Risk Assessment of *Lithobates catesbeianus*

Name of Organism:	*Lithobates catesbeianus* Shaw, 1802 - American Bullfrog
Objective:	Assess the risks associated with this species in Ireland
Version:	Final 15/09/2014
Author(s)	Erin O'Rourke, Colette O'Flynn
Expert reviewer	John Wilkinson

Stage 1 - Organism Information

Stage 2 - Detailed Assessment
Section A - Entry
Section B - Establishment
Section C - Spread
Section D - Impact
Section E - Conclusion
Section F - Additional Questions

About the risk assessment

This risk assessment is based on the **N**on-native species **AP**plication based **R**isk **A**nalysis (NAPRA) tool (version 2.66). NAPRA is a computer based tool for undertaking risk assessment of any non-native species. It was developed by the European and Mediterranean Plant Protection Organisation (EPPO) and adapted for Ireland and Northern Ireland by Invasive Species Ireland. It is based on the Computer Aided Pest Risk Analysis (CAPRA) software package which is a similar tool used by EPPO for risk assessment.

Notes: Confidence is rated as low, medium, high or very high.
Likelihood is rated as very unlikely, unlikely, moderately likely, likely or very likely.
The percentage categories are 0% - 10%, 11% - 33%, 34% - 67%, 68% - 90% or 91% - 100%.
N/A = not applicable.

DOCUMENT CONTROL SHEET

Name of Document:	Risk Assessment of *Lithobates catesbeianus*
Author (s):	Dr Erin O'Rourke and Ms. Colette O'Flynn
Authorised Officer:	Dr Liam Lysaght
Description of Content:	Non-native species risk assessment
Approved by:	Dr Liam Lysaght
Date of Approval:	15/09/2014
Assigned review period:	n/a
Date of next review:	n/a
Document Code	n/a
This documents comprises	TOC	Text	List of tables	List of Figures	No. Appendices
	n/a	YES	n/a	n/a	n/a

Version Control Table

Version No.	Status	Authors(s)	Reviewed by	Approved by	Date of issue
Draft 1	Complete	Dr Erin O'Rourke	Ms Colette O'Flynn		24/01/2014
Expert review	Complete	Dr Erin O'Rourke	Dr John Wilkinson	Dr Liam Lysaght	30/01/2014
Public consultation	Complete	Dr Erin O'Rourke		Dr Liam Lysaght	09/05/2014
Public consultation 2	Complete	Dr Erin O'Rourke		Dr Liam Lysaght	14/08/2014
Final	Complete	Dr Erin O'Rourke		Dr Liam Lysaght	15/09/2014

Stage 1 - Organism Information

The aim of this section is to gather basic information about the organism.

N	QUESTION	RESPONSE	COMMENT
1	What is the reason for performing the risk assessment?	-	A risk assessment is required as this species is listed as a "Non-native species subject to restrictions under Regulations 49 and 50" in the Third Schedule of the European Communities (Birds and Natural Habitats) Regulations 2011, SI 477/2011.
2	Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	YES	*Lithobates catesbeianus* Shaw, 1802 - American bullfrog Taxonomy: Phylum: Chordata (mammals, birds, amphibians, reptiles, birds) Class: Amphibia Order: Anura Family: Ranidae Genus: Lithobates Species: catesbeianus Synonym: *Rana catesbeiana* (Shaw, 1802) Common name (English): Bullfrog, Common bullfrog (Santos-Barrera *et al.*, 2009).
3	If not a single taxonomic entity, can it be redefined? (if necessary use the response box to re-define the organism and carry on)	N/A	
4	Describe the organism.	-	The American bullfrog is a distinctive, large-bodied anuran. It has a typical snout-vent length of 90-152 mm (maximum length 200 mm) and a body weight up to 0.5 kg (Conant 1975; Lorvelec and Detaint, 2009). The posterior legs are robust and long, representing up to 50% of total body length, and up to 40% of total body weight, whilst the anterior limbs are short (CABI, 2014). The adult dorsum (upper side) varies in colouration from pale green, dark olive to brownish and can have brown blotches; the head, which is wide and flat, is lighter green, and the legs are blotched or banded (CABI, 2014). The ventral side is white, grey or yellowish (CABI, 2014; GISD, 2009). The species have large, conspicuous tympanic membranes (eardrums), which have a dark outer ring (Conant 1975). The skin is mostly smooth, with no dorsolateral folds, but has a skin fold, from around the ear to the base of the forelegs (Conant 1975). As they mature they become sexually dimorphic. In males, the upper abdomen (chin and throat) temporally develops yellow skin pigments and the tympanic membranes enlarge to several times the diameter of the eye (CABI, 2014). Males are also smaller than females. Mature females retain the morphology and colouration of the juvenile stage (CABI, 2014). Tadpoles are greenish or brownish with small spots, grow up to 150 mm and can take from 12 to 48 months to reach metamorphosis (Conant 1975). The adult male produces the advertisement call.

Stage 1 - Organism Information

The aim of this section is to gather basic information about the organism.

N	QUESTION	RESPONSE	COMMENT
5	Does a relevant earlier risk assessment exist? (give details of any previous risk assessment for Ireland)	YES	In Ireland, a preliminary risk assessment was previously carried out. This was a prioritisation risk assessment as part of the Risk Analysis and Prioritisation for Invasive and Non-native Species in Ireland and Northern Ireland (ISI, 2012). It designated *Lithobates catesbeianus* as a "high risk" invasive species.
6	If there is an earlier Risk Assessment is it still entirely valid, or only partly valid?	PARTIAL	Only a preliminary risk assessment was previously conducted in Ireland (refer to Question 5).
7	Where is the organism native?	-	The American bullfrog is native to eastern North America, from the Atlantic coast as far west as Kansas and Oklahoma (McKercher and Gregoire, 2011; Santos-Barrera *et al.*, 2009).
8	What is the current global distribution of the organism (excluding Ireland)? (map optional)	-	The species has been introduced in over 40 countries and four continents over the last century (Ficetola *et al.*, 2007b; Lever, 2003). Including its native range (refer to question 6), the species has a global distribution spanning Argentina; Belgium; Brazil; China; Colombia; Cuba; Dominican Republic; Ecuador; France; Germany; Greece; Indonesia; Italy; Jamaica; Japan; Malaysia; Netherlands; Peru; Philippines; Puerto Rico; Singapore; Spain; Taiwan, Province of China; Thailand; United Kingdom; Venezuela and also in western North America, including Hawaii (GISD, 2009; Santos-Barrera *et al.*, 2009)

Stage 1 - Organism Information
The aim of this section is to gather basic information about the organism.

N	QUESTION	RESPONSE	COMMENT
			Figure 1 Global distribution of American bullfrog (Modified from Santos-Barrera *et al.*, 2009).
9	What is the current distribution of the organism in Ireland? (map optional)	N/A	It is not currently known to be present in Ireland.
10	Is the organism known to be invasive anywhere in the world?	YES	It is considered one of the world's most harmful invasive species; negatively affecting native amphibians through competition, predation and spread of disease (Beebee and Griffiths 2005; Govindarajulu *et al.*, 2006; Kats and Ferrer 2003; Lorvelec and Detaint, 2009; Lowe *et al.*, 2000). Doubledee *et al.*, (2003) found, for example, a positive correlation between the absence of California red-legged frogs (*Rana draytonii*) and the presence of introduced American bullfrog (*Lithobates catesbeianus*).

Stage 2 - Detailed assessment: Section A - Entry

This section evaluates the probability of entry of an organism into Ireland. For organisms which are already present, only complete the entry section for currently active pathways of entry and potential future pathways. The entry section need not be completed for pathways which have allowed an organism to enter in the past but are no longer active.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.01	How many active/future pathways are relevant to the potential entry of this organism (n/a, very few, few, moderate number, many or very many)?	FEW	MEDIUM	Known historic, active and future introduction pathways to new locations internationally include: aquaculture/farming, stocking, ornamental/garden trade, pet/aquarium trade, use in landscape/fauna "improvements", use as biological control agents, smuggling and inadvertent importation (CABI, 2014). It is illegal to import American bullfrogs to Europe since 1997 (law of the European Council 2551/1997) (Teixera *et al.*, 2001). Therefore, of the pathways listed above, smuggling and inadvertent importation have the most potential to act as active/future pathways for the entry of this species into Ireland.
1.02	List <u>significant</u> pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways.	1. Smuggling 2. Inadvertent importation		Smuggling: Although it is illegal to import the American bullfrog into the Europe, this species can be ordered on the Internet and shipped worldwide (Lorvelec and Detaint, 2009). It may be expected that smuggling of the species would be undertaken illegally to cater for individuals seeking to keep the animal as a captive pet or enhance ornamental ponds. Potential feral populations would be as a result of releases of unwanted pets and/or escapes from confinement. Inadvertent importation: the species occurs in close proximity with fish traded internationally, and unintentional releases may be possible via this pathway.

	Pathway 1 – Smuggling			
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	INTENTIONAL	HIGH	The species is intentionally smuggled.
1.04	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?	VERY UNLIKELY	MEDIUM	The number of American bullfrogs potentially entering Ireland via this pathway is expected to be low and infrequent. Of the known cases of population establishment in the United Kingdom, two are suspected to be as a result of deliberate release as unwanted pets and escapes from garden ponds (Marchant, 2012).
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	LIKELY	HIGH	It is likely that the species could enter Ireland undetected and without the knowledge of the relevant authority. The species is often difficult to detect (Simberloff *et al.*, 2005). Ficetola *et al.* (2008) developed a detection method for the secretive species using a novel approach, based on the limited persistence of DNA in the environment.
1.06	How likely is the organism to survive during passage along the pathway?	VERY LIKELY	HIGH	This species is robust and can tolerate a range of conditions (CABI, 2014).
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	MODERATELY LIKELY	HIGH	In the species' temperate zone, the breeding season lasts about 90 days from mid to late summer (CABI, 2014). It is moderately likely for the species to arrive during this period.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	LIKELY	HIGH	The species has a good capacity to disperse over long distances (Ficetola *et al.*, 2007a; Smith and Green, 2005) and within the Irish landscape is likely to encounter suitable perennial and seasonal water bodies (CORINE, 2006; Fossitt, 2000).
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	MODERATELY LIKELY	MEDIUM	Entry is moderately likely as importing the species into Europe has been prohibited since 1997. However, it occurs in large numbers in other EU member states, from which smuggling is possible.
1.10	Do other pathways need to be considered?	YES	-	

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
Pathway 2 - Inadvertent importation				
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	ACCIDENTAL	HIGH	
1.04	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?	VERY UNLIKELY	HIGH	The number of American bullfrogs potentially entering Ireland *via* this pathway is expected to be low and infrequent. However, the species occurs in close proximity with fish traded internationally, and unintentional releases may be possible *via* this pathway.
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	LIKELY	HIGH	It is likely that the species could enter Ireland undetected and without the knowledge of the relevant authority. The species is often difficult to detect (Simberloff *et al.*, 2005). However, Ficetola *et al.* (2008) developed a detection method for the secretive species using a novel approach, based on the limited persistence of DNA in the environment and if this surveillance method were introduced at expected potential entry points then it may reduce the likelihood of the species entering undetected.
1.06	How likely is the organism to survive during passage along the pathway?	VERY LIKELY	HIGH	This species is robust and can tolerate a range of conditions (CABI, 2014).
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	MODERATELY LIKELY	HIGH	In the species' temperate zone, the breeding season lasts about 90 days from mid to late summer (CABI, 2014). It is moderately likely for the species to arrive during this period.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	LIKELY	HIGH	The species has a good capacity to disperse over long distances (Ficetola *et al.*, 2007a; Smith and Green, 2005) and within the Irish landscape is likely to encounter suitable perennial and seasonal water bodies (CORINE, 2006; Fossitt, 2000).
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	MODERATELY LIKELY	MEDIUM	The species occurs in close proximity with fish traded internationally, and unintentional releases may be moderately likely via this pathway.
1.10	Do other pathways need to be considered?	NO		

Overall likelihood

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.11	Estimate the overall likelihood of entry into Ireland based on all pathways (comment on the key issues that lead to this conclusion).	MODERATELY LIKELY	MEDIUM	Entry is moderately likely as importing the species in Europe has been prohibited since 1997. However, it occurs in large numbers in other EU member states, from which smuggling is possible. The species is occasionally kept in captivity and escapes are possible. The species also occurs in close proximity with fish traded internationally, and unintentional releases may be possible *via* this pathway.

Stage 2 - Detailed assessment: Section B - Establishment
This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.01	Is the organism well established in Ireland (if there is any uncertainty answer 'unsure')	NO	MEDIUM	No knowledge of the presence of the species in Ireland.
2.02	How likely is it that the organism will be able to establish in Ireland based on the similarity between local <u>climatic conditions</u> and the organism's current global distribution?	VERY LIKELY	MEDIUM	It is currently established in the western part of North America (including Hawaii), in several counties of South America, Greater Antilles, Asia, and Europe. (Lorvelec and Detaint, 2009). The species, therefore, acclimatises readily to climatic conditions ranging from temperate, subtropical to tropical (Conant 1975; Orchard, 2011). This range includes climatic conditions comparable with Ireland; a temperate oceanic climate which is mild, moist and changeable, with abundant rainfall and lack of temperature extremes (Keane and Collins, 2004). The species is known to establish (i.e. breed disperse, feed and hibernate) in the United Kingdom (Banks *et al.*, 2000; Marchant, 2012), Ireland's nearest and climatically similar neighbour. Ficetola *et al.* (2007b) found areas having high precipitation during both summer and winter; high maximum temperature, high human pressure, and intermediate minimum annual temperature were those with the highest predicted suitability for bullfrogs. This 'warm-adapted species' is not likely to be present in areas with very cold winters (-20°C) (Ficetola *et al.*, 2007a). Where established in temperate climates, they hibernate to withstand below-freezing ambient temperatures (CABI, 2014).
2.03	How likely is it that the organism will be able to establish in Ireland based on the similarity between other local <u>abiotic conditions</u> and the organism's current global distribution?	VERY LIKELY	MEDIUM	This species is highly aquatic, and the water-bodies present in Ireland, although smaller in size, are comparable with those in the species natural range.
2.04	How likely is the organism to encounter habitats necessary for the survival, development and multiplication of the organism in Ireland?	VERY LIKELY	MEDIUM	The species is known to inhabit a wide range of habitats, including lakes and ponds, water courses, and wetlands (GISD, 2009). For successful reproduction and over-wintering, permanent water bodies are required (Spitzen – van der Sluijs and Zollinger, 2010). Lakes and large ponds are the preferred habitat in its native range but when introduced it can occupy any habitat that is lentic, or with slow moving water, especially if aquatic and bank vegetation are abundant (CABI, 2014; Lorvelec and Detaint, 2009). They are also known to establish well in highly artificial and highly modified habitats like millponds, livestock grazing ponds, reservoirs and golf course ponds (Doubledee *et al.*, 2003; Ficetola *et al.*, 2007b). Within the Irish landscape the species is likely to encounter suitable perennial

Stage 2 - Detailed assessment: Section B - Establishment
This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				and seasonal water bodies (CORINE, 2006; Fossitt, 2000).There are many species suitable as prey present in Ireland. Prey resources include algae and pond microinvertebrates (for larvae), and invertebrates, amphibians, reptiles and mammals (for post-metamorphic stages).
2.05	How likely is it that establishment will occur despite competition from existing species in Ireland?	VERY LIKELY	MEDIUM	Orchard (2011) describes the species as competitively exclusive, with interspecific competition with native amphibians for prey and other resources unlikely. Competition with non-amphibian species is also unlikely to prevent establishment (Ficetola *et al.*, 2007b; Govindarajulu, *et al.*, 2006; Pearl *et al*, 2004).
2.06	How likely is it that establishment will occur despite predators, parasites or pathogens already present in Ireland?	VERY LIKELY	MEDIUM	Predation of the species in Ireland is unlikely to impact on establishment. Larvae are unpalatable to most vertebrate predators and can have unusually high survival rates (Pearl *et al.*, 2003). Post-metamorphic stages have effective predator avoidance behaviours. Adults may be subject to predation by birds such as grey herons *Ardea cinerea* (Marchant, 2012). If populations were to reach high-densities the main source of predation would be cannibalism (Lorvelec and Detaint, 2009).
2.07	How likely is it that establishment will occur despite existing management practices?	LIKELY	MEDIUM	Overall, management practices would appear to have little bearing on establishment, given that the species' native and non-native range encompasses a vast area with many different management practices. The impacts of management practices are, perhaps, localised.
2.08	How likely is it that management practices in Ireland will facilitate the establishment of the organism?	LIKELY	MEDIUM	The Irish agricultural sector is undergoing landuse change and intensification. The improvement (drainage) of margin wetlands or the removal of lakes, ponds and watercourses to increase agricultural production, causing a reduction in the amount of suitable habitat, may prevent establishment. The creation and management of recreational and urban water bodies may best facilitate establishment.
2.09	How likely is it that the biological characteristics of the organism would allow it to survive eradication campaigns in Ireland?	LIKELY	MEDIUM	The species' high rate of reproduction is the most constraining factor in eradication campaigns, followed by crypis (ability of the species to avoid observation or detection), high density and lack of suitable control methods (CABI, 2014). Eradication is most successful when population establishment is detected in the early stages and when dispersal is strictly limited (Adams & Pearl, 2007; Banks *et al*, 2000; Doubledee, *et al.*, 2003). If just a few adults remain after an eradication campaign, a

Stage 2 - Detailed assessment: Section B - Establishment
This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				new invasion is highly likely in a few generations, rendering the previous management ineffective (Ficetola *et al.,* 2008).
2.10	How likely is it that the biological characteristics of the organism will facilitate its establishment?	VERY LIKELY	HIGH	The species is one of the most fecund anurans, with females capable of laying up to *c.* 30,000 eggs per season. In favourable conditions, females can lay multiple clutches in a given season (CABI, 2014). Egg masses can be difficult to locate and survival rates from egg to metamorphosis is high compared to other anurans.
2.11	How likely is it that the organism's capacity to spread will facilitate its establishment?	MODERATELY LIKELY	HIGH	Natural spread of both juveniles and adults is via rivers and land (Lorvelec and Detaint, 2009), and adult dispersal can be considerable, with rapid individual movements >3km from the home pond recorded (Baker, 1999; GISD, 2009). Successful establishment following translocation by humans is known in Europe and other non-range areas (Ficetola *et al.*, 2007a).
2.12	How likely is it that the organism's adaptability will facilitate its establishment?	VERY LIKELY	HIGH	The large native and non-native range of the species is indicative of its adaptability (Adams and Pearl, 2007). The species is known to adapt well to a wide range of habitats (refer to Question 2.04) and climatic conditions (refer to Question 2.02).
2.13	How likely is it that the organism could establish despite low genetic diversity in the founder population?	VERY LIKELY	HIGH	Low genetic diversity does not relate to probability of establishment for this species. The species has the ability to establish from only a very small number of founders, with most non-native populations deriving from less than six females (Ficetola *et al.*, 2008).
2.14	Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Ireland? If possible, specify the instances of invasion elsewhere in the justification box	VERY LIKELY	HIGH	Invasion depends on environmental characteristics that may predispose a habitat to invasion, refer to Questions 2.04 and 2.02
2.15	If the organism does not establish, then how likely is it that transient populations will continue to occur?	MODERATELY LIKELY	MEDIUM	Some releases may occur through both accidental and intentional import and subsequent poor captive control.

Stage 2 - Detailed assessment: Section B - Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

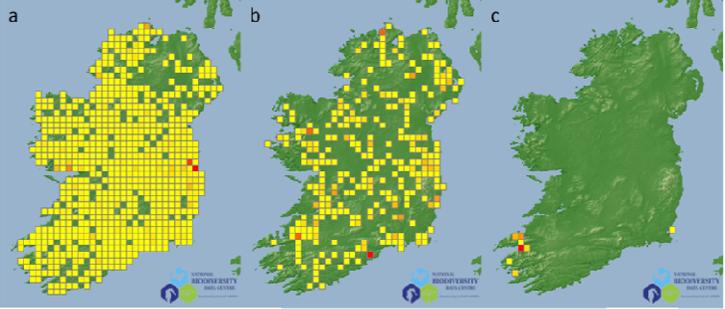| N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.16	Estimate the overall likelihood of establishment. Mention any key issues in the comments box	LIKELY	HIGH	Establishment is likely if the species arrives with at least one frog/tadpole of each sex in founder stock; suitable breeding habitat present nearby; and low vigilance toward invasive amphibians in the local area. Least likely in areas where there are few ponds or ponds are very small and fragmented by large areas of built land.

Stage 2 - Detailed assessment: Section C - Spread
This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
3.01	What area (given in % or 10km squares) in Ireland could the organism establish (0% - 10%, 11% - 33%, 34% - 67%, 68% - 90% or 91% - 100%)?	11%-33%	MEDIUM	Approximately 19% of Irish land cover constitutes the species favoured habitat of water bodies (2.27%) and wetlands (16.417%) (CORINE, 2006).
3.02	How important is the expected spread of this organism in Ireland by <u>natural</u> means (minimal, minor, moderate, major or massive)?	MAJOR	MEDIUM	Evidence from other non-range states indicates spread may be rapid. In south west France, for example, the species is now distributed over *c.* 2000 km sq following initial introduction in 1960s (Ficetola, *et al.*, 2007a,b).
3.03	How important is the expected spread of this organism in Ireland by <u>human assistance</u> (minimal, minor, moderate, major or massive)?	MINOR	MEDIUM	Evidence in other non-range states indicates that translocation by humans often complements natural spread. The species is often seen as charismatic and may be subject to collection and release by interested members of the public, or may be spread unintentionally (Ficetola, *et al.*, 2007b).
3.04	Within Ireland, how difficult would it be to contain the organism (minimal, minor, moderate, major or massive)?	MAJOR	MEDIUM	Long-term containment unlikely, impractical and very costly. Only likely to be possible in very limited circumstances, e.g. in a highly fragmented habitat with few suitable water bodies present.
3.05	What proportion (%) of the area in Ireland suitable for establishment, if any, has already been colonised by the organism?	N/A	N/A	This species is not yet known to be present in Ireland.
3.06	What proportion of the area in Ireland 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%	MEDIUM	If the species was to invade, it may be established in 0-10% of the landscape in five years' time. Potential establishment may always be limited to 19% - the percentage of Irish land cover representative of suitable habitat (CORINE, 2006).
3.07	What other timeframe would be appropriate to estimate any significant further spread of the organism (10, 20, 40, 80 or 160 years)? Please comment on why this timeframe is chosen.	10	MEDIUM	A period of 10 years represents approximately three generations of bullfrogs, during which time significant spread would be possible and should be assessable.
3.08	In this timeframe, what proportion of the area (including any currently occupied areas) is likely to have been invaded by this organism?	0%-10%	LOW	The species is currently unknown to exist in the wild in Ireland. Therefore any introduction to the wild would likely cover a low proportion of the area in the next 10 years.

Stage 2 - Detailed assessment: Section C - Spread
This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
3.09	Based on the answers to questions on the potential for establishment and spread in Ireland, define the area endangered by the organism. Be as specific as possible. If available, provide a map showing the area most likely to be endangered.	-	MEDIUM	The widespread distribution of native amphibians (with the exception of the natterjack toad) in Ireland (Figure 3) is a strong indication of the bullfrog's potential to occupy most available suitable habitat. Perennial water bodies and wetlands are most at risk to invasion. Potential establishment may always be limited to 19% - the percentage of Irish land cover representative of suitable habitat (CORINE, 2006), although potential overall area of occupancy could be substantial – as evidenced by the distribution of the common frog. **Figure 3.** Records of (a) the common frog (*Rana temporaria*), (b) the smooth newt (*Lissotriton vulgaris*) and (c) the natterjack toad (*Epidalea calamita*) in Ireland (National Biodiversity Data Centre, 2014).
3.10	Estimate the overall potential for future spread for this organism in (very slowly, slowly, moderately, rapidly or very rapidly). Use the justification box to indicate any key issues.	RAPID	MEDIUM	*Lithobates catesbeianus* is known to spread rapidly when habitat conditions are favourable. Much of lowland Ireland outside highly urbanised areas could be at risk.

Stage 2 - Detailed assessment: Section D - Impact
This section evaluates the probability of impact of an organism within Ireland.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.01	How great is the economic loss caused by the organism within its global distribution (excluding Ireland), including the cost of any current management?	MODERATE	MEDIUM	There is a lack of obvious economic impacts (Adams & Pearl, 2007), but substantial costs could be incurred through monitoring and management practices. Costs for the control of the species are not well documented but are said to be limited when executed in the early stages of invasion (Lorvelec and Detaint, 2009). Monitoring and control costs in the United Kingdom are so far estimated to be in excess of £100,000 (Lorvelec and Detaint, 2009; Marchant, 2012). Efforts to control the species in Germany have led to a predicted annual cost of € 53,000, per pond per year (Reinhardt *et al.,* 2003).
4.02	How great has the economic cost of the organism been in Ireland from the <u>time of introduction to the present</u>? Exclude any costs associated with managing the organism from your answer.	N/A	N/A	This species is not yet known to be present in Ireland.
4.03	How great is the economic cost of the organism likely to be in the <u>future</u> in Ireland? Exclude any costs associated with managing the organism from your answer.	MODERATE	MEDIUM	The species has the potential to disturb angling and golfing, interfere with reservoirs and impede aquaculture.
4.04	How great have the economic costs of managing this organism been in Ireland from the <u>time of introduction to the present</u>?	N/A	N/A	This species is not yet known to be present in Ireland.
4.05	How great is the economic cost of managing this organism likely to be in the <u>future</u> in Ireland?	MODERATE	MEDIUM	Costs would accrue from monitoring and management practices.
4.06	How important is environmental harm caused by the organism within its global distribution?	MAJOR	HIGH	Environmental harm is possible, through predation of, and competition with, native species and spread of disease (Adams & Pearl, 2007; Doubledee, *et al.*, 2003; Fisher & Garner, 2007; Govindarajulu, *et al.*, 2006; Hanselmann *et al.*, 2004; Pearl *et al.*, 2004).
4.07	How important has the impact of the organism on biodiversity* been in Ireland from the time of introduction to the present? *e.g. decline in native species, changes in community structure, hybridisation	N/A	N/A	This species is not yet known to be present in Ireland.

Stage 2 - Detailed assessment: Section D - Impact
This section evaluates the probability of impact of an organism within Ireland.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.08	How important is the impact of the organism on biodiversity likely to be in the <u>future</u> in Ireland?	MAJOR	HIGH	The ecological impact of bullfrogs on islands can be profound, especially where ecologically vital freshwater resources may be limited (Orchard, 2011). Concern relates to harm through predation, competition and disease transmission (Adams & Pearl, 2007; Doubledee, *et al.*, 2003; Fisher & Garner, 2007; Hanselmann *et al.*, 2004; Pearl *et al.*, 2004). This may result in reduction, displacement or elimination of native species, of conservation importance; namely the common frog (*Rana temporaria*), natterjack toad (*Epidalea calamita*) and smooth newt (*Lissotriton vulgaris*) (King *et al*, 2011).
4.09	How important has alteration of ecosystem function* caused by the organism been in Ireland from the time of introduction to the present? *e.g. habitat change, nutrient cycling, trophic interactions	N/A	N/A	This species is not yet known to be present in Ireland.
4.10	How important is alteration of ecosystem function caused by the organism likely to be in Ireland in the <u>future</u>?	MODERATE	MEDIUM	American bullfrog tadpoles are described as ecosystem engineers, altering the biomass, structure and composition of algal communities (Kupferberg, 1997). The high food intake and population densities, of tadpoles are considered to impact nutrient cycling and primary production in freshwater ecosystems (GISD, 2009).
4.11	How important has decline in conservation status* caused by the organism been in Ireland from the time of introduction to the present? *e.g. sites of nature conservation value, WFD classification, etc.	N/A	N/A	This species is not yet known to be present in Ireland.
4.12	How important is decline in conservation status caused by the organism likely to be in the <u>future</u> in Ireland?	MAJOR	MEDIUM	There is a likelihood, based on known impacts to native amphibian populations in other countries (Doubledee, *et al.*, 2003; Hanselmann *et al.*, 2004), that potential invasions of the American bullfrog would result in negative impacts to native habitat and species in Ireland.
4.13	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within its global distribution?	MINOR	MEDIUM	Possible that people would be concerned by presence of large numbers of invasive frogs. Some annoyance or disturbance may be caused by male vocalisations in summer.

Stage 2 - Detailed assessment: Section D - Impact
This section evaluates the probability of impact of an organism within Ireland.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.14	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within Ireland?	MINOR	MEDIUM	Social harm is likely to be minimal.
4.15	How important is it that genetic traits of the organism could be carried to other organisms / species, modifying their genetic nature and making their economic, environmental or social effects more serious?	MINIMAL	MEDIUM	The species is highly unlikely to hybridise successfully with native species. It is not closely related to the common frog and is now placed in a completely distinct genus (Frost *et al.*, 2006).
4.16	How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	MAJOR	HIGH	Known to be a vector of *Batrachochytrium dendrobatidis*, the causative agent for chytridiomycosis, a potentially catastrophic fungal disease of amphibians (Fisher & Garner 2007; Hanselmann *et al.*, 2004). *Lithobates catesbeianus* appears to be an asymptomatic carrier for the chytrid fungus, and has been implicated in its spread in several countries.
4.17	How important might other impacts not already covered by previous questions be resulting from introduction of the organism? Specify in the justification box.	N/A	MEDIUM	We are not aware of any other impacts the introduction of this species would have.
4.18	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 Ireland?	MINIMAL	HIGH	Predation on American bullfrogs in Ireland area is likely to be minimal. Refer to Question 2.06.
4.19	Indicate any parts of where economic, environmental and social impacts are particularly likely to occur. Provide as much detail as possible, where possible include a map showing vulnerable areas.	-	LOW	Impacts most likely to be severe in areas of the Ireland where there are high densities of medium-large sized water bodies and streams, within or close to areas designated for their importance for amphibian and other wetland biodiversity. Areas subject to economic and social impacts are unknown or unlikely (Ficetola, *et al* 2007b; Banks, *et al*, 2000).
4.20	Estimate the overall potential impact of this organism in Ireland. Use the justification box to indicate any key issues.	MAJOR	MEDIUM	Most important potential environmental impacts are reduction in abundance and diversity of amphibian fauna, and possibly other fauna, through predation, competition and disease transmission. Economic and social harm is likely to be minimal.

Stage 2 - Detailed assessment: Section E - Conclusion

This section requires the assessor to provide a score for the overall risk posed by an organism, taking into account previous answers to entry, establishment, spread and impact questions.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
5.01	Estimate the overall risk of this organism in Ireland. Noting answers given in 1.11, 2.16, 3.10 & 4.20	MAJOR	MEDIUM	Entry is only moderately likely as importing the species into Europe has been prohibited since 1997. However, it occurs in large numbers in other EU member states, from which smuggling is possible. The species is occasionally kept in captivity and escapes are possible. The species also occurs in close proximity with fish traded internationally, and unintentional releases may be possible via this pathway. Establishment is likely once the species arrives in the wild under the following conditions: at least one frog of each sex in founder stock; suitable breeding pond present nearby; low vigilance toward invasive amphibians in the local area. Least likely in areas where there are few ponds or ponds are very small and fragmented by large areas of built land. *Lithobates catesbeianus* is known to spread rapidly when habitat conditions are favourable. Much of lowland Ireland outside highly urbanised areas could be at risk. Most important potential environmental impacts are reduction in abundance and diversity of amphibian fauna, and possibly other fauna, through predation, competition and disease transmission. Economic and social harm is likely to be minimal.

Stage 2 - Detailed assessment: Section F – Additional questions
This section is used to gather information about the potential effects of climate change on the risk posed by an organism. It is also an opportunity for the risk assessor to highlight high priority research that could help improve the risk assessment.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
6.01	What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?	-	HIGH	As the species is already acclimatised to climatic conditions ranging from temperate to subtropical and tropical, climate change would be expected to have very little bearing over the risk assessment.
6.02	What is the likely timeframe for such changes (5, 10, 15, 20, 50 or 100 years)?	N/A	MEDIUM	See justification in Q 6.01
6.03	What aspects of the risk assessment are most likely to change as a result of climate change	-	MEDIUM	See justification in Q 6.01
6.04	If there is any research that would significantly strengthen confidence in the risk assessment, please note this here. If more than one research area is provided, please list in order of priority.	-	MEDIUM	Modelling of the species potential rate of spread and likely distribution in Ireland would significantly strengthen the confidence in this risk assessment.

References

ADAMS, M. J. & PEARL, C. A. 2007. Problems and opportunities managing invasive bullfrogs: is there any hope? . *In:* GHERARDI, F. (ed.) *Biological invaders in inland waters: profiles, distribution and threats.* Springer.

BAKER, J. 1998. Frog culture and declining wild populations. *World Aquaculture,* 29**,** 14-17.

BANKS, B., FOSTER, J., LANGTON, T. & MORGAN, K. 2000. British Bullfrogs? *British Wildlife,* 11**,** 327-330.

BEEBEE, T. J. C. & GRIFFITHS, R. A. 2005. The amphibian decline crisis: A watershed for conservation biology? *Biological Conservation,* 125**,** 271-285.

CABI. 2014. *Rana catesbeiana (American bullfrog) [original text by Marta Stéfani]* [Online]. Invasive Species Compendium: Wallingford, UK: CAB International. Available: www.cabi.org/isc [Accessed 7th January 2014].

CONANT, R. 1975. *Field guide to reptiles and amphibians: eastern and central North America*, Houghton Mifflin, Boston, Massachusetts.

CORINE 2006. Environmental Protection Agency, (2008); CORINE Landcover 2006 update (Ireland). Final Report.

DOUBLEDEE, R. A., MULLER, E. B. & NISBET, R. M. 2003. Bullfrogs, disturbance regimes, and the persistence of California red-legged frogs. *Journal of Wildlife Management,* 67**,** 424-438.

FICETOLA, G. F., BONIN, A. & MIAUD, C. 2008. Population genetics reveals origin and number of founders in a biological invasion. *Molecular Ecology,* 17**,** 773-782.

FICETOLA, G. F., COIC, C., DETAINT, M., BERRONEAU, M., LORVELEC, O. & MIAUD, C. 2007a. Pattern of distribution of the American bullfrog Rana catesbeiana in Europe. *Biological Invasions,* 9**,** 767-772.

FICETOLA, G. F., THUILLER, W. & MIAUD, C. 2007b. Prediction and validation of the potential global distribution of a problematic alien invasive species - the American bullfrog. *Diversity and Distributions,* 13**,** 476-485.

FISHER, M. C. & GARNER, T. W. J. 2007. The relationship between the emergence of Batrachochytrium dendrobatidis, the international trade in amphibians and introduced amphibian species. *Fungal Biology Reviews,* 21**,** 2-9.

FOSSITT, J. A. 2000. *A guide to habitats in Ireland*, Heritage Council/An Chomhairle Oidhreachta.

FROST, D. R., GRANT, T., FAIVOVICH, J., BAIN, R. H., HAAS, A., HADDAD, C. F. & WHEELER, W. C. 2006. The amphibian tree of life. *Bulletin of the American Museum of Natural History*.

GISD. 2009. *Lithobates catesbeianus (=Rana catesbeiana) (amphibian)* [Online]. Global Invasive Species Database. Available: http://www.issg.org/database/species/ecology.asp?si=80 [Accessed 7th January 2014].

GOVINDARAJULU, P., PRICE, W. S. & ANHOLT, B. R. 2006. Introduced bullfrogs (Rana catesbeiana) in western Canada: Has their ecology diverged? *Journal of Herpetology,* 40**,** 249-260.

HANSELMANN, R., RODRIGUEZ, A., LAMPO, M., FAJARDO-RAMOS, L., AGUIRRE, A. A., KILPATRICK, A. M., RODRIGUEZ, J. P. & DASZAK, P. 2004. Presence of an emerging pathogen of amphibians in introduced bullfrogs Rana catesbeiana in Venezuela. *Biological Conservation,* 120**,** 115-119.

ISI 2012. *Rana catesbeiana.* Risk analysis and prioritisation access database: Invasive Species Ireland.

KATS, L. B. & FERRER, R. P. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. *Diversity and Distributions,* 9**,** 99-110.

KEANE, T. & COLLINS, J. F. 2004. *Climate, weather and Irish agriculture, ,* Joint Working Group on Applied Agricultural Meteorology (AGMET), c/o Met Eireann, Dublin.

KING, J. L., MARNELL, F., KINGSTON, N., ROSELL, R., BOYLAN, P., CAFFREY, J. M., FITZPATRICK, Ú., GARGAN, P. G., KELLY, F. L., O'GRADY, M. F., POOLE, R., ROCHE, W. K. & CASSIDY, D. 2011. Ireland Red List No. 5: Amphibians, Reptiles & Freshwater Fish. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

KUPFERBERG, S. J. 1997. Bullfrog (Rana catesbeiana) invasion of a California river: The role of larval competition. *Ecology,* 78**,** 1736-1751.

LEVER, C. 2003. *Naturalized reptiles and amphibians of the world*, Oxford University Press.

LORVELEC, O. & DETAINT, M. 2009. *Lithobates catesbeianus (Shaw), American bullfrog (Ranidae, Amphibia). In:* DAISIE (ed.) *The Handbook of European Alien Species.* Springer, Dordrecht.

LOWE, S., BROWNE, M., BOUDJELAS, S. & DE POORTER, M. 2000. *100 of the world's worst invasive alien species. A selection from the Global Invasive Species Database* [Online]. ISSG, SSC and IUCN. Available: www.issg.org/booklet [Accessed 7th January 2014].

MARCHANT, J. 2012. *American Bullfrog, Lithobates catesbeianus* [Online]. Available: http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=2040 [Accessed 7th January 2014].

MCKERCHER, L. & GREGOIRE, D. R. 2011. *Lithobates catesbeianus (Shaw, 1802)* [Online]. Nonindigenous Aquatic Species. U.S. Geological Survey. Available: http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=71.

NATIONAL BIODIVERSITY DATA CENTRE. 2014. National Biodiversity Data Centre Mapping System. Available: http://maps.biodiversityireland.ie/#

ORCHARD, S. 2011. Removal of the American bullfrog, Rana (Lithobates) catesbeiana, from a pond and a lake on Vancouver Island, British Columbia, Canada. *Island invasives: eradication and management. IUCN (Gland, Switzerland)*, 1-542.

PEARL, C. A., ADAMS, M. J., BURY, R. B. & MCCREARY, B. 2004. Asymmetrical effects of introduced bullfrogs (Rana catesbeiana) on native ranid frogs in Oregon. *Journal Information,* 2004.

PEARL, C. A., ADAMS, M. J., SCHUYTEMA, G. S. & NEBEKER, A. V. 2003. Behavioral responses of anuran larvae to chemical cues of native and introduced predators in the Pacific Northwestern United States. *Journal of Herpetology,* 37**,** 572-576.

REINHARDT, F., HERLE, M., BASTIANSEN, F. & STREIT, B. 2003. Economic impact of the spread of alien species in Germany. Research Report 201 86 211, Federal Ministry of the Environment, Nature Conservation and Nuclear Safety.

SANTOS-BARRERA, G., HAMMERSON, G., HEDGES, B., JOGLAR, R., INCHAUSTEGUI, S., KUANGYANG, L., WENHAO, C., HUIQING, G., SHI, H., DIESMOS, A., ISKANDAR, D., VAN DIJK, P. P., MASAFUMI, M., SCHMIDT, B., MIAUD, C. & MARTÍNEZ-SOLANO, I. 2009. *Lithobates catesbeianus* [Online]. IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. Available: www.iucnredlist.org [Accessed 7th January 2014].

SIMBERLOFF, D., PARKER, I. M. & WINDLE, P. N. 2005. Introduced species policy, management, and future research needs. *Frontiers in Ecology and the Environment,* 3**,** 12-20.

SMITH, M. A. & GREEN, D. M. 2005. Dispersal and the metapopulation paradigm in amphibian ecology and conservation: are all amphibian populations metapopulations? *Ecography,* 28**,** 110-128.

SPITZEN – VAN DER SLUIJS, A. M. & ZOLLINGER, R. 2010. Literature review on the American bullfrog Rana catesbeiana (Shaw, 1802). Stichting RAVON, Nijmegen, the Netherlands.

TEIXEIRA, R. D., PEREIRA MELLO, S. C. R. & LIMA DOS SANTOS, C. A. M. 2001. The world market for frog legs. FAO/GLOBEFISH Research Programme, 68:44 pp.