kingsnake) is found only in North Carolina from Cape Hatteras to Cape Lookout. *Lampropeltis getula nigrita* (black desert kingsnake) can be found in southern Arizona and northwestern Mexico. On the Florida peninsula, the species is found in or near

	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). *L. getula* is regarded as a habitat generalist (Wund et al., 2007). However, an important factor in microhabitat selection by *L. getula* 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 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 *L. getula* 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). In Florida, in descending order, snakes, reptile eggs, and lizards dominate the diet of *L. getula* (Godley et al. 2017). The species can also be cannibalistic.	tropical hardwood hammocks, cypress strands (*Taxodium ascendens* and *T. distichum*), freshwater and sawgrass prairies (*Cladium jamaicense*), salt marshes, estuaries with black (*Avicennia germinans*), red (*Rhizophora mangle*), and white (*Laguncularia racemosa*) mangroves, clay hills, pitcher plant, sphagnum bogs, Australian pine (*Casuarina equisetifolia*), mesic pine flatwoods (*Pinus elliottii*) melaleuca forests (*Melaleuca quinquenervia*), along 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 *L. getula*, although this relationship has rarely been quantified for individual snakes (Steen et al., 2010). Lastly, *L. getula* 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 Regions and outside the risk assessment area (Cabrera-Pérez et al., 2012; Monzón-Argüello et al., 2015). However, there have been numerous introductions outside its native range elsewhere in the world (e.g. Magalhães and São-Pedro 2012), see also Ch3.	
A6. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world?	*Lampropeltis getula* 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 have a certain economic value, but documented evidence was not available.	*Lampropeltis getula* 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
1.1. How many active pathways are relevant to the potential entry of this organism? (If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)	**moderate number**	**medium**	The following pathways are potentially relevant for snake introductions: ● 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 contaminants on live plant material such as ornamental trees (e.g. De Urioste & Mateo 2011); • 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 • Release in nature (biocontrol): release of snakes for control of rats. There are no indications of this happening in the EU therefore this pathway is not further discussed in this risk assessment. • Transport – stowaway (hitchhikers in or on airplane) = unintentionally transported snakes on airplanes. This pathway is considered very unlikely and is therefore not further discussed in this risk assessment;

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.
 	
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.
			• The following pathways are discussed together under the 'pet' pathway as the mechanism may be either release, or escape, or both and there are no data on their relative importance:
			  ○ 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 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, banana and tomatoes(De Urioste & Mateo 2011, Mateo et al. 2011, Silva-Rocha et al. 2015);
Pathway name:	*Pet* pathway which includes [Escape from confinement (pet/aquarium/terrarium species)]		
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**	**high**	This pathway includes accidental escapes of snakes from terraria and private collections. According to the CBD pathway classification, this is an intentional pathway, since 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 may escape/be released sporadically with almost yearly records, published in local newspapers (Nehring & Rabitsch 2015, PETA 2014). This is consistent with the data documenting that *L. getula* was introduced through the pet trade outside its native range in the US, Brazil (Magalhães and São-Pedro 2012) and Europe, particularly in the Canary islands and the UK, but in the latter without successful establishment (Kraus 2009, Krysko et al. 2011). Also, there are many other records of introductions of similar kingsnakes (other than *Lampropeltis getula*) through the pet trade,

			among which *Lampropeltis* sp., *Lampropeltis alterna*, *Lampropeltis calligaster* and *Lampropeltis triangulum*, particularly in the US, Brazil and the UK (Kraus 2009, Krysko et al. 2011). *Lampropeltis getula* 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 *learning species* for private people wanting to keep and rear snakes in terraria. Due to their lack of experience, it can be assumed that escapes of *L. getula* from captivity are likely, e.g. through careless handling or feeding (the species is denominated on some popular websites as an *escape king*). The invasive Gran Canaria population also originated from pet trade, likely from a few captive bred escaped animals (Monzón-Argüello et al., 2015). *Lampropeltis getula* is reproducing and expanding on Gran Canaria despite the low genetic diversity of the population that likely descended from just a few individuals (Monzón-Argüello et al., 2015). Therefore there is no need of a large number of animals to be released for populations to successfully establish in the wild. Although precise data on the extent of animals in trade are not available for the EU, there are clues that *L. getula* may be very popular in the global market. For example, *L. getula* 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). *Lampropeltis getula* 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 *L. getula* 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). The species may have a certain economic value, but

			documented evidence was not available. The risk of reinvasion after eradication is high as long as animals are available in the pet trade.
1.9a. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**likely**	**low**	Transfer from this pathway to a suitable habitat is more likely for released than for escaped *L. getula*, since owners will probably bring snakes to an area they feel resembles its habitat. *L. getula* 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 or escaped in a colder climate, the species could survive by hibernating in burrows or caves. In general, the ability to transfer to a suitable habitat is likely in both cases.
1.10a. Estimate the overall likelihood of entry into Europe based on this pathway?	**likely**	**High**	*L. getula* is a popular pet, and described on many online platforms as a *beginner snake*. 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 *L. getula* when care becomes too much of a burden or is higher than expected. Casual records in several EU Member States illustrate the species is widely kept as a pet in the EU and that escapes may occur sporadically. Incidental reports of released/escaped kingsnakes appear in the popular press regularly. Such reports are not always clear on the exact species but probably reflect commonly kept species (milksnakes, kingsnakes). 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 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 *introduction for biological control*. 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. The Gran Canaria population is believed to have originated from escaped or released captive-bred individuals (Cabrera-Perez et al.2012). 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?	**moderately likely**	**medium**	If *L. getula* 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 *L. getula* 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 so the original introduction was intentional (IUCN 2017).
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? 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.	**moderately likely**	**low**	*Lampropeltis getula* occurs in great numbers in zoological gardens throughout Europe (www.zootierliste.de). *L. getula* is denominated on some popular websites as an *escape king*. 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 databases. It can be assumed that fewer individuals will escape from zoological gardens than from private collections, since anti-escape mechanisms in the former are generally better (Fábregas et al.2010, Scalera et al. 2016). A study by Fábregas et al. (2010) concluded that institutions that are members of professional associations are likely to be already taking this matter seriously in compliance to the current policy and legislation (as in the case of the members of the Spanish AIZA, who have been

			found to have fewer non-secure enclosures than non-members). In Gran Canaria, where *L. getula* 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 enable successful establishment in the wild. The risk of reinvasion after eradication is high as long as animals are present in zoological gardens.
1.9c. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**moderately likely**	**low**	It is more likely that released *L. getula* 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. *L. getula* 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.
1.10c. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	**moderately likely**	**low**	Since *L. getula* is present in zoological gardens throughout Europe, the species is moderately likely to enter the risk assessment area by escape from these facilities. However, the frequency of this happening is lower than for private collections hence moderately likely.
Pathway name:	[Transport – stowaway (hitchhikers on ship/boat)]		
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)? (If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)	**unintentional**	**very high**	This pathway involves unintentionally transported snakes on ships and cargo boats.
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? Subnote: In your comment discuss how likely the organism is to	**unlikely**	**high**	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 *L. getula* will travel along this pathway over the course of one year. However, on the Canary islands *L.getula* was transported to other islands through this

get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.			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 (R. Gallo Barneto pers. comm. 2017). As populations likely descend from just a few individuals large numbers are not a prerequisite for successful establishment. There is a record of an introduction of a closely related species, *L. triangulum*, in the US, Indiana, as cargo stowaway (Kraus 2009). Reinvasion through this pathway can occur after eradication.
1.5d. 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.	**likely**	**medium**	Snakes are known to sustain themselves for longer periods of time with very little food. Therefore it is moderately likely that *L. getula* could survive the long journey between North-America and Europe feeding on rats and mice on ships. For surface cargo, the main factor contributing to snake mortality is time on the dock (Perry & Vice, 2007). In order to reproduce along the pathway, a *L. getula* 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.
1.6d. How likely is the organism to survive existing management practices during passage along the pathway?	**moderately likely**	**low**	Active rat/mice control on the ship might impact snake survival during the journey, since this would impair prey availability for *L. getula*.
1.7d. How likely is the organism to enter the risk assessment area undetected?	**moderately likely**	**high**	*L. getula* 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 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 (*Boiga irregularis*) were accidentally introduced to Guam along 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. This coincides with the period of *L. getula* activity.
1.9d. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**moderately likely**	**low**	There are (at least) two possible ways that *L. getula* 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 *L. getula* 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. Sea ports are often in the vicinity of wetlands or estuaries. These are not per se suitable habitats for *L. getula* 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 *L. getula* 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. However, on Mediterranean islands, ports are often smaller and do have suitable habitat nearby.
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)? (If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)	**unintentional**	**Medium**	This pathway involves accidental introductions of snakes on live plant material (potted plants e.g. citrus and olive trees, banana and tomatoes)
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? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.	**moderately likely**	**medium**	*L. getula* 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.

Subnote: In your comment discuss the volume of movement along this pathway.			There is a record of an introduction of a closely related species, *Lampropeltis triangulum*, 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 (*Podarcis sicula*) that was introduced in the Iberian Peninsula (Silva-Rocha, 2015) through the olive tree trade. In addition, most of the records of horseshoe whip snake *Hemorrhois hippocrepis,* Montpellier snake *Malpolon monspessulanus* and ladder snake *Rhinechis scalaris*, most importantly 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). In Gran Canaria, where *L. getula* 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. Reinvasion through this pathway can definitely occur after eradication.
1.5e. 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.	**likely**	**high**	If *L. getula* would be present as a plant contaminant, it is very likely that it would survive, especially when this transport takes place from the Canary Islands to mainland Europe, a much shorter journey than from the USA. Based on other documented cases of snake introductions in Europe, we can infer the likelihood to be high. Whether the organism could multiply along the pathway is undocumented but unlikely, but gravid females could be transported along this pathway.
1.6e. How likely is the organism to survive existing management practices during passage along the pathway?	N/A	N/A	
1.7e. How likely is the organism to enter the risk assessment area undetected?	**moderately likely**	**low**	*L. getula* is a rather large but inconspicuous snake, and is not easily detected.

			See 1.4e, 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. This coincides with the period of *L. getula* activity.
1.9e. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**likely**	**low**	It is possible that the specimen is able to enter the plant transport undetected and stay undetected throughout its journey. This is more likely during the shorter journey from the Canary Islands to mainland Europe than from the USA. However, when individual plants are sold at their destination, the *L. getula* 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?	**moderately likely**	**Low**	
End of pathway assessment.			
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**	*L. getula* 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, as it is known to be an important pathway for accidental transport of snakes in the Mediterranean and particularly in light of the presence of invasive population on the Canary islands which have live plant exports to several EU member states (Massot 2011).
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 *L. getula* in the European Union.

PROBABILITY OF ESTABLISHMENT

Important instructions:

- 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**	The native range of *Lampropeltis getula* 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: mediterranean (csa, csb), semi-arid (bsk, bsh, bwk), continental (dsb, dfa), tropical (am, af, aw) and subtropical (cfa). 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. In central and northern member states, winter conditions are expected to represent a constraint on the survival of *L. getula* . Additionally, short and cool summers will restrict their foraging and reproductive opportunities (see Ch7 for more detail). *Lampropeltis getula* is oviparous (i.e. lays eggs), while most higher-latitude snake species are viviparous (this allows gravid females to thermoregulate the developmental temperature of their progeny, an option not open to oviparous species, see Gregory, 2009). This will prevent *L. getula* to become established in colder, temperate regions of Europe. However, *L. getula* could escape these limiting conditions in some southern parts of the possible range by behavioural adaptations and

			niche selection at micro scale (e.g. selection of nest sites).
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**	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 al., 2007; Fonseca et al. 2017). Several studies (Jenkins et al., 2001; Plummer, 2010; Wund et al., 2007) indicate that *L. getula* 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 *L. getula* 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, *L. getula* has shown a population decline which could be linked to extreme droughts (Seigel et al., 2007). On Gran Canaria, *L. getula* is also present in urbanized areas. Another study on *L. getula* points out that the species is known to use urban edge habitat (Anguiano & Diffendorfer, 2015). Additionally, one study indicates that California Kingsnakes (*L. getula californiae*) are more capable of persisting in small habitat fragments than other snake species (Anguiano & Diffendorfer, 2015). Given the highly fragmented nature of the European landscape, this may benefit the establishment of *L. getula* in the EU. Neither one of these habitat (components) is in short supply in the EU.

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? Subnote: gardens are not considered protected conditions	**very likely**	**very high**	*L. getula* 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, *L. getula* will be able to survive and establish in protected conditions even in northern regions.
1.16. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Europe?	**Moderately widespread**	**medium**	see 1.14. The species is a generalist predator that feeds on a wide array of prey such as other snakes (including conspecifics), lizards, small mammals (e.g. shrews, rodents, rabbits), birds and eggs of various bird and reptile species (Jenkins et al., 2001; Linehan et al., 2010; Winne et al., 2007). Cabrera-Pérez et al. (2012) note that on average, captured *L. getula* 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 Gran Canaria skinks (*Chalcides sexlineatus*) in its diet, whereas rodents made up a higher proportion of the other population's diet. The breeding season for *L. getula* 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 *L. getula* 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. 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 *L. getula* eggs. For more information about suitable habitat, see A4. We can conclude that habitats and species necessary for the survival, development and multiplication of *L. getula* are widespread in the Mediterranean bioregion. Although in other bioregions there might be sufficient prey available, climatic constraints could impair on reproductive success, rendering the habitats less suitable for *L. getula*. We therefore scored moderately widespread for the entire RA area.
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?	N/A	N/A	There are no indications *L. getula* needs another species for critical stages in its life cycle.
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. *Malpolon monspessulanus, Hierophis viridiflavus, Coronella austriaca*, *Zamenis longissimus*, *Z. situla*, *Rhinechis scalaris*, *Vipera aspis*, *V. berus*) that could potentially compete with *L. getula*, they could probably easily adapt their lifestyle to escape competitive interactions, or exploit alternative food sources to escape competition for food. In its native range, *L. getula* preys on copperheads (Steen et al., 2014), and there is known competition with cottonmouths (*Agkistrodon piscivorus*) (Winne et al., 2007). It is therefore moderately likely that competitive interactions will not prevent *L. getula* from establishing populations in the Union. Confidence is however low as there is no published evidence available.
1.19. How likely is it that establishment will occur despite predators, parasites or pathogens already present in Europe?	**moderately likely**	**medium**	The short-toed snake eagle (*Circaetus gallicus*) in particular is a potential predator for *L. getula*. 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 (*Hierophis viridiflavus*) or Aesculapian snake (*Zamenis longissimus*). Potentially, also four-

			lined snake (*Elaphe quatuorlineata*) or Montpellier snake (*Malpolon monspessulanus*) 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. Both domestic and feral cats and dogs are found on Gran Canaria and are known predators of reptiles. Birds of prey such as kestrels *Falco tinnunculus canariensis* are common on the island and could take juvenile snakes. Other birds of prey on the island include black kites *Milvus migrans*, buzzards *Buteo buteo*, booted eagle *Hieraaetus pennatus* and (although not a resident breeder) short-toed snake eagle *Circaetus gallicus* (García-del-Rey 2018). Despite their presence, *L. getula* established and spread on the Canary islands. Small Asian mongoose (*Herpestes javanicus*), 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 alien species of EU concern is established. Likewise, the presumably native Egyptian mongoose (*Herpestes ichneumon*) 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). Other potential kingsnake predators include (introduced) striped skunk (*Mephitis mephitis*) and invasive raccoon (*Procyon lotor*) (e.g. Urban (1970)), but these are either rare or omnivorous and mostly not present in bioregions predicted currently suitable for establishment of *L. getula*. Foxes *Vulpes vulpes* and

			wild boar *Sus scrofa* are also likely predators and are widespread in the RA area, however these species are not specialist snake predators.
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 *L. getula* 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**	*L. getula* 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 *L. getula* that could establish in the EU will be escapees/releases of captive-bred origin, it must be taken into account that such captive-bred specimens are known to reproduce in great numbers, achieve sexual maturity earlier and produce multiple clutches per year (Seigel et al., 1987). Interestingly, *L.*

			getula californiae individuals from 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 there are more gravid females in the population (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). Monzón-Arguëllo et al. (2015) found genetic, morphological, ecological and life history differences between two Gran Canaria subpopulations consistent with two separate founding groups. This illustrates the adaptability of the species which responded in a few generations to its new environment and has a higher reproductive output. 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, gravid snakes are found from March onward (Cabrera-Pérez et al. 2012). The Gran Canaria population of kingsnakes successfully recruits juveniles (Cabrera-Pérez et al., 2012; Monzón-Argüello et al., 2015). As already mentioned above, *L. getula* is known to occur in highly fragmented areas, meaning it could spread along small fragments of suitable habitat throughout Europe. The breeding season for *L. getula* 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 *L. getula* 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 Canaria, the species lays between 3-2f4 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**	*Lampropeltis* have rather small home ranges but are able to use urban edge habitat for dispersal and spread. This is considered moderately likely because it has occurred at least once in recent years on the Canary islands (see Q 2.1), while the confidence is medium because of the relatively small spatial scale at which this happened.
1.25. How likely is the adaptability of the organism to facilitate its establishment?	**likely**	**medium**	According to Detwiler & Criscione (2014), recently established invasive alien 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. *Lampropeltis getula* is a generalist, ubiquitous species in its native range, and has a flexible life history that fits that description. Even though the Gran Canaria populations of *L. getula* likely descended 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 poultry farms, respectively), indicating that this snake will likely be able to adapt to a variety of habitats (Monzón-Argüello et al., 2015).
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	**moderately likely**	**high**	The species has established in Macaronesia (Monzón-

elsewhere in the world, how likely is it to establish in Europe? (If possible, specify the instances in the comments box.)			Argüello et al., 2015) and similar conditions occur in the Mediterranean bioregion so there is a realistic chance this could happen in Europe in the future. However, despite being a very popular pet with occasional reported escapes, establishment has not occurred in the risk assessment area. Hence, this event is scored moderately likely.
1.28. If the organism does not establish, then how likely is it that casual populations will continue to occur? 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.	**very likely**	**medium**	*Lampropeltis getula* is a popular pet snake, therefore future escapes are very likely. Similarly, the spread of the species through accidental introductions (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).
1.29. Estimate the overall likelihood of establishment in relevant biogeographical regions in current conditions (mention any key issues in the comment box).	**moderately likely**	**medium**	The native range of *Lampropeltis getula* 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: mediterranean (csa, csb), semi-arid (bsk, bsh, bwk), continental (dsb, dfa), tropical (am, af, aw) and subtropical (cfa). Some of these climatic conditions (csa, csb, bsk, bsh and cfa) also occur in the Union, more notably in the Mediterranean region. Hence, it is likely that *L. getula* will be able to establish in the EU under current climatic conditions. Under current climate, establishment of *L. getula* 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, *L. getula*, 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.

			Currently, suitable areas for establishment are mostly determined by temperature, with strong effects of potential evapotranspiration (a variable reflecting available solar and thermal energy, accounts for 50% of the variation), mean temperature of the warmest quarter (33%) and minimum temperature of the coldest month (12%). Potential evapotranspiration is the most strongly limiting factor for establishment of *L. getula* in the EU estimated by the model, especially in northern Europe (Annex IV, figure 6). In more central and northern areas, establishment is less likely, since temperatures are probably too low for egg incubation. Although environmental conditions in temperate EU bioregions and member states are currently less suited for the species, it is possible *L. getula*, like other snake species in northwest Europe (e.g. Russian rat snake *Elaphe schrenkii* (Bugter et al., 2014); beauty rat snake *Orthriophis taeniurus* in 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). For competition, predation, parasites and pathogen details, see 1.18 and 1.19.
1.30. Estimate the overall likelihood of establishment in relevant biogeographical regions in foreseeable climate change conditions	**moderately likely**	**medium**	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

Important notes:

- 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.)	**moderate**	**medium**	Natural spread is movement by slithering. Anguiano & Diffendorfer (2015) indicate *L. getula* only shows small spatial movement patterns. *Lampropeltis* 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 *L. getula* will spread naturally across the island of Gran Canaria. As an example, from 2007 to 2011, the population near Telde increased its range from 25 km² to 45 km². (Monzón-Arguëllo et al. 2015). Anguiano & Diffendorfer (2015) conducted a study on *L. getula* 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 *L. getula californiae* 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. However, Fonseca et al. (2017) clearly regard the species as able to live in disturbed habitats and display human commensalism. *L. getula* reproduction, as well as environmental and climatic requirements have been described above. *L. getula* 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**	*Lampropeltis getula* 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 unintentionally or 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.	Unaided - Natural dispersal across borders of invasive alien species that have been introduced through other pathways.		
Pathway name:	[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**	*L getula* is not yet present in the RA area, however it is moderately likely that spread will happen through natural dispersal once a population is established. We find evidence in Gran Canaria, where at least one population on Gran Canaria is successfully producing juveniles (Monzón-Argüello et al., 2015). It can be assumed that this population is 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**	No existing management practices are known so it is very likely that *L. getula* will survive.
2.6. How likely is the organism to survive existing management practices during spread?	**moderately likely**	**medium**	Efforts to control *L. getula* have been implemented on Gran Canaria since 2007. Initial management practices were visual searching and hand capture of snakes. Passive capture with cages was tested with a variety of traps including funnel 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). From 2007 to 2011, 1064 snakes were caught in Gran Canaria, mainly by visual searching and hand capture, yet despite these management measures the species still survived and spread on Gran Canaria to an area of at least 55 km2 (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 *L. getula* 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**	*Lampropeltis getula* 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 *L. getula*. *Lampropeltis* 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 *L. getula* will spread naturally across the island of Gran Canaria, although the rate of this spread will likely be slow. Anguiano & Diffendorfer (2015) conducted a study on *L. getula* 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 *L. getula californiae* 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.
2.9. Estimate the overall likelihood of spread into or within the Union based on this pathway?	**moderately likely**	**low**	The species can spread unaided in the Canary islands, were it is already established and has spread beyond its area of introduction (Monzón-Argüello et al., 2015). Unaided spread into the Union is very unlikely (see 2.4) but should the species get established in the RA area unaided spread can be an issue.
End of pathway assessment, repeat as necessary.			
2.10. Within Europe, how difficult would it be to contain the organism?	**difficult**	**medium**	Given the secretive nature of *L. getula* 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 *L. getula* 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 *L. getula* include the Mediterranean and Steppic bioregion.	**high**	Under current climate: ● It might be possible for *L. getula* to become invasive in 6 the 10 Mediterranean member states of the EU (Portugal, Spain, France, southern Italy,

	Climate change could increase the area at risk with parts of the Atlantic, Continental and Alpine bioregion becoming suitable.		Croatia, Malta, Greece, Bulgaria, Romania, Cyprus). ● Climatic conditions in the EU member states in central and northern Europe 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). Under foreseeable climate change conditions as described above: ● *L. getula* could also become invasive in France, northern Italy, Hungary, Croatia and Romania.
2.12. What proportion (%) of the area/habitat suitable for establishment (i.e. those parts of Europe were the species could establish), if any, has already been colonised by the organism?	**0-10 (0)**	**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 *L. getula* 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. Also, this species is not communal and will therefore be kept as individual, limiting the potential for establishment.
2.14. What other timeframe (in years) would be appropriate to estimate any significant further spread of the organism in Europe? (Please comment on why this timeframe is chosen.)	**80**	**medium**	Because *L. getula* generally occurs in warmer areas, a temperature increase due to global warming will inherently increase the percentage of suitable habitat for the species in the European Union. Consistent with the SDM (**Annex IV**) which models *L. getula* under greenhouse gas emission scenarios up to in 2100, we considered a timeframe of 80 years to estimate any further spread of *L. getula* in the Union.
2.15. In this timeframe what proportion (%) of the endangered	**10-33**	**low**	The most likely pathway of introduction is escape from pet

area/habitat (including any currently occupied areas/habitats) is likely to have been invaded by this organism?			keepers or zoological gardens. Since *L. getula* is present in captivity throughout the EU, it is likely that there will be 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 *L. getula* will be present in several EU member states within the endangered area. However, since *L. getula* has small home and activity ranges, the species will probably spread rather slowly. 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**	On Gran Canaria, various endemic reptiles are impacted upon by predation. Following analysis of the stomach contents of *L. getula* in Gran Canaria the diet of the species appeared to include the giant lizard (*Gallotia stehlini),* Gran Canaria skink (*Chalcides sexlineatus)* and Boettger's wall gecko (*Tarentola boettgeri)* (Cabrera-Pérez et al., 2012). This is consistent with dietary preferences in the native range. For example, in Florida, in descending order, snakes, reptile eggs, and lizards dominate the diet of *L. getula* (Godley et al. 2017). Gran Canaria giant lizard makes up most of the diet of *L. getula*. 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 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). On Gran Canaria, densities of the endemic giant lizard *G.*

			stehlini, which represents the most important food source of *L. getula* (Cabrera-Pérez et al. 2012), were compared between an invaded and an uninvaded site using capture-mark-recapture. Densities of *G. stehlini* in the invaded site were about 10% of the densities in the uninvaded site. 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 lizard population by impairing recruitment (LIFE+ Lampropeltis 2013). Currently, we could not find any evidence of documented, quantified decline in the conservation status of other native species caused by *L. getula*.
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**	The species may have a major impact on biodiversity, 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 of lizard-pollinated plants), but also through the spread of diseases and parasites. In its native range, *L. getula* is considered as a generalist predator with a preference for aquatic snakes and turtle eggs (Winne et al., 2007). A diet analysis of *L. getula* in South Carolina between 1975 and 2005 identified several food items, including common garter snake *Thamnophis sirtalis*, several species of watersnakes, timber rattlesnake *Crotalus horridus*, southern short-tailed shrew *Blarina carolinensis* and eggs from common snapping turtle *Chelydra serpentina* and pond slider *Trachemys scripta* (Winne et al., 2007). Furthermore, a study by Steen et al. (2017) reported the effect of kingsnakes on copperheads as their prey. Another source

			reports predatory activities on rodents and other small mammals, lizards and their eggs, snakes (including venomous 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, *L. getula* preys on several endemic reptile species (Fritts & Rodda, 1998; Guicking et al. 2006; Martínez-Morales & Cuaron, 1999; Monzón-Argüello et al., 2015). 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 *L. getula* 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 *Hemorrhois hippocrepis*, introduced on the Balearics with potted plants, which is causing declines in native endemic Ibiza wall lizard *Podarcis pityusensis* populations through predation (Hinckley et al. 2016). The historical introduction of the snake false smooth snake *Macroprotodon cucullatus*, together with some introduced mammals, have been considered responsible for the extinction of native Lilford's wall lizard *Podarcis lilfordi* in Mallorca and Menorca (Pinya and Carretero 2011, Silva-Rocha 2015) and an undescribed Discoglossid frog (Pleguezuelos 2004). The restricted current range of Mallorcan midwife toad may also be the result of predation by introduced Viperine Snake *Natrix maura* (Moore et al. 2004; Guicking et al. 2006). These examples illustrate introduced snakes on Mediterranean islands can have profound effects on native, often endemic herpetofauna through predation. 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 *P. lilfordi* went extinct due to snake and rat predation on Menorca causing declines in the endemic perennial shrub *Daphne rodriguezii*

			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 provided by lizards (e.g. Traveset and Saez 1997). Especially in areas under threat, such as Iberia and the Mediterranean islands, the degree of endemism is high e.g. in 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 *L. getula* 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 (*Chalcides ocellatus*) in Sicily, Sardinia, Greece and Malta, the Cyprus whip snake (*Hierophis cypriensis*) in Cyprus, the Cretan wall lizard (*Podarcis cretensis*) in Crete and the North-African white-toothed shrew (*Crocidura pachyura*) in Ibiza, Sardinia and Pantelleria (Italy). Of course, this list is not complete and many other species could become threatened by introduced *L. getula* in the future. *L. getula* may also have an impact as a vector of diseases and parasites. For example, three new species of *Hepatozoon* infecting the Florida kingsnake, *Lampropeltis getula floridana* were recently described (Telford 2010). This parasite 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). *L. getula* 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 *Nannizziopsis guarroi, Paranannizziopsis australiensis, P. californiensis, P. crustacean, P. longispora* and *Ophidiomyces ophiodiicola* (Cabañes et al., 2014). Snake Fungal disease (SFD), caused by the agent *Ophidiomyces ophiodiicola*, has the potential to cause lethal infections and contribute to extinction of wild snake populations. Both wild and captive *Lampropeltis* are 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 (*Natrix natrix*) in the UK and dice snake (*Natrix tessellata*) in the Czech Republic (Franklinos et al. 2017). Genetic and phenotypic differences indicate that the European isolates represent novel strains of *O. ophiodiicola* (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). Furthermore, some reptiles can potentially carry ticks that spread the bacterium *Cowdria ruminantium* 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 *L. getula* however and this phenomenon is more relevant to African reptiles (Burridge 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.). 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 of unknown pathogens to wildlife could be an issue and represents an inherent risk associated with snake introductions. *Lampropeltis getula* 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 venomous 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 precise estimates on this matter. We can say that introductions of *Lampropeltis getula* will be more problematic on small Mediterranean islands without snakes than on mainland Europe. On the continent, *L. getula* will find a wider array of food, thus the impact on endemic prey species may be lower.
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?	**Major**	**high**	On Gran Canaria, various endemic reptiles are preyed upon. Following the analysis of the stomach contents of *L. getula* in Gran Canaria the diet of the species appeared to include the giant lizard (*Gallotia stehlini)*, Gran Canaria skink (*Chalcides sexlineatus)* and Boettger's wall gecko (*Tarentola boettgeri)*. These species are all listed on Annex IV of the European Habitats Directive (Council Directive 92/43/EEC of 21 May 1992). 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 *L. getula*. 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 *L. getula*.
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**	Since *L. getula* 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 already vulnerable species that could be impacted by *L. getula*, for example, is *Arvicola sapidus*, an endemic to France, Spain and Portugal. There are other potentially threatened endemic rodents, amphibians and lizards with restricted ranges, specifically on the Mediterranean islands: the ocellated skink (*Chalcides ocellatus*) in Sicily, Sardinia, Greece and Malta, the Cyprus whip snake (*Hierophis cypriensis*) in Cyprus, the Cretan wall lizard (*Podarcis cretensis*) in Crete and the North-African white-toothed shrew (*Crocidura pachyura*) in Ibiza, Sardinia and Pantelleria (Italy). Other examples include snakes introduced to the Mediterranean islands, such as horseshoe whip snake *Hemorrhois hippocrepis*, introduced on the Balearics with potted plants, which is causing declines in native endemic Ibiza wall lizard *Podarcis pityusensis* populations through predation (Hinckley et al. 2016). The historical introduction of the snake *Macroprotodon mauritanicus*, together with some introduced mammals, have been considered responsible for the extinction of native Lilford's wall lizard *Podarcis lilfordi* in Mallorca and Menorca (Pinya and Carretero 2011, Silva-Rocha 2015) and of the native Menorcan midwife toad *Alytes muletensis* and an undescribed Discoglossid (Pleguezuelos 2004). 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 *L. getula* (Monzón-Argüello et al., 2015). Other endemic species susceptible to predation from *L. getula* include *Gallotia stehlini*, Gran Canaria skink, *Chalcides sexlineatus*, Boettger’s wall gecko and *Tarentola boettgeri*, 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).
Ecosystem Services impacts			
2.23 How important is the impact of the organism on provisioning, regulating, and cultural services in its non-native range excluding the Union?	**minor**	**low**	*Lampropeltis getula* has no known impact on provisioning and regulating ecosystem 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**		The species is not yet established in the risk assessment area. However, on Gran Canaria (outermost region), the species does have an impact on ecosystem services associated with rare endemic reptiles of socio-economic importance for the island (Barahona et al., 2000; Carranza et al., 2002; López-Jurado, 1991). Impact on cultural services (see 2.23) is not unlikely but remains undocumented.
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. See 2.23
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	**major**	**medium**	No quantitative information on direct economic damage by *L. getula* is available. The EU co-financed the LIFE+ Biodiversity project *Lampropeltis* (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 snake biology and reliable detection and capture techniques. Between 2011 and 2017 an increasing number of snakes was 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	**N/A**		The species is not yet established in the risk assessment area.

response)? *i.e. excluding costs of management			
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 neither aggressive nor venomous, therefore any future medical costs incurred if *L. getula* 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 *Salmonella* 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 *L. getula* 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 *Lampropeltis* (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**	*Lampropeltis getula* 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 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. *Lampropeltis getula* is not aggressive nor venomous, but like other reptiles, is a potential carrier/reservoir for *Salmonella* which is well known to pose a significant health risk to humans (Damborg et al. 2016). However, this risk needs to be placed in context, as the vast majority of infections in humans are caused by foodborne *Salmonella* (see review by Pasmans et al. in press.). Also, *Salmonella* is common in reptiles and is not specific to *Lampropeltis*. 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 *L. getula* caused enormous social alarm (Cabrera-Pérez et al., 2012).
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**	*L. getula* 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 *Nannizziopsis guarroi*, *Paranannizziopsis australiensis*, *P. californiensis*, *P. crustacean*, *P. longispora* and *Ophidiomyces ophiodiicola* (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. Furthermore, some reptiles can potentially carry ticks that spread the bacterium *Cowdria ruminantium* that, although not lethal to reptiles, can kill grazing animals (Fisher & Csurhes, 2009). There are no documented records of this bacterium on *L. getula* however.
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 *L. getula* 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).	The above described impact are possible in areas identified suitable for establishment (see Annex IV)		

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 region suitable for the species 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 modelling estimating the effect of climate change on the potential distribution (Annex IV) showed additional bioregions suitable for establishment under modelled future climate conditions for the 2070s, under both medium and high greenhouse gas emission scenarios.
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 significant effect on the successful reproduction and establishment of *L. getula*, since the eggs of this species need sufficiently high average summer temperatures for incubation. Higher reproductive 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 of parasites and pathogens and their possible consequences on native species.

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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**
	Question 2.18-22	*Question 2.23-25*	*Question 2.26-30*	*Question 2.31-32*
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	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,

[1] Not to be confused with „no impact“.

	serious ecosystem effects			irreversible health effects.

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 *and/or* Impacts are recorded at a spatial scale which is unlikely to be relevant to the assessment area *and/or* Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous *and/or* 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 *and/or* 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 *and/or* 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) *and* Impacts are recorded at a comparable scale *and/or* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and/or* 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 *and* Impacts are recorded at a comparable scale *and* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and* Data/information are not controversial or contradictory.

ANNEX IV – Species Distribution Model

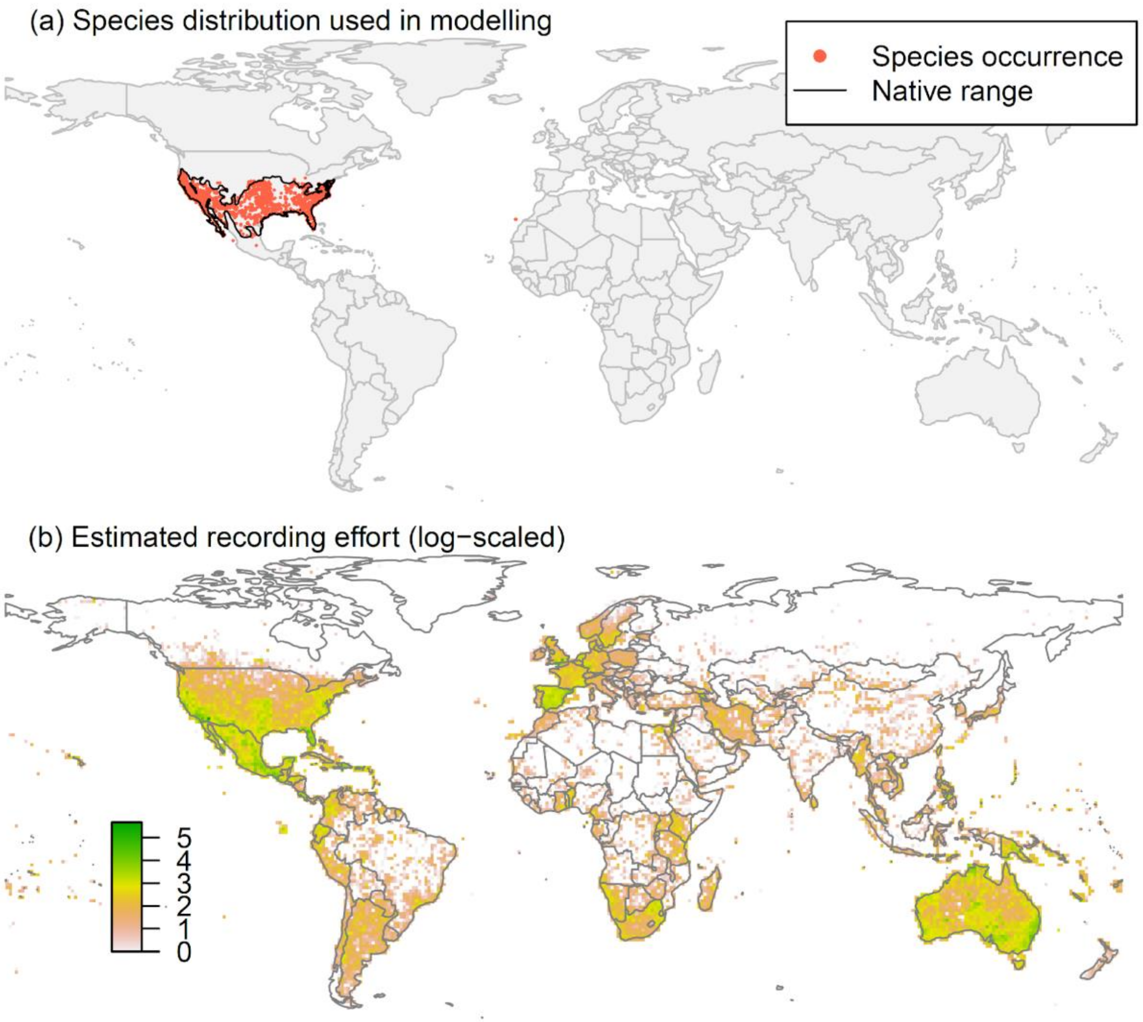
(Projection of climatic suitability for *Lampropeltis getula* establishment)

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 where 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 holbrooki*, *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 Lampropeltus getulus stricticeps*, *Lampropeltis getulus holbrooki*, *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. There 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

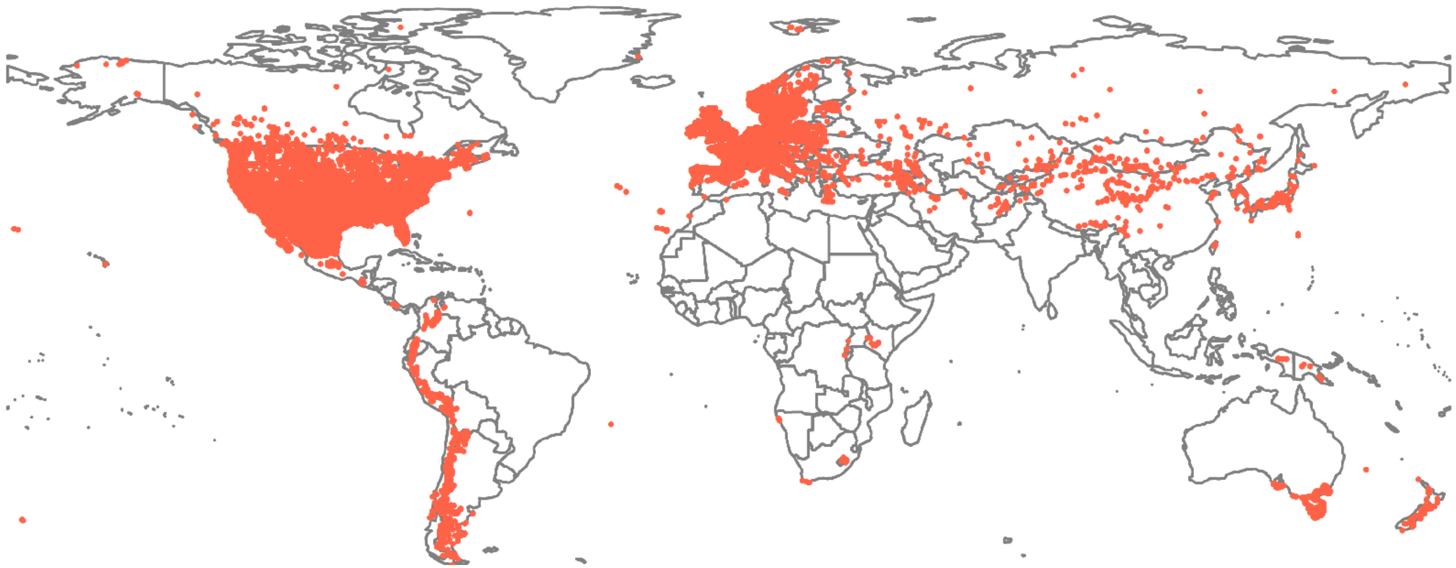
A presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package v3.3-7 (Thuiller et al., 2014, Thuiller et al., 2009). These models contrast the environment at the species' occurrence locations against a random sample of the global background environmental conditions (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 fur 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.

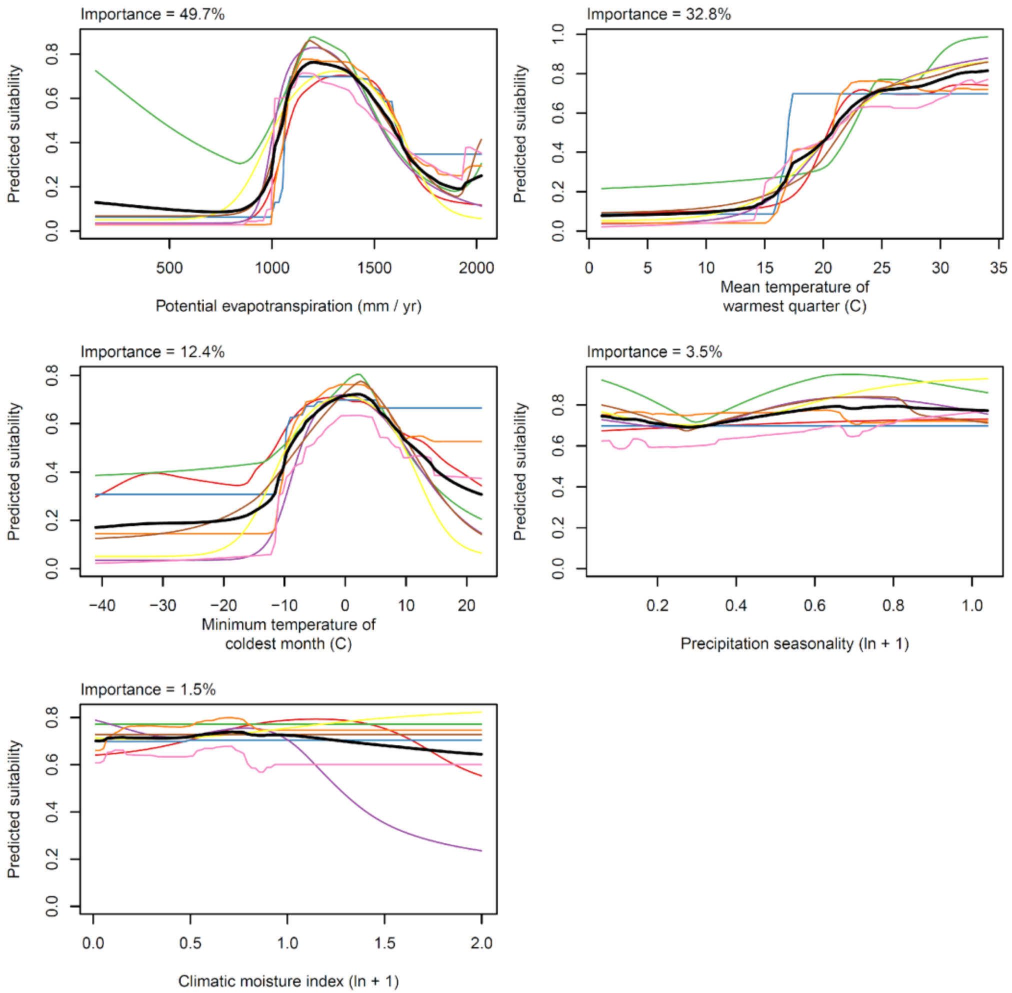


Figure 4. (a) Projected global suitability for *Lampropeltis getula* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Values > 0.5 may be suitable 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.

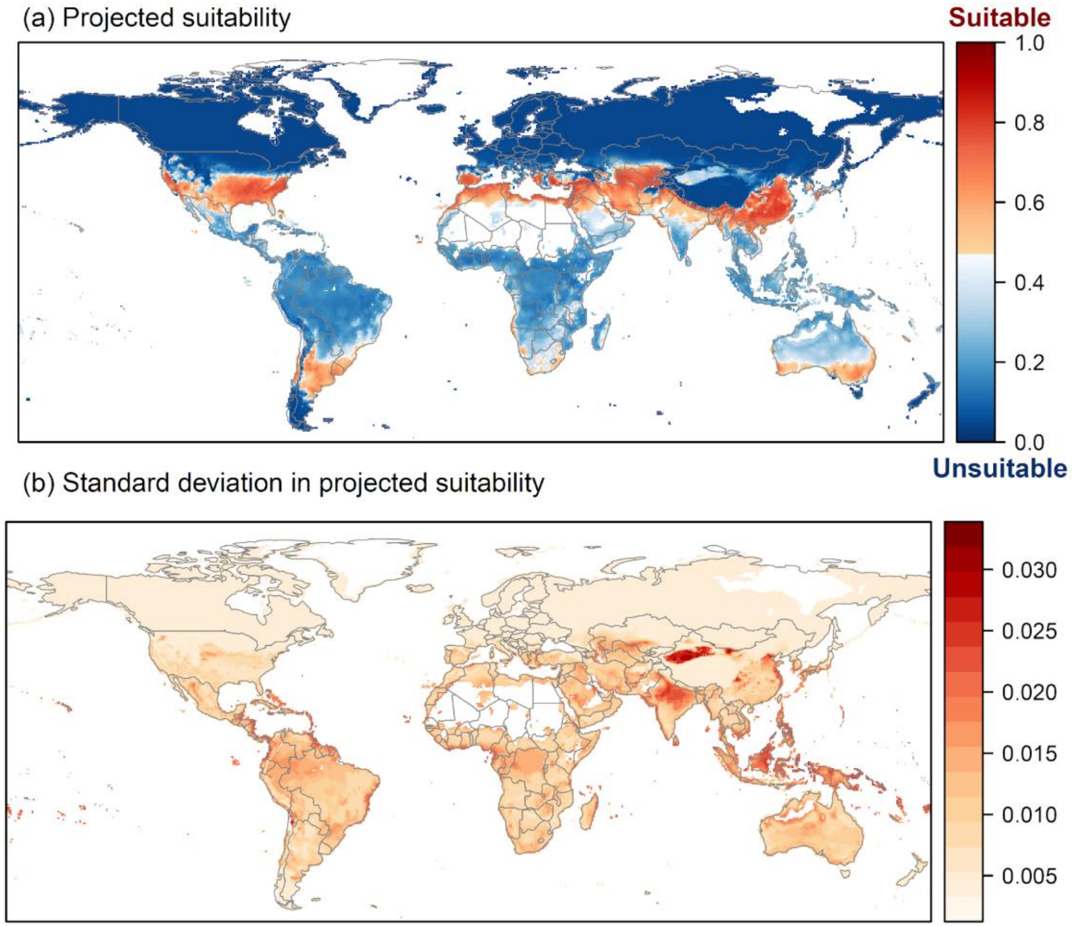


Figure 5. Projected current suitability for *Lampropeltis getula* establishment in Europe and the Mediterranean region. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

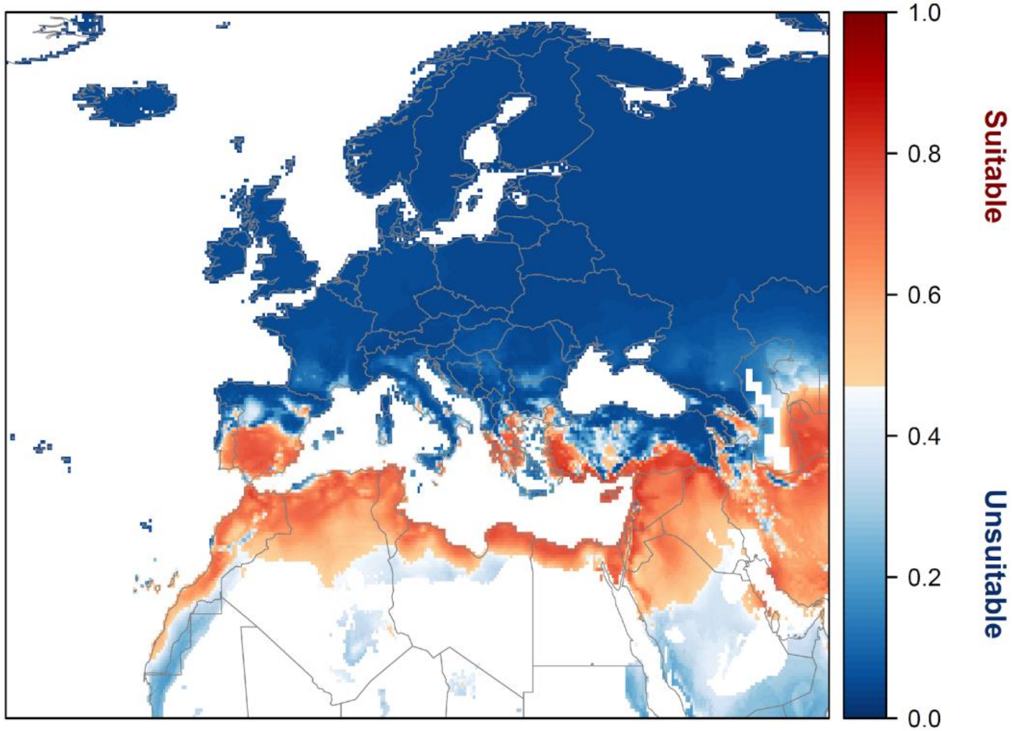


Figure 6. The most strongly limiting factor estimated by the model in Europe and the Mediterranean region in current climatic conditions.

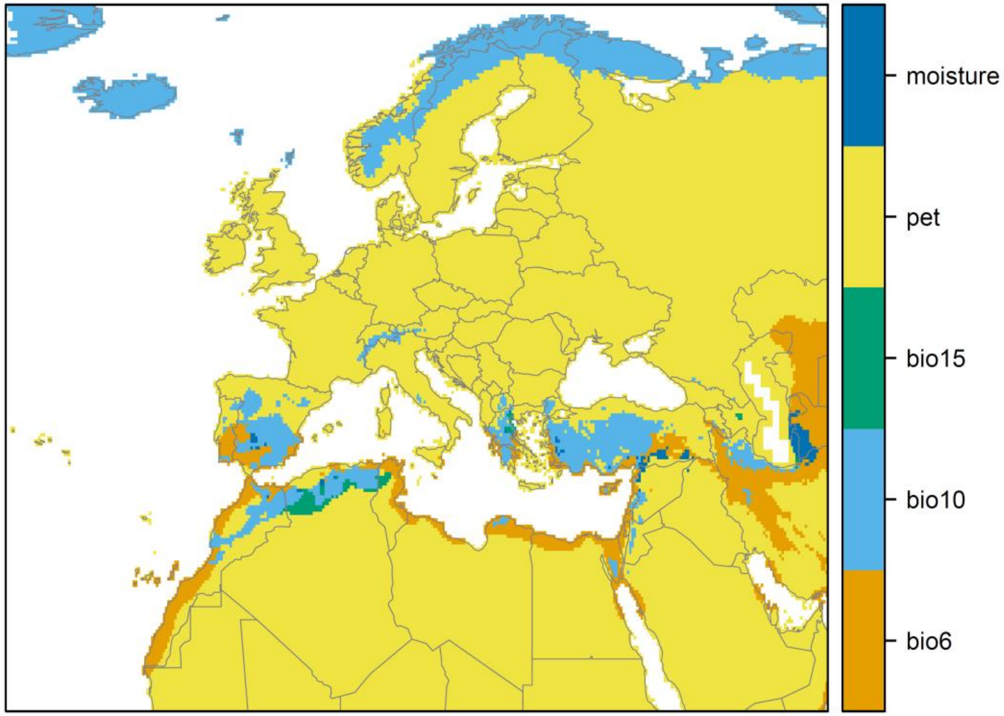


Figure 7. Projected suitability for *Lampropeltis getula* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP4.5, equivalent to Figure 5. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

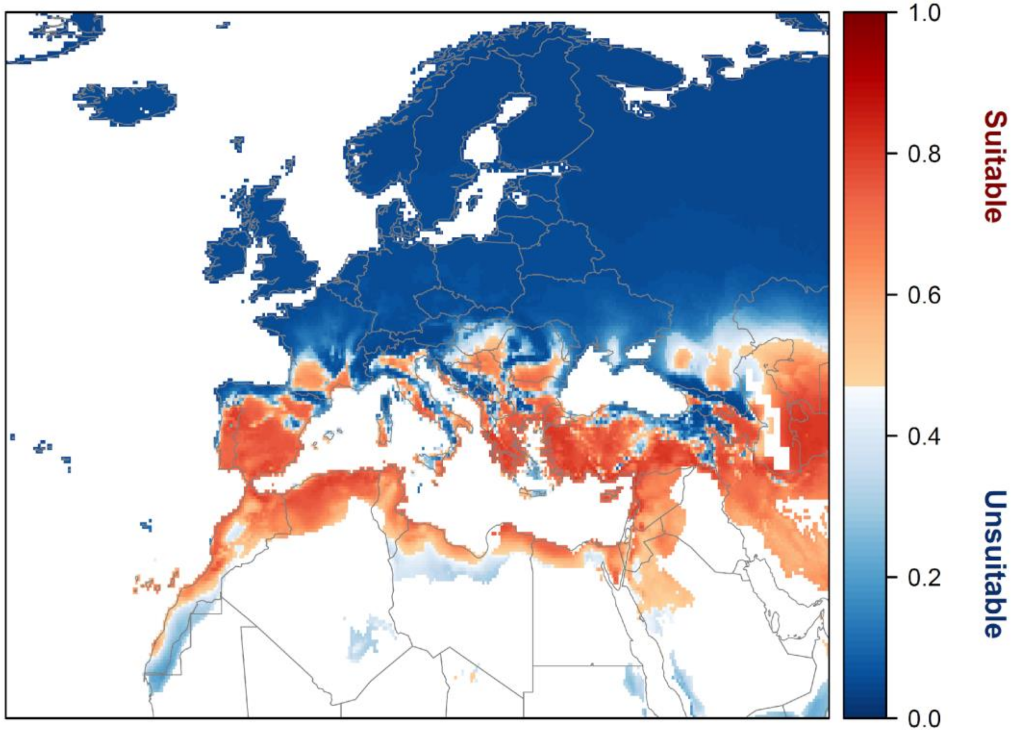


Figure 8. Projected suitability for *Lampropeltis getula* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Figure 5. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

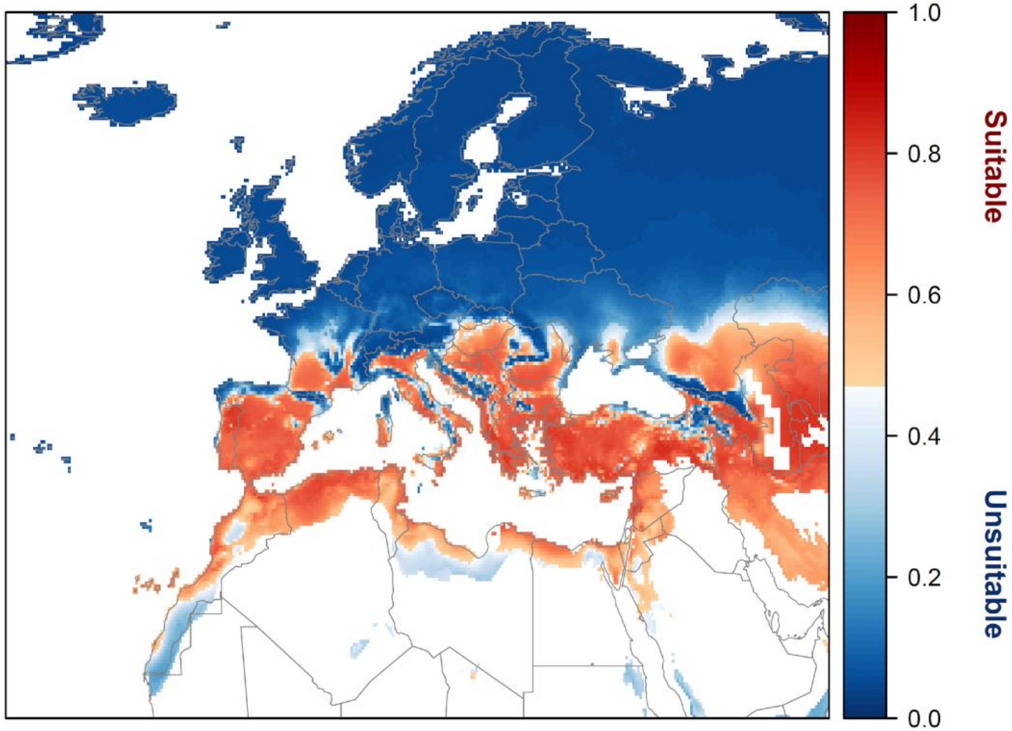
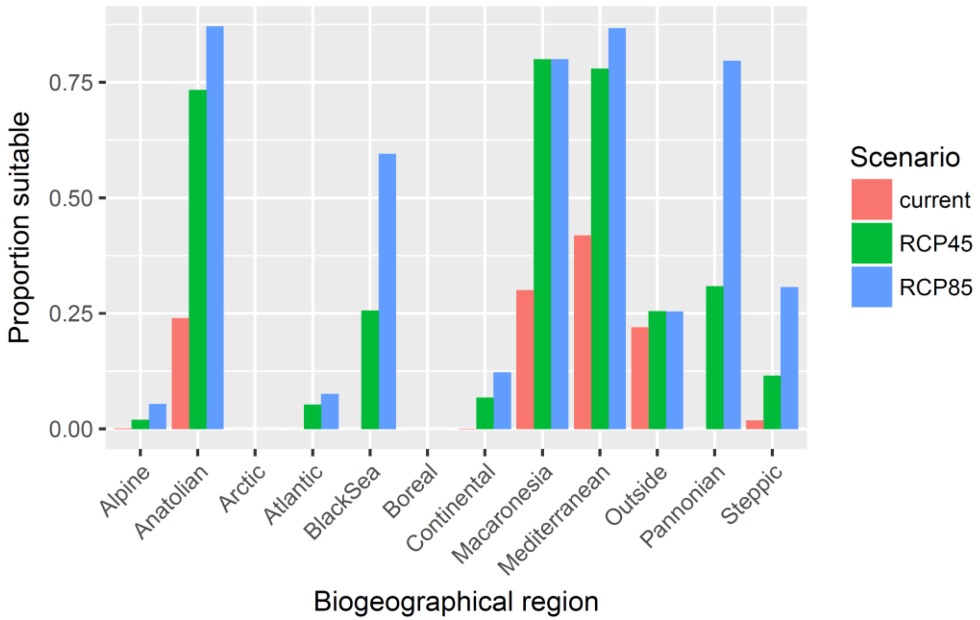
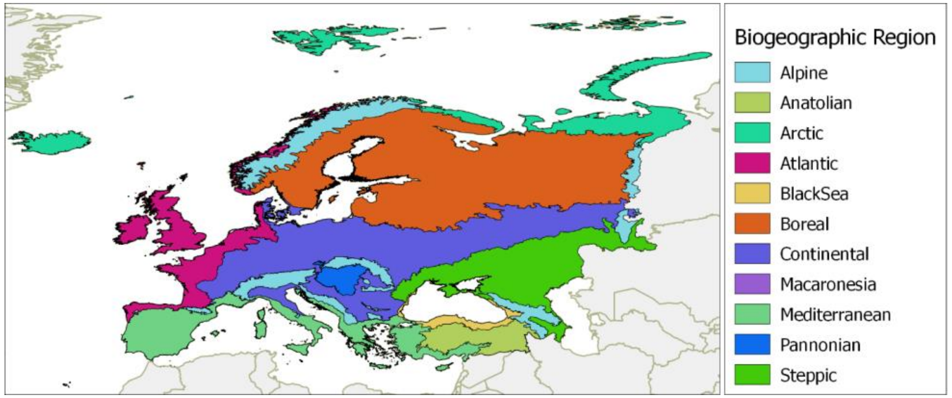


Figure 9. Variation in projected suitability among Biogeographical regions of Europe (Bundesamt fur Naturschutz (BfN), 2003). The bar plots show the proportion of grid cells in each region classified as suitable in the current climate and projected climate for the 2070s under two RCP emissions scenarios.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