Northern Snakehead (*Channa argus*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, September 2017
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1 Native Range and Status in the United States

Native Range

From Froese and Pauly (2017):

"Asia: Amur southward to Xi Jiang and Hainan Island, China [Bogutskaya et al. 2008]."

From Fuller et al. (2017):

"China, Russia and Korea (Courtenay and Williams 2004). More specifically, the northern snakehead is found in the lower Amur River basin, including the Ussuri River basin and Khanka

Lake; the Sungari River in Manchuria; and, the Tungushka River at Khaborovsk, Russia. It is native to all but the northeastern regions of Korea, as well as the rivers of China, southward and southwestward to the upper tributaries of the Yangtze River basin in northeastern Yunnan Province (Courtenay and Williams 2004)."

Status in the United States

From Fuller et al. (2017):

"**Nonindigenous Occurrences:** The first report of this species in the United States came from Silverwood Lake, **California** in 1997 (Courtenay and Williams 2004). Two fish were captured from the St. Johns River below Lake Harney in **Florida** early in 2000. There were unconfirmed reports of another 3 fish nearby. A specimen was collected in Lake Michigan, Burnham Harbor in downtown Chicago, **Illinois** in 2004 (D. Chapman, pers. comm.). In June 2002, an established population of this species was discovered in a pond in Crofton, **Maryland**. This population was eradicated by state biologists using rotenone. Fish have been reported from two locations in **Massachusetts**; once in 2001 and again in 2004. In July 2005, they were reported in Meadow Lake in Queens, **New York** and persisted in 2006 (J. Pane, pers. comm.). In late May and early June 2008, three snakeheads were collected from stream in Wawayanda, New York (M. Flaherty, pers.comm.). An attempt was made to eradicate this population in 2008."

"Two fish were reportedly caught by anglers in August 2002 from Lake Wylie, **North Carolina**. Five years later in 2007, a large adult was caught by a fisherman in South Fork Catawba River in North Carolina (J. Rash, pers. comm.). In July 2004, several individuals were captured from a pond in FDR Park in Philadelphia, **Pennsylvania**. The following year young snakeheads were captured in the park pond (R. Worthington-Kirsch, pers. comm.). In June 2008, a specimen was collected by the city water department from the Schuylkill River in Philadelphia (J. Perillo, pers. comm.)."

"Beginning in April 2004, several fish were captured from the Potomac River in **Maryland** and **Virginia**. Although it was originally thought that these fish may have originated from the Crofton pond population, genetic evidence showed that this was an unrelated introduction (Starnes et al. 2011). The Potomac River population now extends throughout the lower Potomac from Great Falls to the mouth, including some tidal portions with moderate salinity (up to 7.6 ppt; Starnes et al. 2011). Another specimen was collected in Dogue River in Fairfax County, Virginia. A fish was collected from Massey Creek and in 2005 a breeding female was found in Little Hunting Creek, a tributary of the Potomac, **Virginia**. Many others have been collected in 2006 and 2007 in the Potomac basin centering around Dogue and Little Hunting creeks in Virginia and from the Anacostia River in **Maryland** (J. Odenkirk, pers. comm.). In April 2008, the discovery of a single specimen in a ditch near Monroe, **Arkansas**, led to the determination that a population appears to be established (L. Holt, pers. comm.). Their first appearance in **New Jersey** occurred in Delaware River tributaries as early as 2009; they have been caught by fisherman from nearly a dozen streams (C. Smith, pers. comm.). They began to be seen in the state of **Delaware** in 2010 (C. Martin, pers. comm.) and have been collected from both the lower Delaware and lower Chesapeake drainages. In June of 2017, a single specimen was caught while bowfishing in Lake Whittington, an oxbow lake of the Mississippi River in the state of **Mississippi** (D. Riecke, personal communication)."

"**Status:** Established in the United States. Not established in the Great Lakes."

"*Channa argus* is established in Virginia, Maryland, Pennsylvania, New York, and Arkansas, but is **not** established in California, Florida, Illinois, Massachusetts, Delaware, and North Carolina where a few individual fish have been collected. However, the northern snakehead was eradicated from the Crofton pond in Maryland where it was established. The species is well established in the Potomac River and several of its tributaries in Virginia and Maryland (Starnes et al. 2011). Although young fish were found, the status of the Philadelphia population is uncertain. Officials believe fish may have gotten into the lower Schuylkill River and Delaware River in Pennsylvania and see no practical means to eradicate them."

"In March 2009, eradication of the population in Little Piney Creek, Arkansas drainage was attempted through the application [of] rotenone to more 700 km of creeks, ditches, and backwaters (Holt and Farwick 2009); however specimens were collected in Piney Creek later that year, indicating eradication had not been complete (L. Holt, pers. comm.). […] The population in Catlin Creek, New York was also treated with rotenone."

From CABI (2017):

"Additional collections of snakeheads were made […] with an unconfirmed report from Rockport, Texas as well."

From Courtenay and Williams (2004):

"At least 14 states [Alabama, Arizona, California, Colorado, Florida, Kentucky, Georgia, Idaho, Mississippi, Nevada, Oregon, Texas, Utah, Washington] specifically prohibited possession of live snakeheads […] prior to […] September 2002. Since then, the states of Arkansas, Connecticut, Illinois, North Carolina, Rhode Island, Pennsylvania, South Carolina, Tennessee, and Virginia have made possession of live channids illegal […]. Indiana Department of Natural Resources approved emergency fisheries regulations on November 22, 2002, that bans possession of snakeheads effective December 1, 2002. Kansas Department of Wildlife and Parks prohibited possession of snakeheads in early 2003."

"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 of the family Channidae was published in the Federal Register on October 4, 2002 (67 FR 62193). This ruling 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."

Thus, as of October 4, 2012, the importation of all species of snakeheads, family Channidae, were prohibited from importation into the United States. [Note: On April 7, 2017, a court ruled that an injurious listing does not prohibit transport of injurious wildlife between States within the continental United States (U.S. Fish and Wildlife Service 2017a).]

Means of Introductions in the United States

From Fuller et al. (2017):

"According to the Northern Snakehead Working Group (NSWG) of the U.S. Fish and Wildlife Service, northern snakehead likely arrived in U.S. waters by importation for the live food fish market (NSWG 2006). Unauthorized intentional release from this trade, as was the case in the founding individuals of the Crofton pond population in Maryland, continues to be the major mechanism for introduction (Courtenay and Williams 2004). The northern snakehead has become widely popular in ethnic markets and restaurants over the last two decades, such that this species comprised the greatest volume and weight of all live snakehead species imported into the U.S. until 2001 (Courtenay and Williams 2004, NSWG 2006)."

"[…] cases of northern snakehead for sale in areas where possession is illegal are not uncommon (NSWG 2006). Accidental release during transport of live fish is possible, but its probability is unknown (Mendoza-Alfaro et al. 2009)."

"Historical imports to the U.S. have come from a wide range of source populations, including Nigeria, Thailand, Indonesia, China, and Korea (NSWG 2006). Orrell and Weigt (2005) found seven unique mitochondrial DNA haplotypes, none of which were shared, among the five U.S. populations they surveyed, indicating separate introduction events and source populations for each. Such high genetic diversity among introduced populations can promote their establishment and spread (Lee 2002, Sanders 2010)."

From Courtenay and Williams (2004):

"[…] we found a few U.S. aquarium fish retailers that sell snakeheads via the Internet. Three species were purchased from a reputable dealer in Rhode Island who requested a copy of our permit to possess certain restricted fishes, including snakeheads. Private purchases can also be made through several Internet "chat rooms" where possession of permits is doubtlessly of no concern."

"It remains unknown if the snakehead was released into Silverwood Lake [California] or arrived through the California Aqueduct. The aqueduct has been the source of other fishes in the reservoir […]"

From GISD (2017):

"*Channa argus* was cultured on three fish farms in Arkansas until their importation, culture, sale and possession was made illegal by the Arkansas Fish and Game Commision in August 2002 (Courtenay & Williams 2004, NSWG 2006). Accidental release from one fish farm caused *C. argus* to become established in the wild."

Remarks
From Fuller et al. (2017):

"**Synonyms and Other Names:** Amur snakehead, eastern snakehead, ocellated snakehead, snakehead, *Ophicephalus argus* Cantor, 1842; *Ophiocephalus argus kimurai* Shih, 1936; *Ophicephalus argus warpachowskii* Berg, 1909; *Ophicephalus pekinensis* Basilewsky, 1855."

"A specimen collected from Lake Wylie, North Carolina, in 2009 was originally identified as *Channa argus*, but later genetic work combined with a closer morphological analysis determined the specimen to be *Channa maculata* (NCSM 53258; W. Starnes, personal communication)."

From CABI (2017):

"The potential to eradicate or control snakehead populations depends on dispersal location and the level of establishment. If broadly dispersed in large lakes or river systems, eradication or control would likely be impossible. Management options for population control within smaller waterbodies are dependent upon the amount of aquatic vegetation, accessibility of the waterbody, and the effectiveness of the control techniques employed (Hoffman, 2002)."

"Effective removal strategies for established populations of snakehead must rely on several methods to eradicate the species from non-native waterbodies due to their uncommon biological attributes. Chemical removal using piscicides, such as Rotenone, which acts to impede oxygen availability to fish may not be very effective against *C. argus argus* due to its ability for air breathing and would likely only result in the removal of non-target species; however, it was a successful eradication method for the Crofton ponds in Maryland […]. Similarly, electrofishing and netting would provide a level of population control, however, would be ineffective across all size classes."

From Hashimoto et al. (2012):

"A significant portion of the 324 million kg of snakehead produced in China in 2008 was in the form of hybrids between *Channa argus* (Cantor 1842) and *Channa maculata* (Lacepède 1801)."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing
From ITIS (2017):

"Taxonomic Status: Current Standing: valid"

"Kingdom Animalia
 Subkingdom Bilateria
  Infrakingdom Deuterostomia
   Phylum Chordata
    Subphylum Vertebrata
     Infraphylum Gnathostomata

Superclass Actinopterygii
Class Teleostei
Superorder Acanthopterygii
Order Perciformes
Suborder Channoidei
Family Channidae
Genus *Channa*
Species *Channa argus* (Cantor, 1842)
Direct Children:
Subspecies *Channa argus argus* Cantor, 1842
Subspecies *Channa argus warpachowskii* (Berg, 1909)"

Size, Weight, and Age Range

From Froese and Pauly (2017):

"Maturity: L_m 30.0 range ? - ? cm
Max length : 100.0 cm TL male/unsexed; [Novikov et al. 2002]; max. published weight: 8.0 kg [Novikov et al. 2002]"

From CABI (2017):

"The northern snakehead is a long-lived fish species, with one specimen recorded as attaining eight years of age and a length of 760 mm TL (Courtenay and Williams, 2004; Froese and Pauly, 2009; Galveston Bay Invasive Species Risk Assessment, 2002)."

From Courtenay and Williams (2004):

"Nina Bogutskaya (personal commun., 2002) stated she had seen a specimen of *C. argus* that was almost 1.5 m in length, also indicating a relatively long-lived species."

Environment

From Froese and Pauly (2017):

"Freshwater; benthopelagic."

From CABI (2017):

"Water Tolerances

Parameter	Minimum Value	Maximum Value	Typical Value	Status	Life Stage	Notes
Dissolved oxygen (mg/l)	5	8		Optimum	Adult	
Salinity (part per thousand)			0	Optimum	Adult	
Water pH (pH)	6.0	7.5		Optimum	Adult	[…]"

From Fuller et al. (2017):

"*Channa argus* is an obligate air-breather, capable of survival in poorly oxygenated waters. […] Reduced metabolism and oxygen demand at low temperatures allows this species to survive extended periods of ice cover (Frank 1970, in Courtenay and Williams 2004). Upper salinity tolerances have been experimentally determined to be between 15 and 18 ppt (at temperatures of 15-24°C; NSWG 2006)."

Climate/Range

From Froese and Pauly (2017):

"Subtropical; 4°C - 22°C [Baensch and Riehl 1985]; 54°N - 25°N, 111°E - 141°E"

From Fuller et al. (2017):

"While its optimum maximum air temperature range is 5-16°C (Herborg et al. 2007), the northern snakehead has a wider latitudinal range and temperature tolerance (0 to >30°C, including frost days) than other snakehead species (Dukravets and Machulin 1978, in Courtenay and Williams 2004; Okada 1960)."

Distribution Outside the United States

Native

From Froese and Pauly (2017):

"Asia: Amur southward to Xi Jiang and Hainan Island, China [Bogutskaya et al. 2008]."

From Fuller et al. (2017):

"China, Russia and Korea (Courtenay and Williams 2004). More specifically, the northern snakehead is found in the lower Amur River basin, including the Ussuri River basin and Khanka Lake; the Sungari River in Manchuria; and, the Tungushka River at Khaborovsk, Russia. It is native to all but the northeastern regions of Korea, as well as the rivers of China, southward and southwestward to the upper tributaries of the Yangtze River basin in northeastern Yunnan Province (Courtenay and Williams 2004)."

Introduced

From Froese and Pauly (2017):

"**Year / Period**	**From**	**To**	**Established**	**Ecol. effects**
unknown	Unknown	Czechoslovakia	probably not established	
unknown	Unknown	California, Florida, Maryland	established	probably some
1960-1965	China	Uzbekistan	established	
1923	Korea	Japan	established	some
1949	Unknown	USSR	probably not established	

“Year / Period	From	To	Established	Ecol. effects
1956	Unknown	Czech Republic	unknown	unknown
1996	Unknown	Germany	unknown	unknown”

From GISD (2017):

“In the 1960s it was introduced into the Aral Sea basin and has become widespread in that basin s [*sic*] rivers including the Amu Dar ya, Syr Dar ya, and Kashka-Dar ya rivers of Kazakhstan, Turkmenistan and Uzbekistan (Dukravets and Machulin 1978, Usmanova 1982, Guseva 1990, Dukravets 1992, in Courtenay & Williams 2004).”

From CABI (2017):

“*C. argus argus* has been introduced to non-native locations in China and Russian Federation […]”

“The presence of this species in the upper reaches of the Bei (Beijiang) River, Guangdong Province, China, is apparently the result of an introduction (Pearl River Fisheries Research Institute, 1991). It was unintentionally introduced from Korea in the early 1900s and has become successfully established in many waters of central and southern Japan including Hokkaido, Honshu, Kyushu, and Shikoku (Nakamura, 1963; Uyeno and Akai, 1984; Okada, 1960; Courtenay and Williams, 2004).”

Means of Introduction Outside the United States

From GISD (2017):

“The northern snakehead is a popular aquarium fish in Europe and Japan […] Some introductions are believed to be the result of intentional release of aquarium fish as they are very expensive to feed and soon outgrow their aquaria (Courtenay & Williams 2004)[.] Many introductions of the northern snakehead are believed to be the result of intentional release of fish obtained from the live food trade (Courtenay & Williams 2004).”

“*Channa argus* was introduced to Japan from Korea as a sport fish in 1923 […]”

“[Kazakhstan:] Imported accidentally in another shipment of fish”

From CABI (2017):

“The northern snakehead, due to their aggressive nature and strength, have been introduced into a number of locations for culture as a sport fish (Courtenay and Williams, 2004).”

“The initial introduction of the northern snakehead to Russia was unintentional and was as a result of contamination in stocking phytophagous cyprinids (grass carp, *Ctenopharyngodon idella*, and silver carp, *Hypophthalmichthys molitrix*), destined for aquaculture in ponds adjacent to the Syr Dar’ya River. Snakeheads escaped from the ponds in 1964 and soon became established in the Syr Dar’ya (Amanov, 1974). Many other examples exist where snakeheads, which have a strong tendency to escape from ponds, have been introduced and then escaped and subsequently dispersed to new water bodies resulting in the establishment of new populations."

Short Description

From GISD (2017):

"The body of snakeheads is torpedo-shaped, which tapers towards the tail. They have a single, long dorsal fin, a long anal fin, and a small head with a large mouth (Cudmore & Mandrak 2006). […] As the name implies, the scaled head of the fish looks like a snake; they have a large mouth with sharp teeth, a truncated, not rounded tail and are easily identified by dark irregular blotches along their sides (Sea Grant Pennsylvania 2007) on a background of golden tan to pale brown. This fish is capable of darkening its background colors to the point of almost obscuring the blotches. There is a dark stripe from just behind the eye to the upper edge of the operculum with another dark stripe below from behind the orbit extending to the lower quadrant of the operculum. Coloration of juveniles is virtually the same as in adults, a characteristic atypical for many snakehead species."

"Gular part of head without patch of scales; head somewhat depressed anteriorly; interorbital area flat; eye above middle of upper jaw; mouth large, reaching far beyond eye; villiform teeth present in bands with some large canine-like teeth on lower jaw and palatines; lateral line scales 60 to 67; eight scale rows above lateral line to dorsal fin origin; 12 to 13 scale rows below lateral line to anal fin origin; dorsal fin elongated, with 49 to 50 rays; anal fin with 31 to 32 rays; origin of pelvic fin beneath fourth dorsal fin ray; pectorals extending beyond base of pelvic fins (Courtenay & Williams 2004)."

From Fuller et al. (2017):

"Snakeheads (family Channidae) are morphologically similar to the North American native Bowfin (*Amia calva*), and the two are often misidentified. Snakeheads can be distinguished from Bowfin by the position of pelvic fins (directly behind pectoral fins in snakeheads, farther back on body in Bowfin) and the size of the anal fin (elongate and similar in size to dorsal fin in snakeheads, short and much smaller than dorsal fin in Bowfin). Additionally, Bowfin can be identified by the presence of a bony plate between the lower jaws (gular plate) and a distinctive method of swimming through undulation of the dorsal fin."

From CABI (2017):

"The northern snakehead is similar in colouration to the blotched snakehead, *Channa maculata*. The two species are most easily differentiated by the dark markings observed on the caudal peduncle. In *C. maculata*, the most posterior dark mark is a bar-like shape and is bordered by pale, bar-like areas, whereas, in *C. argus argus*, the final bar is more irregular in shape and lacks the pale areas preceding and following the blotch (Courtenay and Williams, 2004)."

"Burbot (*Lota lota*) are also similar in appearance to the northern snakehead but they have a split dorsal fin, the origin of the pelvic fins insert anterior to the pectoral fins, and they possess a single barbel on the lower jaw."

Biology

From Fuller et al. (2017):

"Although this species prefers to live in stagnant shallow (< 2 m) ponds or swamps with mud substrate or aquatic vegetation and slow muddy streams, it also occurs in canals, reservoirs, lakes, and rivers (Courtenay and Williams 2004). This species does show some seasonal changes [in] microhabitat selection and preference, utilizing deeper water in winter months and shallow areas with macrophytes during the spawning season (Lapointe et al. 2010). It can adapt to a wide range of aquatic environments, as evidenced by the spread of reproducing, introduced populations throughout Asia and Japan."

"Although the northern snakehead can survive up to four days out of the water, overland migration is only possible for juveniles (Courtenay and Williams 2004). The rounded body of the adult northern snakehead is not as conducive to overland migration as observed in more horizontally flattened snakehead species."

"In its native range, reproductive maturity is typically reached when fish are 2-3 years old (Dukravets and Machulin 1978), but may occur only after one year of growth in some introduced populations (USACE 2011). In the U.S., northern snakehead spawning has been observed to start by the end of April, peak in June, and continue through August (Gascho [Landis] et al. 2011). Adult females build circular floating nests from clipped aquatic plants and release their pelagic, nonadhesive, buoyant eggs on top (Gascho Landis and Lapointe 2010). Each spawn can consist of 1300-1500 bright orange-yellow eggs (about 1.8 mm diameter), with up to five spawns occurring within a year. Northern snakehead fecundity can range from 22,000-51,000 in its native range (Amur River basin; Nikol'skiy 1956) to 28,600-115,000 in an introduced population (Syr Dar'ya basin, Turkmenistan/Uzbekistan; Dukravets and Machulin 1978). Both parents guard the nest of eggs from predation and continue to guard the hatched fry for several additional weeks (Courtenay and Williams 2004, Gascho Landis and Lapointe 2010). Depending on water temperature, eggs may hatch in fewer than three days ([…] Gascho Landis and Lapointe 2010). Larvae experience rapid growth after their first two weeks, though overall individual growth rate in North American populations appears to be less than that in both native and introduced Asian populations (Gascho Landis et al. 2011)."

"Fry initially feed on zooplankton, before moving on to a diet of small insects and crustaceans (e.g., cladocerans, copepods, small chironimid larvae). Juveniles may feed on small fish, including goldfish (*Carassius* spp.) and roach (*Rutilis* spp.; Courtenay and Williams 2004)."

From CABI (2017):

"Spawning takes place in areas of low turbidity with submerged vegetation and occurs between May and July. During the spawning season, sexually mature fish are highly active and may jump about on the water surface."

"Male snakehead construct mostly circular nests of shallow aquatic vegetation, nearly 1 m in diameter and 60-80 cm in depth. Both the male and female snakehead clear any vegetation that is floating above the nest. Spawning typically occurs on calm days, often before sunrise. Fertilization is external and occurs following egg deposition above the nest (Courtenay and Williams, 2004). The eggs are yellow in colour, pelagic, and buoyant due to the presence of a large lipid droplet which occupies more than three-quarters of the egg's 2 mm diameter (Courtenay and Williams, 2004)."

"This species has been observed consuming prey almost one third of its own body length (Okado, 1960; Courtenay and Williams, 2004). Larger prey items often include loach, bream, carp and perch; whereas, other food items include crayfish, dragonfly larvae, beetles and frogs (Courtenay and Williams, 2004). Gut content analysis of the northern snakehead (n=219) from the Potomac River (2004-2006) indicated 17 different food items, including 15 fish species (Odenkirk and Owens, 2007). Primary prey items consisted mainly of banded killifish (*Fundulus diaphanous*); however, white perch (*Morone americana*), bluegill (*Lepomis macrochirus*) and pumpkinseed sunfish (*Lepomis gibbosus*) were also commonly consumed (Odenkirk and Owens, 2007). Goldfish (*Carassius auratus*), gizzard shad (*Dorosoma petenense*), American eel (*Anguilla rostrata*), yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), spottail shiner (*Notropis hudsonius*), eastern silvery minnow (*Hybognathus regius*), mummichog (*Fundulus heteroclitus*), channel catfish (*Ictalurus punctatus*), green sunfish (*Lepomis cyanellus*), tessellated darter (*Etheostoma olmstedi*), frogs and crayfish were also consumed at low levels (Odenkirk and Owens, 2006; Northern Snakehead Working Group, 2007)."

"Most feeding activity occurs during early and late daylight hours, where the species lies in wait for prey in vegetation near shorelines of ponds or streams. Feeding activity is highly correlated with water temperature, with feeding rates highest between 20-27°C. Feeding rate declines as temperatures drop to 12-18°C and ceases if water temperatures fall below 10°C (Courtenay and Williams, 2004)."

Human Uses

From GISD (2017):

"Snakeheads have long been favored food fishes in India and many parts of Asia, particularly southeastern Asia (Lee and Ng 1991, in Courtenay & Williams 2004). Some are utilised as luxury specialty foods, available alive in aquaria for customer selection at upscale restaurants in larger cities such as Calcutta, Bangkok, Singapore, Hong Kong and other major locales. They also provide easily caught food for poorer people (Wee 1982, in Courtenay & Williams 2004). *C. argus* is the most cultured snakehead in China and the most available snakehead in North American live-food markets. *C. argus* has a modest importance in aquarium fish trade in Japan, Europe and to a lesser extent, the USA (Courtenay & Williams 2004)."

From Courtenay and Williams (2004):

"[…] *C. argus*, *C. maculata*, and *C. striata* are commercially fished in most areas where these species have been introduced. Interestingly, there are cultural differences in acceptance of using introduced *C. argus* as a food fish. Within its native range in China, Korea, and southern Siberia (Berg, 1965), and within its introduced range in Kazakhstan, Uzbekistan, and Turkemistan [*sic*], it is considered a desirable and sought-after food fish (Baltz, 1991; Dukravets, 1992; FAO, 1994); nevertheless, it failed to become popular following its introduction to Japan in the early 1900s (Okada, 1960)."

From CABI (2017):

"In tributaries of the Aral Sea, Kazakhstan, 1-5 metric tonnes of snakehead are fished commercially every year and this amount may increase to 10 metric tonnes annually in reservoirs of the Talas River, Kazakhstan (Baltz, 1991; Dukravets, 1992)."

"The northern snakehead, due to their aggressive nature and strength, have been introduced into a number of locations for culture as a sport fish (Courtenay and Williams, 2004)."

"In some cultures, snakehead fishes are thought to confer good-health and longevity to those in possession of it."

From Fuller et al. (2017):

"Snakeheads' resilient nature reportedly makes them more desirable than carps for ceremonial release, and some interest in recreational fishing may also exist (Mendoza-Alfaro et al. 2009, NSWG 2006)."

Diseases

From GISD (2017):

"The diseases and parasites of snakeheads have not been well studied. However, mortality of snakeheads under intensive culture, such as northern snakehead has been known to occur from epizootic ulcerative syndrome (EUS), a disease which involves several pathogens. Several other species can also be affected by EUS […]"

Epizootic ulcerative syndrome (infection with *Aphanomyces invadans*) is on the 2017 list of OIE-reportable diseases.

From Bailly (2012):

"Host of *Senga ophiocephalina* (Tseng, 1933) Kuchta & Scholz, 2007 (parasitic: endoparasitic)"

From Courtenay and Williams (2004):

"Parasites of northern snakehead (*Channa argus*)
[Adapted from Bykhovskaya-Pavlovskaya and others, 1964]

Parasite	***Group***	***Host tissues***	***Other fishes affected***
Myxidium ophiocephali	Myxosporidia	gallbladder, liver ducts	
Zschokkella ophiocephalli	Myxosporidia	kidney tubules	
Neomyxobolus ophiocephalus	Myxosporidia	gill filaments	
Mysosoma acuta	Myxosporidia	gill filaments	crucian carp
Myxobolus cheisini	Myxosporidia	gill filaments	
Henneguya zschokkei ?	Myxosporidia	gills, subcutaneous, musculature	salmonids (tubercle disease of salmonids)
Henneguya ophiocephali	Myxosporidia	gill arches, suprabranchial chambers	
Henneguya vovki	Myxosporidia	body cavity	
Thelohanellus catlae	Myxosporidia	kidneys	
Gyrodactylus ophiocephali	Monogenoidea	fins	
Polyonchobothrium ophiocephalina	Cestoidea	intestine	
Cysticercus gryporhynchus cheilancristrotus	Cestoidea	gallbladder, intestine	cyprinids, perches
Azygia hwangtsiüi	Trematoda	intestine	
Clinostomum complanatum	Trematoda	body cavity	perches
Pingis sinensis	Nematoda	intestine	
Paracanthocephalus curtus	Acanthocephala	intestine	cyprinids, esocids, sleepers, bagrid catfishes
Paracanthocephalus tenuirostris	Acanthocephala	intestine	
Lamproglena chinensis	Copepoda	gills"	

Threat to Humans

From CABI (2017):

"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."

"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)."

3 Impacts of Introductions

Few sources were found that document observed impacts of *Channa argus* introductions. Many papers cited Chiba et al. (1989) as the source material when describing negative impacts but Chiba et al. (1989) only include "Predation on native species" and "parasites" in a Remarks column of a summary table of invasive species in Japan. They give no further information on the source or evidence behind those statements.

Some information from other countries was not available to the assessor. Many sources from the United States indicate that the species has not been present in sufficient numbers long enough to determine any impacts (Fuller et al. 2017). It should be noted that in spite of this some states and federal agencies have viewed the potential impacts detailed below as enough of a threat to enact costly control and eradication efforts (GISD 2017; Fuller et al. 2017), and the entire snakehead family, Channidae, is listed as injurious wildlife under the Lacey Act (U.S. Fish and Wildlife Service 2017b).

The following sources describe observed impacts of introductions of this species.

From Guseva (1990):

"We recorded 11 species of fishes in the food of the snakehead in Lake Togyztore. Nearly half the consumption consisted of valuable food fish species: carp, grass carp, bream."

"It [*Channa argus*] causes considerable losses to the fishing industry in the summer months in Dautkul' Reservoir and Lake Togyztore [Uzbekistan] by feeding on valuable food fish species: carp, bream, zander, and their young."

"The snakehead has become a permanent element of the ecosystem in the lower reaches of the Amu Darya. Conditions conducive to its colonization, reproduction, and increase in abundance have been established in most of the present-day water bodies of the region; these conditions have also been promoted by the decline in competition from indigenous predators that are disappearing under the influence of anthropogenic factors. The snakehead has occupied the ecological niches vacated and has, in part, displaced the native pike and catfish."

From Saylor et al. (2012):

"Diet overlap was biologically significant between northern snakehead and largemouth bass. Fishes (mainly fundulids) were prevalent in largemouth bass and northern snakehead diets. The main difference between the species was the greater importance of crayfish in largemouth bass diet. Both species prefer littoral habitats with abundant vegetation and structure (Warren 2009; Lapointe et al. 2010), thereby increasing chances of competition. In this case, dietary overlap seemed to highlight the use of abundant forage species by northern snakehead and largemouth bass. Sharing abundant resources may limit competition according to diet; however, if food availability becomes limited, comparable levels of diet similarity may lead to competition (Zaret & Rand 1971; Abrams 1980). […] We cannot infer competition between northern snakehead and largemouth bass because we did not have estimates of prey relative abundance or data suggesting that prey was a limiting resource. […] Additional analyses were robust to various methods of measuring dietary overlap and supported our conclusion that overlap is biologically significant between northern snakehead and largemouth bass.”

From Courtenay and Williams (2004):

“Chiba and others (1989) noted that *C. argus* and *C. maculata* introduced parasites to Japan, but did not detail the parasites involved or fish species affected.”

From Cohen and MacDonald (2016):

“[…] there is no evidence that Snakeheads in MWL [Meadow/Willow lakes system, Queens, NY] are reducing populations of other fish species in the lake. During the study period, CPUE of other fish species, including prey, fluctuated from survey to survey, but showed no evidence of population decline. Other indicators of community health (e.g., species richness, H′) have likewise fluctuated in MWL but not decreased overall since Snakeheads were first reported. Similarly, in the Potomac River, populations of other fish species have not yet been affected, despite the increase in and expansion of the Snakehead population (Jiao et al. 2009). […] It is too early to predict that Northern Snakehead will never have an ecological impact in MWL, as the complete impact of a non-native species may take decades to manifest (Essl et al. 2011).”

The following sources describe potential impacts of introductions of this species.

From Courtenay and Williams (2004):

“Because snakeheads do not occur naturally in the U.S., there is no possibility of introduced snakeheads hybridizing or interbreeding with native fishes. Conversely, 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.”

“Adverse impacts on threatened and endangered species would likely be high. 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.”

“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). 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."

"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). 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."

From Fuller et al. (2017):

"Specific impacts are unknown surrounding the Potomac population. These predatory fishes may compete with native species for food and habitat."

From GISD (2017):

"The introduction of non-native northern snakeheads into waterways has received a great deal of media, public and political attention in the USA (US Fish and Wildlife Service & 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 enemies in its introduced range, make it highly likely to be a formidable invasive if it were to become established."

"In Crofton pond, Maryland (USA) herbicides (Diquat Dibromide and Glyphosate) were used to lower oxygen levels, then a piscicide (Rotenone) was used to poison the fish (Hilton 2002). The total cost of this eradication in a 1.8 ha pond was estimated at $110,000 (Courtenay & Williams 2004). Eradication would be much more complicated in rivers, streams, or larger lakes."

"An attempt was made to eradicate *Channa argus* in Arkansas in 2007 by U.S. Fish and Wildlife Service. However the attempt failed at a cost of over US $750,000 (W. Courtenary [*sic*], pers. comm. 2010)."

From CABI (2017):

"Northern snakeheads have the ability to significantly impact the function of ecosystems and food webs among native biotic communities. Its establishment in an existing biological community would produce cascading impacts to the food chain by reducing the abundance of planktivorous fish through predation, thus enhancing the abundance of zooplankton and reducing the abundance of phytoplankton. These changes would have energetic implications for the entire aquatic ecosystem."

"The northern snakehead is a voracious, apex predator with few, if any, natural enemies. The species has tremendous potential to severely impact native populations of fishes as well as other crustaceans, insects and other biota. Snakehead are able to negatively impact native populations at all lifestages, from egg predation to consumption of adult fishes. Additionally, cascading effects at all trophic levels promote monoculture of snakehead in non-native waterbodies. Northern snakehead are able to tolerate habitats with extremely low dissolved oxygen content which provides a competitive advantage over native species such as pike (*Esox* sp.) or bass (*Micropterus* sp.) (Sea Grant Pennsylvania, 2012)."

From Love et al. (2015):

"Conservation of Largemouth Bass (LMB) *Micropterus salmoides* populations requires an understanding of population dynamics that are influenced by environmental challenges, such as the spread of invasive species. We used an age-structured population model to compare population growth rates (λ) between a simulated population that included invasive Northern Snakehead (NSH) *Channa argus* as a competitor and predator and a simulated population that did not. […] Regardless of the level of LMB recruitment, the size of the LMB population at equilibrium was 20% lower (on average) when including NSH in the model. We conclude that when habitat conditions do not already significantly limit recruitment, populations of LMB may be adversely affected by cohabitation with NSH."

From Odenkirk and Isel (2016):

"Despite copious media reports and popular publications that have sensationalized the invasive characteristics of Northern Snakeheads, the scientific literature is devoid of studies that have evaluated the ecological impacts of this species. Specific impacts attributable to Northern Snakeheads have not been observed in host fish communities, but concern persists, especially since the tidal freshwater Potomac River supports an extensive and acclaimed fishery for Largemouth Bass *Micropterus salmoides* (Markham et al. 2002)."

4 Global Distribution

Figure 1. Known global distribution of *Channa argus*. Map from GBIF (2016).

Only locations of established populations were used as source points for the climate matching analysis. Because they do not represent established populations, locations in Florida, North Carolina, Massachusetts, Illinois, Texas, and California were not included as source points for climate matching (see Section 1). The location in the Artic is marine; *C. argus* is a freshwater species and the observer requested that the location be marked with uncertainty (GBIF 2016), so the location was not used for climate matching. Finally, the location near Vancouver, British Columbia, Canada is the result of a misidentification; the specimen that was caught was *Channa maculata* and not *C. argus* (Scott et al. 2013).

5 Distribution Within the United States

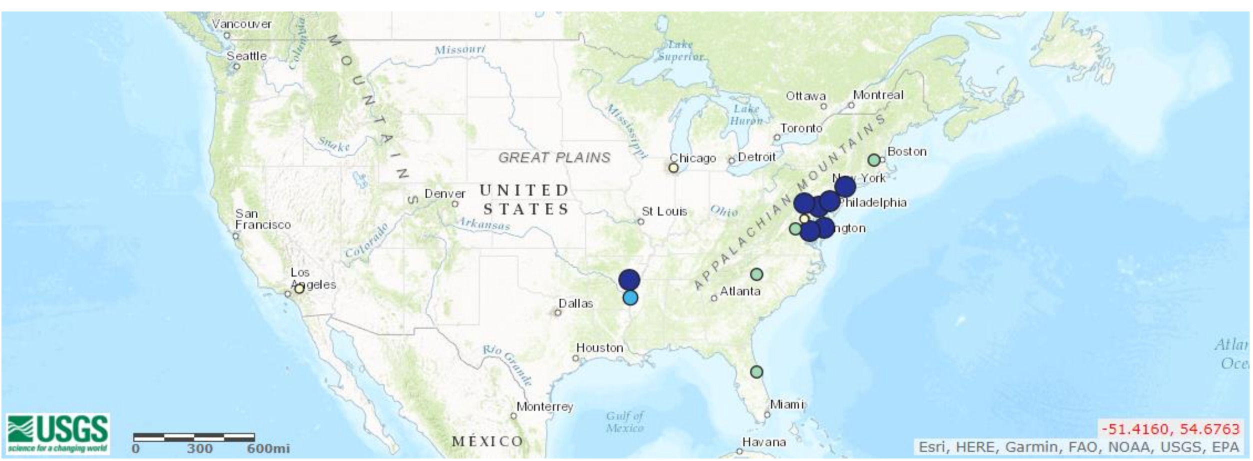

Figure 2. Known distribution of *Channa argus* in the United States. Map from Fuller et al. (2017).

Only locations of established populations were used as source points for the climate matching analysis. Therefore, locations in Massachusetts, North Carolina, Florida, and California were not used as source points (see Section 1).

6 Climate Matching

Summary of Climate Matching Analysis

The climate match (Sanders et al. 2014; 16 climate variables; Euclidean distance) for *Channa argus* was high in the mid-Atlantic, extending west past the Mississippi River. It was also high in the northern Midwest, and in isolated areas of central California. The climate match was low in very small portions of northern New England, the southern Appalachians, the coastal Pacific Northwest, the Interior West, and parts of the Southwest. All other locations in the contiguous U.S. showed a medium climate match. The Climate 6 score for the contiguous U.S. was 0.476, indicating a high match. State-by-state Climate 6 scores indicated high matches for Alabama, Arkansas, California, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Virginia, Vermont, Washington D. C., West Virginia, and Wisconsin.

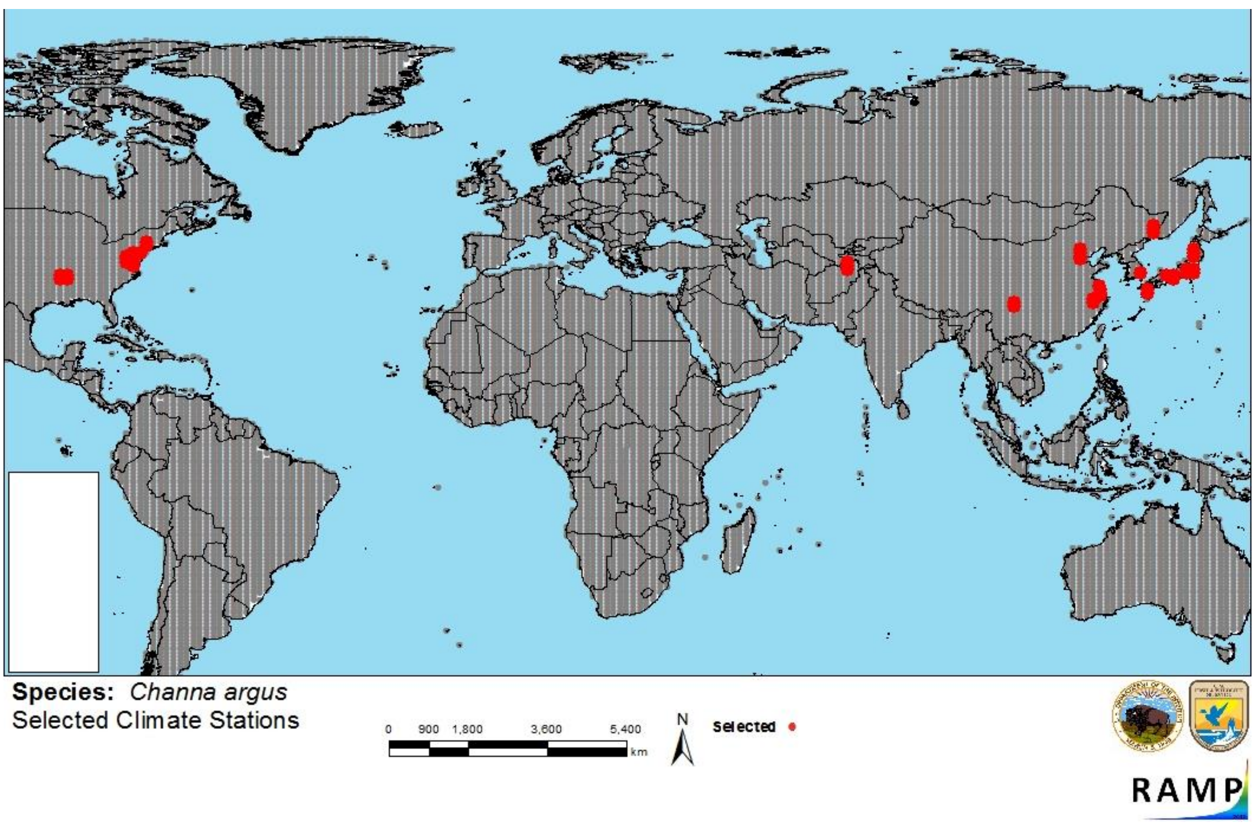

Figure 3. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red) and non-source locations (gray) for *Channa argus* climate matching. Source locations from GBIF (2017) and Fuller et al. (2017).

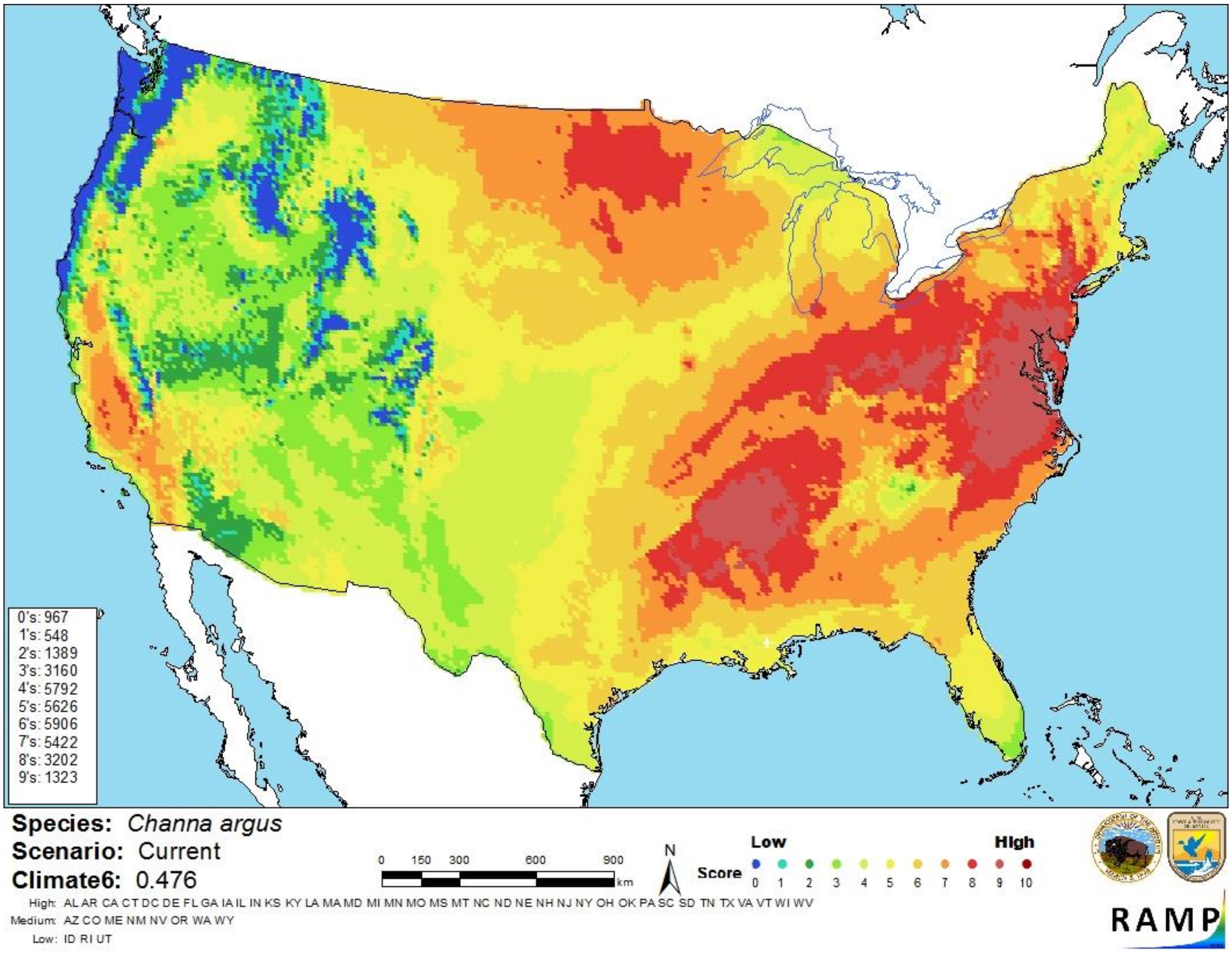

Figure 4. Map of RAMP (Sanders et al. 2014) climate matches for *Channa argus* in the contiguous United States based on source locations reported by GBIF (2017) and Fuller et al. (2017). 0=Lowest match, 10=Highest match.

The "High", "Medium", and "Low" climate match categories are based on the following table:

Climate 6: Proportion of (Sum of Climate Scores 6-10) / (Sum of total Climate Scores)	Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

7 Certainty of Assessment

Abundant information is available on the biology, ecology, and distribution of *C. argus*. There is a long history of this species being introduced intentionally and unintentionally through various pathways. Some of these introductions have resulted in established populations. The longest established populations are from areas in Russia and Asia where if any scientific investigation has occurred, the results may not be available to the assessor due to language barriers. A few detailed, scientifically credible records of documented impacts from *Channa argus* introductions were found. Other credible sources listed a generalized adverse impact but gave no details. One study gave a scientifically credible account of lack of impact at present. With some reliable evidence of specific adverse impacts but also a wide range of described impacts or lack thereof, the certainty of this assessment is medium.

8 Risk Assessment

Summary of Risk to the Contiguous United States

Channa argus is a snakehead species native to the Amur River basin of Russia, the Korean Peninsula, and much of China. The history of invasiveness for *C. argus* is high. There are many records of introductions in the U.S. and elsewhere, with some becoming established populations. *C. argus*, along with all snakeheads in the family Channidae, are listed as injurious wildlife under the Lacey Act and are therefore prohibited from importation into the United States as of 2012. One study described a significant negative economic impact of introduced *C. argus* on commercial fisheries in the lower Amu Darya River basin in central Asia; the same study cited *C. argus* as a contributing factor in the displacement of native predator species. In the U.S., significant dietary overlap has been found between *C. argus* and native *Micropterus salmoides* (largemouth bass) and modeling predicts population-level impacts, but these impacts have not yet been realized. There were a few records found that stated the presence of general 'adverse impacts' but none of those sources or the sources they referenced provided any further information on what those impacts were and how they were determined. There is a substantial body of scientific literature that theorizes potential impacts of this species based on biological and ecological traits. Mostly on the basis of these potential impacts, eradication programs have been implemented at significant cost and with mixed success. The climate match is high; the Climate 6 score was 0.476. Much of the contiguous United States contains climatic conditions that could potentially support established populations of *Channa argus*. The overall risk assessment category is high.

Assessment Elements

- **History of Invasiveness (Sec. 3): High**
- **Climate Match (Sec. 6): High**
- **Certainty of Assessment (Sec. 7): Medium**
- **Remarks/Important additional information:** Susceptible to epizootic ulcerative syndrome, an OIE-reportable disease. This species appears to be readily available through internet trade and in live fish markets despite legislative prohibitions against possession of any Channidae species. Control and eradication efforts for this species can be extremely costly.
- **Overall Risk Assessment Category: High**

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