EU NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME

Name of organism: *Channa* spp.
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Risk Assessment Area: Europe
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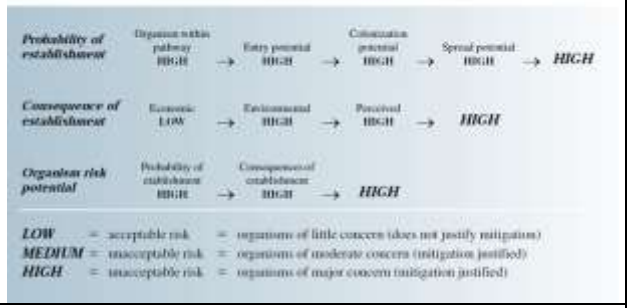
EU CHAPPEAU	
QUESTION	**RESPONSE**
1. In how many EU member states has this species been recorded? List them.	An adult specimen of *Channa micropeltes* was captured on 22 November 2012 at Le Caldane (Colle di Val d'Elsa, Siena, Tuscany, Italy) (43°23′26.67″N, 11°08′04.23″E).This record of *Channa micropeltes*, the first in Europe (Piazzini *et al*. 2014), and it constitutes another case of introduction of an alien species. Globally, exotic fish are a major threat to native ichthyofauna due to their negative impact on local species (Crivelli 1995, Elvira 2001, Smith and Darwall 2006, Gozlan *et al*. 2010, Hermoso and Clavero 2011). *Channa argus* in Slovakia (Courtenay and Williams, 2004, Elvira, 2001) *Channa argus* in Czech Republic (Courtenay and Williams 2004, Elvira, 2001)
2. In how many EU member states has this species currently established populations? List them.	None
3. In how many EU member states has this species shown signs of invasiveness? List them.	None
4. In which EU Biogeographic areas could this species establish?	Central and southern Europe.
5. In how many EU Member States could this species establish in the future [given current climate] (including those where it is already established)? List them.	From central and southern Europe to northern regions
6. In how many EU member states could this species become invasive in the future [given current climate] (where it is not already established)?	In line with what is happening in the United States of America, where this species presents settlement areas from east to west, and to the north of the country, all the Member states in central and southern Europe could be susceptible. The Nordic countries of the Union may be less likely to be invaded.

SECTION A – Organism Information and Screening		
Stage 1. Organism Information	**RESPONSE** **[chose one entry, delete all others]**	**COMMENT**
1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	Yes. **Kingdom:** Animalia – Animal, animaux, animals **Subkingdom:** Bilateria **Infrakingdom:** Deuterostomia **Phylum:** Chordata – cordés, cordado, chordates **Subphylum:** Vertebrata – vertebrado, vertébrés, vertebrates **Infraphylum:** Gnathostomata **Superclass:** Osteichthyes – bony fishes, poissons osseux, osteíceto, peixe ósseo **Class:** Actinopterygii – ray-finned fishes, spiny rayed fishes, poisson épineux, poissons à nageoires rayonnées **Subclass:** Neopterygii – neopterygians **Infraclass:** Teleostei **Superorder:** Acanthopterygii **Order:** Perciformes – perch-like fishes **Suborder:** Channoidei **Family:** Channidae – snakeheads, cabezas de serpiente, têtes-de-serpent **Genus:** *Channa* Scopoli, 1777 – Asian snakeheads	From the Integrated Taxonomic Information System (ITIS) (http://www.itis.gov), there are 27 species belonging to this genus: 1. *Channa amphibeus* (McClelland, 1845); 2. *Channa argus* (Cantor, 1842) – snakehead; 3. *Channa asiatica* (Linnaeus, 1758) – snakehead, Chinafish, snakehead; 4. *Channa aurantimaculata* Musikasinthorn, 2000 5. *Channa bankanensis* (Bleeker, 1852); 6. *Channa baramensis* (Steindachner, 1901); 7. *Channa barca* (Hamilton, 1822); 8. *Channa bleheri* Vierke, 1991; 9. *Channa burmanica* Chaudhuri, 1919; 10. *Channa cyanospilos* (Bleeker, 1853); 11. *Channa diplogramma* (Day, 1865); 12. *Channa gachua* (Hamilton, 1822); 13. *Channa harcourtbutleri* (Annandale, 1918); 14. *Channa lucius* (Cuvier in Cuvier and Valenciennes, 1831); 15. *Channa maculata* (Lacepède, 1801) – snakehead mullet, snakehead mullet; 16. *Channa marulioides* (Bleeker, 1851); 17. *Channa marulius* (Hamilton, 1822) – bullseye snakehead; 18. *Channa melanoptera* (Bleeker, 1855); 19. *Channa melasoma* (Bleeker, 1851) – manu, manu; 20. *Channa micropeltes* (Cuvier in Cuvier and Valenciennes, 1831) – giant snakehead, red

		snakehead; 21. *Channa nox* Zhang, Musikasinthorn and Watanabe, 2002; 22. *Channa orientalis* Bloch and Schneider, 1801 – smooth-breasted snakefish, smooth-breasted snakefish; 23. *Channa panaw* Musikasinthorn, 1998; 24. *Channa pleurophthalmus* (Bleeker, 1851); 25. *Channa punctata* (Bloch, 1793) – green snakehead; 26. *Channa stewartii* (Playfair, 1867); 27. *Channa striata* (Bloch, 1793) – Chevron snakehead, striped snakehead.
2. If not a single taxonomic entity, can it be redefined? (if necessary use the response box to re-define the organism and carry on)		
3. Does a relevant earlier risk assessment exist? (give details of any previous risk assessment)	Not in Europe.	There are documents from North America. Canada: Risk Assessment for Northern Snakehead (*Channa argus*) in Canada. Canadian Science Advisory Secretariat (http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2005/RES2005_075_e.pdf). See following table:

		<table><tr><th>Component Rating</th><th>Element Rating</th><th>Level of Certainty</th></tr><tr><td colspan="3">Part I – Aquatic Organism Ecological and Genetic Risk Assessment Process</td></tr><tr><td>Probability of establishment estimate</td><td>High</td><td>Reasonably Certain</td></tr><tr><td>Consequences of establishment estimate</td><td>High</td><td>Reasonably Certain</td></tr><tr><td>Final Risk Estimate</td><td>High</td><td>Reasonably Certain</td></tr><tr><td colspan="3">Part II – Pathogen, Parasite or Fellow Traveler Risk Assessment Process</td></tr><tr><td>Probability of establishment estimate</td><td>Medium</td><td>Reasonably Uncertain</td></tr><tr><td>Consequences of establishment estimate</td><td>Medium</td><td>Very Uncertain</td></tr><tr><td>Final Risk Estimate</td><td>Medium</td><td>Very Uncertain</td></tr></table> United Sates of America: Snakeheads (Pisces, Channidae)—A Biological Synopsis and Risk Assessment / by Walter R. Courtenay, Jr., and James D. Williams p. cm. — (U.S. Geological Survey circular ; 1251) Includes bibliographical references. ISBN.0-607-93720 (alk. paper) 1. Snakeheads — Pisces, Channidae— Invasive Species 2. Biological Synopsis and Risk Assessment. Title. II. Series. ***ORGANISM RISK POTENTIAL*** 
4. If there is an earlier risk assessment is it still entirely valid, or only partly valid?	N.A.	

5. Where is the organism native?	 Native range of *Channa* spp. Source: Courtenay and Williams (2004) Also, as included in Courtenay and Williams (2004): 1. ***Channa amphibeus*** (McClelland, 1845): Endemic to Chel River basin, Brahmaputra River drainage, northeastern India and Bhutan. 2. ***Channa argus*** (Cantor, 1842) – snakehead: Middle and lower Heilong (Amur) River basin; Songhua (Sungari) River, Manchuria; Tunguska River at Khabarovsk, Russia; Ussuri River basin; Lake Khanka; Korea, except northeastern region; rivers of China southward and southwestward to upper tributaries of the Chang Jiang (Yangtze) River basin in northeastern Yunnan Province. Reported from Guangdong Province, China, likely an introduction there. Widely distributed in Chinese reservoirs. 3. ***Channa asiatica*** (Linnaeus, 1758) – snakehead, Chinafish, snakehead: China, middle and lower	Species and species complexes of the genus *Channa* are native from southeastern Iran and eastern Afghanistan eastward through Pakistan, India, southern Nepal, Bangladesh, Myanmar, Thailand, Laos, Malaysia, Sumatra, Indonesia, Vietnam, Korea, and China northward into Siberia (Courtenay and Williams, 2004).

	Chang Jiang (Yangtze) basin, and Xun River basin in Guangxi and Guangdong provinces. Also reported from Hainan Island, China where it is likely native rather than introduced. 4. ***Channa aurantimaculata*** Musikasinthorn, 2000: Endemic to middle Brahmaputra River basin, northern Assam, India. 5. ***Channa bankanensis*** (Bleeker, 1852): Sumatra: southeastern rivers (Hari and Musi basins) of mainland; Bangka Island; rivers of central, southern, and western Kalimantan; peat swamps of Selangor, peninsular Malaysia 6. ***Channa baramensis*** (Steindachner, 1901): Northern Sarawak, Brunei, and western Sabah (northern Borneo). Also occurs in the Sadong basin, southern Sarawak, and the Segama basin, eastern Sabah. 7. ***Channa barca*** (Hamilton, 1822): Endemic to Ganges and Brahmaputra River basin, India and Bangladesh. Cited in eastern and some areas of western Pakistan but this may be a misidentification. 8. ***Channa bleheri*** Vierke, 1991: Endemic to the Brahmaputra River basin, Assam, India. 9. ***Channa burmanica*** Chaudhuri, 1919: Endemic to headwaters (Kiu River, perhaps Lang basin) of the Ayeyarwaddy (=Irrawaddy) River in northern Myanmar, between the Kumon and Shan-ngaw mountain ranges. 10. ***Channa cyanospilos*** (Bleeker, 1853): Sumatra and probably peninsular Malaysia and Kalimantan. Also found during 1995-1996 in Riau and Jambi, central Sumatra. 11. ***Channa diplogramma*** (Day, 1865): a Western Ghats endemic has a distribution in some rivers of	

	southcentral Kerala (Meenachil, Manimala, Pamba-Achankovil and Kallada), and further south in the Chittar river in southwestern Tamil Nadu (Ebanasar and Jayaprakas (2003) and Jayaram (2010). In Abraham, R. (2011)) 12. ***Channa gachua*** (Hamilton, 1822): Bampur-Haliri basin and Mashkel River, southeastern Iran; Kabol (Kabul) drainage of Afghanistan eastern and western Pakistan; India, Sri Lanka, Bangladesh, Myanmar, Thailand, Laos, Cambodia, Malaysia, Indonesia (Borneo), Java, southern China, recorded from the Punch Valley, in a tributary of the Jhelum River, in the Kashmir Valley of northeastern Pakistan/western Kashmir. Reported in the Toba area of northern Sumatra, and Riau and Jambi in central Sumatra in 1996, as well as in Yunnan Province, China, in 2000. 13. ***Channa harcourtbutleri*** (Annandale, 1918): Yawnghwe and nearby areas of Myanmar, particularly Inlé Lake in southern Shan State. 14. ***Channa lucius*** (Cuvier in Cuvier and Valenciennes, 1831): Rivers of southeastern Sumatra and the Kapuas basin of western Kalimantan; Mekong basin of Laos. Some authors included China, Vietnam, Laos, Thailand, Malaysia, Kalimantan, Java, and Sumatra in the native range. Individuals collected during November 1999 and April 2000 in central Sumatra, southern Sarawak, and the Mahakam and Kayan basins of eastern Kalimantan. 15. ***Channa maculata*** (Lacepède, 1801) – snakehead mullet, snakehead mullet: southern China, south of the Chang Jiang (Yangtze) basin and Hainan; northern Vietnam. 16. ***Channa marulioides*** (Bleeker, 1851): Rivers	

	(Musi, Hari, Indragiri, and others) of southeastern Sumatra; Kapuas basin of western Kalimantan; Bangka (Banka) and Belitung (Billiton). Individuals collected in Samarinda, eastern Kalimantan, in November 1999. In peninsular Malaysia, occurring mostly toward the center of the peninsula in Pahang. Often confused with *Channa melanoptera*. Also recorded from southern Thailand (Malay Peninsula) and reported as the only record from that country. Some authors did not list Thailand within its native range, although it is possible that its range extends northward into extreme southern Thailand. Other experts included Thailand within native range but added that the species was "quite rare" in peninsular Malaysia. 17. ***Channa marulius*** (Hamilton, 1822) – bullseye snakehead: Pakistan; many drainages of India, Sri Lanka, Bangladesh, southern Nepal (Gandaki, Koshi, and Karnali River basins), Myanmar, Thailand, Mekong basin of Laos and Cambodia, and southern China. Cited as "one of the rarest of the serpent-heads found in Thailand." It is not reported from Malaysia or Indonesia where it appears to be replaced by a somewhat lookalike species, *Channa marulioides*. Recorded from the Yangtze drainage, China. Some authors indicated that *C. marulius*, as currently recognized, is possibly a species complex. 18. ***Channa melanoptera*** (Bleeker, 1855): Kapuas River basin of Kalimantan (western Borneo) and possibly the southern tip of Sumatra. These latter authors stated that records of this species from central Sumatra are misidentifications of *Channa marulioides*.	

	19. ***Channa melasoma*** (Bleeker, 1851) – manu, manu: Chao Phraya River, near Bangkok, Thailand (misidentification?); Mekong River in Cambodia (Rainboth, 1996; misidentification?); rivers of southeastern Sumatra; rivers of western Kalimantan, particularly the Kapuas basin (southern Borneo); Bangka and Belitung (Billiton) islands; Palawan Archipelago, Philippines. In 1912 some authors reported the species from Java, later challenged in 1922, and there is no evidence that it occurs there. Also reported this species as rare in Thailand, and stated that because of its preference for acidic waters, the species is more common toward the southern part of the Malay Peninsula. It is present but apparently rare in the North Selangor Peat Swamp Forest of the Malaysia Peninsula. Reported in the Golok area of southern Thailand. Records of this species from northern Borneo (Sarawak, Brunei, and Sabah) are misidentifications of the endemic *Channa baramensis*. 20. ***Channa micropeltes*** (Cuvier in Cuvier and Valenciennes, 1831) – giant snakehead, red snakehead: This snakehead has a markedly disjunctive distribution. Rivers of the Malabar (southwestern) Coast of India; Myanmar (?); Thailand; Mekong basin of Laos; Vietnam; Malaysia; southeastern Sumatra; Kalimantan, particularly the Kapuas basin (southwestern Borneo); Bangka and Belitung (Billiton) islands; northern Java. Its presence in Myanmar (Burma) is questionable. Some authors stated that it is "quite common in peninsular Malaysia." 21. ***Channa nox*** Zhang, Musikasinthorn and Watanabe, 2002: Southern China, near Hepu,	

	Guangzi Province, specifically the lower Nanlui Jiang River, where its range overlaps that of its nearest congener, *Channa asiatica*. Found this snakehead in live-food fish markets in Guangzhou, China, and Hong Kong in July 2000. 22. ***Channa orientalis*** Bloch and Schneider, 1801 – smooth-breasted snakefish, smooth-breasted snakefish: Asiatic snakehead; smooth breasted snakehead; green snakehead; kola kanaya. 23. ***Channa panaw*** Musikasinthorn, 1998: Ayeyarwaddy (=Irrawaddy) and Sittang River basins, Myanmar. 24. ***Channa pleurophthalmus*** (Bleeker, 1851): Padang (?) and rivers (Hari and Musi basins) of southeastern Sumatra; Kapuas and Barito basins of Kalimantan (southern and southwestern Borneo). Absent from peninsular Malaysia. 25. ***Channa punctata*** (Bloch, 1793) – green snakehead: Kabol (Kabul) River basin, Afghanistan, eastward through Khyber Pass into Indus River basin, Pakistan; rivers of the plains of India; Sri Lanka; southern Nepal; Bangladesh; Myanmar; eastward to Yunnan Province, southwestern China. Reported is not present in Myanmar (replaced by *Channa panaw* in the Ayeyarwaddy (=Irrawaddy) and Sittang River basins), and reports from Yunnan Province, China, are probably misidentifications. He further stated that the eastern terminus of the range of *C. punctata* is the Ganges-Brahmaputra River basin. Some authors listed this species as absent from Sri Lanka, but others included Sri Lanka within its native range. 26. ***Channa stewartii*** (Playfair, 1867): Endemic to Brahmaputra (upper, middle, lower) River basin of	

	India and Bangladesh, and the Ganges River basin from southern Nepal southeastward. In southern Nepal, it occurs in the Kamala, Bagmati, Koshi, Gandaki, and Karnali River basins. 27. ***Channa striata*** (Bloch, 1793) – Chevron snakehead, striped snakehead: Pakistan (Indus River basin), most drainages of India, southern Nepal (Koshi, Gandaki, and Karnali River basins), Sri Lanka; Bangladesh, Myanmar, Thailand, Cambodia, southern China, Malay Archipelago including Malaysia, Sumatra, Borneo; Sabah; western Java; Vietnam, Laos. This is an amazingly extensive "native" distribution for any freshwater fish, indicating that *Channa striata* is quite probably a species complex.	
6. What is the global distribution of the organism (excluding Europe)?	Asia, Africa and North America.	One Asian snakehead has been established in Oahu, Hawaii, since before 1900. Another species was discovered established in southeastern Florida in 2000, and a third in a pond in Maryland in 2002. Others have been captured from natural waters of the United States without evidence of reproduction and likely represent released aquarium fishes (Courtenay and Williams, 2004).
7. What is the distribution of the organism in Europe?	There is no evidence of establishment or reproduction in UE countries.	
8. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world?	The introduction of non-native northern snakeheads (*Channa argus*) into waterways has received a great deal of media, public and political attention in the USA (US Fish and Wildlife Service and Arkansas Game and Fish Commission. 2008). The high fertility of and tolerance to a wide range of conditions of the northern snakehead, as well as the lack of natural	The U.S. Fish and Wildlife Service published a proposed rule to list the family Channidae (snakehead fishes) as injurious wildlife in the Federal Register on July 26, 2002 (67 FR 48855) under the Lacey Act (18 U.S.C. 42). The final rule banning importation and interstate transport of live snakeheads was published in the Federal Register on October 4, 2002 (67 FR 62193). This ruling

	enemies in its introduced range, make it highly likely to be a formidable invasive if it were to become established (- Global Invasive Species Database (2017)) In South Africa is a prohibited fresh-water fish (National Environmental Management: Biodiversity Act (10/2004): Alien and Invasive Species List, 2014)	does not affect possession or sale of live snakeheads in states that do not specifically prohibit them, or importation of dead snakeheads refrigerated or frozen for sale as food fishes into states where possession of live snakeheads is illegal. Nevertheless, despite the Federal rule and a long-standing state prohibition, several live *Channa argus* were confiscated by U.S. Fish and Wildlife Service Inspectors in California as recently as July 2003. (https://archive.usgs.gov/archive/sites/fl.biology.usgs.gov/Snakehead_circ_1251/html/us_importations.html) *Channa argus* was ranked as high risk *sensu lato* using FISK methodology for risk assessment in the Iberian Peninsula (see Almeida *et al*., 2013 for methodology).
9. Describe any known socio-economic benefits of the organism in the risk assessment area.	Aquarium species or ornamental species for aquaria	Snakeheads used in the aquarium fish trade include a few small species and brightly colored juveniles of several large snakeheads. They are moderately popular with hobbyists in Japan and Europe. There are no economic data on this specific market for these species, although it is probably very low. Several species are marketed in Canada and have been sold in the U.S., even in states where possession of live snakeheads has been illegal for decades. Hobbyists and importers can purchase snakeheads through a variety of sites on the Internet. Because of their highly predacious nature, however, snakeheads have not had a large following of interested hobbyists in the U.S. (Courtenay and Williams, 2004).

SECTION B – Detailed assessment

PROBABILITY OF ENTRY

Important instructions:

- Entry is the introduction of an organism into Europe. Not to be confused with spread, the movement of an organism within Europe.
- For organisms which are already present in Europe, only complete the entry section for current active pathways of entry or if relevant potential future pathways. The entry section need not be completed for organisms which have entered in the past and have no current pathways of 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)	few	high	Aquarists in Japan, Europe, and, to a lesser extent, North America have kept snakeheads as pet fish (Courtenay and Williams, 2004). There is no currently fishing interest in Europe In Canada, as indicated in their Risk Assessment for Northern Snakehead (*Channa argus*), vectors of northern snakehead introduction may include natural colonization from established populations in the United States, deliberate (e.g. prayer fish (see Severinghaus and Chi 1999), animal rights activism) or accidental (e.g. tanker spill) release related to the availability of northern snakehead in the live food fish industries. The probability of introduction of northern snakehead through these vectors is largely unknown; however, the natural range extension and release of northern snakeheads experienced in the United States is as likely to occur in Canada. Snakeheads have been in the U.S. (Courtenay and Williams, 2004) aquarium fish trade and hobby for

			several decades. Due to their predatory nature, compounded by the high costs of housing and feeding larger snakehead species, they have had a limited following by hobbyists. Therefore, snakeheads have never represented more than a very minor component of the U.S. aquarium fish trade. Consequently, economic impact to the aquarium fish trade through prohibition of importation or interstate transport of live snakeheads would be minor. Importation of snakeheads for the live-food fish market in the mainland U.S. (Courtenay and Williams, 2004) is a more recent trend, to our knowledge dating back to the most recent decade or two. Although snakeheads have been available in live-food fish markets in Hawaii for a far longer period of time (likely several decades), only one market (in Honolulu) was selling live snakeheads for food purposes as of 2002 (Mike Yamamoto, personal commun., 2002 IN: Courtenay and Williams, 2004). Markets that sell live freshwater food fishes also sell species other than snakeheads, including catfishes, tilapias, carp, eels, hybrid striped bass, and sometimes swamp eels. These are typically Asian ethnic food markets, and they frequently carry a large variety of frozen, imported marine and freshwater food fishes. Therefore, as in the aquarium fish trade, snakeheads are only a minor component of live-food fish sales. Economic impact to the live-food fish trade would be minor following a ban on importation and interstate transportation of live snakeheads, as these fishes can be imported frozen or dead on ice for sale. Until Arkansas passed an emergency rule banning importation, possession, and sale of live snakeheads in late July 2002, only three fish farmers in that state were reported to be culturing snakeheads (*Channa argus*) for the live-food

			fish market. There were no other culture facilities in the mainland U.S. known to be raising snakeheads. There is, however, one aquaculture facility on Oahu, Hawaii, that has been rearing *C. striata* since the latter part of the 1990s. Having in mind the paragraphs above, the economic impact to the live-food fish trade and the aquarium fish trade following a ban on importation to the EU would be minimal. These markets are not important nowadays and this situation may facilitate the preventive actions and banning of *Channa* spp. in Europe. Moreover, fish produced can be shipped for sale either dead on ice or frozen. As a result, prohibition of importation of live snakeheads would not present a significant negative impact to aquaculture interests of foreign countries as was pointed out by Courtenay and Williams (2004).
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. For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary).	[Aquariology]		
Pathway name:	[aquariology]		

1.3. 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	**Table 4**—Snakeheads of interest to aquarists in the U.S. [Information assembled from several aquarist-oriented and retailer websites in 2002. Common names are those often used in the aquarium fish trade] *Channa asiatica* — Chinese snakehead *Channa bleheri* — Rainbow snakehead, tiger snakehead, python snakehead *Channa marulius* — Cobra snakehead *Channa micropeltes* — Red snakehead, redline snakehead *Channa punctata* — Spotted snakehead *Channa stewartii* — Golden snakehead *Parachanna africana* — African snakehead Source: Courtenay and Williams, 2004. In Europe, this species are also marketed and used in aquarium. There is no known review study published in this regard, but this fact can be consulted directly on the internet. Some examples of web pages where species of this genus are exposed, including *C. micropeltes*, are: - www.jnk-aquatics.co.uk/livestock-fishhouse/tropical-fish/snakehead-channa.html - www.practicalfishkeeping.co.uk/features/articles/quick-guide-to-snakeheads - www.tropicalfishfinder.co.uk/news-article?id=1279
1.4. 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.	likely	low	*Channa* spp. are an imminent threat to invade U.S. waters by way of aquarium release, live trade, and natural dispersal post-introduction (Courtenay and Williams 2004; Fuller *et al*. 2015). Not being able to localize import data in Europe, we will

include here U.S. data to have an idea of possible numbers:

Table 5—U.S. importations of live snakeheads (Channidae, all species) during 1997-2002

Year	Number of individuals[1]	Number of kilograms[2]	Total declared $ value (individuals and weight combined)
1997	372	892	5,085
1998	1,488	1,883	12,632
1999	6,044	8,512	27,718
2000	8,650	9,240	39,990
2001	18,991	1,681	21,185
2002[3]	15,688	--	26,077
Totals	51,233	22,208	$132,687

[1] Not included in number of kilograms.
[2] Not included in number of individuals.
[3] Data are for January–May 2002.

Data source: https://archive.usgs.gov/archive/sites/fl.biology.usgs.gov/Snakehead_circ_1251/html/us_importations.html

			Table 6—Origin of snakehead shipments (Channidae, all species) during the past 5 or more years [1997–2002; records for 2002 extend through May 31] **Country** / **Number of individuals[1]** / **Number of kilograms[2]** / **Total declared $ value (individuals and weight combined)** China 48,533 20,323 125,295 Hong Kong 2 -- 50 India 572 -- 1,498 Indonesia 300 -- 96 Nigeria 970 -- 659 Switzerland 50 -- 100 Thailand 1,084 -- 1,420 United States 25 -- 38 Vietnam 1,079 1,435 4,265 [1]Not included in number of kilograms. [2]Not included in number of individuals. Data source: https://archive.usgs.gov/archive/sites/fl.biology.usgs.gov/Snakehead_circ_1251/html/us_importations.html As indicated in this link sources of imported snakeheads are varied (table 6). These records are probably incomplete, but China is clearly the major exporter of live snakeheads.
1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	likely	medium	This transfer has occurred in other countries like United States of America under similar climate conditions as in Europe. The aquarium trade has been identified as an important vector of aquatic invasive species but this question has mostly been investigated in North America. Maceda-Veiga *et al* (2013) investigated the variation in diversity and species composition in different trade types in

			southwestern Europe (three major international wholesalers, different retail store types, and local internet forums), mostly in Spain and Portugal. Their results imply that frequency in the trade varies strongly among species and commerce types and although general pet stores have usually low diversity, this is compensated with a higher species turnover. Many of the most popular species are well known invasive species and some of the species available are temperate species that might establish in Europe, reinforcing the need for more careful implementation of education programs, regulation and monitoring of trade, and internalization of environmental costs by the industry. Some snakeheads living in natural waters of the U.S. may have been released by aquarium hobbyists or those hoping to establish a local food resource. Also, some cultures practice "prayer animal release," a faith-based activity in which individuals purchase, then release, an animal (fish, amphibian, reptile, or bird) to earn merits with a deity (USGS, 2004).
1.10. Estimate the overall likelihood of entry into Europe based on this pathway?	very likely	medium	Courtenay and Williams (2004) in their Biological Synopsis and Risk Assessment for snakeheads in U.S. estimated the probability of the exotic organism being on, with, or in the pathway as High with very certain. Four species of snakeheads have been recorded as reproducing in waters of the United States. These are *Channa argus* in Crofton, Maryland (isolated population, eradicated in September 2002), *C. maculata* in Oahu, Hawaii, *C. marulius* in southeastern Florida, and *C. striata*, being cultured in confined waters in Oahu, Hawaii, since the early 1990s. Specimens of *C.*

			micropeltes have been collected from waters of four states, the earliest records being from Maine and Rhode Island from the 1970s. Snakeheads have had a limited market in the aquarium fish trade for several decades and, more recently, four species of snakeheads (*C. argus*, *C. maculata*, *C. marulius*, and *C. striata*) were sold in live-food fish markets within the U.S. Therefore, snakeheads have been and are in the United States pathway.
End of pathway assessment, repeat as necessary.			
1.11. Estimate the overall likelihood of entry into Europe based on all pathways (comment on the key issues that lead to this conclusion).	very likely	medium	These species are not yet established in European countries. Aquaculture maybe increase and facilitate its entry from ponds or other kind of aquatic installations has it has happened in other countries. By the moment *C. argus* has a modest importance in aquarium fish trade in Japan, Europe and to a lesser extent, the USA (Courtenay and Williams 2004). *Channa micropeltes* is the most popular aquarium species of all the species in the snakehead family. The juveniles are targeted and known as 'red' or 'redline' snakeheads in the North American aquarium trade. It is also a highly regarded food fish in southeastern Asia and has been imported into Canada for this reason (Commission for Environmental Cooperation, 2009).

PROBABILITY OF ESTABLISHMENT

Important instructions:

- For organisms which are already well established in Europe, only complete questions 1.15 and 1.21 then move onto the spread section. If uncertain, check with the Non-native Species Secretariat.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
1.12. How likely is it that the organism will be able to establish in Europe based on the similarity between climatic conditions in Europe and the organism's current distribution?	very likely	high	The northern snakehead –*C. argus*- has a broad range of environmental tolerances and is extremely resilient; it inhabits freshwater within a temperature range of 0 to 30°C. Northern snakeheads prefer stagnant shallow ponds or swamps with mud substrate and vegetation; they can also be found in slow muddy streams and in canals, reservoirs, lakes, and rivers. As an obligate airbreather it can survive out of water for up to four days by breathing oxygen; cold temperatures reduce metabolism rates and oxygen demand, allowing them to survive under ice (Global Invasive Species Database (2017)). In the U.S. the prediction map developed by Poulos *et al* (2012) indicates that *Channa argus* could also spread to warmer parts of the southeastern United States and Florida. Although other, more tropical snakehead species maintain reproductive populations in the southeastern United States, the more temperate northern snakehead has failed to do so to date. Yet, their models suggest that this region has environmental conditions that could promote the success of this species with repeated future introductions (Poulos *et al*., 2012). This may happen also in Europe.

			 *Channa marulius* occurs in sluggish or standing water in rivers, canals, lakes and swamps. It tends to inhabit waters with submerged aquatic vegetation and is usually found only in deep pools in rivers and occasionally in lakes. It also enters flooded forests. The ideal temperature for this species is in the tropical range of approximately 24°C to 28°C. This species can exist in tropical, subtropical and warm temperate climates. In a study by Lief-Mattias (2007), the mean air temperature was found to be the most significant environmental variable in regard to habitat suitability. This would help to explain the more tropical distribution of *C. marulius*, compared to other snakeheads like *C. argus*, that have also invaded the United States (Global Invasive Species Database (2017)). *Channa amphibeus:* No specific information, but distribution indicates preference for rivers, streams, ponds, perhaps swamps in the Chel River basin, Brahmaputra drainage, of northeastern India and Bhutan (Musikasinthorn, 2000). Shaw and

			Shebbeare (1938) reported that during rainy periods, young are found "in flooded paddy-fields enclosed by forest; large fish can be found in pools of dried streams in forests." *Channa asiatica*: No information available. Probably a riverine species. *C. aurantimaculata*: Forest streams, ponds, and swamps adjacent to the Brahmaputra River in subtropical rainforest conditions (Musikasinthorn, 2000). *C. micropletes*: Lakes, rivers, canals, and reservoirs stated a preference for "deep water bodies." This species is nearly incapable of overland movements except for the young, but he has observed large individuals attempting to move on dry land. Preference for "standing or slowly flowing waters" (Courtenay and Williams, 2004). *C. orientalis*: Deraniyagala (1929) and Munro (1955) cited "clean freshwater pools close to streams" as the preferred habitat. Pethiyagoda (1991) stated that it occurs in "shaded, clear, flowing water with a silt or gravel substrate" and "shallow rivulets barely deeper than its own body." He also predicted pollution and destruction of rainforest habitat in Sri Lanka would likely negatively affect populations of this species (Courtenay and Williams, 2004). Out of their native range four species of snakeheads have been recorded as reproducing in waters of the United States (Courtenay and

			Williams, 2004).
1.13. How likely is it that the organism will be able to establish in Europe based on the similarity between other abiotic conditions in Europe and the organism's current distribution?	very likely	high	*C. argus*, as indicated above, inhabits fresh waters within a temperature range from 0 to 30°C. This species is also tolerant to a wide range of oxygen levels and pH. These conditions provide broad possibilities for the establishment of the species in European waters.
1.14. 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	Many of the species of this genus are common in aquaculture. These protected conditions facilitie their maintenance. Some examples: Stoye (1935) (In: Courtenay and Williams, 2004) mentioned availability of *Channa bankanensis* species as an aquarium fish. *Channa bleheri* is sometimes listed on aquarist-oriented websites and has been available for sale through aquarium fish retailers (Courtenay and Williams, 2004). *Channa gachua* is occasionally mentioned on aquarist-oriented websites and has been available for sale from certain aquarium fish dealers. As included in Gogoi *et al* (2016) study, most of the wild species do not breed in confined water and require hormonal injection for induced breeding (Singh and Biswas, 2011.In: Gogoi *et al* (2016)). Also proper dose is important for successful breeding (Purkayastha 2012 In: Gogoi *et al* (2016)). Like other murrel, too, hibernates during winter months (December to February). Low temperature as well as scarcity of water in

			(wetlands) may be the reason for such behavioural adaptation. As pre-monsoon starts in March, and water temperature rises, they come out from the burrowing hole and start feeding intensely. In the present study, it was also found to breed naturally during April-June. Identical breeding period was also reported for by Saikia ((2011) In: Gogoi *et al* (2016)) and also in by Gogoi ((2013) In: Gogoi *et al* (2016)). 'Pairing' of males and females were noticed prior to pre-monsoon (March-April) and just after a downpour, chasing and jumping behaviour among the brooders was noticed. Choudhury and Biswas (2004) also observed similar spawning behaviour in and also opined that the species can be bred in captivity. Recently, Hazarika ((2014) In: Gogoi *et al* (2016)) was successful in breeding simply by providing brooders with favorable environment. Therefore, it may be concluded that by manipulating the habitat, murrel (*Channa aurantimaculata*) can be bred under captive condition without much difficulty.
1.15. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Europe?	widespread	very high	There are plenty of suitable habitats for *Channa* throughout Europe, where lentic habitats and regulated rivers are very common in central and southern regions.
1.16. 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?	very unlikely	high	
1.17. How likely is it that establishment will occur despite competition from existing species in Europe?	likely	medium	The predatory nature of snakeheads indicates that their introduction could negatively impact populations of native fishes through direct predation, competition for food resources, and

			alteration of food webs. Larger species of snakeheads are considered to be "top predators" in their native ranges. Unlike U.S. highly predatory native fishes, snakeheads are very protective of their young, thus enhancing survival beyond early life history stages and suggesting the possibility of eventual dominance in suitable waters (Courtenay and Williams, 2004). In the Iberian Peninsula native species which are generally small in size (Vila-Gispert *et al*., 2005). This means that competition against large snakeheads may be difficult. In North America several species of the genus have been established and are expanding although there are numerous predatory species, native or not, potentially competing.
1.18. How likely is it that establishment will occur despite predators, parasites or pathogens already present in Europe?	moderately likely	low	There are not specific data on this issue. Parasites or pathogens may affect them.
1.19. How likely is the organism to establish despite existing management practices in Europe?	likely	high	The establishment of *Channa* may display a similar success as per previous introductions of piscivorous fishes throughout Europe (e.g. *Silurus glanis*, *Esox lucius*, *Sander lucioperca*, *Perca fluviatilis)*. The removal of unwanted organisms from aquatic environments (water) is much harder to address compared to the terrestrial environment (land). In a large water system, it could be especially difficult to eradicate the newcomer. Once they are introduced to a water body, it is very difficult to control their spread or completely eradicate them. Therefore, preventing the

			introduction and spread of these species is the best line of defence.
1.20. How likely are management practices in Europe to facilitate establishment?	unlikely	low	Management practices are not specific, these may affect to all kind of fishes, including native or exotic ones. Illegal activities, like fish transfers by anglers between water bodies, may facility the invasion of these new species.
1.21. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in Europe?	likely	medium	Courtenay and Williams (2004) included in the Risk Assessment for the U.S. that there is a likelihood that damage to ancillary wildlife resources through control measures could be substantial. Netting and/or electrofishing would be too selective on size classes to remove a population of snakeheads, even in an isolated situation. Despite preliminary fears that rotenone would be ineffective against airbreathing snakeheads, the Crofton, Anne Arundel County, Maryland, eradication program on *Channa argus* in September 2002 proved to be effective. Young northern snakeheads captured from the pond were exposed experimentally to several different ichthyocides, and rotenone did kill the fish. Nevertheless and as expected, when rotenone was applied to the three adjacent ponds in Crofton, it also killed all other fishes. An estimated 500 kg of native fishes died and were disposed of (Bob Lunsford and Steve Early, personal commun., 2002. In Courtenay and Williams (2004)). Control methods in a nonisolated pond or lake, or in flowing water (streams, rivers) situations would be ineffective in eliminating snakeheads whether or not they were established. There are few successful experiences of removal,

			eradication or effective control of alien fish populations in EU, and existing experiences are limited to small water bodies. So, global eradication programs seem to be not feasible, at present.
1.22. How likely are the biological characteristics of the organism to facilitate its establishment?	likely	high	A mature northern snakehead female can carry as many as 50,000 eggs. Depending on water temperature, eggs can hatch in about 24-48 hours. When the fry hatch, they remain clustered at the surface of the nest until their fins develop. At that time, the young (early juveniles) begin swimming by diving down into the centre of the nest, then rising back to the surface. Early juveniles remain in the nest for 3-4 weeks, schooling, and being guarded by one or both parents. All species of snakeheads guard their eggs and young, a behaviour that is rare in our native fishes. Juvenile snakeheads (fry) cluster at the surface of their "nest," a column of water cleared from vegetation in 2-3 feet of water. Their parents will aggressively guard their nest for 3-4 weeks while the fry develop their fins, learn to school, and are ready to fend for themselves (U.S. Fish and Wildlife Service: https://www.fws.gov/fisheries/ans/pdf_files/Snakeheads.pdf) Within their native and introduced ranges, they live in small and large streams, canals, rivers, ponds, reservoirs, and lakes. Many species can tolerate a wide range of pH, and one species living in Malaysia and parts of Indonesia prefers highly acid waters (pH 2.8-3.8). The northern snakehead and several other species prefer to live in

			somewhat dense aquatic vegetation where they feed and reproduce (U.S. Fish and Wildlife Service: https://www.fws.gov/fisheries/ans/pdf_files/Snakeheads.pdf)
1.23. How likely is the capacity to spread of the organism to facilitate its establishment?	moderately likely	high	Although claims of their mobility have been greatly exaggerated, several species of snakeheads are able to wriggle overland from one body of water to another, particularly if the ground is wet. They do this by flexing their body and pushing with their tail, while using their broad pectoral fins to stabilize their head. It is unknown how far they can travel on land. This crawling ability is reduced in larger species of snakeheads as they reach adulthood. The introduced blotched snakehead in Madagascar is known to crawl onshore, allow its body to be covered with ants, then return to the water where the ants are dislodged and subsequently eaten by the fish. (U.S. Fish and Wildlife Service: https://www.fws.gov/fisheries/ans/pdf_files/Snakeheads.pdf)
1.24. How likely is the adaptability of the organism to facilitate its establishment?	moderately likely	high	Kottelat (1998) reported a preference for "standing waters" of *Channa striata*. Lee and Ng (1991) noted that this species seems to be the most adaptable snakehead, tolerating "quite foul water" and able to move overland.
1.25. How likely is it that the organism could establish despite low genetic diversity in the founder population?	very likely	high	It has already happened in the U.S. The northern snakehead was first found in the wild in the United States in California in 1977. It was not found again until 2000, when it was found in Florida. In 2002, the first established population

			found was in a Maryland retention pond, which has since been treated with rotenone, eradicating the population (Orrell and Weigt 2005). Two specimens were also angled in North Carolina in 2002. Beginning in April 2004, several fish were found from the Potomac River in Maryland and Virginia (USGS 2004). It has been determined that these populations were the result of several independent introductions and that the populations are reproducing naturally (Odenkirk and Owens 2005, Orrell and Weigt 2005) Several individuals were also captured from a pond in a park in Philadelphia, Pennsylvania (USGS 2004). One northern snakehead was also captured in downtown Chicago in Burnham Harbor, Lake Michigan in 2004 (USGS 2004). Follow-up sampling in the area did not detect any more individuals. In July 2005, officials found five northern snakeheads of two different year classes in a lake in a New York City park (W. Courtenay, pers. comm. In: Risk Assessment for Northern Snakehead (*Channa argus*) in Canada, 2005).
1.26. Based on the history of invasion by this organism elsewhere in the world, how likely is to establish in Europe? (If possible, specify the instances in the comments box.)	very likely	high	As written in Canada Risk Assessment (2005) Non-native Distribution of *Channa argus*: **a.** China: Although the northern snakehead is native to some areas of China, they have been reported from non-native areas where current status has not been documented (ISSG 2005). **b.** Eurasia: The northern snakehead was introduced into eastern Europe and western Asia (vector unknown) during the 20th century; current status has not been documented (ISSG 2005). **c.** Japan: The northern snakehead was introduced in 1923 to Japan from Korean populations to establish a recreational fishery. These populations

			have since become established through natural reproduction (Chiba *et al*. 1989, FIGIS 2005). **d.** Kazakhstan: The northern snakehead was accidentally introduced to Kazakhstan in 1961 as a stock contaminant with shipment of other fish species; current status has not been documented (ISSG 2005). **e.** Korea (Democratic People's Republic of, and Republic of,): This species has been introduced into northeastern Korea; although date, means of introduction and current status is unknown (FishBase 2005, ISSG 2005). **f.** Russia: Northern snakehead was intentionally introduced in eastern Russia, although reason, date of introduction and current status is unknown (ISSG 2005). This species was also introduced into western Russia in 1949 (vector unknown), but it is suspected that the species is not established (Holcik 1991, Elvira 2000, ISSG 2005). **g.** Turkmenistan: In 1961, the northern snakehead was imported accidentally into Turkmenistan in a shipment of another species; current status has not been documented (ISSG 2005). h. Uzbekistan: The northern snakehead is now established in Uzbekistan after being introduced to the country in 1961 for aquaculture purposes (FIGIS 2005, ISSG 2005). i. United States: The northern snakehead was first found in the wild in the United States in California in 1977. It was not found again until 2000, when it was found in Florida. In 2002, the first established population found was in a Maryland retention pond, which has since been treated with rotenone, eradicating the population (Orrell and Weigt 2005). Two specimens were also angled in North

			Carolina in 2002. Beginning in April 2004, several fish were found from the Potomac River in Maryland and Virginia (USGS 2004). It has been determined that these populations were the result of several independent introductions and that the populations are reproducing naturally (Odenkirk and Owens 2005, Orrell and Weigt 2005) Several individuals were also captured from a pond in a park in Philadelphia, Pennsylvania (USGS 2004). One northern snakehead was also captured in downtown Chicago in Burnham Harbor, Lake Michigan in 2004 (USGS 2004). Follow-up sampling in the area did not detect any more individuals. In July 2005, officials found five northern snakeheads of two different year classes in a lake in a New York City park (W. Courtenay, pers. comm.). **j.** Canada: The northern snakehead has not been found in any natural waters in Canada.
1.27. If the organism does not establish, then how likely is it that transient populations will continue to occur? Subnote: Red-eared Terrapin, a species which cannot re-produce in GB but is established because of continual release, is an example of a transient species.	moderately likely	low	This will depend on the number of imported fishes. These data are no easy to obtain. Snakeheads are capable of breathing air, many being obligate airbreathers, and easily transported by air or land vehicle without water as long as they are kept moist. They have survived importation from overseas as well as interstate truck transportation (Courtenay and Williams 2004).
1.28. Estimate the overall likelihood of establishment (mention any key issues in the comment box).	very likely	high	Appropriate habitats and climates are found throughout most of the United States (Courtenay and Williams 2004). Europe may have similar conditions. As Courtenay and Williams (2004) indicate, this does not infer that all species of snakeheads could become established in most of the U.S., but that

			there are habitats in all states, with the possible exception of Alaska, where one or more species could establish a reproducing population. Preferred food of snakeheads (that is, fishes, crustaceans, insects and insect larvae) is locally abundant. Also this may happened in Europe. Several species of snakeheads have established in waters outside their native ranges of distribution in the Northern Hemisphere. These include *Channa argus* in Japan, Czechoslovakia, Russia for a period of time, the Aral Sea basin (Amu Dar'ya, Syr Dar'ya, Kaska-Dar'ya, Sarysu, Chu, and reservoirs on the Talus rivers); *C. asiatica* in Taiwan; *C. maculata* in Taiwan, several prefectures of Japan, Madagascar, and Hawaii; *C. melasoma* on Palawan, Philippines; *C. orientalis* in Kalimantan and Greater Sunda Islands; and *C. striata* in many Pacific Islands and most recently (early 1990s) in confined waters of Oahu, Hawaii.

PROBABILITY OF SPREAD

Important notes:

- Spread is defined as the expansion of the geographical distribution of a pest within an area.

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 the mechanisms for natural spread.)	moderate	medium	Several snakehead species can exist in warm temperate conditions. Both *Channa argus* and *C. maculata*, especially the former, can tolerate cold climates, making the likelihood of their becoming established a probability even in some northern countries if released. Introductions into rivers, streams, or canal systems would likely spread whereas releases into lakes or ponds could be more restrictive as to range expansion. (Courtenay and Williams 2004). Because most snakeheads build nests in aquatic vegetation, some might argue that these fishes would be incapable of colonizing waters devoid of macrophytes. Nevertheless, at least three snakeheads, *Channa gachua*, *C. marulius*, and *C. punctata*, have successfully reproduced in waters lacking vegetation. The same may be true for *C. argus* that has colonized reservoirs on the Talas River of Kazakhstan. This suggests that there is likelihood that other species of snakeheads have the potential to establish in waters lacking vegetation. Predictions as to where or under what environmental conditions a nonindigenous aquatic species might or might not become established have been proven unreliable in several instances (Courtenay and Williams 2004).

2.2. How important is the expected spread of this organism in Europe by human assistance? (Please list and comment on the mechanisms for human-assisted spread.)	major	high	People can move fish in tanks; considering that larger species of snakeheads are popular for anglers in several locations within their native and introduced ranges abroad, the likelihood of anglers moving snakeheads to novel waters from colonized areas is reasonably great (Courtenay and Williams 2004).
2.3. Within Europe, how difficult would it be to contain the organism?	very difficult	very high	Once established in a river basin, control is almost impossible. Containment is almost impossible because of the great connection between basins, and also because of the possible role of anglers and other agents who move organisms and water, involuntarily or not.
2.4. Based on the answers to questions on the potential for establishment and spread in Europe, define the area endangered by the organism.	[Most of central and southern Europe]	high	Several snakehead species can exist in warm temperate conditions. Both *Channa argus* and *C. maculata*, especially the former, can tolerate cold climates, making the likelihood of their becoming established a probability even in some northern countries if released.
2.5. 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	low	Currently in Europe there are only few records in 3 EU countries but not demonstrated establishment.
2.6. 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	low	Given the recent data from Italy (2012) it is estimated that its colonization in five-years from now may be of this order.
2.7. 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.)	20	low	There is not a follow-up of its expansion, but considering the conditions of expansion in which the species occurs, this can be significant in this period.
2.8. In this timeframe what proportion (%) of the endangered area/habitat (including any currently occupied	10-33	low	There is no information about the endangered areas/habitats occupied by the species in other

areas/habitats) is likely to have been invaded by this organism?			countries, but given the endangered situation of the habitats in the river basins in Europe, it is estimated that it could be of the order of this proportion.
2.9. Estimate the overall potential for future spread for this organism in Europe (using the comment box to indicate any key issues).	high	low	According to what is happening in U.S. is establishment occurs in Europe the overall potential for future spread may be high. Courtenay and Williams (2004) estimated the probability of the organism to spread beyond the colonized area as High with reasonably certain, based on the following information: Appropriate habitats (rivers, streams, lakes, reservoirs, ponds, canals) and climate are suitable for establishment of snakeheads in U.S. waters. Suitable habitat for subtropical/tropical species exists in southern Florida, Hawaii, perhaps southern Texas, and thermal springs and their outflows in several western states. Several snakehead species can exist in warm temperate conditions that exist in southern states. Both *Channa argus* and *C. maculata*, especially the former, can tolerate cold climates, making the likelihood of their becoming established a probability even in some northern states if released. Introductions into rivers, streams, or canal systems would likely spread whereas releases into lakes or ponds could be more restrictive as to range expansion. Nevertheless, people move fish; considering that larger species of snakeheads are popular with anglers in several locations within their native and introduced ranges abroad, the likelihood of anglers moving snakeheads to novel waters from colonized areas is reasonably great. Because most snakeheads build nests in aquatic vegetation, some might argue that these fishes would be incapable of colonizing waters devoid of

			macro¬phytes. Nevertheless, at least three snakeheads, *Channa gachua*, *C. marulius*, and *C. punctata*, have successfully reproduced in waters lacking vegetation. The same may be true for C. argus that has colonized reservoirs on the Talas River of Kazakhstan. This suggests that there is likelihood that other species of snakeheads have the potential to establish in waters lacking vegetation. Predictions as to where or under what environmental conditions a nonindigenous aquatic species might or might not become established have been proven unreliable in several instances. The prediction map developed by Poulos *et al* (2012) indicates that *Channa argus* could also spread to warmer parts of the south eastern United States and Florida. Although other, more tropical snakehead species maintain reproductive populations in the south-eastern United States, the more temperate northern snakehead has failed to do so to date. Yet, their models suggest that this region has environmental conditions that could promote the success of this species with repeated future introductions (Poulos *et al*., 2012). This may happen also in Europe. Copying information from Courtenay and Williams (2004), several species of snakeheads have established in waters outside their native ranges of distribution in the Eastern Hemisphere. These include *Channa argus* in Japan, Czechoslovakia, Russia for a period of time, the Aral Sea basin (Amu Dar'ya, Syr Dar'ya, Kaska-Dar'ya, Sarysu, Chu, and reservoirs on the Talus rivers); *C. asiatica* in Taiwan; *C. maculata* in Taiwan, several prefectures of Japan, Madagascar,

			and Hawaii; *C. melasoma* on Palawan, Philippines; *C. orientalis* in Kalimantan and Greater Sunda Islands; and *C. striata* in many Pacific Islands and most recently (early 1990s) in confined waters of Oahu, Hawaii. Within the continental U.S., two species of snakeheads have been recorded as established. *Channa argus* was established in a pond in Crofton, Anne Arundel County, Maryland, for at least 2 years before being eradicated in September 2002. There remains some concern that the species may have escaped into the Little Patuxent River during that period of occupancy. In addition, specimens of this species have been collected from the St. Johns River, Seminole and Volusia Counties, Florida, a pond in Shrewsbury, Worcester County, Massachusetts, and from a reservoir serving Los Angeles, located just north of San Bernardino, California, in 1997. There was a reported capture of two individuals of the same species from a reservoir near Charlotte, Mecklenburg County, North Carolina. Subsequent sampling of that reservoir by North Carolina Wildlife Resources Commission biologists did not reveal the presence of additional specimens. *Channa marulius* has been established for several years in a series of interconnected artificial lakes and canals in Tamarac, Broward County, Florida. This system of waterways is connected to the gridwork of flood control canals of southeastern Florida. *Channa maculata* has been established since before 1900 on Oahu, Hawaii. Although the species was once widely distributed on Oahu, it is now largely confined to Wahiawa Reservoir and adjoining canal systems. Yamamoto and Tagawa (2000) reported the largest snakehead captured from waters of Oahu was

			"over 5 feet in length," and that species had to have been *C. maculata*. Two specimens were also reported to have been captured by an angler from the Charles River, Boston, Massachusetts, in 2002. Since the early 1990s, C. striata was imported into Hawaii and it is now being cultured. *Channa micropeltes*, a species largely sold through the pet fish trade, has been collected from open waters of Maine, Massachusetts, Maryland, Rhode Island, and Wisconsin. This tropical/subtropical species could not survive winters in those states. Nevertheless, these releases, likely made by hobbyists, is indicative of what could happen if similar introductions of this or other tropical/subtropical snakeheads were made in states, such as Florida or Hawaii, or into thermal springs and their outflows in western states.

PROBABILITY OF IMPACT

Important instructions:

- When assessing potential future impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment.
- Where one type of impact may affect another (e.g. disease may also cause economic impact) the assessor should try to separate the effects (e.g. in this case note the economic impact of disease in the response and comments of the disease question, but do not include them in the economic section).
- Note questions 2.10-2.14 relate to economic impact and 2.15-2.21 to environmental impact. Each set of questions 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. Key words are in bold for emphasis.

QUESTION	RESPONSE	CONFIDENCE	COMMENTS
2.10. How great is the economic loss caused by the organism within its existing geographic range, including the cost of any current management?	high	medium	The economic cost of eradication efforts would be high. Costs associated with control or eradication efforts of northern snakehead are high. Eradication of northern snakeheads from a small pond in Crofton, Maryland was estimated to cost $110,000. Costs were incurred from personnel time, convening and conducting two meetings of the Maryland Snakehead Scientific Advisory Panel, application of herbicides and rotenone, and disposing of dead fish. Costs of eradication efforts in larger water bodies would be greater. Eradication from an open system such as the Potomac River may be impossible and control efforts would be fiscally and physically challenging (Courtenay and Williams, 2004). Costs in responding to ongoing reports from the public also are significant (NSWG, 2006). The predatory nature of snakeheads indicates that their introduction could negatively impact populations of native fishes through direct predation, competition for food resources, and alteration of food webs. Larger species of snakeheads are considered to be “top

			predators" in their native ranges. Unlike U.S. highly predatory native fishes, snakeheads are very protective of their young, thus enhancing survival beyond early life history stages and suggesting the possibility of eventual dominance in suitable waters.
2.11. How great is the economic cost of the organism currently in Europe excluding management costs (include any past costs in your response)?	minimal	medium	It is not established.
2.12. How great is the economic cost of the organism likely to be in the future in Europe excluding management costs?	moderate	low	It is difficult to estimate but it can affect to other fishing interest.
2.13. How great are the economic costs associated with managing this organism currently in Europe (include any past costs in your response)?	minimal	high	Not yet established.
2.14. How great are the economic costs associated with managing this organism likely to be in the future in Europe?	moderate	medium	To predict what the economic impact could be to the recreational fishing industry or to sport fishing is difficult to assess, but could prove to be substantially detrimental over time. Introduction of the northern snakehead, *Channa argus*, to a single pond in Crofton, Anne Arundel County, Maryland, serves as an example. The original purchase of the snakeheads that were eventually introduced at least 2 years ago was likely no more than $40. A recent estimate of the costs to the State of Maryland during 2002 in personnel, creating and conducting two meetings of the Maryland Snakehead Scientific Advisory Panel, application of herbicides and rotenone, and disposing of dead fish was about $110,000 (Steve Early, personal commun., 2003. In: Courtenay and

			Williams (2004)). Introduction of non-native aquatic species is illegal in Maryland, but the perpetrator must be found and charged of such action within a 2-year period. In this instance, the time limitation had expired before the individual making the introduction was identified. Had that person been charged before the limitation expired, the fine would have been $40. At present, no state requires a liability bond before an intentional introduction is made by individuals or an agency, and there are no laws that hold an individual (or individuals) responsible for the costs of eradicating or controlling an unintentional introduction should the species involved become established. The northern snakehead introduction in Maryland was a rare instance where the fish was confined to a single pond from which it could be eradicated. The costs of eradicating an introduced species in an isolated small lake would be greater and could be substantial in a larger lake. Eradication from flowing waters or large lakes with connecting drainages is physically and fiscally impossible, and the same applies to control measures. Some species of snakeheads are capable of short overland migrations. This presents a potential economic threat to fish culture interests if those species enter culture facilities from adjacent waters, such as occurred with another introduced airbreathing predator, the walking catfish, in Florida (Courtenay and Miley, 1975. In: Courtenay and Williams (2004)). Maryland Department of Natural Resources Inland Fisheries (DNR) has offered a $200 gift card to Bass Pro Shops if fishermen manage to hook and kill a snakehead, Fox News reports
2.15. How important is environmental harm caused by the organism within its existing geographic range excluding	major	high	Because snakeheads do not occur naturally in the Europe, there is no possibility of introduced snakeheads

Europe?			hybridizing or interbreeding with native fishes. Conversely, as stated by Courtenay and Williams (2004), competition for food resources is probably high; competition for habitat is probably low except during spawning seasons. Moreover, potential to cause habitat degradation and/or destruction is low. Courtenay and Williams (2004) indicated in its Biological Synopsis and Risk Assessment for the U.S. that all snakeheads are predators, particularly on fishes. Therefore, negative impacts to populations of native fishes could be quite high, as well as predation on crustaceans. Predation on other invertebrate species would be moderate to low, based on literature references supplied in individual species accounts. Larger snakeheads, however, are known to also feed on birds (particularly young waterfowl), amphibians, small reptiles (snakes, lizards), and small mammals. Adverse impacts on native wildlife and wildlife resources would likely be few, other than through predation. Ecosystem balance, however, could be substantially modified should snakeheads become established in waters with low diversity of native fishes and low abundance or absence of native predatory species (Courtenay and Williams, 2004). Probably as stated for the U.S. adverse impacts on threatened and endangered species would likely be high also in Europe. Of all the taxa listed as endangered or threatened in U.S. aquatic habitats, 16 amphibians, 115 fishes, and 5 of the 21 crustaceans (surface dwelling crayfish and shrimp), would be the most likely to be affected. Based

			on habitat requirements and life history, amphibians and surface dwelling crustaceans would generally be less likely to be affected by introduced snakeheads than would fishes. The possibility of a nonindigenous predator in the aquatic community with any listed amphibian or crustacean would constitute a threat (Courtenay and Williams, 2004). Taking into consideration also the evaluation for the U.S., we can suppose that likelihood and magnitude of the effect on designated critical habitats of threatened or endangered species would be significant on the living component of the aquatic ecosystem. Depending on the habitat, snakeheads have the potential to detrimentally alter aquatic communities (Courtenay and Williams, 2004). The most likely scenario would be an alteration of the fish and crustacean community structure through predation (Courtenay and Williams, 2004). For listed fishes there could be competition for food in addition to direct predation. Like amphibians, fishes and crustaceans listed as threatened or endangered species, candidate taxa of these three groups or aquatic organisms would likewise be at risk. (Courtenay and Williams, 2004). Also Courtenay and Williams (2004) included in the Risk Assessment that the introduction of a small number of snakeheads (for example, less than five) into isolated spring habitats could result in extinction of endemic spring-adapted fishes or crustaceans. Introductions of fishes considered to be far less aggressive than snakeheads (that is, guppies, *Poecilia reticulata*) in such habitats have had major negative impacts (Courtenay and others, 1985. In: Courtenay and

			Williams (2004)). Snakeheads would not have to establish a reproducing population to reduce or eliminate a fish or crustacean species confined to a small section of a stream or isolated spring habitat. A small number of snakeheads introduced, but not established, in a stream or lake would likely have less of an impact. Nevertheless, any snakehead that becomes established in a water body would represent a significant threat and could potentially put any listed amphibian, fish, or crustacean at risk of local extinction (Courtenay and Williams, 2004).
2.16. How important is the impact of the organism on biodiversity (e.g. decline in native species, changes in native species communities, hybridisation) currently in Europe (include any past impact in your response)?	minimal	high	It is not established.
2.17. How important is the impact of the organism on biodiversity likely to be in the future in Europe?	major	high	It has been classified like that in other northern countries like Canada or the U.S. See question 2.15.
2.18. How important is alteration of ecosystem function (e.g. habitat change, nutrient cycling, trophic interactions), including losses to ecosystem services, caused by the organism currently in Europe (include any past impact in your response)?	minimal	high	It is not established.
2.19. How important is alteration of ecosystem function (e.g. habitat change, nutrient cycling, trophic interactions), including losses to ecosystem services, caused by the organism likely to be in Europe in the future?	major	high	It has been classified like that in other northern countries like Canada or the U.S. See question 2.15.

2.20. How important is decline in conservation status (e.g. sites of nature conservation value, WFD classification) caused by the organism currently in Europe?	minimal	high	It is not established.
2.21. How important is decline in conservation status (e.g. sites of nature conservation value, WFD classification) caused by the organism likely to be in the future in Europe?	major	high	It has been classified like that in other northern countries like Canada or the U.S. See question 2.15.
2.22. How important is it that genetic traits of the organism could be carried to other species, modifying their genetic nature and making their economic, environmental or social effects more serious?	minimal	high	Because snakeheads do not occur naturally in the Europe there is no possibility of introduced snakeheads hybridizing or interbreeding with native fishes
2.23. How important is social, human health or other harm (not directly included in economic and environmental categories) caused by the organism within its existing geographic range?	moderate	medium	Some might host human parasites, and one snakehead species has been found to be a carrier for gnathostomiasis. The fact that one species has been shown as a carrier indicates that there are others which could present a similar threat to human health, yet to be investigated (Courtenay and Williams, 2004). Social consequences may exist should a population of snakehead become established, which negatively impacts commercial fisheries or other industries resulting in economic losses or reduction in quality of recreational usage of waterbodies. Cultural ramifications may be experienced, but more likely would be the economic and recreational losses of affected communities (CABI, 2017). Human health may be impacted by zoonotic diseases attributed to snakehead fishes. Gnathostomiasis, a disease which may be transmitted to humans as a result of the helminth parasite (*Gnathostoma spinigerum*), relies on the chevron snakehead (*Channa striata*) as an intermediate host in the disease cycle (Cudmore and

			Mandrak, 2006. In CABI, 2017).
2.24. 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	medium	Potential to transfer pathogens (parasites, diseases) is largely unknown (Courtenay and Williams, 2004). Nevertheless, all snakehead species are hosts to at least several species of parasites. At least two snakehead species utilized in intense aquaculture, *Channa punctata* and *C. striata*, are susceptible to epizootic ulcerative syndrome (EUS), a disease believed to be caused by several species of bacteria, a fungus, and perhaps a retrovirus. EUS is not specific to snakeheads and has affected other fishes, such as clariid catfishes, bagrid catfishes, two cyprinid genera, mastacembalid eels, a nandid fish in India, and giant gourami and climbing perch in Thailand. There have been no studies undertaken to examine transfer of parasites or diseases to native North American fishes (Courtenay and Williams, 2004). Epizootic ulcerative syndrome (EUS), which causes high mortality in these fishes, particularly *Channa triata* and *C. punctata* under intensive culture. EUS involves several pathogens, including motile aeromonad bacteria (for example, *Aeromonas hydrophila*, *A. caviae*, *Pseudomonas fluorescens*; Prasad and others, 1998; Qureshi and others, 1999), a fungus, *Aphanomyces invadans* (considered a primary pathogen; Mohan and others, 1999; Miles and others, 2001. In: Courtenay and Williams, 2004), and perhaps a rhabdovirus (Kanchanakhan and others, 1999; Lio-Po and others, 2000. In: Courtenay and Williams, 2004). Another bacterium, Aquaspirillum sp., also has been implicated (Lio-Po and others, 2000 In: Courtenay and Williams, 2004.). EUS may have originated in India in

			the 1980s, but has since been found in Pakistan, Thailand, and the Philippines, with outbreaks reported from all of these areas during the 1990s. Snakeheads are not the only fishes affected by this disease. It is also known to occur in airbreathing catfish (Clarias), the bagrid catfish genus Mystus, two cyprinid genera (*Cyprinus* and *Puntius*), mastacembelid eels (Mastacembelus), and the nandid genus *Nand*us in India (Mukherjee, 1998). In Thailand, it has been found in giant gourami (*Osphronemus goramy*) and climbing perch (*Anabas testudineus*) during an outbreak in 1996-1997 (Kanchanakhan and others, 1999. In: Courtenay and Williams, 2004). A parasitic disease that can affect humans is gnathostomiasis, caused by a helminth parasite, *Gnathostoma spinigerum*. It has been recognized as a highly important disease with about 800 suspected cases per year in two hospitals in Bangkok, Thailand, between 1985 and 1988 (Setasuban, 1990. In: Courtenay and Williams, 2004). Channa striata has been identified as an intermediate host for this parasite, found mostly in muscle tissue and occurring in 100 percent of fish examined over 41 cm in length (Setasuban and others, 1991. In: Courtenay and Williams, 2004). It is unknown if additional species of snakeheads in Thailand and other countries of southeastern Asia may serve as an intermediate host for larvae of this parasite (Courtenay and Williams, 2004).
2.25. How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (specify in the comment box)	NA	low	
2.26. How important are the expected impacts of the	minimal	medium	It is not yet established.

organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in Europe?			
2.27. Indicate any parts of Europe where economic, environmental and social impacts are particularly likely to occur (provide as much detail as possible).	[Most of central and southern areas Europe]	medium	These European areas are the most prone to receive negative environmental impacts, as freshwater fauna is commonly high in endemism and it is very threatened. On the contrary, the *Channa* fishing may provide positive socio-economic impacts, as many European people travel to these areas for sport fishing.

RISK SUMMARIES			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	very likely	medium	As indicated above, these species are not yet established in European countries. Aquaculture may increase and facilitate its entry from ponds or other kind of aquatic installations has it has happened in other countries. By the moment *C. argus* has a modest importance in aquarium fish trade in Japan, Europe and to a lesser extent, the USA (Courtenay and Williams 2004). *Channa micropeltes* is the most popular aquarium species of all the species in the snakehead family. The juveniles are targeted and known as 'red' or 'redline' snakeheads in the North American aquarium trade. It is also a highly regarded food fish in southeastern Asia and has been imported into Canada for this reason (Commission for Environmental Cooperation, 2009).
Summarise Establishment	very likely	high	Appropriate habitats and climate are found throughout most of the United States (Courtenay and Williams 2004). Europe may have similar conditions. As Courtenay and Williams (2004) also indicated, this does not infer that all species of snakeheads could become established in most of the U.S. (*similarly in Europe*), but that there are habitats, where one or more species could establish a reproducing population. Preferred food of snakeheads (that is, fishes, crustaceans, insects and insect larvae) is locally abundant. Also this may happened in Europe. Several species of snakeheads have established in waters outside their native ranges of distribution in the Northern Hemisphere. These include *Channa argus* in

			Japan, Czechoslovakia, Russia for a period of time, the Aral Sea basin (Amu Dar'ya, Syr Dar'ya, Kaska-Dar'ya, Sarysu, Chu, and reservoirs on the Talus rivers); *C. asiatica* in Taiwan; *C. maculata* in Taiwan, several prefectures of Japan, Madagascar, and Hawaii; C. melasoma on Palawan, Philippines; *C. orientalis* in Kalimantan and Greater Sunda Islands; and *C. striata* in many Pacific Islands and most recently (early 1990s) in confined waters of Oahu, Hawaii
Summarise Spread	moderately	low	Courtenay and Williams (2004) estimated the probability of the organism to spread beyond the colonized area as high with reasonably certain, based on the following information: Appropriate habitats (rivers, streams, lakes, reservoirs, ponds, canals) and climate are suitable for establishment of snakeheads in U.S. waters (similarly in Europe). Both *Channa argus* and *C. maculata*, especially the former, can tolerate cold climates, making the likelihood of their becoming established a probability even in some northern states if released. Introductions into rivers, streams, or canal systems would likely spread whereas releases into lakes or ponds could be more restrictive as to range expansion. Nevertheless, people move fish; considering that larger species of snakeheads are popular with anglers in several locations within their native and introduced ranges abroad, the likelihood of anglers moving snakeheads to novel waters from colonized areas is reasonably great.
Summarise Impact	major	high	Courtenay and Williams (2004) included in their Risk Assessment that the introduction of a small number of snakeheads (for example, less than five) into isolated spring habitats could result in extinction of endemic spring-adapted fishes or crustaceans. As stated by Courtenay and Williams (2004) competition for food resources is probably high.

			Some species of snakeheads are capable of short overland migrations. This presents a potential economic threat to fish culture interests if those species enter culture facilities from adjacent waters, such as occurred with another introduced airbreathing predator, the walking catfish, in Florida (Courtenay and Miley, 1975. In: Courtenay and Williams (2004)).
Conclusion of the risk assessment	high	medium	This species may have economic, environmental and also health impacts. The actual situation in Europe where only in 3 countries there have been records of individual but not confirmed establishment is the best situation to act in banning the trade.

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
3.1. What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?	[The increase in temperature]	medium	Some species of this genus are tropical or subtropical. The climate change may increase temperature in European countries facilitating their potential establishment.
3.2. What is the likely timeframe for such changes?	20 years	medium	For the next two decades, a warming of about 0.2°C per decade is projected for a range of different emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected (IPCC Fourth Assessment Report: Climate Change 2007). Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks (IPCC Fifth Assessment Report: Climate Change 2014).
3.3. What aspects of the risk assessment are most likely to change as a result of climate change?	[Establishment, spread and invasion]	medium	All these stages of the invasion process are highly influenced by temperature in 'cold blood' species, such as fish.
ADDITIONAL QUESTIONS - RESEARCH			
4.1. If there is any research that would significantly strengthen confidence in the risk assessment please summarise this here.	[habitat requirements dietary traits, growth and reproduction in invaded areas]	medium	All these biological and ecological aspects are key to properly determine the potential invasiveness of non-native fish.

REFERENCES:

- Abraham, R. 2011. *Channa diplogramme*. The IUCN Red List of Threatened Species 2011: e.T196095A8994895. http://dx.doi.org/10.2305/IUCN.UK.2011-1.RLTS.T196095A8994895.en. Downloaded on 06 February 2017.
- Almeida D., Ribeiro F., Leunda P.M., L. Vilizzi, and Copp G.H. 2013. Invasiveness Screening Tool for Non-Native Freshwater Fishes, to Perform Risk Identification Assessments in the Iberian Peninsula. Risk Analysis, Vol. 33, No. 8
- CABI. 2017. *Channa argus argus* (northern snakehead). In: Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.
- Commission for Environmental Cooperation. 2009. Trinational Risk Assessment Guidelines for Aquatic Alien Invasive Species Test Cases for the Snakeheads (Channidae) and Armored Catfi shes (Loricariidae) in North American Inland Waters. ISBN 978-2-923358-60-4 (electronic version)
- Courtenay W.R. and Williams J.D. 2004. Snakeheads (Pisces, Channidae)—A Biological Synopsis and Risk Assessment. U.S. Geological Survey circular; 1251). ISBN.0-607-93720 (alk. paper)
- Elvira B. 2001. Identification of non-native freshwater fishes established in Europe and assessment of their potential threats to the biological diversity. Convention on the Conservation of European Wildlife and Natural Habitats. Standing Committee .21st meeting. Strasbourg, 11 December 2000 T-PVS (2001) 6
- Froese R. and Pauly D. Editors. 2016. FishBase. World Wide Web electronic publication. www.fishbase.org, version (10/2016).
- Fuller P.F., Benson A.J., Nunez G., Fusaro A. 2015. *Channa argus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/factsheet.aspx?speciesid=2265
- Global Invasive Species Database. 2017. Species profile: *Channa argus*. Downloaded from http://www.iucngisd.org/gisd/species.php?sc=380 on 11-01-2017.
- Gogoi N., Hazarika L.P. and Biswas S.P. 2016. Studies on the reproductive biology and captive breeding of *Channa aurantimaculata*, an endemic fish from Assam. Journal of Environmental Biology. Volume 37. Number 3. Page No: 369-374

- Harvey H.H. 1975. Fish populations in a large group of acid-stressed lakes. Ver. Theor. Angew. Limnol. 19: 2406–2417
- Jackson D.A., Peres-Neto P.R. and Olden J.D. 2001. What controls who is where in freshwater fish communities the roles of biotic, abiotic and spatial factors. Can. J. Fish. Aquat. Sci., 58: 157-170.
- Lee P.G. and Ng P.K.L. 1991. The snakehead fishes of the Indo-Malayan Region: Nature Malaysiana, v. 16, no. 4, p. 113-129.
- Maceda-Veiga A., Escribano-Alacid J., de Sostoa A. and García-Berthou E. 2013. The aquarium trade as a potential source of fish introductions in southwestern Europe. Biological Invasions 15: 2707–2716
- Northern Snakehead Working Group (NSWG). 2006. National control and management plan for the northern snakehead (*Channa argus*). Department of the Interior, unpublished manuscript. Available http://www.fws.gov/northeast/marylandfisheries/reports/National%20Management%20Plan%20for%20the%20Northern%20Snakehead.pdf Accessed: 20 September 2011
- Odenkirk J. and Owens S. 2005. Northern snakeheads in the tidal Potomac River system. Trans. Am. Fish. Soc. 134: 1605-1609.
- Orrell T.M. and L. Weigt. L. 2005. The northern snakehead *Channa argus* (Anabantomorpha: Channidae), a non-indigenous fish species in the Potomac River, U.S.A. Proc. Biol. Soc. Washington. 118(2): 407-415
- Piazzini S., Segos I., Favilli L., Manganelli G. 2014. The first European record of the Indonesian snakehead, *Channa micropeltes* (Actinopterygii: Perciformes: Channidae). Acta Ichthyologica et Piscatoria 44 (2): 153–155 DOI: 10.3750/AIP2014.44.2.09. Available from: https://www.researchgate.net/publication/266398849_The_first_European_record_of_the_Indonesian_snakehead_Channa_micropeltes_Actinopterygii_Perciformes_Channidae [accessed Jan 11, 2017].
- Poulos H.M., Chernoff B., Fuller P.L. and Butman D. 2012. Ensemble forecasting of potential habitat for three invasive fishes. Aquatic Invasions Volume 7, Issue 1: 59–72
- Sala O.E., Chapin III S.F., Armesto J.J., Berlow E., Bloomfield J., Dirzo R., HuberSanwald E., Huenneke L.F., Jackson R.B., Kinzig A., Leemans R., Lodge D.M., Mooney H.A., Oesterheld M., Poff N.L., Sykes M.T., Walker B.H., Walker M. and Wall D.H. 2000. Global biodiversity scenarios for the year 2100. Science, 287: 1770–1774

- United States Geological Survey (USGS). 2004. Non-indigenous aquatic species database – northern snakehead (*Channa argus*). www.nas.er.usgs.gov.
- Vilà M., Basnou C., Pyšek P., Josefsson M., Genovesi P., Gollasch S., Nentwig W., Olenin S., Roques A., Roy D., Hulme P.E. and DAISIE partners. 2010. How well do we understand the impacts of alien species on 6 ecosystem services? A pan-European cross-taxa assessment. Frontiers in Ecology and the Environment (8:135-144).
- Vilà M., Pino J. and Font X. 2007. Regional assessment of plant invasions across different habitat types. Journal of Vegetation Science, 18: 35–42
- Vila-Gispert A., Alcaraz C., García-Berthou E. 2005. Life-history traits of invasive fish in small Mediterranean streams. Biol Invasions 7:107–116
- Zalewski M. and Naiman R.J. 1984. The regulation of riverine fish communties by a continuum of abiotic–biotic factors. In Habitat modification and freshwater fisheries. Edited by J.S. Alabaster. Batterworth Scientific Ltd., London, U.K. pp. 3–9.