Information on measures and related costs in relation to species considered for inclusion on the Union list

This technical note has been drafted by a team of experts under the supervision of IUCN within the framework of the contract No 07.0202/2016/739524/SER/ENV.D.2 "Technical and Scientific support in relation to the Implementation of Regulation 1143/2014 on Invasive Alien Species". The information and views set out in this note do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this note. Neither the Commission nor any person acting on the Commission's behalf may be held responsible for the use which may be made of the information contained therein. Reproduction is authorised provided the source is acknowledged.

This document shall be cited as:
Zogaris, S. 2017. Information on measures and related costs in relation to species considered for inclusion on the Union list: *Channa spp*. Technical note prepared by IUCN for the European Commission.

This technical note provides information on the effectiveness of measures, alongside the required effort and resources, used to prevent the introduction, and to undertake early detection, rapid eradication, and management for the invasive alien species under review. Each table represents a separate measure.

Date of completion: 14/12/2017
Comments which could support improvement of this document are welcome. Please send your comments by e-mail to ENV-IAS@ec.europa.eu

Species (scientific name)	Genus: *Channa* 1. *Channa amphibeus* (McClelland, 1845) 2. *Channa argus* (Cantor, 1842) 3. *Channa asiatica* (Linnaeus, 1758) 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) 16. *Channa marulioides* (Bleeker, 1851) 17. *Channa marulius* (Hamilton, 1822) 18. *Channa melanoptera* (Bleeker, 1855) 19. *Channa melasoma* (Bleeker, 1851) 20. *Channa micropeltes* (Cuvier in Cuvier and Valenciennes, 1831) 21. *Channa nox* Zhang, Musikasinthorn and Watanabe, 2002 22. *Channa orientalis* Bloch and Schneider, 1801 23. *Channa panaw* Musikasinthorn, 1998 24. *Channa pleurophthalmus* (Bleeker, 1851) 25. *Channa punctata* (Bloch, 1793) 26. *Channa stewartii* (Playfair, 1867) 27. *Channa striata* (Bloch, 1793) *28. Channa andrao Britz, 2013* *29. Channa hoaluensis Nguyen, 2011* *30. Channa longistomata Nguyen, Nguyen & Nguyen, 2012* *31. Channa melanostigma Geetakumari & Vishwanath, 2011* *32. Channa ninhbinhensis Nguyen, 2011* *33. Channa ornatapinnis Britz, 2008* *34. Channa pulchra Britz, 2007* *35. Channa pomanensis Gurumayum & Tamang, 2016*
Species (common name)	Snakehead 1. *Channa amphibeus:* borna snakehead; 2. *Channa argus:* northern snakehead; 3. *Channa asiatica:* small snakehead; 4. *Channa aurantimaculata*: orange-spotted snakehead; 5. *Channa bankanensis:* bangka snakehead 6. *Channa baramensis*: snakehead 7. *Channa barca:* barca snakehead 8. *Channa bleheri:* rainbow snakehead 9. *Channa burmanica*: Burmese snakehead 10. *Channa cyanospilos*: bluespotted snakehead 11. *Channa diplogramma*: malabar snakehead

	12. *Channa gachua*: dwarf snakehead 13. *Channa harcourtbutleri*: nga ohn-ma snakehead 14. *Channa lucius*: forest snakehead 15. *Channa maculate*: blotched snakehead 16. *Channa marulioides*: emperor snakehead 17. *Channa marulius*: bullseye snakehead; 18. *Channa melanoptera*: snakehead 19. *Channa melasoma*: black snakehead 20. *Channa micropeltes*: giant snakehead, Indonesian snakehead, red snakehead; 21. *Channa nox*: night snakehead 22. *Channa orientalis*: smooth-breasted snakefish, smooth-breasted snakefish; 23. *Channa panaw*: panaw snakehead 24. *Channa pleurophthalmus*: ocellated snakehead *25. Channa punctate*: green snakehead; 26. *Channa stewartii*: assamese sn*akehead* 27. *Channa striata*: chevron snakehead, striped snakehead *28. Channa andrao* *29. Channa hoaluensis* *30. Channa longistomata* *31. Channa melanostigma* *32. Channa ninhbinhensis* *33. Channa ornatapinnis* *34. Channa pulchra* *35. Channa pomanensis*
Author(s)	Stamatis Zogaris, Institute of Marine Biological Resources and Inland Waters, Hellenic Centre for Marine Research, Greece.
Date Completed	14/12/2017
Reviewer	Frances Lucy, Department of Environmental Science, School of Science, Institute of Technology, Sligo, Ireland.

Summary Highlight of measures that provide the most cost-effective options to prevent the introduction, achieve early detection, rapidly eradicate and manage the species,

including significant gaps in information or knowledge to identify cost-effective measures.

Prevention

Currently in Europe there are just a few records of only two species of snakehead fishes of the Genus *Channa*: a single record of Indonesian/giant snakehead *Channa micropeltes* at a warm-spring system in Italy and older records of northern snakehead *Channa argus* in Slovakia and in the Czech republic (Deputy Direction of Nature, 2017). However, with modern trade conditions, *Channa* species could possibly invade EU waters by way of aquarium release, live food trade, and natural dispersal after illegal/unofficial introduction. Implementation of bans on the import, trade and keeping *Channa* species and awareness programs could all be used to reduce the risk of introduction within EU. At the moment *C. argus* has a modest importance in aquarium fish trade in Europe, while several tropical snakeheads (e.g. *Channa micropelte*s) are commonly traded among aquarists and are available in pet shops in most EU countries. Campaigns should target *Channa argus* but also all other Channidae. *Channa argus* is the most cold tolerant of the snakehead species and could become invasive if allowed into large river basin areas. Some *Channa* species are also a highly regarded food fish in south-eastern Asia and they are often exported live from fish farms or after capture in Asia.

Early detection

The genus *Channa* currently includes at least 35 described species, and recent phylogenetic studies have revealed the existence of more undescribed channid species in South Asia. The taxonomic difficulties make the use of genetic analyses important in species identification. Edna and other novel molecular techniques based on water sampling show great potential as a cost-efficient early detection approach. Furthermore, scientific field surveys, surveys of fishers' catches and citizen scientist observations are also important ways to monitor for detection of snakeheads in European waters. Fish may escape notice after initial entry and they may be found in different habitats including artificially or geothermally spring warmed waters (in the case of tropical or subtropical snakehead species). They may also be detected in semi-aquatic habitats such as riparian areas and wetlands as they are capable of surviving out of water for several days.

Rapid eradication

Most *Channa* species are very difficult to eradicate if they become established in large open waters; one widespread species, *Channa argus* is known to be particularly difficult or practically impossible to exterminate in large waterbodies in temperate zone waterbodies. In small enclosed waterbodies piscicides (rotenone) and drastic habitat changes (e.g. water-level drawdown of reservoirs or ponds) could be effective in eradicating populations.

Management

Mechanical removal using electrofishing and other fishing tools is suggested as a means to contain populations if established.

Prevention – measures for preventing the species being introduced, intentionally and unintentionally. **This table is repeated for each of the prevention measures identified.**

Measure description Provide a description of the measure	**A ban on importing, keeping and trading of *Channa spp.,* including the aquarium trade to reduce the risk of intentional introductions**. The genus *Channa* currently includes at least 35 described species, and recent phylogenetic studies have revealed the existence of more undescribed species in South Asia (Gurumayum & Tamang 2016; Froese & Pauly (Eds), 2017)). While there are currently no known established populations of *Channa spp*. in Europe, it is very likely that at least one species will be able to establish (*C. argus*) based on the climatic similarity of native ranges (Deputy Direction of Nature, 2017). The main pathway of introduction into Europe is through the aquarium trade, though level of trade in Europe is unknown it is likely to be relatively minor as they are relatively expensive and difficult to keep as most species cannot be kept in community tanks as they are predatory (see 2016 article on Practical Fishkeeping UK). A possible additional pathway is via live imports and aquaculture, while there is currently no known aquaculture production of the species within Europe, there are limited markets for live imports of the species (a trend reflected in the USA) (Deputy Direction of Nature, 2017). Concerning alien species in aquaculture, regulation 708/2007/EC provides provisions limiting the introduction of such species (demanding permits, inventory of species trade, etc.); there may be some difficulties in tracking species that are also considered of an “ornamental” nature, for which this regulation does not apply. The regulation allows Member States the option to impose controls, for example for a species that has not previously been used in aquaculture in the Member State concerned (Copp et al. 2016). Deliberate introductions may also result from releases by animal rights activists or for ceremonial/prayer purposes, or release from live-food-fish fisheries; these have been documented in North America (Leung & Von Finster, 2016). Therefore banning the import, trade, live transport, keeping and any proposed aquaculture of all *Channa* species, would reduce the risk of intentional introductions of *Channa* species into Europe. Voluntary codes of conduct and international trading bans can be implemented to stop aquarium based trade of animals and plant invasive alien species (IAS) (Verbrugge et al., 2014) and to inform of specialty fishes, such as large-sized fishes (see http://www.bigfishcampaign.org/index.html). Clearly defined exceptions where the species could be kept under licensed ownership and registered facilities can be included and supported through the development of codes of conduct (i.e. public aquaria, zoos, and in education centres at all levels). Controlling trade through permit taxing and regulations has been suggested for many tropical animals [e.g. in some USA states a special permit (costing ca. $100) is required for possession of certain "reptiles of concern" (Hardin, 2007)]. These regulations are designed to discourage so-called impulse purchases that may lead to illegal release and potential establishment in the wild.

	To date in Europe there are very few records of only two snakehead species in three EU countries; a single record of Indonesian/giant snakehead *Channa micropeltes* at a warm-spring system in Italy (Piazzini et al., 2014) and older records of northern snakehead *Channa argus* in territories of Slovakia and the Czech republic (Holcik, 1991). The latter species was introduced into former Czechoslovakia sometime since 1949, but with no evidence of permanent establishment west of these former Soviet Union states (Holcik, 1991). Isolated accounts of recently released fishes in freshwaters, such as a presumed *Channa micropeltes* in a river near Lincoln UK (2008) have been recorded. However, with modern globalised trading, EU waters are now at risk from snakehead invasion by aquarium releases, live trade (food or ornamental use), and by natural spread following any illegal introduction into waters (Courtenay & Williams, 2004). Some *Channa* species are also a highly regarded food fish in south-eastern Asia and they may be exported live and kept live in Asian restaurants in the EU, as was recorded in North America (Cudmore & Mandrak, 2006; Leung & Von Finster, 2016).
Effectiveness of measure e.g. has the measure previously worked, failed	Banning the import, trade, and keeping of *Channa* species is likely to be more cost-effective that using market anti-incentives, particularly as the genus has limited commercial value and for some species a high likelihood of establishment within Europe. This is supported by the following: a) Most *Channa* species that are marketed, especially the popular *Channa macrolepis* outgrow their tanks and are susceptible to being released in nature; b) Channids are difficult to identify especially when mature and their taxonomy is not fully settled; c) The genus includes many hardy species that can survive long periods out of water or may be able to disperse over land for short stretches as well and are capable of reproducing quite rapidly (Global Invasive Species Database, 2017). Such restrictions would only be effective if fully implemented and enforced. Tracking snakeheads, through monitoring species' movement through trade is difficult; for example special interest buyers can purchase fish via the internet trade, which is difficult to monitor and regulate. In the USA, several snakehead species are marketed even in states where possession of live snakeheads has been illegal for decades (Courtenay & Williams, 2004). Because of their highly predacious nature, however, snakeheads have not had a large following of interested hobbyists, compared to many other larger-sized species, however there is a strong interest in various aquarium forums (specialty large-fish tanks) (Courtenay & Williams, 2004). Hobbyists and importers can purchase snakeheads through a variety of sites on the Internet (review of aquarium forums, this

	study). Trading bans can be costly to implement and their success is difficult to quantify and assess (Gren, 2008), and this depends on various factors, e.g. on the species identification capacity of the responsible authorities controlling the fish imports. There is no comprehensive morphological key for the Channidae and confirming identification usually involves genetic screening (Serrao et al., 2016). Overall, the species-level identification of *Channa* spp. is difficult due to the high phenotypic variation and morphological variation with age in these species. This is the primary reason an all-taxa ban within the Genus is the only way to proceed effectively. An additional benefit of such measures is that they can be broadened out to incorporate additional species sharing the same or similar pathways of introduction, and "guild" characteristics (i.e. in this case aquarium trade fishes).
Effort required e.g. period of time over which measure need to be applied to have results	The restrictions and associated measures need to be maintained indefinitely. The implementation of trading bans requires genus/species knowledge and identification skills on the part of the responsible authorities. Training effort is required to apply this measure.
Resources required [1] e.g. cost, staff, equipment etc.	There is no information available about the costs and the equipment or infrastructure that may be required to implement these measures, but it is a widely accepted that prevention is more cost effective than management of the entry or establishment of such a species group (Savior, 2016). These measures would need to include the provision and training of administration and staff to enforce the regulations. Research into the trade of *Channa* species in Europe is very low and perhaps the presence of the species in the aquarium and aquaculture market is overlooked. More information is required concerning the imports of snakehead species into the European Union Member States, and their status in the aquarium, aquaculture and the internet trade. The following costs have provided for implementing similar measures in Kentucky USA (Mahala, 2008): a) Development of an alien invasive education specifically for the state: $15,000/year; b) Target and educate key groups: $23,000/year; c) Identify and secure outside funding to develop, maintain and continue the education/awareness program: $250/year; d) Assess public and stakeholder awareness with surveys: $5,000/year;

	e) Provide programs to assist against entry of species by appointing a coordinator position $5,800/year; f) Annual review and update of plan to address gaps and needs (study, review): $1,000/year. g) In addition, the plans call for the funding of scientific meetings, dissemination and building alliances among stakeholders (estimated costs of meetings etc: $6,000/year). In addition to the costs outlined above, media development/advertising initiative could also be considered with estimated cost of ca. €20,000 to €50,000 /year.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Economic impact to the aquarium fish trade through prohibition of importation or transport of live snakeheads would be minor if only Channa *argus* was involved. Banning all *Channa* species including the tropical species will have some negative financial impact to the aquarium/pet industry. Though the value of trade within Europe is currently unknown, in some EU countries the presence of the Channid fishes in trade is of minor importance (Maceda-Veiga et al., 2013; Papavlasopoulou et al., 2014). The sale of *Channa* for live food (primarily for the Asian food industry) is poorly known in Europe. Snakeheads are probably only a minor component of live-food fish sales in Europe (i.e. compared to the Asian food market in North America). Economic impact to the live-food fish trade would be minor following a ban on importation and transportation of live snakeheads, as these fishes can be imported frozen or dead on ice for sale.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Currently in England and Wales *Channa argus* is the only *Channa* species banned from sale, although all *Channa* species are restricted in Scotland – where a special licence is required to keep the species. It is highly likely that aquarists in the UK, and possibly other Member States with similar climates, would oppose such restriction made at a genus level as many *Channa* species are tropical/subtropical and unlikely to survive winters in UK waters (Ornamental Aquatic Trade Association, 2017). It is believed that banning of live imports of *Channa* species would not present a significant negative impact to aquaculture interests of foreign countries (Deputy Direction of Nature, 2017).
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness	Costs cannot be completely assessed. The cost of inaction would be related to management costs needed to eradicate or mitigate the impacts of established populations. In Europe, investment in measures such as import bans to exclude unwanted organisms are most developed with regard to economic production sectors, particularly agriculture. Costs of developing such trade controls for a predatory invasive fish group such as *Channa* spp. could be similar.

- the socio-economic aspects	Socio-economic aspects may impact slightly the aquarium hobbyist community since snakeheads are of special interest.
Level of confidence [2] See guidance section	**Low**. Information and reliable sources on such measures are not widely available; but bans and other normative measures have been applied to other predatory fish species in several jurisdictions. Many *Channa* species are popular aquarium fishes, however inventories or knowledge of how best to track their trade are not available.

Prevention – measures for preventing the species being introduced, intentionally and unintentionally. **This table is repeated for each of the prevention measures identified.**	
Measure description Provide a description of the measure	**Awareness raising activities, including education and training to reduce the risk of intentional, and un-intentional introductions.** Public awareness campaigns and sector specific best practice guidance and training is needed to reduce the risk of introductions and escape into the wild, especially if their import, keeping or trade is not banned (see Prevention table above). These measures need to be developed for those involved in the ornamental aquarium trade, aquaculture, and the oriental food industry. Audio-visual material (video, cartoons etc.) can be utilized to make effective training on measures clear and comprehensible across a wide range of stakeholders. An information campaign targeting the relevant stakeholders can also be utilised, and should be implemented for at least five years in each member state. Monitoring of the effectiveness of sensitization/awareness of such a programme should be undertaken. These measures can be developed through government initiatives or by government research agencies in collaboration with other interested groups, and could include many other potentially invasive species that share similar pathways of introduction. Aside from educating stakeholders on the risks posed by *Channa* species, activities should cover guidance on developing measures to reduce the risk of escape from aquaculture, "accidental" translocations with commonly stocked fishes, and the promotion of alternative aquarium species that are not potential invasive alien species. Also the inclusion of additional species, sharing the same pathways of invasion is recommended. It is also important to explain that while all *Channa* species, except Channa *argus*, currently have low invasiveness potential in norther Europe due to climatic constraints, this may soon be altered by climate change affects (Poulos et al., 2012). *Channa argus* is a high risk species especially in the warmer parts of Europe (Almeida et al., 2013) and inhabits freshwaters within a temperature range from 0 to 30°C. This species is also tolerant to a wide range of oxygen levels and pH. These requirements and life history traits provide broad

	possibilities for the establishment of the species in European waters. If the import, and trade of *Channa* species is not banned they could establish footholds in some parts of Europe and perhaps even go unnoticed for several years. Life history traits of the tropical and subtropical *Channa* species restricts their ability to establish and spread in temperate waters, however they may be able to survive in the southern part of Europe and in special warm-water habitats (Piazzini et al., 2014).
Effectiveness of measure e.g. has the measure previously worked, failed	**High.** Awareness raising campaigns, and stakeholder specific guidelines are frequently used to reduce risk of the introduction or spread of invasive species, and seem to have been effective in many countries (e.g. USA and Canada) (Cudmore & Mandrak, 2006; Savior, 2016). There are no reports of information or awareness campaigns regarding *Channa* species in Europe.
Effort required e.g. period of time over which measure need to be applied to have results	Awareness raising campaigns and stakeholder engagement/education activities need to be undertaken indefinitely, especially if a ban on the import, trade and keeping of the species is not in place.
Resources required [1] e.g. cost, staff, equipment etc.	Ideally the development of awareness raising campaigns and educational materials needs to be done for each member state, guided by scientific expertise and co-ordinated by an "education committee" or a similar initiative. Resources required, and associated costs, are dependent upon the activities and materials developed, but maybe include media campaigns, websites, marketing materials, or outreach training and education schemes (Roy et al., 2015).
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	**No negative side effects**. Positive effects may develop if the campaign is coupled with citizen science initiatives to promote early detection. In many countries, education and sensitization of the problem is much more effective than any strict normative approaches (i.e., laws and inspections) (Azevedo-Santos et al., 2015). Also, additional invasive alien species can be included in all the activities.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	**Moderate.** The species group in question will not provide specific problems or barriers (including issues of public perception) however many critical stakeholders, such as the aquarium industry and specialist hobbyists may be reluctant to engage.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	**Implementation cost per member state** would include the establishment of a central body to co-ordinate activities, and the development of marketing and education initiatives to build an awareness and educational campaign. The costs per member state will vary and a case-specific development should take place. **-Cost of inaction:** High. Without such awareness raising activities, especially in the absence of a ban on the import, trade and keeping of *Channa* species, there would likely be more frequent introductions of *Channa* species into the wild in Europe. There is a possibility of a future rise in the

	interest in *Channa* species use in both aquarium (i.e. as a novelty species) and within the growing Asian food market of Europe (Latham & Wu, 2013). Therefore accidental or misinformed release of *Channa* fish in the wild is very possible (i.e. perhaps through food-related transport and uninformed or misinformed fish hobbyists). **-Cost-effectiveness:** High. Informed public and stakeholder groups support prevention of species spread, and this is cheaper than any form of site-based eradication. **-Socio-economic aspects:** See "acceptability of stakeholders" above.
Level of confidence [2] See guidance section	**High.** Education and awareness campaigns focusing on *Channa* spp. have made the issue of fish IAS popular in North America (e.g. Courtenay & Williams, 2004; Cudmore & Mandrak, 2006; Savior, 2016). Education campaigns are the main ways to encourage fish importers, dealers, and aquarium hobbyists to prevent releases in to the wild. This should discourage the accidental or purposeful introduction of this species group into local ecosystems and have positive synergies among relevant stakeholders. These campaigns can rapidly change attitudes about invasive species.

Early detection - Measures to run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16 of the IAS Regulation). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the early detection measures identified.**	
Measure description Provide a description of the surveillance method	**Field surveys using electrofishing and involvement of angling community.** Trained researchers can effectively detect the species especially when supplemented with citizen science input (especially from the angling community). Snakeheads are often discovered by researches on routine or special surveys (Piazzini et al., 2014; Savior, 2016). Surveillance sampling should target a variety of water bodies as snakeheads could be released in a variety of waters, including urban and peri-urban waters and artificially or natural warm waters. Electrofishing by boat is the least intrusive fish-catching method for general surveying of a variety of rivers, wetlands and lakeshores. For *C. argus* surveys in the Potomac River, North America, Odenkirk & Isel (2016) used daytime DC (844 V) electrofishing surveys, concentrated in shallow waters (<2m deep) along channel margins and along aquatic vegetation transition lines. Gill-netting or other netting and trapping survey methods may result in mortalities of high numbers of other fishes, possibly including protected species (and other wildlife) and should be used only

	during routine survey work based on wider research/survey programmes (e.g. EU Water Framework Directive (WFD)fish monitoring in lakes). Efforts should be made to create synergies between routine monitoring such as the WFD application and the effort for early detection. The species grow to a large size so their presence can be easily reported by amateur fishers and even by informed general public. The early detection of invasive alien fish species is a key factor in the successful eradication of newly established populations (see tables below).
Effectiveness of the surveillance e.g. has the surveillance previously worked, failed	**High**. A combination of electrofishing and angler reporting has been used to document the trends and abundance of snakehead populations in the Potomac River in North America (Odenkirk & Isel, 2016; Saviour, 2016).
Effort required e.g. required intensity of surveillance (in time and space) to be sufficiently rapid to allow rapid eradication	High amounts of effort is required. However, such methods can be used to survey for a wide variety of invasive alien fish species or incorporate searches/surveying for aliens within extant monitoring frameworks. Intensity of surveillance for *Channa* spp. will depend on possibility of entry in the system, the indication for entry may be detected by other surveys such as citizen detection and eDNA (see below).
Resources required [1] e.g. cost, staff, equipment etc.	Early detection is achievable by comprehensive surveying and repeated sampling of likely areas where the species may enter or be established. By developing identification keys for the public and developing apps for mobiles, the cost of monitoring can be reduced and larger areas can be surveyed. Costs of this may be foreseen for a wider variety of alien fish species not just the snakehead. Electrofishing sampling generally costs between 380€ to 2,900€ per 100 meter of lotic ecosystem sample (Schmutz et al., 2007) depending on stream type, equipment used and other parameters (this does not include staff costs or institutional support). In general, a guide cost of 1,500 € per boat-based electrofishing sample may be given; from this the estimation of effort can be generally calculated (based on the FAME project; see Schmutz et al., 2007). Costs of public participation campaigns for detection could be in the range of 10,000 to 30,000 € per year with a start-up development of about 80,000€ (i.e. for app development, website, advertising, management, staff costs) (Author's opinion).
Side effects (incl. potential) i.e. positive or negative side effects of the method on public health, environment, non-targeted species, etc.	**Negative**: Netting should be used primarily in work that is related to general or monitoring surveys, and its use in waters harbouring protected species should be limited due to the risk of mortality. **Positive**: Electrofishing and detection by the public have very low impacts compared to other fish-catching techniques.

Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	All stakeholders are likely to find these measures acceptable and there is evidence of this from North America (Savior, 2016).
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	There is no information available on the overall costs of specific efforts for detection. These must be developed for a variety of other fishes and should be strategically costed within routine government-supported fish monitoring (both WFD and threatened species monitoring can support surveys for alien species). Detection work will have far less impact on ecosystems and economic and recreational activities than other management efforts.
Level of confidence [2] See guidance section	**Low.** While there is experience abroad of the use of these approaches for surveying a wide variety of alien fishes, the effectiveness of the effort in regards to early detection is not well documented.

Early detection - Measures to run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16 of the IAS Regulation). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the early detection measures identified.**	
Measure description Provide a description of the surveillance method	**Environmental DNA.** DNA barcoding technologies, high-throughput sequencing and environmental DNA (eDNA), are becoming increasingly important in monitoring for invasive alien fishes (Roy et al., 2017). Environmental DNA surveying is based on genetic material obtained directly from environmental samples (water samples for fishes) without any obvious signs of biological source material; it is an efficient, non-invasive and easy-to-standardize sampling approach (Thomsen & Willerslev, 2015; Leese et al., 2016). Compared to other methods of surveying, rapid assessment sampling using eDNA methods and DNA barcoding is a rapid, easy and cheap method to detect non-indigenous species in various environments (Ardura & Planes, 2017).Despite the attention snakeheads have received, there are substantial difficulties for accurate species identification and genetic methods will be critically important in the detection and screening of these species (Serrao et al., 2016).

Effectiveness of the surveillance e.g. has the surveillance previously worked, failed	eDNA methods certainly represents a cost-effective means by which to establish knowledge of the entry and establishment of *Channa* species. The effort required for high-probability, early detection of aquatic non-native species is substantial (Hoffman et al., 2011) and eDNA surveying could be combined with other surveying techniques in parallel to work more effectively and to compare its efficacy under different conditions. The overall sensitivity of eDNA detection is likely to vary between studies due to differences in field and laboratory methods, environmental conditions and the target species (Furlan et al., 2016). Population size of the target species affects the detectability of DNA from water samples; so a single or very few *Channa* fishes may not be detected. The detection success of aquatic species in these studies were found to be higher than visual surveys regardless of the population size and life stage of the target species.
Effort required e.g. required intensity of surveillance (in time and space) to be sufficiently rapid to allow rapid eradication	The method requires an inventory of all available genetic forms of the fishes and the testing and calibration of the methods. A molecular archive of genetic forms should be established and overseen by a specialized scientific team. The taxonomy of the genus *Channa* is incomplete and a comprehensive revision of the family has not been performed (Adamson et al., 2010; Simmons et al., 2015), this may make the foundational genetic-level work obligatory. In surveying for eDNA, it is important to strategically organize the campaign to explore priority habitats that may hold the newly introduced populations of the species. With eDNA approaches sampling for DNA in water can be relatively cheap and also wide-ranging as a screening level procedure. Since much wider areas will be surveyed, costs for collecting in many different waterbodies and waterbody types will be considerable if a thorough effective inventory and monitoring application can be established.
Resources required [1] e.g. cost, staff, equipment etc.	An estimate given by Dr. Marlen I. Vasquez, (Cyprus University of Technology) (Pers. Comm.): The cost of research and development of the eDNA application for a small Member state in the EU is approximately € 30,000 with consumables (€24,000 personnel and travel + lab €6,000 consumables). This equates to six months development, 12 months sampling campaign and six month analysis. The method requires the collection of water samples (1 to 10 L of water) from strategically placed sampling sites to search for the targeted species. These costs are lower if a lab is already equipped and doing similar routine work (Evans et al., 2017). Future studies on detection of invasive species from different ecosystems will widen our knowledge about the applicability of eDNA and initial costs are forecast to be less in the future. If a lab facility does not exist, a small lab and instruments (PCR machine etc) cost about €30,000.

	These costs are lower if a lab is already equipped and doing similar routine work (Evans et al., 2017). Other examples of cost estimates relate to work in the USA, where the cost of detection of a single reptile species per site have been given as approximately US $500 to detect eDNA at a site (Davy et al., 2015). Although routine eDNA sampling for fishes will cost much less, this is definitely less than most electrofishing or sampling campaigns using nets or traps. Michelin et al. (2011) indicated that traditional surveys cost 250% more in terms of expenditure and time. Any lab and field oriented enterprise will need the establishment and maintenance of a scientific team. Expenses associated with obtaining reference archival data were not included in total cost estimates, nor were planning, data compilation and management and other synthesis costs. These costs will vary based on circumstances in each Member State.
Side effects (incl. potential) i.e. positive or negative side effects of the method on public health, environment, non-targeted species, etc.	**Positive.** Positive side effects may include discovery of other rare, threatened or protected species in water bodies. There is no negative impact to any human activity or biodiversity by sampling water for e-DNA analyses.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	**Positive**. The method is acceptable to stakeholders as it does not intrude or damage biodiversity.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	No information available.
Level of confidence [2] See guidance section	**Medium**. The method is well developed. However, the *Channa* species group includes many species and their taxonomy is not well known, therefore trials and demonstration of detection ability of several species may be required.

Rapid eradication - Measures to achieve rapid eradication after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**	
Measure description Provide a description of the measure	**Chemical removal.** Rotenone is a plant based piscicide that does not dissolve in water, used for eradicating unwanted fish species. For it to be effective in low concentrations, it needs to be formulated with solvents in order for it to be dispersed in water. Two commercial product formulations containing rotenone as the active ingredient are considered here; Nusyn-Noxfish®, and CFT Legumine®. It is important to note that EU/national/local legislation on the use of plant protection products and biocides must be respected. When rotenone formulations are administered to rivers and streams for the removal of invasive fishes, the resulting concentrations are too low to impact human health, or the welfare of other mammals and birds that may come in contact with the rotenone-treated water (Ott, 2006). As the half-life of rotenone in the water column may be longer than is needed to remove undesired fish, rotenone is often 'neutralized' after the desired fish kill has been accomplished by the addition of potassium permanganate solution to the stream or lake. Potassium permanganate is a powerful oxidant that oxidizes rotenone to less toxic, more water soluble products, rotenone being a major Specific guidance on product use and approaches are well documented especially in North America (e.g Wynne & Masser, 2010).
Effectiveness of measure e.g. has the measure previously worked, failed	Despite preliminary fears that rotenone would be ineffective against air-breathing snakeheads, the Crofton, Anne Arundel County, Maryland, eradication program on *Channa argus* in September 2002 proved to be effective, however treatment also killed native fish (Lazur et al., 2006; Savior, 2016). For information on case-studies, in the USA, Europe, Australia and Pakistan on the application of rotenone for other invasive fish species see the conservation evidence site (Smith et al., 2017) Effectiveness can be maximised if timed prior to spawning or juvenile dispersal (Jiao et al., 2009).
Effort required e.g. period of time over which measure need to be applied to achieve rapid eradication	The application of rotenone may take very little time (a few hours depending on the waterbody). Results are fast and even if applications need to be repeated within a few days a small reservoir or pond will be treated effectively. In small reservoirs and ponds rotenone is now a routine fish management procedure abroad (USA, Australia) (Wynne & Masser, 2010).Experience in the use of rotenone for restoration and invasive fish control is developing, however more research is needed especially within adaptive management frameworks.
Resources required [1] e.g. cost, staff, equipment etc.	There is relatively very little information from previous trials specifically targeting this species

	group (Savior, 2016) and in some cases no confirmation of complete eradication in treated waterbodies (CABI, 2017) . The cost of the eradication could be very expensive because *Channa* species are considered fairly resistant to the toxicant. For example at Crofton, Anne Arundel County, Maryland USA was estimated at $110,000 for a 1.8 ha pond (CABI, 2017). In some cases, rotenone campaigns have failed. An attempt was made to eradicate *C. argus argus* in Arkansas in 2007 by U.S. Fish and Wildlife Service; however, the effort was unsuccessful and cost more than $750,000 (CABI, 2017). In general, the application of rotenone requires a carefully designed and scientifically expert guided approach.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Rotenone will kill all other fish not just the targeted species. In species-rich running waters the application will be difficult to control, especially when there are no or poor barriers to fish movement (i.e. weirs). Rotenone will not harm many higher animals (mammals, birds, reptiles) but some species are vulnerable, including some invertebrates (Turner et al., 2007). Certain water insects, such as some mayfly species may be much more sensitive. A rotenone treatment in a lake/pond or wetland results in much longer exposure to the chemical and a higher death rate of invertebrates compared to a stream treatment where the chemical gets rapidly flushed from the system after the treatment ends. As for amphibians, lethal concentrations of rotenone are species dependent, but in general amphibians are less sensitive than fish or some invertebrates (Ott, 2006). Despite routine use in the last two decades, there are still specific concerns for non-target species, especially invertebrates (Dalu et al. 2015). A review of published laboratory toxicity tests showed the following general results (Vinson & Vinson 2007): 1) there has been little rotenone toxicity work done on stream dwelling aquatic invertebrates, 2) there is a wide range of sensitivity both within and among taxonomic divisions, 3) benthic invertebrates appear less sensitive than planktonic invertebrates, 4) smaller invertebrates appear more sensitive than larger invertebrates, 5) aquatic invertebrates that use gills to extract aqueous oxygen appear more sensitive than invertebrates that acquire aqueous oxygen cutaneously, or through lamellae or spiracles, make use of respiratory pigments, or that can breathe atmospheric oxygen, 6) mortality was typically near 100% for rotenone x formulation concentrations >1 to 1.5 ppm for lotic invertebrates and >3 ppm for many lentic or aquatic adult insect taxa (e.g., Heteroptera, Coleoptera) depending on the exposure time.

	The human health risks for those undertaking the treatment are minimal if applied correctly. Rotenone ingestion through inhalation results in significantly higher toxicity, as there is a more direct pathway into the bloodstream. Therefore it is essential that appropriate respiratory protection is used while handling concentrated formulations containing rotenone during preparation of materials for piscicidal applications. Once the compound is diluted in the water column, the risk of ingestion via inhalation is insignificant because of the very low concentrations of rotenone added to the water, and the remote chance of humans, mammals, or birds aspirating treated water in huge quantities into the lungs (Ott, 2006).
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Chemical piscicides still have a negative public perception and a careful interpretation and communication strategy must be developed in any proposal for its use. Wildlife, fisheries and animal welfare advocates will often find the use of the chemical piscicides problematic and may object to this taking place in protected areas or other sites (Ott, 2006). Rotenone may become more acceptable as stakeholders become increasingly well informed and the science-guided restoration action is well communicated. Potassium permanganate is commonly used as a municipal water purification agent in instances where the addition of chlorine is not practical to disinfect water for drinking, because the by products are safe and largely non-toxic at the concentrations of intended use. Chemical piscicides, such as the use of rotenone, are not appropriate in some restoration projects, because of their low efficiency for the target species or because of the extensive damage they may cause to populations of other species.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Costs should include an information and interpretation campaign. It is important to consider that in most European countries a communication and interpretation framework must be developed for each treatment campaign; the public is usually sensitive to chemical treatments of water bodies.
Level of confidence [2] See guidance section	**Medium.** Although there are uncertainties, the available data and the extensive use experience with rotenone for fish control purposes indicate that it can be used safely. Beyond the intended target fish, some direct effects are expected on other fish species, certain aquatic invertebrates, primarily zooplankton, and indirect effects can be expected as well (Turner et al. 2007). An

	important aspect in any such campaign is a close linkage between the research and eradication programme. The research should monitor progress of the campaign and estimate of the variables necessary to model the population or institute adaptive management. This should allow improvements to be made in management techniques and strategy (Koike et al., 2006).

Rapid eradication - Measures to achieve rapid eradication after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**	
Measure description Provide a description of the measure	**Mechanical removal.** Eradication once the species is established is highly unlikely. However, if the population is low and the waterbody enclosed or semi-closed this may be achieved using a combination of overfishing approaches targeting the species. Mechanical removal of *Channa* species can be done by gill netting, seine netting, perhaps by fyke/hoop nets, and electrofishing. Protocols for removal are well developed for a wide variety of fishes including predatory fishes similar to *Channa* species (e.g West et al., 2007) but electrofishing is preferred because it has the least amount of bycatch and damage to native fish populations (Mueller, 2005). Electrofishing is practiced in boat, ground based, and back-pack methods (as routine sampling, see Schmutz et al., 2007); while nets include gill and siene nets; perhaps fyke/hoop nets are also effective. Angling is also locally effective in removing large numbers of these predatory fishes (Savior, 2016). Open season fishing for *Channa* species is a good incentive and the fish can be caught using various methods available to recreational and commercial fishermen. All fishers must humanely eliminate all captured individuals. Eradication campaigns may be most effective during particular parts of the year when many specimens may gather and make removal applications more accurately targeted. In temperate waters the spring spawning season prior to juvenile dispersal (Jiao et al., 2009) some species such as *Channa argus* -are least mobile (Lapointe et al., 2010). For *Channa argus* spawning occurs between May and July (CABI 2017). Habitat selection is the strongest during the spawning season, suggesting that locations likely to harbour *Channa argus* can be most easily targeted at this time of year. Mechanical removal may be the only way to treat a system where chemical piscicides cannot be applied. Angling and increased fishing effort by amateurs could also be part of the overfishing effort (Savior, 2016). Finally, the possibility of combing mechanical removal with drastic habitat alteration may also help or increase the synergistic pressures on an isolated population of large

	predatory fishes such as these. This approach is case-specific and would involve draining reservoirs or altering water levels to increase fish density and localize them in an enclosed waterbody.
Effectiveness of measure e.g. has the measure previously worked, failed	Low. Most researchers do not support that mechanical eradication can effectively cause extirpation (Mueller, 2005). Most species of this genus are tropical or subtropical and could survive only in warm, artificially heated or natural hot spring conditions. These species perhaps could be eradicated out if they are in a very small area through intensive mechanical removal (e.g. Piazzini et al., 2014), however there is no recorded evidence that this has ever been achieved.
Effort required e.g. period of time over which measure need to be applied to achieve rapid eradication	Probably very high effort is required, but this depends on nature of waterbody – (isolated or not) and its size and other case-specific circumstances (see for example, Mueller, 2005)
Resources required[1] e.g. cost, staff, equipment etc.	Site and situation specific. Depending on range of established populations and waterbody characteristics various resource and efforts are required. If the population is established in naturally limited are artificial warm-water conditions the campaign to eradicate may be focused and adaptive based on the response (monitoring within and adaptive framework is required). Each case is totally different and an estimation of resources is not easily possible. Usually campaigns of predatory fishes such as these may take years and be quite expensive, especially in open lotic waters (see Mueller, 2005). Costs of various electrofishing approaches have been well documented (Schmutz et al. 2007) however the precise costs of a campaign will depend on local conditions. Costs may be very high in larger water bodies, especially in river waterbodies. In the San Juan river, USA, predatory fish removal has continued for more than a decade, with costs rising to about $250,000 USD per year (Mueller, 2005).Moreover, synergies with fishing, angling and other removal/overfishing campaigns are sought in order to promote an overfishing effect on the populations (Savior, 2016).
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Negative: Gill nets and other fish-catching methods will kill or harm large numbers of non-targeted fishes and other aquatic species. In addition, a concern with the use of passive fishing gear is the unintended spread of invasive species while sampling. Biosecurity measures to decontaminate gear, boats, and other equipment used prior to moving among water bodies are advised and must be enforced. Positive: Encouraging the participation of anglers and amateur fishers will raise awareness.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Acceptability will depend on the specific situation and site. Mechanical removal using nets or other non-selective tools that harm fishes and other wildlife will be unacceptable to some stakeholders, especially in protected areas.

Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Extra costs depend on site specific conditions and plans for application. Due to the low chance of eradication this technique is probably low priority in terms of use. Costs of research and adaptive monitoring frameworks should also be considered and will vary widely (e.g. see Mueller, 2005; Propst et al. 2015).
Level of confidence [2] See guidance section	**Low.** Confidence for extirpation by mechanical means is poorly documented (CABI 2017). Extirpation may have taken place in the waters of eastern Europe but this is poorly documented (Holcik 1991).

Management - Measures to achieve management (cf. Article 19). This section assumes that the species is already established in a Member State, or part of a Member State's territory. **This table is repeated for each of the management measures identified.**	
Measure description Provide a description of the measure	**Mechanical removal to suppress populations** Several snakehead species can exist in warm temperate conditions. Both *Channa argus* and *C. maculata*, especially the former, can tolerate temperate climates, making the likelihood of their becoming established a probability even in some northern and central European countries if entry is made possible. Introductions into rivers, streams, or canal systems would likely allow spread whereas releases into lakes or ponds could be more restrictive as to range expansion (Courtenay & Williams, 2004: CABI, 2017). Snakeheads are capable of breathing air, many being obligate air breathers, and thus easily transported for long-periods (even without water as long as they are kept moist) (Courtenay & Williams, 2004: CABI, 2017). Control in a management framework to reduce population numbers once the species is established can be done using electrofishing, gill and seine nets and sometimes by traps (fyke/hoop nets). Efforts to control other similar sized fishes show that through moderate effort and resources applied systematically, mechanical removal can benefit some native fish species, but movement of the predatory species from surrounding areas into removal reaches necessitates continued control efforts. Control has to be studied and be adaptive (Mueller, 2005). Researching the natural history of the species and the case specific behaviours is critically important to increase efficacy of the effort. Control may be most effective during the spawning season prior to juvenile dispersal (Jiao et al., 2009) when, some species such as *Channa argus* are least mobile (Lapointe et al., 2010). Habitat

	selection is the strongest during the spawning season, suggesting that locations likely to harbour *Channa argus* can be most easily targeted at this time of year. If they are detected when established, efforts at overfishing may assist in keeping the population low and confining it within a specific area at low density. Furthermore, beyond depressing local populations, mechanical removal may also facilitate the creation of predator-free zones that may assist native species to increase populations (see for example, Mueller, 2005). This could be combined with creating barriers to *Channa* species dispersal if site conditions allow. For details on different mechanical removal methods, please see the Eradication - mechanical removal table above. In the USA, recreational anglers have been used to help manage the population of snakehead species. Proposals have been made to promote angling and that the caught fish must be kept or killed. Fishing contests have also caught large numbers of snakeheads. Giving the fish legitimacy as a good sporting fish species could increase its popularity and increase the fishing pressure on the species (Savior, 2016).
Effectiveness of measure e.g. has the measure previously worked, failed	Generally, results are still poorly reported even though *Channa* has received much attention in the USA (see Savior, 2016). As a management measure, even small intensive campaigns can have a positive effect in some cases. In the USA Propst et al. (2014) report that an annual 4- to 5-day intensive removal effort of predatory fishes in a small river open to immigration, several non-native species could be reduced, and in doing so, at least one native threatened species benefitted.
Effort required e.g. period of time over which measure need to be applied to have results	Effort must necessarily be high to lower predatory fish populations but approaches vary depending on waterbody type and conditions (e.g. Propst et al. 2014). This exclusively depends on site specific conditions. The time period (ranging from at least 12 months to indefinitely) will depend on the local strategy for containment. In most cases, these measures need to be indefinite to permanently suppress populations in order to have desired results on biodiversity and ecological restoration targets.
Resources required [1] e.g. cost, staff, equipment etc.	Costs of mechanical removal in areas were predatory fish species have established may be forseen for a wider variety of alien fish species not just the snakehead species. Depending on the conditions of the situation (i.e. warm water conditions for tropical/subtropical species) or wider areas and varied water bodies for *Channa argus* different costs and resources will required. A standard method is electrofishing, where sampling costs are reasonable compared to gill-netting (i.e. between 380 € to 2,900 € per 100 meter of lotic ecosystem sample (Schmutz, 2007)).

	Propst et al. (2014) report the following: Field crews were composed of summer interns, technicians, staff biologists and supervisors, with a commensurate salary range. Collectively, daily salary and benefits for the field crew was about \$3300 for a 10-h day (includes per diem, \$30 per person). Equipment and supply costs were not included, but vehicle expenses were estimated at \$250 each for the five vehicles used each year (4-5 days survey work per year). Expenses associated with obtaining reference site data were not included in total annual cost estimates, nor were planning and data compilation and synthesis costs.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Negative: Nets and traps are problematic as they may have serious impacts upon native biodiversity and species of conservation importance. Gill nets and fyke nets kill large numbers of non-targeted fish and other wildlife. A serious problem associated with many passive entanglement and entrapment gears is continued capture of animals by the gear if it is lost—a process called ghost fishing.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	**Medium**. Relative to chemical treatment, removal by mechanical means should have higher acceptability among stakeholders. Electrofishing is usually approved of by the general public. In protected areas or areas of high amenity values public perception may be against using gillnets, fyke nets or traps that will have high bycatch.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Depending on the case-specific situation specific management plans / action plans for management should be developed. Mechanical removal has poor cost-effectiveness since it is poorly known if it will suppress *Channa* spp. populations sufficiently to have an effect. Cost of inaction is greater for the temperate water species such as *Channa argus* which could spread and become invasive. The tropical *Channa* species could become a local scale problem in warmer waters. No other socio-economic or cost aspects can be foreseen without reference to specific conditions and circumstances (which will most probably be local upon early detection of the species).
Level of confidence [2] See guidance section	**Low**. There are few successful experiences of effective control of alien fish populations with respect to *Channa* species. Existing experiences are limited to small water bodies (ponds etc).

Bibliography [3]

See guidance section

Adamson, E.A.S., Hurwood, D.A. & Mather, P.B. (2010). A reappraisal of the evolution of Asian snakehead fishes (Pisces, Channidae) using molecular data from multiple genes and fossil calibration. *Molecular Phylogenetics and Evolution*, 56 (2), 707–717.

Almeida, D., Ribeiro, F., Leunda, P. M., Vilizzi, L., & Copp, G. H. (2013). Effectiveness of FISK, an invasiveness screening tool for non‐native freshwater fishes, to perform risk identification assessments in the Iberian peninsula. *Risk Analysis*, 33(8), 1404-1413.

Ardura, A., & Planes, S. (2017). Rapid assessment of non-indigenous species in the era of the eDNA barcoding: A Mediterranean case study. *Estuarine, Coastal and Shelf Science*, 188, 81-87.

Azevedo-Santos, V. M., Pelicice, F. M., Lima-Junior, D. P., Magalhães, A. L. B., Orsi, M. L., Vitule, J. R. S., & Agostinho, A. A. (2015). How to avoid fish introductions in Brazil: education and information as alternatives. *Natureza & Conservação*, 13(2), 123-132.

CABI (2017). *Channa argus argus* (northern snakehead). In: Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.

Copp, G. H., Godard, M. J., Russell, I. C., Peeler, E. J., Gherardi, F., Tricarico, E., ... & Vilizzi, L. (2016). A preliminary evaluation of the European Non‐native Species in Aquaculture Risk Assessment Scheme applied to species listed on Annex IV of the EU Alien Species Regulation. *Fisheries management and ecology*, *23*(1), 12-20.

Courtenay, W. R., & Williams, J. D. (2004). Snakeheads (Pisces, Channidae): a biological synopsis and risk assessment (Vol. 1251). US Geological Survey.

Cudmore, B., & Mandrak, N.E. (2006). Risk assessment for northern snakehead (*Channa argus*) in Canada. Canadian Science Advisory Secretariat, Department of Fisheries and Oceans, Ottawa, ON, Canada.

Dalu, T., Wasserman, R. J., Jordaan, M., Froneman, W. P., & Weyl, O. L. (2015). An assessment of the effect of rotenone on selected non-target aquatic fauna. *PloS one*, 10(11), e0142140.

Davy, C. M., Kidd, A. G., & Wilson, C.C. (2015). Development and validation of environmental DNA (eDNA) markers for detection of freshwater turtles. *PloS one*, 10(7), e0130965.

Deputy Direction of Nature (Spanish Ministry of Agriculture and Fisheries, Food and Environment). 2016. EU non-native species risk analysis – risk assessment *Channa* spp.

Evans, N. T., Shirey, P. D., Wieringa, J. G., Mahon, A. R., & Lamberti, G. A. (2017). Comparative cost and effort of fish distribution detection via environmental DNA analysis and eectrofishing. *Fisheries*, 42(2), 90-99.

European Commission (2007) Commission Regulation (EC) No 708/2007 concerning use of alien and locally absent species in aquaculture. Official Journal of the European Union (28.6.2007) L 168/1.

Froese, R. & D. Pauly. Editors. (2017). FishBase. World Wide Web electronic publication. www.fishbase.org, version (06/2017).

Furlan, E. M., Gleeson, D., Hardy, C. M., & Duncan, R. P. (2016). A framework for estimating the sensitivity of eDNA surveys. *Molecular ecology resources*, *16*(3), 641-654.

Global Invasive Species Database. (2017). Species profile: *Channa argus*. Downloaded from http://www.iucngisd.org/gisd/species.php?sc=380 on 11-01-2017.

Goffaux, D., Grenouillet, G., & Kestemont, P. (2005). Electrofishing versus gillnet sampling for the assessment of fish assemblages in large rivers. *Archiv für Hydrobiologie*, 162(1), 73-90.

Gren, I. M. (2008). Economics of alien invasive species management-choices of targets and policies. *Boreal environment research*, 13, 17-32.

Gurumayum, S.D., & Tamang, L. (2016). *Channa pomanensis*, a new species of snakehead (Teleostei: Channidae) from Arunachal Pradesh, northeastern India. *Species*, 17(57), 175-186

Hardin, S. (2007). "Managing Non-Native Wildlife In Florida: State Perspective, Policy And Practice" Managing Vertebrate Invasive Species. 14.http://digitalcommons.unl.edu/nwrcinvasive/14

Helfman, G. S. (2007). *Fish conservation: a guide to understanding and restoring global aquatic biodiversity and fishery resources*. Island Press.

Holcik, J. (1991). Fish introductions in Europe with particular reference to its central and eastern part. *Canadian Journal of Fisheries and Aquatic Science,* 48, (Suppl. 1):13-23.

Hoffman, J.C., Kelly, J.R., Trebitz, A.S., Peterson, G.S. and West, C.W., (2011). Effort and potential efficiencies for aquatic non-native species early detection. *Canadian journal of fisheries and aquatic sciences*, 68(12), 2064-2079.

Jiao, Y., N. W. R. Lapointe, P. L. Angermeier, & Murphy B. R. (2009). Hierarchical demographic approaches for assessing invasion dynamics of non-indigenous species: an example using northern snakehead (*Channa argus*). *Ecological Modelling*, 220, 1681-1689.

Koike, F., Clout, M. N., Kawamichi, M., De Poorter, M. &Iwatsuki, K. (eds). (2006). Assessment and Control of Biological Invasion Risks. SHOUKADOH Book Sellers, Kyoto, Japan and the World Conservation Union (IUCN), Gland, Switzerland. 216pp.

Lapointe, N. W. R., Thorson, J. T., & Angermeier, P. L. (2010). Seasonal meso-and microhabitat selection by the northern snakehead (*Channa argus*) in the Potomac river system. *Ecology of Freshwater Fish*, 19(4), 566-577.

Lazur, A., Early, S. & Jacobs, J.M., (2006). Acute toxicity of 5% rotenone to northern snakeheads. *North American Journal of Fisheries Management*, 26(3), 628-630.

Leese F, Altermatt F, Bouchez A, Ekrem T, Hering D, … & Zegura B (2016). DNAqua-Net: Developing new genetic tools for bioassessment and monitoring of aquatic ecosystems in Europe. *Research Ideas and Outcomes,* 2: e11321.

Leung M., & Von Finster, A. (2016). *Development of a framework for management of aquatic invasive species of concern for Yukon: Literature review, risk assessment and recommendations*. Prepared for Environment Yukon. Yukon Fish and Wildlife Branch Report MRC-14-01, Whitehorse, Yukon, Canada.

Maceda-Veiga A., Escribano-Alacid J., de Sostoa A. & García-Berthou E. (2013). The aquarium trade as a potential source of fish introductions in southwestern Europe. *Biological Invasions,* 15: 2707–2716

Mahala, M. (2008). Kentucky Aquatic Nuisance Species Management Plan. Commonwealth of Kentucky, Kentucky Department of Fish and Wildlife. Kentucky, USA.

Michelin G, Heckly X, & Rigaux B. (2011). Rapport d’etude – ADN Environnemental, Detection de l’Espece Exotique Envahissante Grenouille Taureau. Sologne, France.

Mueller, G. A. (2005). Predatory fish removal and native fish recovery in the Colorado River main stem: what have we learned? *Fisheries*, 30(9), 10-19.

Odenkirk, J.S. & Isel, M.W. (2016). Trends in abundance of northern snakeheads in the Virginia tributaries of the Potomac River. *Transactions of the American Fisheries Society*, 145(4).

Ornamental Aquatic Trade Association (2017). *Channa* under the spotlight for EU Ban. Davey, P. Monday, July 31, 2017. https://ornamentalfish.org/channa-spotlight-eu-ban/

Ott, K.C., (2006). Rotenone. A brief review of its chemistry, environmental fate, and the toxicity of rotenone formulations. Unpublished summary. http://www.newmexicotu.org/Rotenone%20summary.pdf

Papavlasopoulou, I., Vardakas, L., Perdikaris, C., Kommatas, D., & Paschos, I. (2014). Ornamental fish in pet stores in Greece: a threat to biodiversity? *Mediterranean Marine Science*, 15(1), 126-134.

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

Poulos H.M., Chernoff B., Fuller P.L. & Butman D. (2012). Ensemble forecasting of potential habitat for three invasive fishes. *Aquatic Invasions* Volume 7, Issue 1: 59–72

Propst, D. L., Gido, K. B., Whitney, J. E., Gilbert, E. I., Pilger, T. J., Monié, A. M., ... & Myers, D. M. (2015). Efficacy of mechanically removing nonnative predators from a desert stream. *River research and applications*, *31*(6), 692-703.

Roy, M., Belliveau, V., Mandrak, N. E., & Gagné, N. (2017). Development of environmental DNA (eDNA) methods for detecting high-risk freshwater fishes in live trade in Canada. *Biological Invasions*, doi.org/10.1007/s10530-017-1532-z

Savior, T., (2016). Angler Perception and Population Dynamics of the Invasive Northern Snakehead (Channa argus) in the Potomac River & Tributaries. Thesis submitted in partial fulfilment of the requirements of the Gemstone Program University of Maryland 2016, Maryland, USA.

Schmutz, S., Cowx, I. G., Haidvogl, G., & Pont, D. (2007). Fish‐based methods for assessing European running waters: a synthesis. *Fisheries Management and Ecology*, 14(6), 369-380.

Serrao NR, Steinke D, & Hanner RH (2014). Calibrating sakehead diversity with DNA Barcodes: Expanding taxonomic coverage to enable identification of potential and established invasive species. *PLoS ONE* 9(6): e99546. doi:10.1371/journal.pone.0099546

Simmons, M., Tucker, A., Chadderton, W.L., Jerde, C.L. & Mahon, A.R., (2015). Active and passive environmental DNA surveillance of aquatic invasive species. *Canadian Journal of Fisheries and Aquatic Sciences*, 73(1), pp.76-83.

Smith, R.K., Meredith, H. & Sutherland, W.J. (2017) Amphibian Conservation. Pages 9-65 in: W.J. Sutherland, L.V. Dicks, N. Ockendon & R.K. Smith (eds) What Works in Conservation 2017. Open Book Publishers, Cambridge, UK. https://www.conservationevidence.com/actions/828

Thomsen, P. F., & Willerslev, E. (2015). Environmental DNA–An emerging tool in conservation for monitoring past and present biodiversity. *Biological Conservation*, 183, 4-18.

Turner, L., Jacobson, S. & Shoemaker, L. (2007). Risk assessment for piscicidal formulations of rotenone. Compliance Services International, Lakewood, p.25.

Verbrugge, L.N.H., Leuven, R.S.E.W., van Valkenburg, J.L.C.H. & van den Born, R.J.G. (2014). Evaluating stakeholder awareness and involvement in risk prevention of aquatic invasive plant species by a national code of conduct. *Aquatic Invasions*, 9: 369-381.

Vinson, M.R. & Vinson, D.K. (2007). An analysis of the effects of rotenone on aquatic invertebrate assemblages in the Silver King Creek Basin, California. Unpublished report prepared for U.S. Forest Service Humboldt-Toiyabe National Forest Carson City, NV, USA.

West, P., Brown, A. & Hall, K. (2007). Review of alien fish monitoring techniques, indicators and protocols: Implications for national monitoring of Australia's inland river systems. Invasive Animals Cooperative Research Centre, Canberra, Australia.

Wynne, F & Masser, M.P. (2010). Removing fish from ponds with rotenone. SRAC Publication No. 4101 (Available at: http://fisheries.tamu.edu/files/2013/09/SRAC-Publication-No.-4101-Removing-Fish-from-Ponds-with-Rotenone.pdf)

Websites:

- 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
- www.tropicalfishfinder.co.uk/stores/products?store=54&cat=61
- www.ebay.com/sch/Live-Aquarium-Fish/168141/bn_827528/i.html?_fsrp=1http://news.bbc.co.uk/2/hi/uk_news/england/lincolnshire/7252908.stm
- http://www.aquaticcommunity.com/channa/burmanica.php
- https://www.conservationevidence.com/actions/828
- https://www.monsterfishkeepers.com/forums/threads/identification-help-channa-andrao-or-bleheri.684779/
- https://www.monsterfishkeepers.com/forums/threads/albino-channa-argus.672884/
- http://www.bigfishcampaign.org/species_of_concern.html

Notes

1. Costs information. The cost information depends on the information available.

2. Level of confidence provides an overall assessment of the confidence that can be applied to the information provided for this method.

- **High**: Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third country with similar environmental, economic and social conditions.
- **Medium**: Information comes from published data or expert opinion, but it is not commonly applied, or it is applied in regions that may be too different from Europe (e.g. tropical regions) to guarantee that the results will be transposable.
- **Low**: data are not published in reliable information sources and methods are not commonly practiced or are based soley on opinion; This is for example the case of a novel situation where there is little evidence on which to base an assessment.

3. Citations and bibliography. The APA formatting style for citing references in the text and in the bibliography is used.
e.g. Peer review papers will be written as follows:
In text citation: (Author & Author, Year)
In bibliography: Author, A. A., & Author, B. B. (Publication Year). Article title. *Periodical Title*, Volume(Issue), pp.-pp.

(see http://www.waikato.ac.nz/library/study/referencing/styles/apa)