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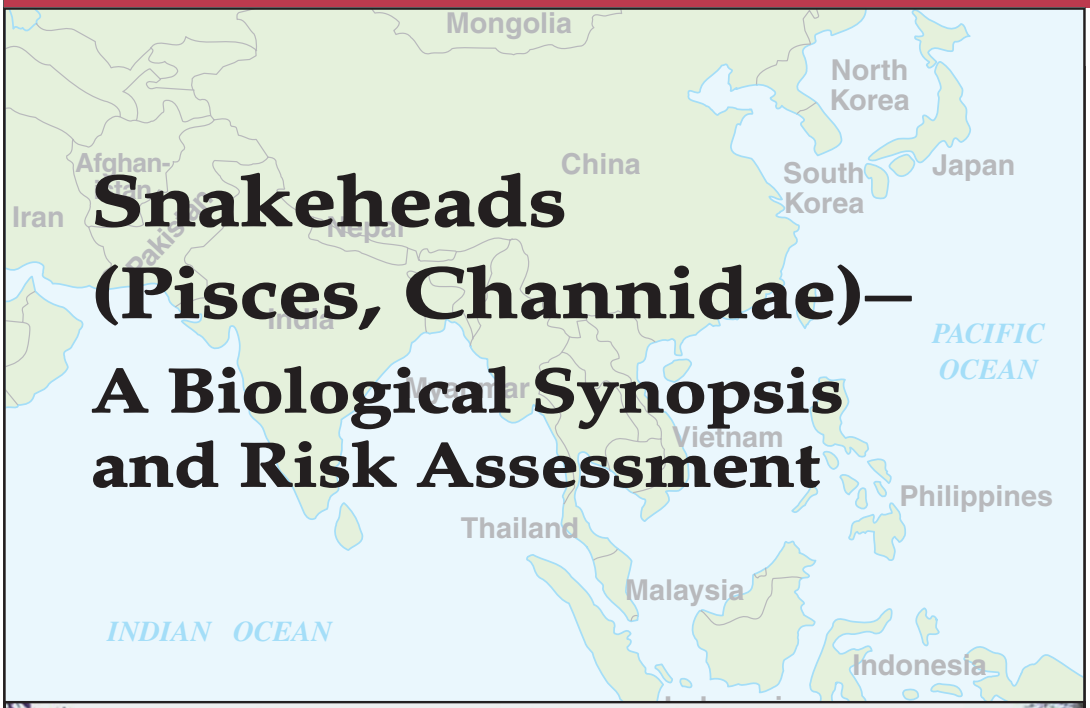

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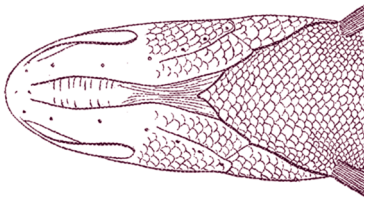

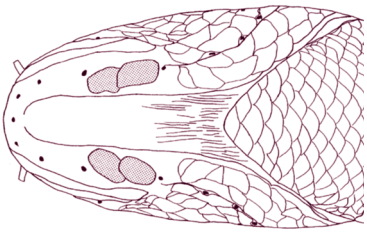

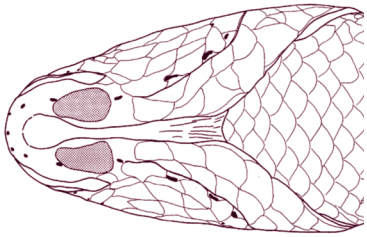

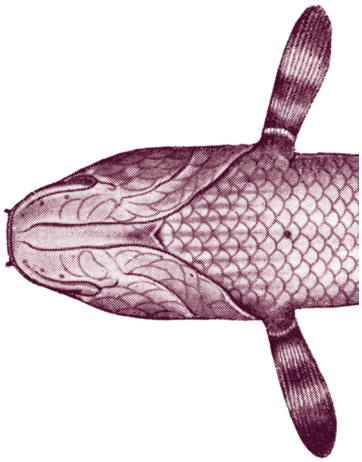

U.S. Department of the Interior
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SNAKEHEADS (Pisces, Channidae)—A Biological Synopsis and Risk Assessment

By Walter R. Courtenay, Jr., and James D. Williams

U.S. Geological Survey Circular 1251

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ACRONYMS, and ABBREVIATIONS

Multiply	*By*	*To obtain*
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilogram (kg)	2.2046	pound

Degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F = 1.8 x (°C + 32)

FAO	Food and Agriculture Organization of the United Nations
FFWCC	Florida Fish and Wildlife Conservation Commission
U.S.	United States
USGS	U.S. Geological Survey
ppm	part per million
S$	Singapore currency
$	United States currency

Unless otherwise stated in this report, measurement of fish refers to **total length**, defined as the measurement made from the tip of the snout to the posterior tip of the caudal or tail fin. **Standard length** refers to the measurement made from the tip of the snout to the base of the caudal fin.

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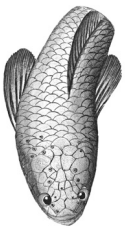
ABSTRACT

Snakeheads (family Channidae) are airbreathing freshwater fishes containing two genera, *Channa* with 26 species native to Asia, Malaysia, and Indonesia; and *Parachanna* with 3 species native to tropical Africa. Some snakeheads are small, reaching about 17 centimeters, but most are much larger, the largest reported to be 1.8 meters in length. All are considered thrust predators with most being piscivorous as adults.

A few of the smaller snakeheads and colorful juveniles of some larger ones have been available to hobbyists through the aquarium fish trade. Several species are highly valued as food fishes within parts of their native ranges, especially in Asia where they are an important part of capture fisheries and aquaculture.

Because of these uses by humans, introductions far beyond native ranges have occurred. One Asian snakehead has been established in Oahu, Hawaii, since before 1900. Another species was discovered established in southeastern Florida in 2000, and a third in a pond in Maryland in 2002. Others have been captured from natural waters of the United States without evidence of reproduction and likely represent released aquarium fishes. That snakeheads at or near sexual maturity were being sold alive in ethnic food markets raised fears that they could be introduced into novel waters. These concerns led to this study on the biology of snakeheads. A risk assessment is included that examines environmental and related aspects of snakehead introductions.



INTRODUCTION

Snakeheads (family Channidae) are airbreathing freshwater fishes containing two genera, *Channa,* native to Asia, Malaysia, and Indonesia, and *Parachanna*, endemic to tropical Africa. Taxonomy of these fishes is in flux, but leading authorities on snakehead systematics currently recognize 26 species of *Channa* and 3 of *Parachanna*. A few snakeheads are small, reaching about 17 centimeters; most, however, are much larger, the largest reported to be 1.8 meters in length. All are considered thrust predators with most being piscivorous as adults.

Within parts of their native ranges, some species of snakeheads are highly valued as food fishes, particularly in India, southeastern Asia, China, and to a lesser extent in Africa. They have long been an important part of capture fisheries and, in recent decades, some species have been utilized in aquaculture and a few used as predators to control density of tilapiine fishes in culture.

Because of its popularity as a food fish in southern China and adjacent southeastern Asia, the chevron snakehead (*Channa striata*) has been reported as widely introduced into islands from the western Indian Ocean eastward to Hawaii. The northern snakehead (*C. argus*) has been a market leader, and is cultured in China and Korea. This species has been exported to other nations, including Canada and the United States where it has been sold alive in certain ethnic markets and restaurants. Although purposefully introduced and established in Japan in the early 1900s, its introduction and subsequent establishment in ponds, rivers, and reservoirs of Kazakhstan, Turkmenistan, and Uzbekistan (formerly part of the Soviet Union) in the early 1960s appear to have been accidental.

Other snakeheads utilized as food fishes include the Chinese snakehead (*Channa asiatica*), blotched snakehead (*C. maculata*), and spotted snakehead (*C. punctata*). The bullseye snakehead (*C. marulius*), found in the live-food and aquarium fish trades, is now established in Broward County, Florida, and the blotched snakehead has been established in Oahu, Hawaii, prior to 1900.

Snakeheads used in the aquarium fish trade include a few small species and brightly colored juveniles of several large snakeheads. They are moderately popular with hobbyists in Japan and Europe. Several species are marketed in Canada and have been sold in the U.S., even in states where possession of live snakeheads has been illegal for decades. Hobbyists and importers can purchase snakeheads through a variety of sites on the Internet. Because of their highly predacious nature, however, snakeheads have not had a large following of interested hobbyists in the U.S. Those who purchased attractively colored juveniles of the larger species typically found that snakeheads became incompatible with other fishes (even killing others of their own kind), required expensive food (preferably live), and quickly outgrew their aquaria. This apparently has led to releases of “pet” snakeheads. As a result of these habits and their prohibition in several states, snakeheads have had a limited market in the U.S. aquarium fish trade. The fact remains, however, that they have been available for purchase.

The earliest known record of snakehead imports into the contiguous U.S. was published by Brind (1914). The importation consisted of about 60 juvenile fish that we believe were blotched snakeheads. Their progeny are thought to have been consumed by parent fish (Brind, 1914). Klee (1987) noted that a snakehead species, the chevron snakehead, probably a misidentification of the Chinese snakehead, was in the U.S. aquarium fish trade by 1912. Ross B. Socolof (personal commun., 2003) said that the Chinese snakehead was the first snakehead imported for the U.S. aquarium fish trade in the very late 1800s or early 1900s. Innes (1917) mentioned snakeheads as aquarium fishes, but did not include individual species. Innes (1920) reported on his having received a "breeding pair" of what he cited as *Channa fasciata* from a colleague who brought the fish to him from San Francisco. He indicated that a "single adult pair and a few young" of this snakehead had been "recently imported into California from Southern Asia." The photograph of this fish in Innes (1920) is clearly that of the Chinese snakehead, and the same photograph appeared in the account of the Chinese snakehead by Innes (1955). Armstrong (1923) purchased four progeny of Inne's snakehead in 1922, and included his failures and success in breeding these fish and their care under aquarium conditions. Stoye (1935) and Axelrod and Schultz (1955) provided descriptions, illustrations, and information on the care and breeding of Chinese snakehead, leading us to believe that it was available for sale to aquarium hobbyists through at least the 1950s.

The Chinese snakehead is one of a few species known to crawl short distances overland—references to this snakehead in the aquarium fish literature may have played a role in creation of an information "strip" on this species, published by Walt Disney Productions in 1959 (fig. 1), and brought to our attention by Robert Howells of the Texas Department of Parks and Wildlife.

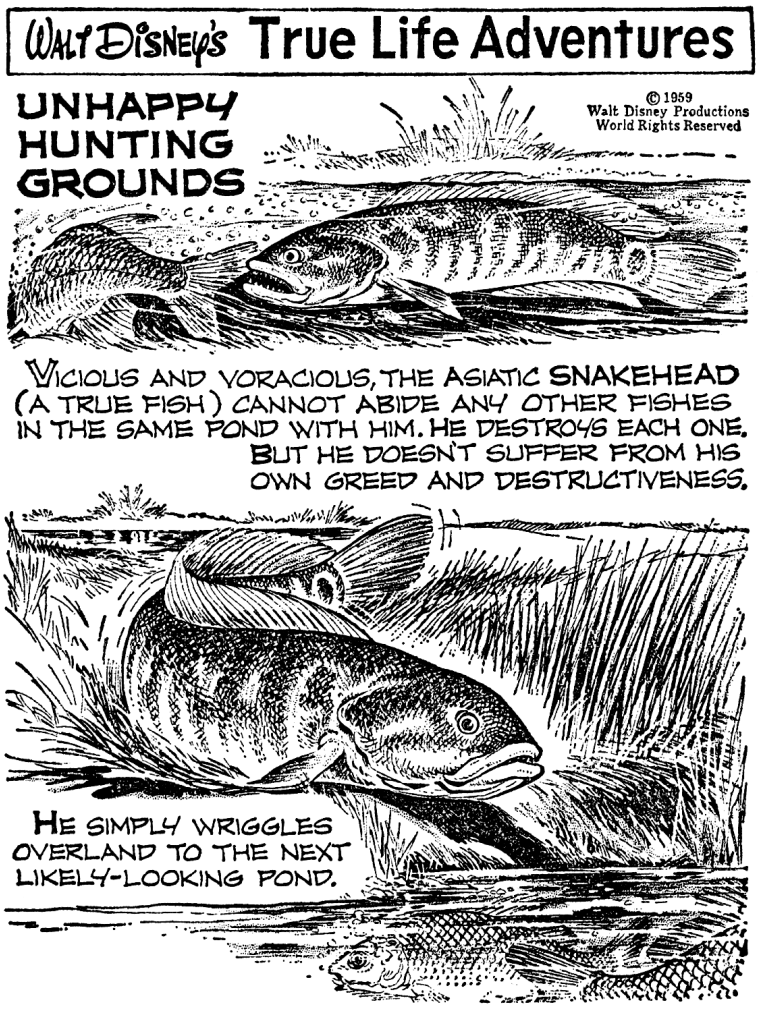


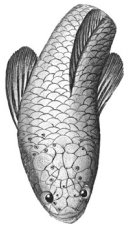
Figure 1—Perhaps due to its availability in the aquarium fish hobby through the 1950s, Walt Disney Productions published this depiction of the Chinese snakehead, *Channa asiatica*, in 1959. This is a species of snakehead known to crawl overland for short distances. Reprinted with permission of Disney Publishing Worldwide.

A comprehensive snakehead fish study, including a biological synopsis, risk assessment, and accounts for each species, was conducted between September 2001 and September 2002 by the U.S. Geological Survey, with support provided by the Division of Scientific Authority and Fisheries Management of the U.S. Fish and Wildlife Service. This study was prompted for several reasons—

- The discovery of an established population of *Channa marulius* in Broward County, Florida, in 2000;
- A well established snakehead (*C. maculata*) population in Oahu, Hawaii, since the late 1800s;
- Recent captures of introduced snakeheads in several states; and
- Recognition that channid fishes (at or near sexual maturity) were being sold in live-food fish markets in the U.S.

A limited number of snakeheads have been available for sale through the aquarium fish trade for several decades, but a new pathway— introduction of these fishes in live-food fish markets—had been largely overlooked.

Because snakeheads are highly predatory, some having the ability to travel overland to new water bodies, the inevitable release of these fishes by hobbyists, escapes from aquaculture, and liberation of live-food fish into U.S. waters threatens aquatic ecosystems. This report provides a comprehensive assessment of the risks involved with introductions of potentially invasive snakeheads into non-native waters.



LITERATURE REVIEW AND BACKGROUND INFORMATION

TAXONOMY AND SYNONYMY

According to Nelson (1994), the group of teleostean fishes known as snakeheads is classified as follows:

- *Class* Actinopterygii
  - *Subclass* Neopterygii
    - *Order* Perciformes
      - *Suborder* Channoidei
        - *Family* Channidae

Two genera are currently recognized as comprising the family Channidae. They are *Channa* (Scopoli, 1777; snakeheads of Asia, Malaysia, and Indonesia) and *Parachanna* (Teugels and Daget, 1984; African snakeheads). Generic synonyms of *Channa* include *Channa* Gronow, 1763, a *nomen nudum*; *Ophicephalus* Bloch, 1793, and its misspelled version *Ophiocephalus*; *Bostrychoides* Lacepède, 1801; and *Philypnoides* Bleeker, 1849. Synonyms of *Parachanna* are *Ophiocephalus* Günther, 1861; *Parophiocephalus* Senna, 1924 (originally proposed as a subgenus, but preoccupied in the fish family Anabantidae by *Parophiocephalus* Popta, 1905); and *Channa* Scopoli, 1777. Synonyms of the 29 species of snakeheads described herein are included in the individual species accounts contained in the section “Species Accounts.”

Myers and Shapovalov (1932) reviewed the status of the genera *Ophicephalus* and *Channa*, and they concluded that the practice of separating the two based on presence (*Ophicephalus*) or absence (*Channa*) of pelvic fins was invalid, based on specimens of *C. gachua* from India and one from Taiwan (introduced) that lacked pelvic fins. They placed *Ophicephalus* as a junior synonym of *Channa*. Five species of *Channa* lack pelvic fins.

Vierke (1991b), Musikasinthorn (2000), Musikasinthorn and Taki (2001), and Zhang and others (2002) consider 29 species of this family as valid (table 1). Nevertheless, 87 species and 4 subspecies have been described (Eschmeyer, 1998, in part) and current taxonomy is in flux. Although many described species are now considered synonyms of recognized species, there are about 20 names that cannot be associated with valid taxa. The plethora of scientific names for snakeheads is in part due to the sometimes dramatic color changes that occur between early and late juvenile stages, and adult patterns, a factor then unknown and hence unrecognized by early taxonomists using color as one of the distinguishing characteristics. Moreover, some descriptions lack detail, illustrations, or type specimens that could assist in solving these taxonomic mysteries. Four new species have been described since 1990, another put into synonymy, and two removed from synonymy and recognized as valid during that same time period. A taxonomic revision of the family is being prepared (Prachya Musikasinthorn, personal commun., 2002) and will likely result in more species being recognized as valid, and new species will perhaps be described.

Table 1—Currently recognized species of the family Channidae

[After Vierke (1991b), Musikasinthorn (2000), Musikasinthorn and Taki (2001), and Zhang and others (2002). Bibliographic sources are cited in the References section of this report or in Eschmeyer (1998)]

Channa amphibeus (McClelland, 1845) - Chel snakehead[1]
Channa argus (Cantor, 1842) - northern snakehead[1]
Channa asiatica (Linnaeus, 1758) - Chinese snakehead
Channa aurantimaculata Musikasinthorn, 2000 - orangespotted snakehead [1]
Channa bankanensis (Bleeker, 1852) - Bangka snakehead[1]
Channa baramensis (Steindachner, 1901) - Baram snakehead[1]
Channa barca (Hamilton, 1822) - barca snakehead
Channa bleheri Vierke, 1991 - rainbow snakehead
Channa burmanica Chaudhuri, 1919 – Burmese snakehead[1]
Channa cyanospilos (Bleeker, 1853) - bluespotted snakehead[1]
Channa gachua (Hamilton, 1822) - dwarf snakehead[3]
Channa harcourtbutleri (Annandale, 1918) - Inle snakehead[1]
Channa lucius (Cuvier, 1831) - splendid snakehead
Channa maculata (Lacepède, 1802) - blotched snakehead[1]
Channa marulius (Hamilton, 1822) - bullseye snakehead [1,3]
Channa marulioides (Bleeker, 1851) - emperor snakehead
Channa melanoptera (Bleeker, 1855) - blackfinned snakehead[1]
Channa melasoma (Bleeker, 1851) - black snakehead
Channa micropeltes (Cuvier, 1831) - giant snakehead[3]
Channa nox Zhang, Musikasinthorn, and Watanabe, 2002 – night snakehead[1]
Channa orientalis Schneider, 1801 - Ceylon snakehead[2]
Channa panaw Musikasinthorn, 1998 - panaw snakehead[1]
Channa pleurophthalma (Bleeker, 1851) - ocellated snakehead[1]
Channa punctata (Bloch, 1793) - spotted snakehead[3]
Channa stewartii (Playfair, 1867) - golden snakehead
Channa striata (Bloch, 1797) - chevron snakehead[3]
Parachanna africana (Steindachner, 1879) - Niger snakehead[1]
Parachanna insignis (Sauvage, 1884) - Congo snakehead[1]
Parachanna obscura (Günther, 1861) - African snakehead

[1] Proposed common name. [2] Common name tentative. [3] Species complex.

COMMON NAMES

As is typical of fishes of foreign origin, there has been a history of different English common names utilized for snakeheads. It is not unusual to find dissimilar names used for juveniles and adults of the same species, particularly in the aquarium fish trade. Moreover, one can find several English common names in the scientific literature for the same species in different parts of its native range. This also is true for common names used by indigenous people for the same species. In India, for example, various common names for a single species are often used by people from diverse regions, states, or cultures. For purposes of this report, we have followed Robins and others (1991) in using common names for the two snakeheads they treated, selected names we felt appropriate primarily from those used in the aquarium fish trade, and have added proposed names for some species that lacked English common names (table 1). The common names are identified in table 1 and appear in bold type in the section "Species Accounts."

Accounts for each of these species are detailed in the section "Species Accounts," which includes illustrations or photographs, source of original description, type specimens, synonyms, common name(s), native range, introduced range, size, habitat preference, temperature range, reproductive habits, feeding habits, characters, commercial importance in the United States, commercial importance in native range, and environmental concerns. Where known, the diploid chromosome number is included. Each account also contains a map showing native range and, where known, location or range of introductions. Literature citations for some synonyms are not included in the "References" section but can be found in Eschmeyer (1998) or on the Internet at http://www.calacademy.org/research/ichthyology/catalog/fishcatsearch.html.

DESCRIPTION AND DISTINGUISHING CHARACTERISTICS

Fishes of the family Channidae are commonly referred to as snakeheads (sometimes serpent-heads), primarily because of their somewhat elongated and cylindrical bodies, but particularly due to the presence of large scales on the head of most species, reminiscent of the large epidermal scales (cephalic plates) on the heads of snakes. Another snake-like feature is the somewhat flattened head with eyes located in a dorsolateral position on the anterior part of the head. Anterior nostrils are present and tubular. Dorsal and anal fins are elongated, and all fins are supported only by rays. A few species lack pelvic fins (Nelson, 1994; Berra, 2001). The caudal fin is rounded. The mouth is terminal and large with a protruding lower jaw, which is toothed, often containing canine-like teeth. The prevomer and palatines may or may not be toothed, depending on species. Scales are cycloid or ctenoid. All species possess paired suprabranchial chambers located behind and above the gills. The chambers in *Channa* are bordered by two plates, one from the epibranchial of the first gill arch and the other as an expansion of the hyomandibular. Those in *Parachanna* have a simple cavity not involving processes from the first epibranchial or hyomandibular. These chambers are not labyrinthic (Berg, 1947), but are lined with respiratory epithelium. All species occupy freshwater and a few can tolerate extremely low salinities.

Illustrations or photographs of certain species of *Channa* appear in Nichols (1943), Munro (1955), Nakamura (1963), Mohsin and Ambak (1983), Masuda and others (1984), Lim and Ng (1990), Ng and Lim (1990), Lee and Ng (1991, 1994), Pethiyagoda (1991), Talwar and Jhingran (1992), Kottelat and others (1993), Jayaram (1999), and Kottelat (1998, 2001a). The three species of *Parachanna* were illustrated by Bonou and Teugels (1985), who provided a key for identification of *Parachanna*. But, there is no single key to identify all species of *Channa*, at least five of which appear to be species complexes rather than single, distinct species.

Two larger snakehead species, the bullseye snakehead (*Channa marulius*) and emperor snakehead (*C. marulioides*), superficially resemble the native bowfin (*Amia calva*) in that all three are elongated fishes, have long dorsal fins, tubular nostrils, and an ocellus near the base of the upper part of the caudal fin. The bowfin, however, has its pelvic fins in an abdominal rather than thoracic or anterior-abdominal position, and the anal fin is not elongated. Moreover, the bowfin lacks a rosette of enlarged scales on top of its head. Other than this example, there are no native fishes in North America or within their native ranges with which snakeheads could be confused.

Native Distribution

Species and species complexes of the genus *Channa* are native from southeastern Iran and eastern Afghanistan eastward through Pakistan, India, southern Nepal, Bangladesh, Myanmar, Thailand, Laos, Malaysia, Sumatra, Indonesia, Vietnam, Korea, and China northward into Siberia (fig. 2).

Of the currently recognized 26 species of *Channa*, 8 species and representatives of 4 species complexes occur in peninsular Malaysia, Sumatra, and/or Indonesia. Of the same 26 species, 13 species and 1 species complex are tropical to subtropical; members of 6 species and 2 species complexes are warm temperate to subtropical/tropical, 2 species complexes are cold temperate to subtropical/tropical, and 1 species is warm temperate to boreal and can live beneath ice in the northern part of its range. The three species of *Parachanna* are native to Africa and are tropical (fig. 2).

Snakeheads are non-ostariophysan primary freshwater fishes (Mirza, 1975, 1995) and have little or no tolerance for seawater. Habitat preferences vary by species or species complex, with a majority occurring in streams and rivers. Others live in swamps, rice paddies, ponds, and ditches. All can tolerate hypoxic conditions because they are airbreathers from late juvenile stages. The pH range, where known, varies by species with one, the Bangka snakehead (*Channa bankanensis*), preferring highly acidic (pH 2.8-3.8) waters (Lee and Ng, 1991; Ng and Lim, 1991). At least three species are tolerant of a wide pH range: the dwarf snakehead (*C. gachua*), spotted snakehead (*C. punctata*), and chevron snakehead (*C. striata*) survived for 72 hours at pH levels ranging from 4.25 to 9.4 (Varma, 1979).

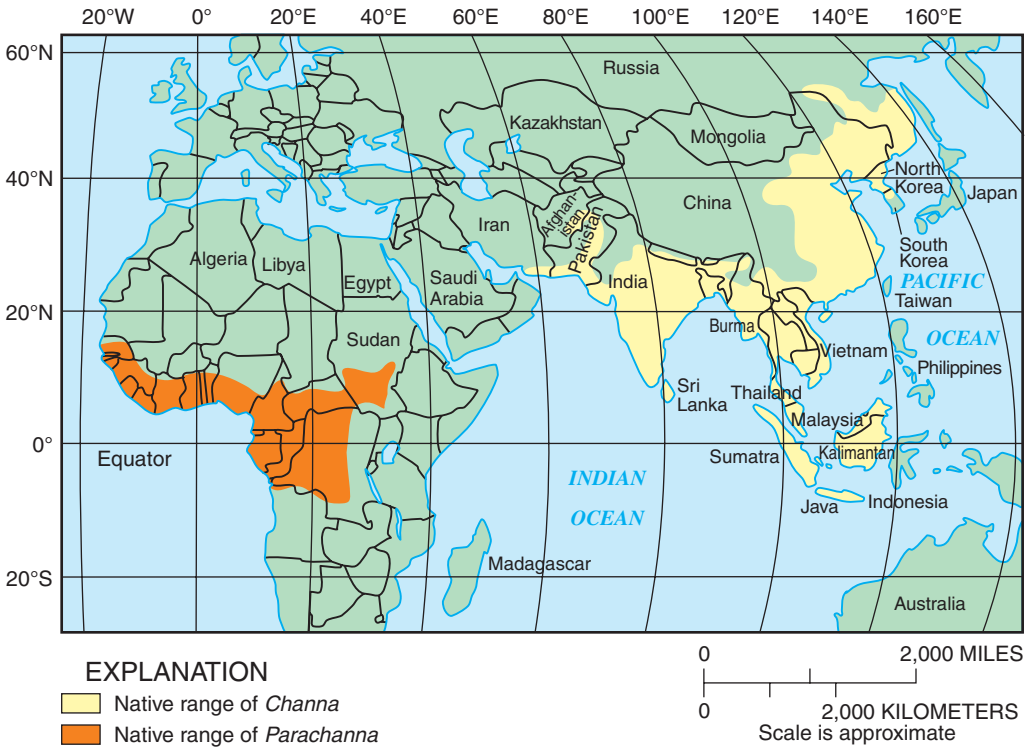


Figure 2—Native distribution of the family Channidae.

Biology and Natural History

• ***Paleogeographic origins***—The fossil record indicates the presence of channid fishes during the upper Oligocene/lower Miocene in what is now western Switzerland and eastern France (Reichenbacher and Weidmann, 1992). Nevertheless, Ralf Britz (personal commun., 2003) noted that identification of these fishes is based on fossilized otoliths and may not be reliable.

Lydekker (1886) reported on fossilized skull bones of snakeheads from the Siwalik Hills, Himachal Pradesh, northern India. These fossils and additional material of Pontian age (early Pliocene) were described in more detail by Sahni and Khare (1977) who described *Channa bhimachari*, *C. gregoryi*, and *C. romeri* based on fossilized skull-bone material found in stream sediments. Comparing these skeletal elements to osteological preparations of recent snakeheads, they suggested that *C. bhimachari* was most closely related to *C. striata* and *C. gregoryi* to *C. marulius*. They were unable to determine a recent relative of *C. romeri*.

Boeseman (1949) described skull-bone fossils of a snakehead from Pleistocene deposits from Trinil, central Java. Based on comparisons with osteological preparations of recent snakeheads, he concluded that these fossilized remains were of a species closely related to living *Channa striata*, and he named the species *Ophicephalus palaeostriatus*. Coupled with data presented by Lydekker (1886), Boeseman (1949), and Sahni and Khare (1977), there is convincing evidence that congeners of living snakeheads were present in Asia by and probably well before the Pleistocene.

A majority of living snakeheads are native to southeastern Asia, with most species found from Myanmar eastward and southeastward through Malaysia, Sumatra, Java, and Borneo (Kalimantan). Boeseman (1949) confirmed that at least one species of what is now included in the genus *Channa* was present in Java in the Pleistocene. Jocano (1975) noted that during the Pleistocene, the Malay Peninsula, Sumatra, Borneo, and the "Sundas" to Palawan were connected by what is termed the "Sunda Shelf." He described conditions as "a vast dryland covering 1.8 million square kilometers," containing a "great river," adding that many of the present river systems of Kalimantan, Sumatra, and surrounding localities were tributaries of that river. He also added that this "may explain the striking similarities of fish faunas in Sumatra, Borneo, and the Philippines," the latter restricted to the Palawan region of the Philippines.

From an evolutionary standpoint and considering a Pliocene to Pleistocene presence of channid fishes in Asia, it is likely that the "great river" of the Sunda Shelf began to dry during the late Pleistocene and speciation of snakeheads in the region was in advanced stages. This probably occurred before parts of that shelf became isolated as peninsulas and islands, with species evolving in differing kinds of habitats separated from their ancestral origin(s) by geographic and biological factors. Such an evolutionary scenario explains why, for example, species known from Sumatra also occur in the southern part of the Malay Peninsula and Kalimantan, Bangka, Billiton, perhaps Bali, and nearby areas. Moreover, isolation of such species "populations" between continental and insular ranges over geologic time has doubtless led to genetic and phenotypic differences that complicate taxonomic interpretations. Similar linkages between what are now continental areas and nearby islands (for example, Vietnam and China with Hainan) are known from the Pleistocene (Sterling and others, 2003). India and Sri Lanka are reported to have been connected as recently as 8,000 years ago (www.tamilinfo.org).

Fossils of snakeheads have also been identified from post-Pleistocene deposits in the Sahara Desert (Van Neer, 1989). Banerjee and others (1988) suggested an origin of the family from the area of Yunnan Province, southern China, dating back to the Pliocene or earlier, but based their suggestion on ecological habitats currently occupied by snakeheads rather than from fossil evidence. A more accurate picture of where this family evolved and its ancestor(s) is yet to be determined.

- ***Spawning seasons and reproductive behavior—***There is a paucity of information on reproductive biology of many species, but several conclusions can be drawn for those that are known. Spawning seasons vary by species. Spawning in several species occurs primarily in summer months (June through August) but, in at least two (the *Channa striata* and *C. punctata* species complexes), breeding pairs can be found throughout the year. Some species spawn twice to three or more times each year. Okada (1960) reported that female northern snakehead are capable of spawning five times per year. There are several reports that when snakeheads pair, they remain monogamous for a spawning season, perhaps longer, but this may not apply across the life history of any individual snakehead.

Most snakeheads build nests by clearing a generally circular area in aquatic vegetation, often weaving the removed vegetation around the centrally cleared area. This results in a vertical column of water surrounded by vegetation. Sometimes the

surface of this column contains pieces of removed vegetation. One species complex (*Channa punctata*) prepares elaborate tunnels through vegetation leading into the nest column. In general, the male entwines his body around that of the female, with some species appearing to "dance" in the water column as eggs are released and fertilized (Breder and Rosen, 1966; Ng and Lim, 1990). Eggs are buoyant, due to a large oil droplet in the yolk mass, and rise to the surface where they are vigorously guarded by one or both parents. Some snakeheads in one species complex (*C. gachua*) and *C. orientalis* are reported to be mouthbrooders, with the male being the mouthbrooder of fertilized eggs and, later, fry in *C. orientalis*. Peter Ng (personal commun., 2002) suggested that *C. asiatica* may also be a mouthbrooder. Most snakeheads, however, are not mouthbrooders and one or both parents vigorously guard their young. One species (*C. micropeltes*) is reported to have attacked and, in some instances killed, humans who approached the mass of young (Kottelat and others, 1993). Thus, parental care, whether by guarding or mouthbrooding, is a behavioral characteristic of snakeheads.

One might assume, based on reported spawning habits, that presence of vegetation is mandatory for successful spawning, but this is not the case. Wee (1982) cited Parameswaran and Murugesan (1976b) as having documented *Channa gachua, C. marulius,* and *C. punctata* spawning in ponds lacking vegetation. Alikunhi (1953) noted that *C. striata* is also known to spawn in the absence of vegetation. These observations, however, imply that other snakeheads are also capable of reproducing in waters lacking vegetation.

- ***Fecundity and early development—***There is limited information on fecundity except for snakeheads of commercial importance. Nevertheless, that information shows a pattern that likely applies to the entire family Channidae. An unfertilized "egg" is an oöcyte. Once an oöcyte is fertilized by fusion of oöcyte and sperm nuclei, it becomes an egg, with an embryo resulting if fertilization is successful. Smaller snakeheads, such as *Channa gachua* and *C. orientalis*, produce few oöcytes (about 20 when sexual maturity is first reached and up to 200 later; Lee and Ng, 1991, 1994). Low fecundity is a general rule among mouthbrooding fishes (Breder and Rosen, 1966). Fecundity increases greatly in larger snakeheads and appears to be linear, increasing in volume with increasing body length. For example, Quayyum and Qasim (1962) recorded fecundity ranging from 2,300-26,000 oöcytes for *C. striata*, increasing in number with increasing body length. Large female bullseye snakeheads, *C. marulius*, among the largest species, have been reported to produce as many as 40,000 oöcytes (Jhingran, 1984). A fecundity for the northern snakehead, *C. argus*, was about 50,000 oöcytes (Frank, 1970). Frank's data came from Nikol'skiy (1956), who recorded fecundity of 22,000-51,000 in northern snakeheads from the Amur basin. Dukravets and Machulin (1978) gave fecundity rates of 28,600 to a high of 115,000 for northern snakehead (probably from Yangtze River stock) introduced into the Syr Dar'ya basin of Turkmenistan/Uzbekistan. They also noted that, whereas growth of northern snakeheads is slower than that reported for this species from the Amur basin, growth rates from both stocks became equal once sexual maturity was reached.

Oöcytes, when released from the female parent, are small, ranging from about 1 mm to slightly over 2 mm in diameter, depending on species. Fertilization takes place by the male releasing milt (sperm) on the oöcytes as they emerge from the female. Development time to hatching varies with water temperature and, to a lesser extent, with the species involved. For example, hatching occurred in 54 hours at 16-26 ºC and 30 hours at 28-33 ºC in *Channa punctata* (Kahn, 1924). In the northern snakehead, *C. argus,* eggs hatch in 28 hours at 31 ºC, 45 hours at 25 ºC, and 120 hours at 18 ºC. In general, newly hatched fry, depending on species, are about 3.0-3.5 mm in length.

• ***Early life history—***Following yolk resorption, snakehead fry begin feeding on zooplankton. Fry typically remain together until they reach early juvenile stage, guarded by one or both adults, when they can fend for themselves (Lee and Ng, 1994). Late juveniles of the giant snakehead, *Channa micropeltes*, school and feed in packs (Lee and Ng, 1991). Although there are few reports of early life history except for species of commercial importance, it appears that as larval snakeheads mature to early juvenile stages, the diet changes to small crustaceans and insects, particularly insect larvae. Presence of phytoplankton, plant material, and detritus in the digestive system of young snakeheads, as well as adults, appears to occur from incidental ingestion. Juveniles frequently differ in colors and color patterns from late juveniles to adults, making young of interest to some aquarium hobbyists (Lee and Ng, 1991, 1994).

• ***Respiration and overland migrations—***Snakeheads are highly evolved airbreathing teleostean fishes, and several are capable of overland migration by wriggling motions (Lee and Ng, 1991; Berra, 2001; Peter Ng, personal commun., 2002) despite the fact their pectoral fins lack spines like those of clariid catfishes. They possess suprabranchial chambers for aerial respiration, and the ventral aorta is divided into two parts to permit bimodal (aquatic and aerial) respiration (Das and Saxena, 1956; Graham, 1997). The suprabranchial chambers become functional during the juvenile stage of growth (Graham, 1997), following which some species of snakeheads are obligate and others are facultative airbreathers. In some large species of snakeheads, such as *Channa marulius*, the young are facultative airbreathers and adults are obligate breathers (Wee, 1982), but all species are airbreathers.

These suprabranchial chambers lie above the pharynx and gill arches, lateral to the otic chambers of the skull. In *Channa*, the chambers open into the pharynx through inhalant apertures. The chamber lining contains respiratory “islets” with vascular papillae. The chambers can be filled with air or water. In addition, in *C. striata*, there are also vascular papillae in the epithelium of the mouth and pharynx that can be utilized for respiration; these, however, can be retracted into depressions in the epithelium to prevent damage when feeding (Munshi and Hughes, 1992).

Some channids, perhaps all, have a circadian rhythm in frequency of oxygen uptake. *Channa marulius*, for example, showed a peak in oxygen uptake at night. *Channa striata* and *C. gachua* peaked in early night hours, and *C. punctata* at dusk. These rhythms are attributed to evolution in swamp ecosystems (that is, the rhythm is a property of the ecosystem) (Munshi and Hughes, 1992).

The number of species of snakeheads capable of overland migrations is unknown, but several display such behavior (Khin, 1948). These migrations often are assumed to be the result of fish relocating from drying habitats in search of those with water, perhaps driven by instinctive behavior for better feeding conditions, or both.

Overland migrations likely apply to those species whose native range is subject to seasonal dry/wet (or monsoonal) conditions, which encompass much of western to southeastern Asia where the majority of snakehead species exist.

The species of *Channa* most capable of overland migrations are those that are somewhat flattened ventrally (Peter Ng, personal commun., 2002). These include *C. asiatica*, *C. gachua*, *C. micropeltes*, *C. melasoma*, *C. nox*, *C. orientalis*, and *C. striata*. Even large *C. micropeltes* are capable of "crawling" in a sinuous motion on dry or wet land, although movement is slow (Peter Ng., personal commun., 2002). Those snakeheads with more rounded bodies (for example, *C. argus*, *C. lucius*, and *C. maculata*) have very limited ability to move on land except as young, and only when some water is present, as under mild flooded conditions. Liem (1987) noted that *Channa*, like airbreathing catfishes (*Clarias* and *Heteropneustes*), do not migrate on land to escape drying habitats, but burrow into mud to survive droughts. These species only migrate during or soon after heavy rains, allowing these fishes to invade new habitats, which permits a wider dispersal from more crowded environments (Liem, 1987).

- ***Hypoxic survival—***Snakeheads are either obligate or facultative airbreathers. Therefore, survival in hypoxic waters is not problematic to these fishes. When prevented from access to the surface, adult snakeheads of many species will drown due to lack of oxygen (Day, 1868; Lee and Ng, 1991). Cold temperatures reduce metabolism as well as oxygen demand, allowing such species as *Channa argus* to survive under ice (Frank, 1970). Moreover, snakeheads can remain out of water for considerable periods of time as long as they remain moist. Some snakeheads, especially *C. striata,* can bury themselves in mud during times of drought (Smith, 1945). They are known to secrete mucus that helps to reduce desiccation and facilitates cutaneous breathing (Mittal and Banerji, 1975; Lee and Ng, 1991). Fishers in Thailand are aware of this habit and, during drought periods, will slice into the mud until they locate the fish (Smith, 1945).

- ***Lifespan—***No specific information appears in literature. One species (*Channa marulius*) is reported to reach a total length of 1.8 m in Maharashtra State, India (Talwar and Jhingran, 1992), a size that would suggest a relatively long lifespan. Nevertheless, we have been unable to find an ichthyologist who knows of preserved specimens of such a length. The typical maximum length stated for *C. marulius*, the largest snakehead, is 1.0-1.2 m. 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. Moreover, Peter Ng (personal commun., 2003) reported that *C. micropeltes* is known to reach 1.5 m in length. Smaller snakeheads, such as members of the *C. gachua* and *C. orientalis* species complexes, may not live for more than a few years. Most larger snakeheads are reported to reach sexual maturity within 2 years, after which growth slows but fecundity increases with increasing size. The few publications that discussed growth rates in snakeheads based on examination of scales or otoliths were inconclusive as to the interpretation of "growth" markings. Moreover, timeframes of these studies were of such short duration (a few years) that they documented no evidence of maximum lifespan.

● ***Feeding habits*—**Few studies analyze the feeding habits of snakeheads. For those species studied, however, snakehead fry feed mostly on zooplankton following yolk-sac resorption. Munshi and Hughes (1992) cited Banerji (1974) that fry of *Channa punctata* feed on phytoplankton. As juveniles, they feed on insect larvae, small crustaceans, and fry of other fishes (Munshi and Hughes, 1992). What is universal in reports of adult feeding habits is that all snakeheads are predators, with many species showing a preference for other fishes, although they may also consume crustaceans, frogs, smaller reptiles, and sometimes young birds and small mammals. Welcomme (1985) cited *C. lucius, C. micropeltes, C. pleurophthalma* and *C. striata* as "large predators eating fish of all sizes, shrimps, prawns and crabs." Under conditions of food depravation, snakeheads can become cannibalistic on their young. The piscivorous nature of snakeheads has led to the use of some species (*C. striata* and *Parachanna obscura* in particular) to control tilapia fish populations in aquaculture.

School of young giant snakehead, *Channa micropeltes*, feeding at the surface in Thailand. Photo courtesy of Jean-Francois Helias, Fishing Adventures Thailand.

ASSOCIATED DISEASES AND PARASITES

Investigations of diseases and parasites of snakeheads concentrate on those species of importance in aquaculture. Hoffman and Schubert (1984) noted that most fishes can sometimes be hosts of parasites. Snakeheads are no exception.

Jinhui (1991) listed parasitic crustaceans of *Channa argus, C. asiatica,* and *C. punctata* from Chinese waters. A listing of known parasites of *C. gachua, C. marulius, C. punctata,* and *C. striata* from Bangladesh was provided by Arthus and Ahmed (2002). In that study, parasites of all but *C. gachua* equaled or far outnumbered the parasites reported by Bykhovskaya-Pavlovskaya and others (1964) for *C. argus* (table 2).

Literature on parasites of snakeheads includes numerous descriptions of new species, not detailed herein, but indicates that most studies concentrate on cultured fishes, such as *Channa argus, C. punctata, and C. striata*. 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. None of the parasite literature we reviewed on snakeheads indicated that any of these represent a potential threat to native North American fishes. Conversely, such potential has not been examined.

A disease of snakeheads that has received broad attention is epizootic ulcerative syndrome (EUS), which causes high mortality in these fishes, particularly *Channa striata* and *C. punctata* under intensive culture. EUS involves several

Table 2—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, supra-branchial 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	

pathogens, including motile aeromonad bacteria (for example, *Aeromonas hydrophila, A. caviae, Pseudomonas fluorescens*; Prasad and others, 1998; Qureshi and others, 1999), a fungus, *Aphanomyces invadans* (considered a primary pathogen; Mohan and others, 1999; Miles and others, 2001), and perhaps a rhabdovirus (Kanchanakhan and others, 1999; Lio-Po and others, 2000). Another bacterium, *Aquaspirillum* sp., also has been implicated (Lio-Po and others, 2000). EUS may have originated in India in the 1980s, but has since been found in Pakistan, Thailand, and the Philippines, with outbreaks reported from all of these areas during the 1990s. Snakeheads are not the only fishes affected by this disease. It is also known to occur in airbreathing catfish (*Clarias*), the bagrid catfish genus *Mystus*, two cyprinid genera (*Cyprinus* and *Puntius*), mastacembelid eels (*Mastacembelus*), and the nandid genus *Nandus* in India (Mukherjee, 1998). In Thailand, it has been found in giant gourami (*Osphronemus goramy*) and climbing perch (*Anabas testudineus*) during an outbreak in 1996-1997 (Kanchanakhan and others, 1999).

A parasitic disease that can affect humans is gnathostomiasis, caused by a helminth parasite, *Gnathostoma spinigerum*. It has been recognized as a highly important disease with about 800 suspected cases per year in two hospitals in Bangkok, Thailand, between 1985 and 1988 (Setasuban, 1990). *Channa striata* has been identified as an intermediate host for this parasite, found mostly in muscle tissue and occurring in 100 percent of fish examined over 41 cm in length (Setasuban and others, 1991). It is unknown if additional species of snakeheads in Thailand and other countries of southeastern Asia may serve as an intermediate host for larvae of this parasite.

HISTORY IN FISHERIES AND AQUACULTURE

Most snakeheads are part of capture fisheries. Few details were found in the literature on fishing methods, but most appear to involve hook and line, traps, gillnets, or seines.

Species for which we have found no information that they are of importance as a fishery resource include *Channa amphibeus, C. bankanensis, C. burmanica, C. cyanospilos,* and *C. melasoma.* Some do not appear to be targets of active fisheries, but are believed or known to be periodically available in local markets as incidental catches. These species include *C. aurantimaculata* (Musikasinthorn, 2000), *C. baramensis* (Ng and others, 1996), *C. barca* (also in the aquarium trade; Talwar and Jhingran, 1992), *C. bleheri* (wild caught for the aquarium trade; Ralf Britz, personal commun., 2002), *C. gachua* (Talwar and Jhingran, 1992), *C. harcourtbutleri* (Ng and others, 1999), perhaps *C. melanopterus, C. nox* (Zhang and others 2002), *C. panaw* (Musikasinthorn, 1998), *C. stewartii* (Talwar and Jhingran, 1992), and possibly *Parachanna africana* and *P. insignis*. Those for which there are active commercial fisheries are *C. argus* (Berg, 1965; Baltz, 1991; Dukravets, 1992), *C. asiatica* (Nichols, 1943; Daiqin and others, 1999), *C. lucius* (for food and aquarium purposes; Ng and Lim, 1990), *C. maculata* (Nichols, 1943; Atkinson, 1977; Hay and Hodgkiss, 1981), *C. marulioides* (aquarium purposes; Ng and Lim, 1990), *C. marulius* (Sriramlu, 1979; Rao and Durve, 1989; Talwar and Jhingran, 1992), *C. micropeltes* (Lee and Ng, 1991; Dudley, 2000), *C. orientalis* (Rainboth, 1996), *C. pleurophthalma* (Lee and Ng, 1991; Kottelat and others, 1993; Dudley, 2000), *C. punctata* (Quayyum and Qasim, 1962; Bhuiyan and Rahman, 1984; Rao and Durve, 1989; also in aquarium trade, Talwar and Jhingran, 1992), *C. stewartii* (minor importance in India, also in aquarium trade; Talwar and Jhingran, 1992), *C. striata* (Roa and Durve, 1989; Talwar and Jhingran, 1992), and *P. obscura* (aquarium and food purposes; Dankwa and others, 1999) . In addition, *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, 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).

Snakeheads known to be cultured are summarized in table 3. The most important and widely cultured species appears to be *Channa striata*. This may apply, however, only within its native range and perhaps where it has been introduced into southern China. It is becoming evident that it has been misidentified in places where this species has been reported as introduced (Madagascar and Hawaii in particular), and the introduced snakehead is *C. maculata* (Ralf Britz, personal commun., 2002). Thus, the many reported introductions of *C. striata* to Pacific Islands summarized by Eldredge (1994) and Lever (1996) will require reexamination. *Channa maculata* is the second most important snakehead cultured in China (Fang Fang, personal commun., 2002), and its culture appears to be concentrated primarily in Guangdong Province, where it is native. During 2001, imports of snakeheads (likely *C. maculata*) into the U.S. increased, the point of export having been Ghangzhou, Guangdong Province. Until identification of introduced "*C. striata*" is verified, its reputation as the most widely cultured snakehead

Table 3—Species of the family Channidae currently known to be cultured for food and/or aquarium fish trade

Channa argus[1]	*Channa maculata*
Channa asiatica	*Channa micropeltes*[2]
Channa marulius	*Channa striata*[3]
Channa punctata	*Parachanna obscura*

[1]Second most important species cultured for food. Also, the only species that has been in culture in the contiguous United States (Arkansas).
[2]Appears to be the most important species cultured for the aquarium fish trade.
[3]Species most widely cultured for food. Being cultured in Hawaii.

remains in question. We have verified that it is in culture in Hawaii (Qin and Fast, 1996a,b,c; Qin and others, 1997; Qin, Fast, and Kai, 1997; Qin, He, and Fast, 1997; Qin and Fast, 1998; Pam Fuller, personal commun., 2002). Moreover, it is considered to be the most important species economically in India (Bhatt, 1970), and is being cultured there and in Thailand, Java (Hofstede and others, 1953); Vietnam (Pantulu, 1976; Bard, 1991); the Philippines (Conlu, 1986; Guerrero, 2000); Sri Lanka (Kilambi, 1986); Pakistan (Talwar and Jhingran, 1992); Malaysia (Ali, 1999); and Cambodia (Balzer and others, 2002).

Channa argus is the most important snakehead cultured in China (Fang Fang, personal commun., 2002) where it is grown in ponds, rice paddies, and reservoirs (Atkinson, 1977; Sifa and Senlin, 1995; Liu and others, 1998). It was being cultured on three fish farms in Arkansas until importation, culture, sale, and possession of snakeheads was prohibited by the Arkansas Fish and Game Commission in August 2002.

Channa micropeltes is cultured for food in Vietnam (Pantulu, 1976; Wee, 1982), Malaysia (Lee and Ng, 1991), Thailand (FAO, 1994), and Cambodia (Rainboth, 1996), and often in floating cages (Pantulu, 1976; Rainboth, 1996). Young of this species are sold in the aquarium fish trade where this species, at least in the U.S., has been the most available snakehead.

Channa marulius is cultured in ponds, ricefields, and irrigation wells that do not support other fishes in Pakistan and India (Bardach and others, 1972). Wee (1982) noted that it is reared in monoculture in India, where it is fed tilapia. Mirza and Bhatti (1993) contradicted Bardach and others (1972) in stating that this species is unsuitable for aquaculture in Pakistan due to its highly piscivorous nature. Young have been available in the aquarium fish trade and are presumed to have originated from cultured stock.

Channa punctata has been an important food fish in India, where it is fished commercially and reared in ponds (Quayyum and Qasim, 1962; Talwar and Jhingran, 1992). Some snakehead species, including *C. punctata,* used in intensive aquaculture, are subject to outbreaks of EUS, and this has been reported for this species in India (Prasad and others, 1998; Qureshi and others, 1999).

Parachanna obscura is being cultured in the Central African Republic (Micha, 1974), Ondo State, Nigeria (Ajana, 1983; Victor and Akpocha, 1992), Benin (Jackson, 1988), and Ghana (Morrice, 1991).

HISTORY OF INTRODUCTIONS

Eastern Hemisphere

Locations where snakeheads have been introduced beyond their native ranges in the Eastern Hemisphere are shown in figure 3.

- *Channa argus*—Reported as introduced into "Czecho-Slovakia" and Russia beginning in 1949 (Holcík, 1991). No specific localities of introduction or information on status of the releases were provided by Holcík (1991). Nina Bogutskaya (personal commun., 2002) reported early introductions that failed into the Volga delta and ponds in Ekaterinburg (formerly Sverdlovsk) Province in the southern Urals. An experimental introduction was made in ponds of Moscow Province during 1949-1950 that established. In 1953, it was recommended that the species be stocked widely, but that failed to happen. There was a report in a Russian aquarium journal in 1963 noting occurrence of this species in small lakes in the Podolsk Region, Moscow Province, but the species is presently absent from the Moscow area. Tandon (1976) reported that acclimatization experiments were conducted in the former Soviet Union after 1950, and that fry were collected from ponds near Moscow and the Ukraine in 1955 and sent to Czechoslovakia for acclimatization purposes. He concluded that the source of the original stock was the Amur basin.

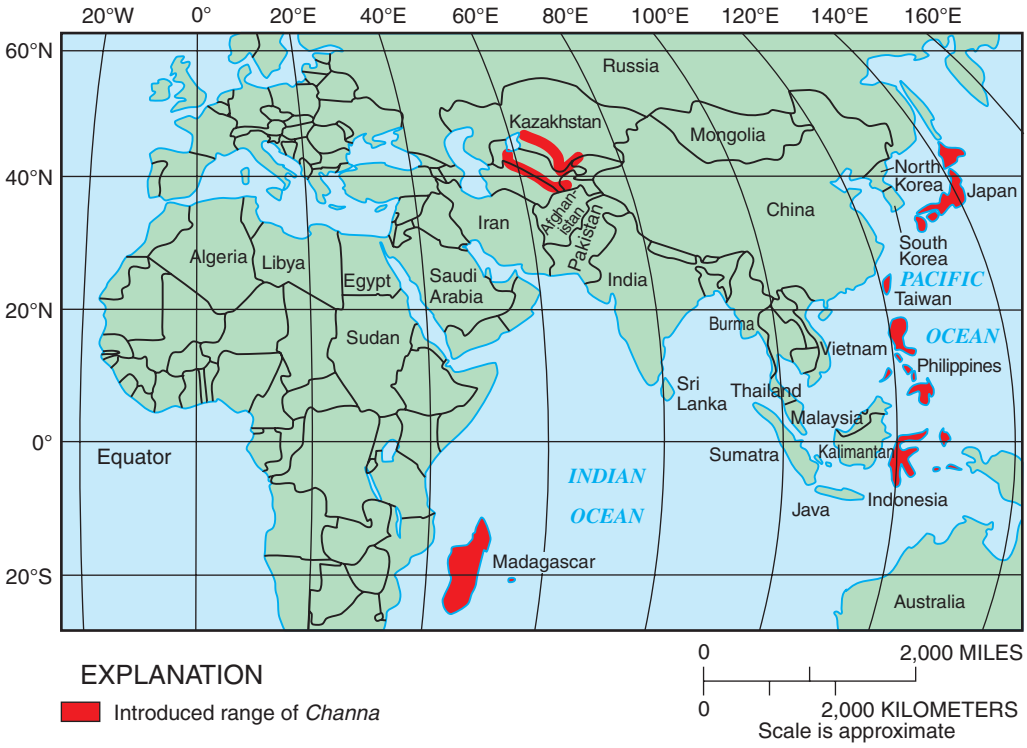


Figure 3—Introductions of snakeheads in the Eastern Hemisphere.

The northern snakehead was introduced into the Aral Sea basin in the early 1960s where it became established in 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). The initial introduction was apparently accidental, with snakeheads mixed with shipments of Asian carps. All introductions were apparently from Yangtze basin stock (Sal'nikov, 1998), although some authors claim the stock came from the Amur basin and were purposeful releases to establish a food resource. Dukravets (1992) recorded additional introductions that became established in the Sarysu River, reservoirs on the Talus River, and Chu River of Kazakhstan during the 1980s. He also reported that 10 metric tons of northern snakeheads was harvested from reservoirs along the Talus River in 1989.

The northern snakehead was introduced from Korea in the early 1900s and became established in many waters of central and southern Japan (Okada, 1960; Nakamura, 1963; Uyeno and Akai, 1984), which includes the islands of Hokkaido, Honshu, Kyushu, and Shikoku (Hiroshi Ueda, personal commun., 2002).

- ***Channa asiatica*—**Introduced and established in Taiwan (Musikasinthorn, 2000), probably released as a food resource.

- ***Channa gachua*—**Ismail (1989), misidentifying this snakehead as *C. orientalis* (Ralf Britz, personal commun., 2003), included Kalimantan (southern Borneo) in the native range of this species, and Kottelat (1985) noted its presence in the Greater Sunda Islands of Indonesia (probably including Kalimantan). This may represent an introduction, but the rationale for introducing this very small snakehead is not apparent. Myers and Shapovalov (1932) recorded this species in Taiwan.

- ***Channa maculata*—**Introduced and established as a food resource in Taiwan; Nara, Hyôgo, Hiroshima, Mie, and Shiga prefectures, Japan; and the Philippines (Okada, 1960; Liang and others, 1962; Hay and Hodgkiss, 1981; Uyeno and Akai, 1984). Ralf Britz (personal commun., 2002) confirmed that it is this species, not *C. striata*, that is established in Madagascar. He has also identified this species as present in Oahu, Hawaii, since about 1900, based on specimens examined at the U.S. National Museum of Natural History.

- ***Channa melasoma*—**Perhaps introduced and established in Palawan, Philippines (Kottelat, 1985). Pathway and rationale unknown.

- ***Channa micropeltes*—**We believe the presence of the giant snakehead in Kerala State, southwestern India, and described by Day (1865a) as *Ophiocephalus diplogramma* was the result of an introduction from southeastern Asia that occurred prior to the mid-1800s.

- ***Channa punctata*—**Smith (1950) reported this species as introduced in the vicinity of Delagoa Bay, southern Mozambique. Paul Skelton (personal commun., 2001) stated that no snakehead has been found or reported from southern Africa since the Smith (1950) record.

• ***Channa striata*—**This species has been reported as the most widely introduced species of snakehead. It was recorded as introduced and established in Madagascar (Raminosoa, 1987; Reinthal and Stiassny, 1991; Stiassny and Raminosoa, 1994; Lévêque, 1998), although Ralf Britz (personal commun., 2002) stated that this was a misidentification of *C. maculata*. The chevron snakehead is also recorded from the following locations, although some of these records may prove to be *C. maculata*, misidentified as *C. striata*: Mauritius (Parameswaran and Goorah, 1981; Welcomme, 1988, Lever, 1996); Philippines (Seale, 1908; Herre, 1924, 1934; Conlu, 1986); Vogelkop Peninsula, Papua, Indonesia (Allen, 1991); Sundaland, Sulawesi, Lesser Sundas, Moluccas (Welcomme, 1981; Kottellat and others, 1993; Lever, 1996). Kottelat and others (1993) reported introductions into China but gave no specific localities. Its presence in Papua, Indonesia, was confirmed through photographs supplied by Gerald L. Allen (personal commun., 2002). The species was also introduced into Fiji and New Caledonia where establishment is questionable, and its introduction to Guam failed (Maciolek, 1984). *Channa striata* is regarded as a prized food fish in many parts of southeastern Asia, and in some localities its oils are used to heal wounds and prevent scarring. Introductions beyond its native range were primarily to establish a live-food resource.

Western Hemisphere

Five species of snakeheads have been reported from open waters of the United States (California, Florida, Hawaii, Maine, Maryland, Massachusetts, North Carolina, Rhode Island, and Wisconsin), and three became established as reproducing populations (fig. 4). One species was being cultured in Arksansas until possession of live snakeheads was prohibited in August 2002 and a fifth species is under culture in Hawaii.

• *California* •

A northern snakehead, *Channa argus*, was collected by California Department of Fish and Game personnel by electrofishing in a reservoir, Silverwood Lake, October 22, 1997. This represents the earliest known record of a live snakehead captured from open waters of the western United States. Silverwood Lake is in the Mohave River drainage, east-northeast of Los Angeles and north of San Bernardino in the San Bernardino Mountains, and receives water from the California Aqueduct. The specimen was subsequently frozen and, apparently, later discarded (Camm Swift, personal commun., 2002). A photograph of the 71 cm specimen that weighed 3.4 kg was taken, which allowed identification of the fish (John Sunada, personal commun. to Camm Swift, 2002). It remains unknown if the snakehead was released into Silverwood Lake or arrived through the California Aqueduct. The aqueduct has been the source of other fishes in the reservoir, including inland silverside (*Menidia beryllina*), striped bass (*Morone saxatilis*), bigscale logperch (*Percina macrolepida*), and tule perch (*Hysterocarpus traskii*) (Swift and others, 1993; Camm Swift, personal commun., 2002).

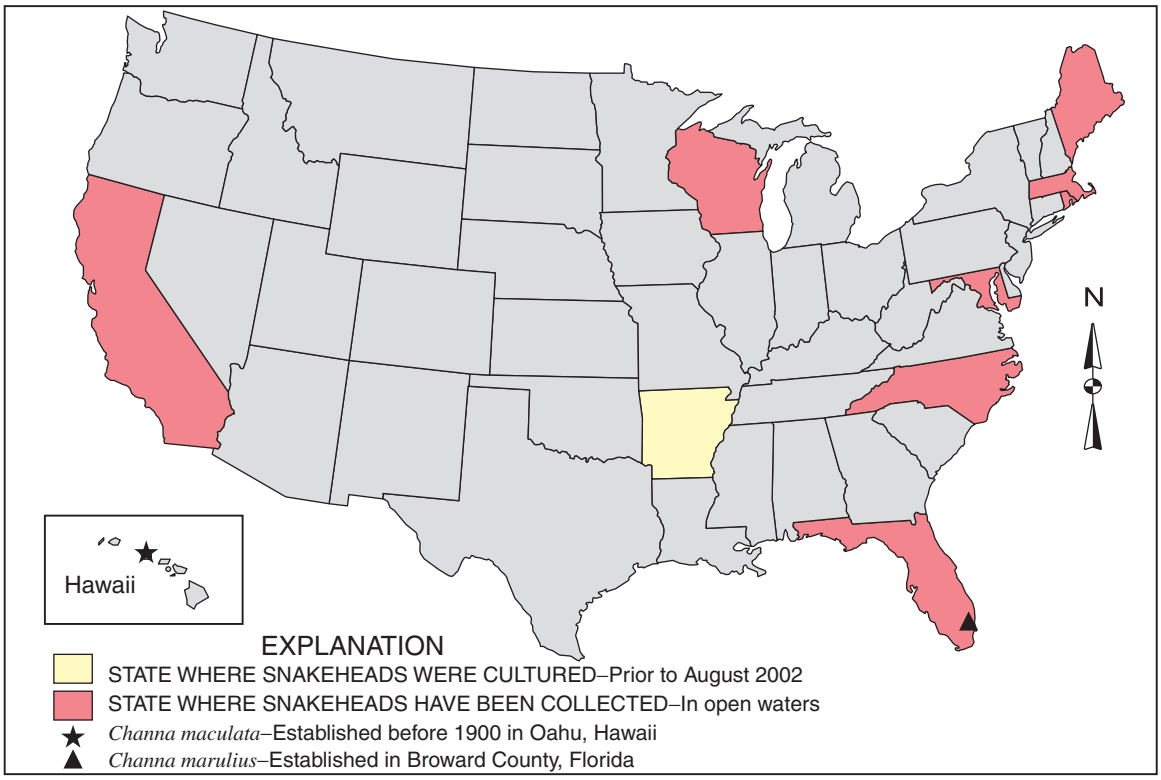


Figure 4—States where snakeheads have been collected from open waters, were cultured prior to August 2002, or are established.

• *Florida* •

An established population of the bullseye snakehead, *Channa marulius*, was discovered in residential lakes and adjoining canals in Tamarac, Broward County, Florida, in 2000 (Florida Fish and Wildlife Conservation Commission, 2001). It is unknown how long this species has occupied these waters, perhaps several years, but both juveniles and adults have been collected, indicating reproductive success. This species is a large snakehead with adults commonly reaching lengths of 120-122 cm (Talwar and Jhingran, 1992). In Maharashtra State, India, it can reach a length of 1.8 m and a weight of 30 kg, and was observed to reach a length of 30 cm in 1 year (Talwar and Jhingran, 1992).

The pathway for the introduction in Broward County, Florida, is unknown. The species may have been purposefully introduced to establish a food or aquarium fish resource or could have been released accidentally by aquarists, in which case several must have been released almost simultaneously. Because this species is considered as a game fish in its native range (http://www.fishingasia.com), it also could have been released illegally to establish a new sport fishing resource. Tamarac is located just east of Water Conservation Area II, north of Everglades National Park, and interconnected canal systems lead into this area. It is likely that *Channa marulius* will expand its range in peninsular Florida as its native range includes tropical to temperate climates. The bullseye snakehead is considered predacious (Jhingran, 1984; Talwar and Jhingran, 1992), especially on other fishes (Schmidt, 2001).

The northern snakehead, *Channa argus*, is also reported from Florida waters. Two individuals were caught in the St. Johns River below Lake Harney, Seminole and Volusia Counties in 2000, with unconfirmed reports of an additional three individuals caught nearby. An attempt to collect additional specimens by Florida Fish and Wildlife Conservation Commission (FFWCC) and U.S. Geological Survey (USGS) personnel by electroshocking in 2001 was unsuccessful, but will be repeated. Until reproduction has been confirmed, we consider the species as present but not established. This fish is not involved in the aquarium fish trade but has been sold in ethnic food markets as a food fish. The most likely pathway is introduction of live-food fish, perhaps to establish a local source.

A live northern snakehead was purchased in a live-food fish market in Orlando, Florida, in March 2002, another indication of its availability in a state where possession is illegal. Moreover, 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.

• *Hawaii* •

The blotched snakehead (*Channa maculata*), misidentified as the chevron snakehead (*C. striata*), has been established on Oahu, Hawaii, since the late 1800s, possibly introduced from southern China (Herre, 1924). For whatever reasons, it does not appear to have been introduced into other waters of Hawaii, although Morita (1981) reported the species from Kauai. It is now mainly confined to one or more reservoirs on Oahu (Maciolek, 1984). Ralf Britz (personal commun., 2002) has examined two specimens at the U.S. National Museum of Natural History, labeled as *C. striata* that were collected about 1900, and confirmed that they are *C. maculata.* We have examined other specimens, collected in the early 1900s on Oahu, borrowed from the American Museum of Natural History in New York City, Bernice P. Bishop Museum in Honolulu, the California Academy of Sciences in San Francisco, and the Field Museum of Natural History in Chicago, and they, too, are *C. maculata*. Two photographs, reported to be of *C. striata* in Yamamoto and Tagawa (2000) from Hawaii, are that of *C. maculata*. It was those photographs that alerted us to the likelihood that *C. maculata* existed in Hawaii. We believe that all past published records of *C. striata* in Hawaiian waters were based on misidentifications of *C. maculata*.

Channa striata is now being cultured as a food fish on Oahu, first imported in the early 1990s under permit to Arlo Fast of the University of Hawaii (Domingo Cravalho, Jr., personal commun. 2002). Peter Ng (personal commun., 2002) reported that he saw *C. striata* in a market in Honolulu in recent years. Pam Fuller (USGS, Gainesville, Florida) purchased five chevron snakeheads in Honolulu in September 2002. This species is regarded as carnivorous with a preference for other fishes (Mohsin and Ambak, 1983; Conlu, 1986), and was described as a "territorial ambush feeder" (Lee and Ng, 1991). Chevron snakeheads are used to control tilapia populations in culture ponds in the Philippines (Conlu, 1986; Milstein and Prein, 1993), and is one of the species of snakeheads capable of overland migration (Peter Ng., personal commun., 2002).

• *Maryland* •

A northern snakehead, *Channa argus*, was caught by an angler in a 1.8-ha pond in Maryland on May 18, 2002 (Beth Rogers, personal commun., 2002). The angler, unable to identify the fish, took three photographs of the specimen before releasing it into the pond. Estimated total length of the specimen was 43-45 cm. On June 30, 2002, another angler captured a larger (66-67 cm) specimen from the same pond and dipnetted eight juveniles from the pond on the evenings of July 7-8. Maryland Department of Natural Resources personnel subsequently captured over 100 juveniles from the pond, proving that a well established population was present. When the pond was treated with rotenone (a pesticide used for fish management, as well as other uses) in August 2002, more than 1,200 northern snakeheads were recovered (Bob Lunsford and Steve Early, personal commun., 2002). In addition, at least three specimens of the giant snakehead, *C. micropeltes*, have been caught in Maryland waters in recent years (Bob Lunsford, personal commun., 2002). Presence of this subtropical/tropical species in Maryland waters where it could not overwinter likely resulted from releases by aquarists.

Maryland DNR fishery biologist Bob Lunsford examines a berm of sandbags and silt fences strategically placed to prevent pond water overflow or overland fish migration from Crofton Pond to the Little Patuxent River. Photo by Walter R. Courtenay, Jr., USGS.

Biologists dipnetting for snakeheads. Photo by Tom Darden, Governor's office, Annapolis, Maryland.

• *New England States* •

A specimen of the northern snakehead, *Channa argus*, was collected in October 2001 from Newton Pond, Sudbury, Worcester County, Massachusetts, by Massachusetts Department of Fish and Wildlife personnel (Hartel and others, 2002). The likely source is live-food fish markets, as this species was the most common snakehead available in ethnic food markets and restaurants as a live-food fish. Moreover, it is capable of establishment in most freshwaters of the United States. Okada (1960) reported adults as voracious feeders, particularly on other fishes.

Specimens of the giant snakehead, *Channa micropeltes*, have been collected from open waters in Maine, Massachusetts, and Rhode Island (Courtenay and others, 1984; Fuller and others, 1999). This tropical/subtropical species could not establish itself in those temperate waters (Hartel and others, 2002). Juveniles of the species are cardinal red with two dark stripes on either side of the body, and are sold by aquarium fish retailers as red or redline snakeheads. Aquarist-oriented websites note that this species requires much animal food and that growth is rapid. These sites often advise that once these fish reach about 15-20 cm in length, no more than one individual should be kept in a single aquarium because they are aggressive predators. The pathway for release into these New England States was likely aquarists when their "pets" grew too large for their aquaria and/or because of the costs of feeding them. Releases of this species into sub-tropical waters in southern Florida or Hawaii could lead to establishment of this snakehead, regarded as the most predacious channid and known to have attacked humans (Ng and Lim, 1990; Lee and Ng, 1991; Kottelat and others, 1993).

Example of a poster alerting the public about the invasive, non-native snakehead (this poster courtesy of the Maryland Department of Natural Resources).

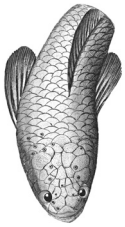
An angler reported having caught two blotched snakeheads, *Channa maculata*, from a bridge over the Charles River in Boston in late July 2002 (Karsten Hartel, personal commun., 2002). We confirmed that two live snakeheads purchased in an ethnic market in Boston in October 2001 by Karsten Hartel were *C. maculata*, thus proving local availability of this species at that time.

• *North Carolina* •

On July 31, 2002, two anglers reported catching two northern snakeheads from Lake Wylie, a reservoir on the Catawba River, Mecklenburg County, North Carolina (Wayne Starnes, personal commun., 2002). North Carolina Wildlife Resources Commission biologists sampled the lake using electrofishing equipment on August 14, 2002, but failed to find any snakeheads (Russell Wong, personal commun., 2002).

• *Wisconsin* •

A single specimen of the giant snakehead, *Channa micropeltes*, was captured by personnel of the Wisconsin Department of Natural Resources in the Rock River near Beloit on September 4, 2003 (Karl J. Scheidegger, personal commun., 2003). This species would not overwinter in Wisconsin and was undoubtedly released by an aquarist.



USES

AQUARIUM TRADE

Aquarists in Japan, Europe, and, to a lesser extent, North America have kept snakeheads as pet fish. Because these fishes are predators (some growing quite large) and high costs are involved with providing preferred live food, few hobbyists become dedicated snakehead enthusiasts. Judging from questions asked in 2002 on various Internet chat rooms dealing with aquarium fishes in general and predatory species in particular, interest in snakeheads seemed to be concentrated among a small number of serious collectors and a slightly larger group of amateur aquarists curious about keeping predators as pets. Most questions appeared to originate from persons who had experience with cichlid fishes, were curious as to whether snakeheads could coexist with other fishes (particularly cichlids), and wanted to know how to maintain snakeheads, what to feed them, what species could be purchased, and where they could be bought. Experienced hobbyists typically cautioned that large aquaria are needed for several available species, that larger snakeheads were intolerant of other fishes and typically another of their own species, and warned of the expenses of providing live food.

Snakeheads that have been periodically available to hobbyists in the U.S. are listed in table 4. This information was assembled in 2002 from various Internet sites in the U.S. and Canada that represent retailers and hobbyist groups and should not be considered a complete "shopping list." Moreover, availability of snakehead species from retailers has been often sporadic. For example, two retailers located in states where importation and possession of snakeheads is legal and who advertise on the Internet rarely have them in stock for sale. A visit to one of these dealers in June 2002 found no snakeheads. A salesperson said they only have them available periodically, adding that among the most popular are "red" snakeheads (a "trade name" for juvenile *Channa micropeltes*, a species that can reach a length of 1 m as an adult and is a voracious predator). Snakeheads have been only a minor part of the aquarium fish trade in the U.S. (Marshall Myers, personal commun., 2002).

Retail aquarium store, Nashville, Tennessee. Photo by Walter R. Courtenay, Jr., USGS.

Table 4—Snakeheads of interest to aquarists in the U.S.

[Information assembled from several aquarist-oriented and retailer websites in 2002. Common names are those often used in the aquarium fish trade]

Channa asiatica	Chinese snakehead
Channa bleheri	Rainbow snakehead, tiger snakehead, python snakehead
Channa marulius	Cobra snakehead
Channa micropeltes	Red snakehead, redline snakehead
Channa punctata	Spotted snakehead
Channa stewartii	Golden snakehead
Parachanna africana	African snakehead

Nevertheless, hobbyists, wholesalers, and retailers have been able to import snakeheads from many exporters in India and southeastern Asia that advertise on the Internet. Individual hobbyists occasionally advertised snakeheads for sale, whereas others inquired about availability on Internet aquarium fish "classifieds" and chat rooms; sometimes these ads or inquiries originated in states where possession of snakeheads is illegal.

Ng and Lim (1990) noted that smaller, colorful snakeheads are important in the aquarium fish trade in southeastern Asia. For example, they mentioned that *Channa gachua* was selling for S$30-60 per individual, and that slightly larger species such as *C. melanoptera* and *C. pleurophthalma* from Borneo, Sumatra, and Malaysia can garner prices as high as S$100 per fish. These fishes are caught wild, are primarily found in forest streams, and with deforestation occurring at a rapid pace, there is fear of overexploitation (Ng and Lim, 1990). In the U.S., prices for *C. bleheri* have ranged from $55-75 per individual for sizes of 8-15.5 cm specimens. Larger species of snakeheads can cost well over $100 per fish, depending on size, with young individuals of the same species fetching prices of $15 or more. Therefore, with their predatory nature, periodic availability, and relatively high prices for purchase and maintenance, snakeheads cannot be considered an important staple of the U.S. aquarium fish industry.

Because 14 states prohibited importation and possession of live snakeheads prior to the Federal ban on importation and interstate transport, the potential aquarium market for these fishes would appear to be limited. Nevertheless, there have been violations of these prohibitions in several states (see section "Regulations as of July 2002").

Larger snakeheads can outgrow their aquaria and/or the interest of their owner(s). Some have been released, as witnessed by the capture of *Channa micropeltes* from the wild in waters of Maine, Maryland, Massachusetts, and Rhode Island (see section "Literature Review and Background Information, History of Introduction, Western Hemisphere"). Fortunately, this subtropical species cannot overwinter in these states.

LIVE-FOOD FISH TRADE

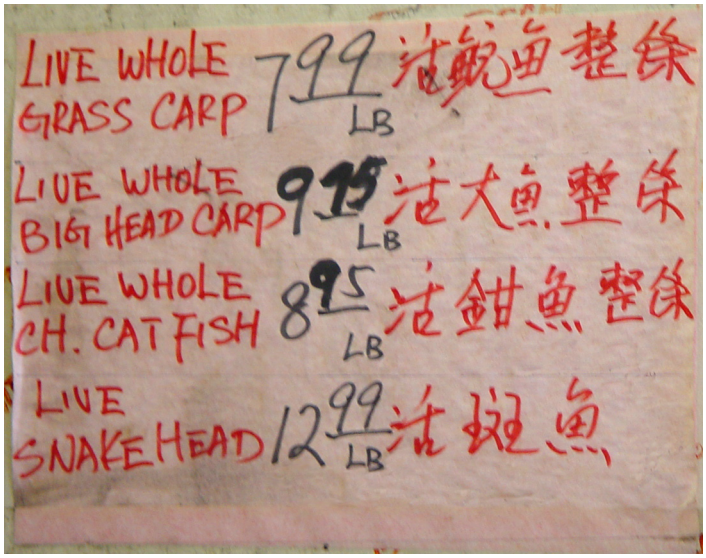
Snakeheads have long been favored food fishes in India and many parts of Asia, particularly southeastern Asia (Lee and Ng, 1991). Some are utilized as luxury specialty foods, available alive in aquaria for customer selection at upscale restaurants in larger cities such as Calcutta, Bangkok, Singapore, Hong Kong, and other major locales. They also provide easily caught food for poorer people (Wee, 1982). These fishes are typically freshly killed, often cooked whole or prepared as filets or steaks, fried or steamed, or included in soups. Excess catches in Thailand and Cambodia are often dried for storage and future use (Wee, 1982; Balzer and others, 2002).

Lee and Ng (1991) noted that snakeheads can remain alive out of water for long periods of time if kept moist. They added that some people believed that this ability may have provided these fishes with healing properties, making them prized as food, particularly to people with illnesses or recovering from surgery. In such situations, the fish are killed just before cooking, the thinking being that healing properties are lost if the fish are killed sooner. They also mentioned that some people in Myanmar believed that one species of snakehead represented humans transformed into fish because of their sins, and that eating one would result in the consumer becoming a lion. Day (1875) noted that some people in India believed that snakeheads that suddenly appeared from mud in the bottom of dried ponds after monsoonal rains actually fell from the sky with the rains.

To illustrate the value of snakeheads in the Orient, Wee (1982) recorded 1977 market prices as $2.50/kg in Taiwan and $1.00/kg in Hong Kong. Ng and Lim (1990) reported prices of S$10 to S$20/kg for live *Channa lucius*, *C. micropeltes*, and *C. striata*, three of the larger snakeheads, in markets in Singapore in the late 1980s.

Asian food market in Nashville, Tennessee, showing tubs and aquaria containing live-food fishes, June 2002. Photo by Walter R. Courtenay, Jr., USGS.

They commented that even smaller species (such as *C. gachua* and *C. melasoma*) are utilized as food in some parts of Asia (such as Myanmar and Sri Lanka), adding that *C. gachua* is sometimes used as bait to catch larger snakeheads. Peter Ng (personal commun., 2003) commented that *C. gachua* was sold alive in May 2000 in fish markets and restaurants in Xishuangbanna and Luxi, Yunnan Province, China, for about S$5/kg, and served in restaurants as whole fish soup. He also noted that *C. marulioides* was sold fresh and dry salted in Sambas and Sintang markets, western Kalimantan, in April 1998. He also saw *C. marulioides* being sold alive in November 1999 in Samarinda, east Kalimantan, and, in 2002, freshly sliced fillets of *C. micropeltes* were sold at S$20/kg in Singapore. In cities such as Hong Kong and Singapore, snakeheads are imported for food from Malaysia and Indonesia. This appears to have led to declines and scarcities of such species as *C. striata* in Malaysia where this fish is considered the most valuable and important snakehead in the nation as food and for medicinal purposes (Wan Ahmad, personal commun., 2001).



Fish market sign at an Asian food market in Honolulu, Hawaii, showing snakehead availability. Photo by Pam L. Fuller, USGS.

As noted earlier, some snakeheads, particularly *Channa striata*, called "haruan" in Malaysia, are important for medical use, particularly in Malaysia and Indonesia. Ng and Lim (1990) and Lee and Ng (1991) noted that *C. lucius* and *C. micropeltes* are also utilized for such purposes in both nations. Mention was made of use in a postnatal diet and during recuperation from illnesses or surgery (Lee and Ng, 1991). Although no specific information was given as to how the fishes were used following surgery, a neighbor of one of the authors (WRC), a Malaysian by birth, stated that the oils from the haruan are used to greatly reduce scarring following surgery, adding she had seen the results and scar tissue was dramatically reduced to a minimum. It has been demonstrated that haruan tissues contain substantial levels of arachidonic acid, a precursor of prostaglandin, essential amino acids (especially glycine), and polyunsaturated fatty acids required to promote prostaglandin synthesis, important factors in wound healing (Baie and Sheikh, 2000).

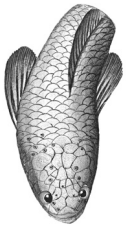
Channa striata is an important food fish throughout its native range (a species complex distributed from Pakistan eastward to southern China including Malaysia, Indonesia, and Java). Its supposed medicinal value doubtlessly explains why this species is often said to be the most widely introduced species of snakehead as persons of Asian origin emigrated to other locations. *Channa maculata*, often misidentified as *C. striata*, have been imported and released in a similar manner.

BIOLOGICAL CONTROL

There is no evidence that any species of snakehead has been suggested for use as a biological control agent in the U.S. Nevertheless, certain species of snakeheads have been investigated or utilized as biological controls abroad. For example, Kehar and others (1995) reported experiments in which spotted snakeheads, *Channa punctata*, were used at different levels of pH and salinity in controlling mosquito larvae. They concluded that this snakehead could be utilized as a potential biological control of mosquito larvae in waters up to 10 ppm salinity. Mansuri and others (1979), however, determined that this species was intolerant of salinities above 6 ppm. Nevertheless, Khora and Rao (1994) recorded the spotted snakehead from estuaries entering the Bay of Bengal. Only young spotted snakeheads feed on insect larvae before dietary changes to larger prey (Quayyum and Qasim, 1962).

Predatory teeth and jaws of a snakehead. Photo by Walter R. Courtenay, Jr. USGS.

A more common use of snakeheads in biological control has been as a predator in fish culture. Conlu (1986) and Milstein and Prein (1993) reported that chevron snakeheads, *Channa striata*, are used to control overproduction of tilapias in culture ponds in the Philippines. Wee (1982) also noted this practice, adding, as did Bardach and others (1972), that they are also used in carp culture to control unwanted "pest fish" in culture ponds. In turn, snakeheads utilized in this manner are also sold as products of culture. Similarly, African snakeheads, *Parachanna obscura*, are used to control young of tilapias in aquaculture ponds in Bénin (Bonou and Teugels, 1985).



U.S. IMPORTATIONS

Some species of snakeheads have been imported for several decades for the aquarium fish trade. In the past two decades, however, snakeheads have also been imported to the U.S. for sale in certain ethnic markets that sell live-food fishes and some restaurants that hold live fishes in aquaria for customer selection. In most states and the District of Columbia, such importation and sale is legal, but there have been violations in at least six states where possession and sale of live snakeheads is illegal. Until recently, the live-food fish pathway for potential introduction of live fishes into U.S. waters was largely overlooked. Because *Channa maculata* (misidentified as *C. striata*) and other eastern Asian food fishes (common carp, *Cyprinus carpio*; oriental weatherfish, *Misgurnus anguillicaudatus*; whitespotted clarias, *Clarias fuscus*; and swamp eel, *Monopterus albus*) were introduced from China into Hawaii before 1900, doubtlessly encouraged and perhaps initiated by Asian immigrants (Maciolek, 1984), this pathway should have been of concern.

Imports of snakeheads into the U.S. have been increasing in recent years (table 5). Importation records unfortunately report quantities either in numbers or by weight, but not both. Hence, the two columns (Number of individuals, Number of kilograms) in table 5 consist of 51,233 fish and an additional 22,208 kg of snakeheads. Furthermore, records do not provide a detailed breakdown of species imported or indication of the intended reason for importation (pet trade or live-food fish markets). Moreover, these records are probably incomplete (Marshall Myers, personal commun., 2001) and may represent only part of the total number/weight of imported snakeheads. This, coupled with not knowing how much of the weight represents small snakeheads and juveniles of larger species destined for the aquarium fish trade versus market-size, larger fish, makes projecting the total number of individuals a precarious guess at best.

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

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

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

Sources of imported snakeheads are varied (table 6). Again, these records are probably incomplete, but China is clearly the major exporter of live snakeheads. As in table 5, there is no breakdown by species.

The number of species that have been imported for the aquarium fish trade or the live-food fish trade could not be determined. Nevertheless, *Channa argus* is the most widely cultured snakehead in China (Fang Fang, personal commun., 2002), and has been available for sale in ethnic live-food fish markets in New York (James Stephen Lee, personal commun., 2001) and St. Louis, Missouri (Leo Nico, personal commun., 2002). A total of 80 live individuals in transit to Seattle were confiscated in Blaine, Washington, in 2001 (Ted Pietsch, personal commun., 2001; Mike Williams, personal commun., 2003), and others were seized from markets in Houston, Texas (Howells and others, 2002), Miami and Pembroke Pines (Florida Fish and Wildlife Conservation Commission, 2001), and Orlando, Florida. Snakeheads had been illegal in California, Florida, Texas, Washington, and 10 other states for many years prior to

Table 6—Origin of snakehead shipments (Channidae, all species) during the past 5 or more years

[1997–2002; records for 2002 extend through May 31]

Country	*Number of individuals*[1]	*Number of kilograms*[2]	*Total declared $ value (individuals and weight combined)*
China	48,533	20,323	125,295
Hong Kong	2	--	50
India	572	--	1,498
Indonesia	300	--	96
Nigeria	970	--	659
Switzerland	50	--	100
Thailand	1,084	--	1,420
United States	25	--	38
Vietnam	1,079	1,435	4,265

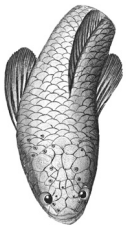
[1]Not included in number of kilograms.
[2]Not included in number of individuals.

July 2002. The first specimen of this species to have been captured from U.S. waters was taken by electrofishing in Spiritwood Lake, a reservoir north of San Bernadino, California, in 1997. Two individuals were caught by angling in the St. Johns River, below Lake Harney, Seminole and Volusia Counties, Florida, in 2001 (with three more reported as having been caught nearby); another was captured by electrofishing in Newton Pond, Worcester County, Massachusetts, in late 2001. The discovery of an established population of this species in a pond in Crofton, Anne Arundel County, Maryland, proved that this species was capable of invading U.S. waters. In July 2002 *C. argus* was being sold in a live-food fish market in Orlando, Florida. That market was raided by FFWCC agents who confiscated several specimens. Northern snakeheads were reported to be in culture in Arkansas, and this may or may not have been a source of northern snakeheads in Florida. *Channa argus* was likely available in live-food fish markets in Boston, although two snakeheads purchased there in late 2001 by Karsten Hartel were later identified as *C. maculata*. Live-food fish markets in Vancouver, British Columbia, also sold *C. argus* (Margarita Reimer, personal commun., 2002).

In conclusion, *Channa argus* is known to have been the most widely available snakehead in North American live-food fish markets, followed by *C. maculata*. *Channa marulius* was also available in New York City live-food fish markets (Leo Smith, personal commun., 2002). There have been no reports of *C. striata* being available for sale in live-food fish markets in the contiguous U.S., even though it is considered the most important snakehead used for food in southeastern Asia and is being cultured in Hawaii. Nevertheless, a freshly killed

C. striata was purchased from an oriental market in San Diego, California, on July 29, 2002 (Richard Rosenblatt, personal commun., 2002). There was no cloudiness in the eyes of the specimen, indicating that it had never been frozen and may have been kept in a live fish tank, perhaps on the premises of the market, until a very short time before being placed on ice for sale. The specimen was deposited in the fish collection of Scripps Institution of Oceanography (SIO 64-228). *Channa striata* is being sold in a market in Honolulu, Hawaii (Pam Fuller, personal commun., 2002).

Another observation from importation data shows that imports of live snakeheads from Ghangzhou and Shenzhen, both in Guangdong Province, China, began to increase in the latter part of 2001 and accounted for the majority of imports through May 2002. *Channa argus* is not native to southern China. Therefore, importation data suggest that many snakeheads imported during late 2001 well into 2002 may have been *C. maculata*, destined for the live-food fish trade.



REGULATIONS AS OF JULY 2002

At least 14 states specifically prohibited possession of live snakeheads (table 7) prior to the discovery of an established population of northern snakeheads in a pond in Crofton, Anne Arundel County, Maryland, which was eradicated in 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 (fig. 5). 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.

Table 7—States prohibiting snakeheads as of July 2002

Alabama	Idaho
Arizona	Mississippi
California	Nevada
Colorado	Oregon
Florida	Texas
Kentucky	Utah
Georgia	Washington

The U.S. Fish and Wildlife Service published a proposed rule to list the family Channidae (snakehead fishes) as injurious wildlife in the Federal Register on July 26, 2002 (67 FR 48855) under the Lacey Act (18 U.S.C. 42). The final rule banning importation and interstate transport of live snakeheads was published in the Federal Register on October 4, 2002 (67 FR 62193). This ruling does not affect possession or sale of live snakeheads in states that do not specifically prohibit them, or importation of dead snakeheads refrigerated or frozen for sale as food fishes into states where possession of live snakeheads is illegal. Nevertheless, despite the Federal rule and a long-standing state prohibition, several live *Channa argus* were confiscated by U.S. Fish and Wildlife Service Inspectors in California as recently as July 2003.

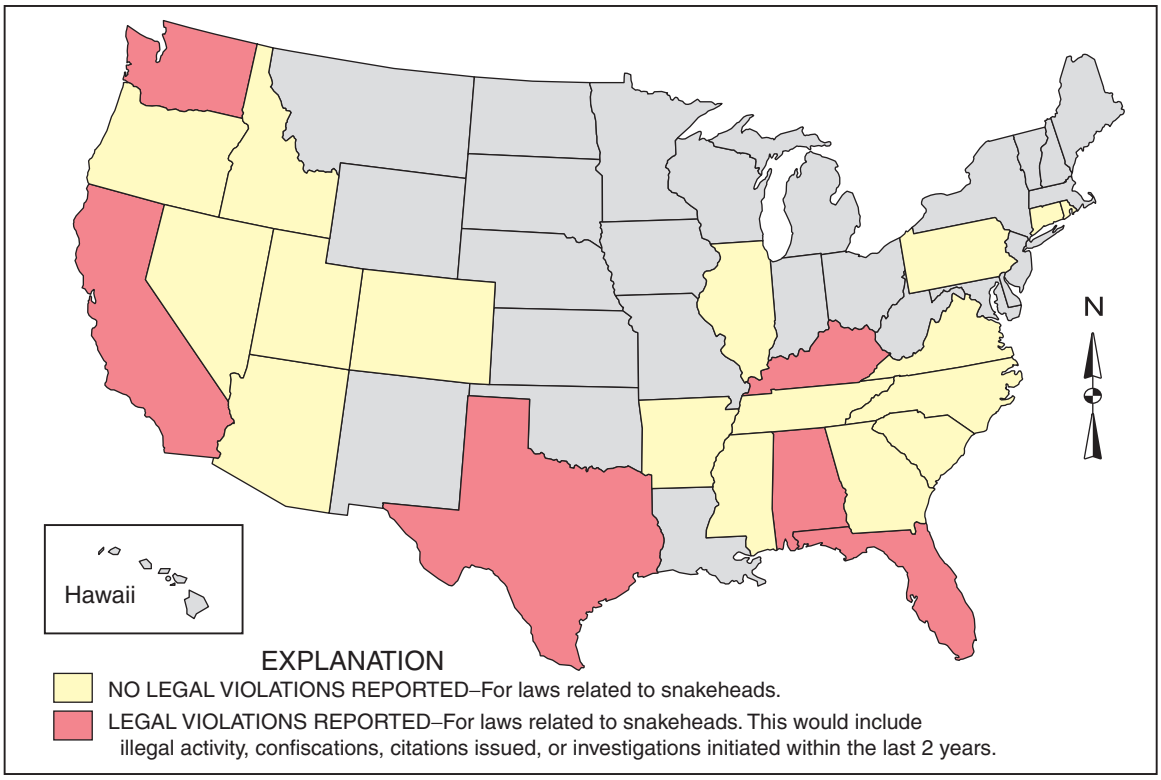
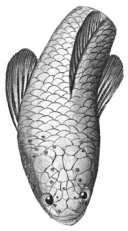


Figure 5—States prohibiting possession of live snakeheads as of November 2002.

Prior to 2002, there were illegal activities involving snakeheads in states that prohibited their sale or possession. A total of 80 live *Channa argus*, destined for markets in Seattle, was discovered in 2001 on a truck from British Columbia. Specimens of *C. micropeltes* and *C. marulius* were confiscated from pet shops in the Los Angeles area, southern California, in the past 2 years. *Channa argus* was confiscated from live-food fish markets in Miami, Orlando, and Pembroke Pines, Florida, and Houston, Texas, in 2001. Illegal traffic in pet snakeheads, involving mostly *C. bleheri*, was discovered in Alabama and Kentucky in the past 2 years. It has been suggested that these snakeheads came from a distributor in Atlanta, Georgia, a state where snakehead possession is also illegal.



POTENTIAL RANGE

Temperature is the most important environmental factor that would determine potential range of snakeheads in the United States. Because there are few data providing thermal tolerance ranges for snakeheads, potential range must be inferred from distribution within native ranges (fig. 6).

The family Channidae contains 10 species that are strictly tropical and, if introduced, would survive in only the warmest waters, such as extreme southern Florida, perhaps parts of southern California and Hawaii, and certain thermal spring systems and their outflows in the American west. Another four species can be considered

tropical to subtropical, indicating a similar potential range of distribution as for tropical species, but with a greater likelihood of survival during cold winters and more northward limits. One is subtropical. Another 11 snakeheads (3 that appear to be species complexes) can tolerate tropical or subtropical to warm temperate conditions, indicative of species that could survive in most southern states. One is warm temperate, and another is warm temperate to cold temperate (*Channa argus* has a temperature range of 0-30 ºC). In summary, there are no waters in the United States that, based on temperature, would preclude some member(s) of the family Channidae from becoming established.

RISK ASSESSMENT PROCESS

Snakehead fishes have had a modest following among U.S. aquarists for several decades. Nevertheless, they are more popular in the Japanese and European aquarium fish trade (Ralf Britz, personal commun., 2002). It is only within the past two decades that snakeheads, limited to a few species, have been imported and marketed in the U.S. as live-food fishes. Thus, pathways for introduction into U.S. waters have been through importations and releases by aquarists and introductions of market-size snakeheads, the latter typically at or near sexual maturity. Release or introduction of snakeheads out of both of these pathways has been documented in open waters of the U.S. All snakeheads prey on other aquatic organisms, most showing a preference for fishes, and many are regarded as thrust predators, hiding and attacking prey by surprise. As with any introduction of a nonindigenous aquatic species, there is always the possibility that they may host parasites or diseases that could spread to native species. Some might host human parasites, and one snakehead species has been found to be a carrier for gnathostomiasis. The fact that one species has been shown as a carrier indicates that there are others which could present a similar threat to human health, yet to be investigated.

There are seven rating elements in the risk model (Risk Assessment Management Committee, 1996). Each element is assigned an estimated level of risk, rated as high, medium, or low. Uncertainty codes after each element rating are as follows (with descriptions): Very Certain (as certain as we are going to get); Reasonably Certain (reasonably certain); Moderately Certain (more certain than not); Reasonably Uncertain (reasonably uncertain); and Very Uncertain (a guess).

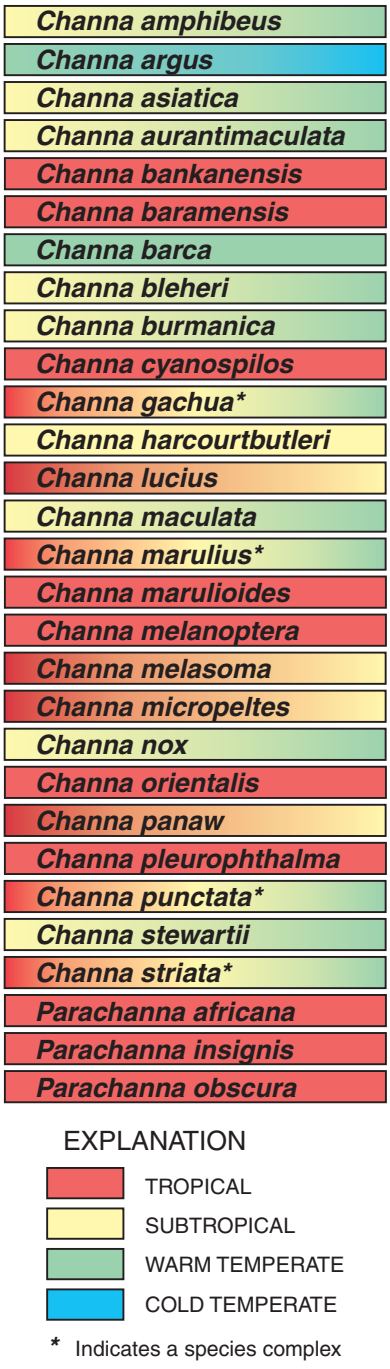


Figure 6—Thermal range of snakeheads (Channidae) based largely on native range of distribution.

RATING ELEMENTS OF RISK MODEL

• 1 • Estimate probability of the exotic organism being on, with, or in the pathway.
High—very certain

Four species of snakeheads have been recorded as reproducing in waters of the United States. These are *Channa argus* in Crofton, Maryland (isolated population, eradicated in September 2002), *C. maculata* in Oahu, Hawaii, *C. marulius* in southeastern Florida, and *C. striata*, being cultured in confined waters in Oahu, Hawaii, since the early 1990s. Specimens of *C. micropeltes* have been collected from waters of four states, the earliest records being from Maine and Rhode Island from the 1970s. Snakeheads have had a limited market in the aquarium fish trade for several decades and, more recently, four species of snakeheads (*C. argus, C. maculata, C. marulius,* and *C. striata*) were being sold in live-food fish markets within the U.S. Therefore, snakeheads have been and are in the United States pathway.

• 2 • Estimate probability of the organism surviving in transit.
High—very certain

Snakeheads are capable of breathing air, many being obligate airbreathers, and easily transported by air or land vehicle without water as long as they are kept moist. They have survived importation from overseas as well as interstate truck transportation.

• 3 • Estimate probability of the organism successfully colonizing and maintaining a population where introduced.
High—very certain

Appropriate habitats and climate are found throughout most of the United States. This does not infer that all species of snakeheads could become established in most of the U.S., but that there are habitats in all states, with the possible exception of Alaska, where one or more species could establish a reproducing population. Preferred food of snakeheads (that is, fishes, crustaceans, insects and insect larvae) is locally abundant.

Several species of snakeheads have established in waters outside their native ranges of distribution in the Eastern Hemisphere. These include *Channa argus* in Japan, Czechoslovakia, Russia for a period of time, the Aral Sea basin (Amu Dar'ya, Syr Dar'ya, Kaska-Dar'ya, Sarysu, Chu, and reservoirs on the Talus rivers); *C. asiatica* in Taiwan; *C. maculata* in Taiwan, several prefectures of Japan, Madagascar, and Hawaii; *C. melasoma* on Palawan, Philippines; *C. orientalis* in Kalimantan and Greater Sunda Islands; and *C. striata* in many Pacific Islands and most recently (early 1990s) in confined waters of Oahu, Hawaii.

Within the continental U.S., two species of snakeheads have been recorded as established. *Channa argus* was established in a pond in Crofton, Anne Arundel County, Maryland, for at least 2 years before being eradicated in September 2002. There remains some concern that the species may have escaped into the Little Patuxent River during that period of occupancy. In addition, specimens of this species have been collected from the St. Johns River, Seminole and Volusia Counties, Florida,

a pond in Shrewsbury, Worcester County, Massachusetts, and from a reservoir serving Los Angeles, located just north of San Bernardino, California, in 1997. There was a reported capture of two individuals of the same species from a reservoir near Charlotte, Mecklenburg County, North Carolina. Subsequent sampling of that reservoir by North Carolina Wildlife Resources Commission biologists did not reveal the presence of additional specimens. *Channa marulius* has been established for several years in a series of interconnected artificial lakes and canals in Tamarac, Broward County, Florida. This system of waterways is connected to the gridwork of flood control canals of southeastern Florida.

Channa maculata has been established since before 1900 on Oahu, Hawaii. Although the species was once widely distributed on Oahu, it is now largely confined to Wahiawa Reservoir and adjoining canal systems. Yamamoto and Tagawa (2000) reported the largest snakehead captured from waters of Oahu was "over 5 feet in length," and that species had to have been *C. maculata.* Two specimens were also reported to have been captured by an angler from the Charles River, Boston, Massachusetts, in 2002. Since the early 1990s, *C. striata* was imported into Hawaii and it is now being cultured.

Channa micropeltes, a species largely sold through the pet fish trade, has been collected from open waters of Maine, Massachusetts, Maryland, Rhode Island, and Wisconsin. This tropical/subtropical species could not survive winters in those states. Nevertheless, these releases, likely made by hobbyists, is indicative of what could happen if similar introductions of this or other tropical/subtropical snakeheads were made in states, such as Florida or Hawaii, or into thermal springs and their outflows in western states.

Joe Hennessey with a giant snakehead (*Channa micropeltes*) caught in a Wisconsin river, September 4, 2003, undoubtedly after being released by an aquarium enthusiast. Fortunately, this species will not survive the winter (see fig. 6). Photo by Mike Sorge, Wisconsin Department of Natural Resources, Bureau of Fisheries Management and Habitat Protection.

- 4 • Estimate probability of the organism to spread beyond the colonized area.
  High—reasonably certain

Appropriate habitats (rivers, streams, lakes, reservoirs, ponds, canals) and climate are suitable for establishment of snakeheads in U.S. waters. Suitable habitat for subtropical/tropical species exists in southern Florida, Hawaii, perhaps southern Texas, and thermal springs and their outflows in several western states. Several snakehead species can exist in warm temperate conditions that exist in southern states. Both *Channa argus* and *C. maculata*, especially the former, can tolerate cold climates,

making the likelihood of their becoming established a probability even in some northern states if released. Introductions into rivers, streams, or canal systems would likely spread whereas releases into lakes or ponds could be more restrictive as to range expansion. Nevertheless, people move fish; considering that larger species of snakeheads are popular with anglers in several locations within their native and introduced ranges abroad, the likelihood of anglers moving snakeheads to novel waters from colonized areas is reasonably great.

Because most snakeheads build nests in aquatic vegetation, some might argue that these fishes would be incapable of colonizing waters devoid of macrophytes. Nevertheless, at least three snakeheads, *Channa gachua, C. marulius,* and *C. punctata*, have successfully reproduced in waters lacking vegetation. The same may be true for *C. argus* that has colonized reservoirs on the Talas River of Kazakhstan. This suggests that there is likelihood that other species of snakeheads have the potential to establish in waters lacking vegetation. Predictions as to where or under what environmental conditions a nonindigenous aquatic species might or might not become established have been proven unreliable in several instances.

- 5 • Estimate economic impact if established.
  Medium—moderately certain

The predatory nature of snakeheads indicates that their introduction could negatively impact populations of native fishes through direct predation, competition for food resources, and alteration of food webs. Larger species of snakeheads are considered to be "top predators" in their native ranges. Unlike U.S. highly predatory native fishes, snakeheads are very protective of their young, thus enhancing survival beyond early life history stages and suggesting the possibility of eventual dominance in suitable waters. To predict what the economic impact could be to the recreational fishing industry or to sport fishing is difficult to assess, but could prove to be substantially detrimental over time.

The economic cost of eradication efforts would be high. Introduction of the northern snakehead, *Channa argus*, to a single pond in Crofton, Anne Arundel County, Maryland, serves as an example. The original purchase of the snakeheads that were eventually introduced at least 2 years ago was likely no more than $40. A recent estimate of the costs to the State of Maryland during 2002 in personnel, creating and conducting two meetings of the Maryland Snakehead Scientific Advisory Panel, application of herbicides and rotenone, and disposing of dead fish was about $110,000 (Steve Early, personal commun., 2003). Introduction of non-native aquatic species is illegal in Maryland, but the perpetrator must be found and charged of such action within a 2-year period. In this instance, the time limitation had expired before the individual making the introduction was identified. Had that person been charged before the limitation expired, the fine would have been $40. At present, no state requires a liability bond before an intentional introduction is made by individuals or an agency, and there are no laws that hold an individual (or individuals) responsible for the costs of eradicating or controlling an unintentional introduction should the species involved become established.

The northern snakehead introduction in Maryland was a rare instance where the fish was confined to a single pond from which it could be eradicated. The costs of eradicating an introduced species in an isolated small lake would be greater and could be substantial in a larger lake. Eradication from flowing waters or large lakes with connecting drainages is physically and fiscally impossible, and the same applies to control measures.

Some species of snakeheads are capable of short overland migrations. This presents a potential economic threat to fish culture interests if those species enter culture facilities from adjacent waters, such as occurred with another introduced airbreathing predator, the walking catfish, in Florida (Courtenay and Miley, 1975).

- 6 • Estimate environmental impact if established.
  High—very certain

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.

All snakeheads are predators, particularly on fishes. Therefore, negative impacts to populations of native fishes could be quite high, as well as predation on crustaceans. Predation on other invertebrate species would be moderate to low, based

A blue tilapia (*Oreochromis aureus*), an introduced species in Thailand, was sheared in half by a giant snakehead (*Channa micropeltes*). Photo courtesy of Jean-Francois Helias, Fishing Adventures Thailand.

on literature references supplied in individual species accounts. Larger snakeheads, however, are known to also feed on birds (particularly young waterfowl), amphibians, small reptiles (snakes, lizards), and small mammals.

Potential to transfer pathogens (parasites, diseases) is largely unknown. Nevertheless, all snakehead species are hosts to at least several species of parasites (see table 2). At least two snakehead species utilized in intense aquaculture, *Channa punctata* and *C. striata*, are susceptible to epizootic ulcerative syndrome (EUS), a disease believed to be caused by several species of bacteria, a fungus, and perhaps a retrovirus. EUS is not specific to snakeheads and has affected other fishes, such as clariid catfishes, bagrid catfishes, two cyprinid genera, mastacembalid eels, a nandid fish in India, and giant gourami and climbing perch in Thailand. There have been no studies undertaken to examine transfer of parasites or diseases to native North American fishes.

Adverse impacts on native wildlife and wildlife resources would likely be few, other than through predation. Ecosystem balance, however, could be substantially modified should snakeheads become established in waters with low diversity of native fishes and low abundance or absence of native predatory species.

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.

Likelihood and magnitude of the effect on designated critical habitats of threatened or endangered species would be significant on the living component of the aquatic ecosystem. Depending on the habitat, snakeheads have the potential to detrimentally alter aquatic communities. The most likely scenario would be an alteration of the fish and crustacean community structure through predation. For listed fishes there could be competition for food in addition to direct predation. Like amphibians, fishes and crustaceans listed as threatened or endangered species, candidate taxa of these three groups or aquatic organisms would likewise be at risk.

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.

- 7 • Estimate impact from social and/or political influences.
  Low—moderately certain

Snakeheads have been in the U.S. aquarium fish trade and hobby for several decades. Due to their predatory nature, compounded by the high costs of housing and feeding larger snakehead species, they have had a limited following by hobbyists. Therefore, snakeheads have never represented more than a very minor component of the U.S. aquarium fish trade. Consequently, economic impact to the aquarium fish trade through prohibition of importation or interstate transport of live snakeheads would be minor.

Importation of snakeheads for the live-food fish market in the mainland U.S. is a more recent trend, to our knowledge dating back to the most recent decade or two. Although snakeheads have been available in live-food fish markets in Hawaii for a far longer period of time (likely several decades), only one market (in Honolulu) was selling live snakeheads for food purposes as of 2002 (Mike Yamamoto, personal commun., 2002). Markets that sell live freshwater food fishes also sell species other than snakeheads, including catfishes, tilapias, carp, eels, hybrid striped bass, and sometimes swamp eels. These are typically Asian ethnic food markets, and they frequently carry a large variety of frozen, imported marine and freshwater food fishes. Therefore, as in the aquarium fish trade, snakeheads are only a minor component of live-food fish sales.

Economic impact to the live-food fish trade would be minor following a ban on importation and interstate transportation of live snakeheads, as these fishes can be imported frozen or dead on ice for sale. Until Arkansas passed an emergency rule banning importation, possession, and sale of live snakeheads in late July 2002, only three fish farmers in that state were reported to be culturing snakeheads (*Channa argus*) for the live-food fish market. There were no other culture facilities in the mainland U.S. known to be raising snakeheads. There is, however, one aquaculture facility on Oahu, Hawaii, that has been rearing *C. striata* since the latter part of the 1990s.

Fish produced by that facility can be shipped for sale either dead on ice or frozen to any state or U.S. territory, or sold within Hawaii. As a result, Federal prohibition of importation and interstate transport of live snakeheads would not present a significant negative impact to most U.S. aquaculture interests. Although political entities could be negatively impacted by the costs of eradication or attempts to control introduced snakeheads, no political entity is known to support importation, culture, sale, or any other use of live snakeheads.

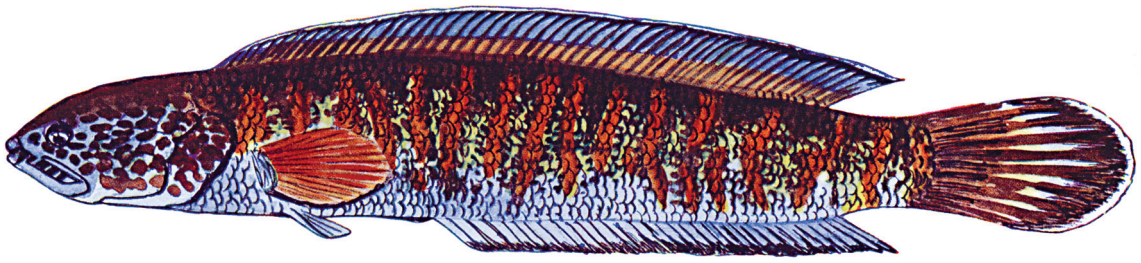
ORGANISM RISK POTENTIAL

Probability of establishment	Organism within pathway **HIGH**	→	Entry potential **HIGH**	→	Colonization potential **HIGH**	→	Spread potential **HIGH**	→ ***HIGH***
Consequence of establishment	Economic **LOW**	→	Environmental **HIGH**	→	Perceived **HIGH**	→	***HIGH***	
Organism risk potential	Probability of etablishment **HIGH**	→	Consequences of establishment **HIGH**	→	***HIGH***			

LOW	= acceptable risk	=	organisms of little concern (does not justify mitigation)
MEDIUM	= unacceptable risk	=	organisms of moderate concern (mitigation justified)
HIGH	= unacceptable risk	=	organisms of major concern (mitigation justified)

SPECIES ACCOUNTS

Channa amphibeus (McClelland, 1845)
Chel Snakehead



After Shaw and Shebbeare, 1938

Original description: *Ophiocephalus amphibeus* McClelland, 1845:274-282. Description of four species of fishes at the foot of the Boutan Mountains. Journal of Natural History, Calcutta, 5(18):274-282. Type locality: vicinity of tributaries of the Teesta (=Tista) River below the Boutan (Bhutan) mountains. Neotype: ZSI F 11435.

Synonyms: *Ophiocephalus amphibius* [sic], Day, 1877:365.

Ophiocephalus amphibius [sic], Shaw and Shebbeare, 1938:119-121 (vicinity of Chel River, northern Bengal).

Channa amphibia [sic], Jayaram, 1981.

Channa amphibius [sic], Talwar and Jhingran, 1992.

Channa amphibious [sic], Eschmeyer, 1998:92.

Common names: In northern Bengal: bora cheng (Mechi), borna (Rabha) (Shaw and Shebbeare, 1938). We suggest **Chel snakehead**.

Native range: Endemic to Chel River basin, Brahmaputra River drainage, northeastern India and Bhutan (Musikasinthorn, 2000).

Introduced range: No introductions known.

Size: To about 25 cm.

Habitat preference: No specific information, but distribution indicates preference for rivers, streams, ponds, perhaps swamps in the Chel River basin, Brahmaputra drainage, of northeastern India and Bhutan (Musikasinthorn, 2000). Shaw and Shebbeare (1938) reported that during rainy periods, young are found "in flooded paddy-fields enclosed by forest; large fish can be found in pools of dried streams in forests."

Temperature range: No specific information. Habitat preference and range indicate a warm temperate to subtropical species.

Reproductive habits: No specific information, but probably builds a cylindrical nest in vegetation and produces pelagic eggs.

Feeding habits: No specific information, but likely a carnivorous predator as an adult.

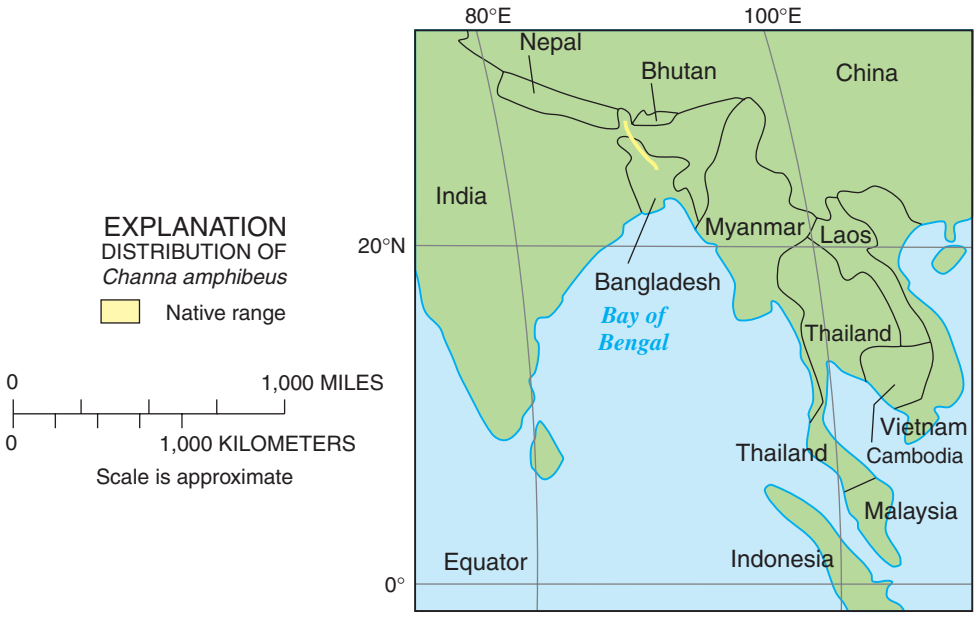
Characters: Gular part of head without patch of scales. Dorsal fin rays 50; anal fin rays 35; pectoral fin rays 15, pelvics 6; lateral line scales 81; cheek scales 9; scale rows above lateral line 5, below lateral line 13; predorsal scales 17; two large scales on underside of both sides of lower jaw. Head length 27.6 percent standard length; anal fin length less than 50 percent of pectoral fin length. Mouth large, maxilla extending far beyond posterior margin of eye. Many small conical teeth in premaxilla; three large conical teeth in prevomer; about four medium-sized canines on each

side of palatine; row of about five canine teeth on each dentary, smaller than those on palatine; many small conical teeth on outer part of dentary. Characters based on neotype (Musikasinthorn, 2000).

Commercial importance in the United States: Unlisted on aquarist-oriented websites. Negligible likelihood of being imported for sale in aquarium fish trade or live-food fish markets.

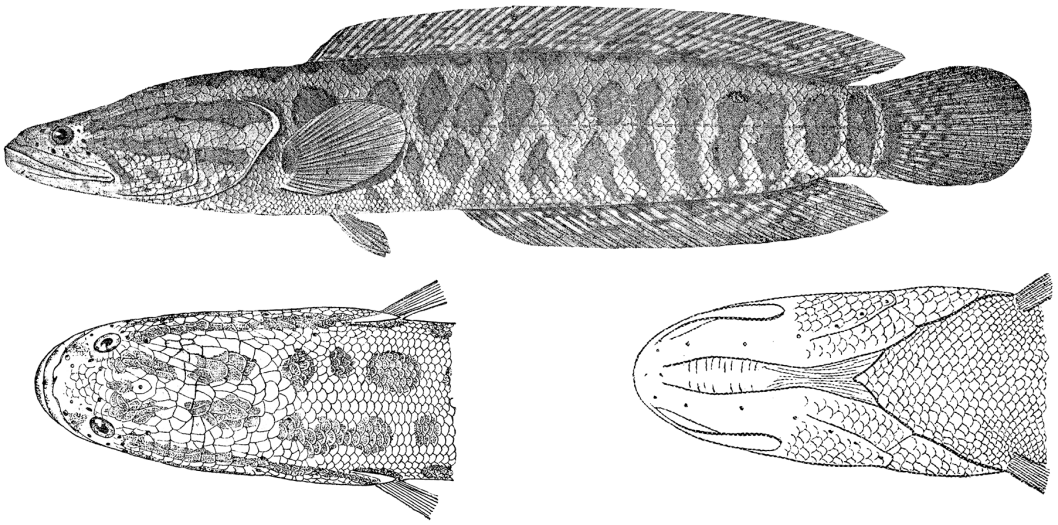
Commercial importance in native range: Unknown.

Environmental concerns: Unknown, but the species is probably a predator on other fishes and invertebrates.



Channa amphibeus

Channa argus (Cantor, 1842)
Northern Snakehead



After Berg, 1933

Original description: *Ophicephalus argus* Cantor, 1842:484. General features of Chusan, with remarks on the flora and fauna of that island. Ann. Mag. Nat. Hist. (n.s.), 9(60):481-493. Type locality: Zoushan Dao (Chusan Island), China. Syntypes: BMNH 1843.7.21.3; BMNH 1860.3.10.

Synonyms: *Ophicephalus pekinensis* Basilewsky, 1855:225, tab. 9, fig. 3.

Ophicephalus argus warpachowskii Berg, 1909:200.

Ophiocephalus argus kimurai Shih, 1936:81, fig. 5.

Common names: **northern snakehead**; Amur snakehead; eastern snakehead; ocellated snakehead; zmeegolov (Russian, Ussuri Basin and Lake Khanka region; Berg, 1965); her-yu (China; Evermann and Shaw, 1927); ga mul chi (Korea); kamuruchi, raigyo (Japan; Bailey and Haller, 1977; Uyeno and Arai, 1984; Hosoya, 2002).

Native range: Middle and lower Heilong (Amur) River basin; Songhua (Sungari) River, Manchuria; Tunguska River at Khabarovsk, Russia; Ussuri River basin; Lake Khanka (Herzenstein and Warpachowski, 1887; Berg, 1965; Popova, 2002); Korea, except northeastern region (Okada, 1960; Berg, 1965); rivers of China southward and southwestward to upper tributaries of the Chang Jiang (Yangtze) River basin in northeastern Yunnan Province (Evermann and Shaw, 1927; Kimura, 1934; Nichols, 1943; Mori, 1952; Berg, 1965; Xinluo and Yinrui, 1990; Ruihua, 1994). Reported from Guangdong Province, China (Pearl River Fisheries Research Institute, 1991), likely an introduction there. Widely distributed in Chinese reservoirs (Sifa and Senlin, 1995).

Introduced range: Occurrence 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). Introduced from Korea in the early 1900s and established in many waters of central and southern Japan (Nakamura, 1963; Uyeno and Akai, 1984), considered as a "careless importation" (Okada, 1960). Chiba and others (1989) recorded the dates of these introductions as 1923-1924, noting that the species was reproducing in experimental or natural ponds and adding "Predation on native species" as a remark. In Japan, present and established in Hokkaido, Honshu, Kyushu, and Shikoku (Hiroshi Ueda, personal commun., 2001).

Holcík (1991) reported this species as introduced into "Czecho-Slovakia" and Russia, beginning in 1949. Holcík did not provide specific localities of introduction or information on status of the releases. Bogutskaya and Naseka (2002) listed *Channa argus* as having been transplanted within Russia. Nina Bogutskaya (personal commun., 2002) reported failed early introductions of the northern snakehead into the Volga Delta and ponds in Ekaterinburg (formerly Sverdlovsk) Province in the southern Urals. An experimental introduction was made in ponds of Moscow Province during 1949-1950 that established. In 1953, it was recommended that this

Juvenile northern snakehead, about 4 cm long, captured from pond in Crofton, Anne Arundel County, Maryland, July 9, 2002. Photo by Algerina Perna; reproduced with permission of the Baltimore Sun.

species should be stocked widely but that failed to happen. There was one report in a Russian aquarium journal in 1963 noting occurrence of this snakehead in small lakes in the Podolsk Region, Moscow Province, but the species is presently absent from the Moscow area. Tandon (1976) reported that acclimatization experiments were conducted in the former Soviet Union after 1950, and that fry were collected from ponds near Moscow and the Ukraine in 1955 and sent to Czechoslovakia for acclimatization purposes. He concluded that the source of the original stock was the Amur basin, not the Yangtze of China. In further support of the Amur basin having been the source of the stock, Zhadin and Gerd (1963) noted that "rearing of many Amur fishes possessed of frost resistance and great plasticity was recently initiated in water bodies in the European U.S.S.R." and included the northern snakehead among species imported.

Frank (1970) was more specific on introduction of northern snakehead to Czechoslovakia. He stated that the first shipment (three individuals) was made in December 1956 by V. Nikol'skiy of the Department of Ichthyology, Moscow University. These fish were introduced into a pond near Nižbor during Spring 1957 that later flooded into a nearby creek, resulting in the loss of the snakeheads. Nikol'skiy authorized a second shipment of 51 fish less than a year in age in December 1960. Several of these were released into three "natural ponds" near the Elbe River, with the remainder introduced to the same ponds during summer 1961. These ponds contained small cyprinids, roach (*Rutilus rutilus*) and white bream (*Blicca bjoerkna*), that served as prey for the snakeheads. In one pond that contained less vegetation, rudd (*Scardinius erythrophthalmus*) were used to supplement the food base. Snakeheads were periodically sampled from 1961-1964 to determine growth rates. Winters between 1961-1963 were unusually severe. All of the ponds became covered with ice during winter. The winter of 1963 was particularly cold over a long period of time (air temperatures often reaching -30 ºC and ice cover present for over 3 months). Due to decaying vegetation in two of the ponds producing hydrogen sulfide, a lack of oxygen, and thick ice on the surface, snakeheads and all other fishes perished in these ponds. Snakeheads did survive in the third pond, which was also being used experimentally to test if brown trout (*Salmo trutta*) could be used to control overpopulation of perch (*Perca fluviatilis*). During the winter 1963, the supply of roach and white bream was eliminated in the third pond by snakeheads and brown trout; the food base was supplemented with perch fry and snakeheads survived, but failed to grow. It was concluded that the northern snakehead could be acclimatized to Czechoslavakia as long as sufficient food existed. Interestingly, when the pond was cleared of vegetation for fish removal at the end of the experimental period, the northern snakeheads buried themselves in mud on the pond bottom making their capture difficult.

Borisova (1972), Amanov (1974), Dukravets and Machulin (1978), Usmanova (1982), Guseva (1990), and Dukravets (1992) documented introduction of *Channa argus* into the Aral Sea basin (about 45º N) in the early 1960s and its presence in the Amu Dar'ya, Syr Dar'ya, and Kashka-Dar'ya rivers of Kazakhstan, Uzbekistan, and Turkmenistan. The initial importation in 1961 of the northern snakehead was accidental when it was included with target phytophagous cyprinids (grass carp, *Ctenopharyngodon idella*, and silver carp, *Hypophthalmichthys molitrix*) that were destined for use in ponds adjacent to the Syr Dar'ya River. Introduction into the ponds occurred at "the 'Akkurgan' fish combine" (Amanov, 1974). Snakeheads escaped from ponds in 1964 and soon became established in the Syr Dar'ya (Amanov, 1974). Dukravets and Machulin (1978) reported that this snakehead migrated downstream into the Aral Sea about 1965. Similar escapes from ponds along the Kashka-Dar'ya in southern Uzbekistan in 1964 also led to establishment. It was also released with carp (*Cyprinus carpio*) in 1964 into Chimkurgan Reservoir in the Kashka-Dar'ya basin from a fish farm (Amanov, 1974; Usmanova, 1982; Baltz, 1991). Baltz (1991), however, cited 1963 as the year of introduction into the Aral Sea basin. At present,

the Aral Sea has almost disappeared and there are now hundreds of kilometers between the terminal reaches of these rivers and the former coastline of the Sea (Nina Bogutskaya, personal commun., 2002). Moreover, the salinity of the Aral Sea (10-12 ppm in about 1990; Baltz, 1991) is well above the tolerance limits of snakeheads.

All introductions into western Asia and eastern Europe were thought by some to have originated from China, perhaps from Amur basin stock of *Channa argus*. Sal'nikov (1998), in a comprehensive study of the inland waters of Turkmenistan, stated that the Aral Sea introduction source was the Yangtze basin of China. He reported the initial introductions of northern snakehead into Uzbekistan, with later migration through the Aral Sea into the Amu Dar'ya and other waters of Turkmenistan. Dukravets and Machulin (1978) and Usmanova (1982) noted that the characters of the introduced stock mostly agreed with those of northern snakehead from the Amur basin. Dukravets (1992) reported additional introductions of this fish beginning in 1976 from the lower part of the Sarysu River, north of the middle Syr Dar'ya, followed by further releases into reservoirs of the Talas and Chu Rivers, north and northeast of Tashkent, the capitol of Kazakhstan, during the middle 1980s. The species was thriving in irrigation reservoirs and isolated ponds on the Talas River, and more than 10 metric tons were commercially harvested from the reservoirs in 1989 (Dukravets, 1992). The latitude of this area of Kazakhstan parallels those of the Vermont/Quebec border, Minneapolis, Minnesota, and Salem, Oregon, in North America, indicating a possible northern range of distribution should this snakehead become established in U.S. waters.

As noted earlier, presence of this species in Guangdong Province, southern China (Pearl River Fisheries Research Institute, 1991), is likely the result of an introduction.

This species is recorded from open waters of the United States. A large snakehead was captured by electroshocking by California Fish and Game Department personnel in Silverwood Lake, located in the San Bernardino Mountains, north of San Bernardino, California, on October 22, 1997. The lake receives water from the California Aqueduct and serves as a reservoir for Los Angeles. A photograph of the specimen was taken and the specimen was frozen but later discarded without being preserved. The photograph has not yet been located. We sent a digital photograph of an adult *Channa argus* to the biologist who reported the capture in 1997 and he responded that this appeared to be the same species (John Sunada, personal commun., 2002). It is unlikely that another species of snakehead could survive in this high-altitude reservoir.

Two specimens were captured from the St. Johns River below Lake Harney, Seminole and Volusia Counties, Florida. The first was collected February 11, 2000, and the second on March 4, 2000. There are unconfirmed reports of three additional specimens having been caught nearby (Franklin N. Snelson, Jr., personal commun., 2001). An attempt was made by USGS personnel to collect additional specimens at this site by electrofishing in 2001, but none were collected. Additional attempts to collect this species will be undertaken.

On May 14, 2002 a Maryland angler caught a 43-45 cm long snakehead in a 1.8-ha retention pond behind a shopping mall in Crofton, Anne Arundel County, Maryland. The angler took photographs of the unusual looking fish before releasing it back into the pond. A month later, the angler took one of the photos to the Maryland Department of Natural Resources (MDDNR) headquarters in Annapolis for identification, and one of the biologists thought it might be a snakehead. That same day, the photograph was emailed to the USGS in Gainesville, Florida, where we readily identified the fish as a northern snakehead and immediately notified MDDNR. In fact, we had just completed and submitted a document on the risk assessment and evaluation potential for establishment (among other biological factors) to the U.S. Fish and Wildlife Service on the entire family of snakeheads about a week prior to when the Crofton pond fish was initially caught.

A second snakehead (about 66 cm long) was caught by a second angler in the same retention pond on June 30, 2002. On the evenings of July 7-8, he dipnetted eight juvenile snakeheads from the pond, which we subsequently confirmed as northern snakeheads. This was the first proof that the species was established as a reproducing population. Later that week (July 11), MDDNR biologists captured an additional 99 juveniles ranging 5-6 cm in length, using backpack electrofishing units close to shore (Steve Early, personal commun., 2002). During the following week, more juveniles about the same size were captured by electrofishing. The pond and two adjacent smaller ponds were treated with herbicides by MDDNR personnel on August 18, 2002. Two dead juveniles, about 10 cm in length, were collected from the largest pond on August 20, 2002.

All three ponds were treated with rotenone on September 4. No snakeheads were found in the two smaller ponds. Dead fish ceased rising to the surface of the largest pond on September 7. The lengths of recovered northern snakeheads included two ranging from 69-70 cm, two 59 cm individuals, two ranging from 41-43 cm, more than 800 from 10-10.5 cm, and 566 young juveniles about 3.5 cm. The total number of snakeheads recovered was greater than the number of native fishes killed (Bob Lunsford, personal commun., 2002), although the biomass of natives was greater (Steve Early, personal commun., 2002).

A specimen of northern snakehead was captured by Massachusetts Department of Fish and Wildlife personnel in Newton Pond, Shrewsbury, Worcester County, Massachusetts, on October 4, 2001 (Karsten Hartel and Todd Richards, personal commun., 2001; Hartel and others, 2002). The likely source for both the Florida specimens and the one from Massachusetts is live-food fish markets.

In early August 2002, Gene Polk from Charlotte, North Carolina, reported that he and an angling partner caught two northern snakeheads from Lake Wylie, a reservoir on the Catawba River, near the U.S. Route 74 bridge. These fish were identified as *Channa argus* (Wayne Starnes, personal commun., 2002).

The USGS received an unconfirmed report of an angler who caught a snakehead near Rockport, southeastern Texas, that he believed was a northern snakehead based on illustrations in Howells and others (2002). He reportedly released the specimen without photographing it and has not followed up on his promise to provide a collection location or size of the fish (Robert Howells, personal commun. 2002).

Size: To 85 cm (Okada, 1960), although Nina Bogutskaya (personal commun., 2002) reported seeing captured specimens in Russia approaching 1.5 m total length. In the Amur River where the species is native and the Syr Dar'ya of Kazahkstan where it is introduced, males tend to be larger than females, with a higher dorsal fin, wider interorbital distance, and longer snout, postorbital distance, and upper jaw. Moreover, morphometrics vary with age (Dukravets and Machulin, 1978).

Habitat preference: Stagnant shallow ponds or swamps with mud substrate and aquatic vegetation; slow muddy streams (Okada, 1960). Also occurs in canals, reservoirs, lakes, and rivers (Dukravets and Machulin, 1978; Dukravets, 1992; Nina Bogutskaya, personal commun., 2002). This species is an obligate airbreather (Uchida, 1933). It appears to occupy waters, usually with vegetation, close to shore, and also feeds in schools (Nina Bogutskaya, personal commun., 2002).

Temperature range: 0 to >30 ºC (Okada, 1960).

Reproductive habits: Soin (1960) provided a detailed, illustrated report on spawning and development of the northern snakehead from within its native range. His study was based on observations made at a fish farm adjacent to the Songhua Jiang (Sungari River), northeastern China, in July 1958. He found fertilized eggs, about 1 day old, within an open nest (=cleared of vegetation) about 1 m in diameter and 60-80 cm deep. The eggs were guarded by two adults. Eggs were described as buoyant due to presence of a large lipid droplet that was more than three-quarters the diameter of the egg. Each egg had a diameter of 1.8-1.85 mm and the yolk was bright yellow. At 1 day of age, the length of an embryo removed from a fertilized egg was 3.2 mm. Hatching occurred 12 hours later at temperatures of 23-25 °C, about 2 days after spawning, and each larva was about 4.5 mm long. Respiration was through the caudal vein, the subintestinal vein that covers much of the yolk sac, and the enlarged ducts of Cuvier. Pectoral fins appeared about 1 day after hatching and larvae were about 5.7 mm long. Yolk was noticeably resorbed, ducts of Cuvier were reduced in size, and respiration was primarily through the subintestinal and hepatic veins that covered about two-thirds of the yolk sac surface. An oral aperture was present and an operculum covered the developing gills. A length of 7.1 mm was reached at 2 days following hatching and most of the yolk was resorbed. Nevertheless, the large lipid droplet was still present and caused what remained of the yolk sac to protrude laterally, producing a pair of cystiform structures. Melanophores had become well developed in the skin, giving the larvae a very dark color. By 3 days old, very little yolk remained, external blood vessels became markedly reduced, respiration by gills had begun, and the cystiform outpocketings remained visible on top of what remained of the yolk sac. Pectoral fins, used in locomotion, had enlarged, and the larvae, at 7.3 mm in length, had begun to feed. Larvae remained near the nest surface, grouped together, guarded by adults. About 2 weeks after hatching, larvae were approaching 11 mm in length, the yolk sac and cystiform processes had disappeared, fin rays were visible in the pectorals, coloration was black, and the epibranchial cavities that will later be used for aerial respiration had begun to develop. A length of 2 cm was reached by the fourth week after hatching, pelvic fins were developing, epibranchial

breathing cavities had become functional, and body color had changed from black to brown. Larvae of this size had lost their aggregative behavior and moved to slightly deeper water. Scales did not develop until the early juveniles had reached a length of 4-4.5 cm, when the mottled pattern of dark blotches characteristic of the species had appeared.

Many of the reports on this species vary considerably from what was observed following its introduction into Maryland. The northern snakehead has been said to reach sexual maturity in about 3 years at a length of 30-35 cm in the Amur and Syr Dar'ya, although some can spawn during the second year (Dukravets and Machulin, 1978). Okada (1960) reported spawning at 2 years at a length of 30 cm in Japan, and Nikol'skiy (1956) indicated the same for northern snakeheads in the Amur basin, differing from the age report given by Dukravets and Machulin (1978). This species builds a mostly circular nest of pieces of aquatic plants, about 1 m in diameter, in shallow aquatic vegetation. The water surface above the nest is cleaned by the parents, and spawning occurs at dawn or in early morning. The female rises near the surface and releases eggs, which are then fertilized by the male. Eggs are pelagic, nonadhesive, spherical, yellow, and about 2 mm in diameter. Eggs hatch in 28 hours at 31 ºC, 45 hours at 25 ºC, and 120 hours at 18 ºC. Number of eggs released ranges between 1,300-15,000, with an average of 7,300. Wee (1982) cited Frank (1970) who reported fecundity for this species of about 50,000 oöcytes. The report by Frank (1970) was based on examination of individuals in Czechoslovakia, imported from Moscow, Russia, and apparently of Amur basin stock. Additionally, fecundity in the Syr Dar'ya basin is higher than reported for the species in the Amur basin by Nikol'skiy (1956), about 22,000-51,000 in the Amur basin and a low of 28,600 to a high of 115,000 in reservoirs and lakes of the Syr Dar'ya basin (Dukravets and Machulin, 1978). Berg (1965) reported that the northern snakehead spawned five times per year in the Amur basin. Dukravets and Machulin (1978), however, noted that it spawns two to three times in the Syr Dar'ya basin, and in one group of lakes only once per year, typically from May to June at a water temperature of 18-20 ºC. Newly hatched larvae are about 4 mm in length and black. Larvae remain in the nest, guarded by one or both parents, until the yolk is resorbed and body length is about 8 mm. Larvae leave the nest as a group after yolk resorption and begin feeding on plankton. A post-larval stage follows until a length of about 18 mm is reached at which time aerial respiration begins. Young then begin feeding on small crustaceans and fish larvae. Parental care continues through the post-larval stage.

Feeding habits: Post-larvae feed on plankton, juveniles on small crustaceans and fish larvae, adults on fishes, frogs, crustaceans, and aquatic insects. This species is reported to be a voracious feeder (Okada, 1960). Dukravets and Machulin (1978) noted that in the Syr Dar'ya basin, northern snakeheads fed on 17 species of fishes, including young and fish up to 33 percent of the predator's body length. Larger prey included loach (*Cobitis*), bream (*Abramis*), carp (*Cyprinus carpio*), and perch (*Perca fluviatilis*). Other food items included crayfish, dragonfly larvae, beetles, and frogs, as well as plant material that was probably ingested incidentally with prey. Guseva (1990) summarized dietary changes in the Amu Dar'ya basin related to age based on Guseva and Zholdasova (1986). Northern snakeheads feed on "crustacean zooplankton, Cladocera," copepods, and small chironimid larvae for the first month of life. Once a length of 4 cm is reached, they begin to feed on fishes and when juveniles become 13-15 cm, fishes dominate 64-70 percent of the diet. Juveniles up to 30 cm feed almost exclusively on fishes (90 percent of diet), mostly small goldfish (*Carassius*) and roach (*Rutilis*). Moreover, in the Amu Dar'ya basin, northern snakehead feed only from late March to the end of October. Feeding begins when water temperature reaches 10 ºC with 45 percent of its annual food consumption completed by May. Roach dominated in the diet, but commercial species such as carp, zander (*Sander*), bream, grass carp (*Ctenopharyngodon idella*), and various catfishes were also consumed. Another 46 percent of annual food consumption occurred during June and July at temperatures of 20-27 ºC with carp, zander, grass carp, and bream dominating (50 percent of diet; Guseva, 1990). Feeding declined by autumn as water temperatures decreased to 12-18 ºC and ceased when temperatures dropped below 10 ºC.

This species is reported to feed in schools, with most activity at dusk into early night and again before dawn, typically in vegetation close to shore. It is also reported that actively feeding adults make grunting noises "like pigs" (Nina Bogutskaya, personal commun., 2002). Similarly, Soin (1960) noted clicking sounds produced by the northern snakehead in ponds adjacent to the Songhua Jiang (Sungari River), northeastern China, as the fish rose to the surface to breathe air.

Characters: 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 60-67; 8 scale rows above lateral line to dorsal fin origin; 12-13 scale rows below lateral line to anal fin origin. Dorsal fin elongated, with 49-50 rays; anal fin with 31-32 rays. Origin of pelvic fin beneath 4th dorsal fin ray. Pectorals extending beyond base of pelvic fins.

The body has a very distinctive color pattern. Background color is golden tan to pale brown with a series of dark blotches on the sides and saddle-like blotches across the back interrupted by the dorsal fin. The species is capable of darkening its background colors to the point of almost obscuring the blotches (personal observation). The upper blotches on the sides are typically separate anteriorly, but more posterior blotches may coalesce with ventral 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.

Coloration of the northern snakehead is quite similar to that of the blotched snakehead, *Channa maculata*. A key character for separating these two is the bar-like markings on the caudal peduncle. In *C. maculata*, the most posterior dark bar (usually complete) is preceded and followed by pale bar-like areas, whereas in *C. argus*, such pale markings are absent and the final dark marking is irregular, often blotch-like.

Commercial importance in the United States: Generally not listed on aquarist-oriented websites. Nevertheless, this species has been imported for sale in live-food fish markets and has been the most widely available snakehead in the U.S. It likely has comprised the largest volume and greatest weight of live snakeheads imported into the U.S. until 2001. The authors obtained specimens that were procured alive from fish markets in New York, Houston, Pembroke Pines, and Orlando, as well as photographs of live northern snakehead in markets in New York and St. Louis that were taken by Leo Nico of the USGS. Photographs from the St. Louis market were taken in mid-July 2002, after northern snakeheads were found established in Maryland; the storeowner had the fish marked as "mudfish." Also, see below under **Environmental concerns**.

A fish farmer in Arkansas was discovered culturing northern snakeheads in 2001 when possession of live snakeheads was legal. This was verified in July 2002 when it was also learned that two additional Arkansas aquaculturists were then culturing northern snakehead. The report included information that the original snakehead aquaculturist had been approached by a live-food fish importer in New York and asked if he could culture snakeheads for sale in U.S. markets. Apparently, the second two fish farmers decided that they too might profit from snakehead culture. Thus, as of July 2002, there were three domestic sources of cultured northern snakehead, although the importation, culture, and possession of snakeheads in Arkansas were prohibited on July 29, 2002.

Commercial importance in native or introduced range: This species is cultured in ponds, rice paddies, and reservoirs in China (Atkinson, 1977; Sifa and Senlin, 1995) and considered a valuable commercial fish in Korea (Berg, 1965). FAO (1994) listed a production of 500 metric tons in Korea in 1992. It is the most important snakehead cultured in China, with most culture activities centered in the Chang Jiang (Yangtze) basin (Fang Fang, personal commun., 2002). It never became a popular food fish following introduction into Japanese waters (Okada, 1960). In tributaries of the Aral Sea, Kazakhstan, large populations of this species are fished commercially with an annual catch reported of 1-5 metric tons (Baltz, 1991). Dukravets (1992), however, reported an annual catch of 10 metric tons from reservoirs on the Talas River, Kazakhstan.

Environmental concerns: This species is described as a voracious predator on other fishes, and also feeds on freshwater crustaceans. Moreover, its native range (24-53º N) and temperature tolerance (0-30 ºC) indicates a species that, if introduced, could establish feral populations throughout most of the contiguous United States and possibly some waters in adjoining Canadian provinces. Because it was found to be established in Maryland in 2002, perhaps also in Florida, and was the most widely available snakehead sold as a live-food fish in the U.S., the likelihood of its becoming more widely established is real.

Fourteen states banned possession of live snakeheads prior to August 2002. Among those states is Texas where possession of live snakeheads has been illegal for almost four decades (Howells and others, 2002). During Summer 2001, game wardens from the Texas Parks and Wildlife Department discovered large numbers of *Channa argus* being sold in live-food fish markets in Houston. Raids resulted in seizure of the fish and shipping documentation that traced the fish to a distributor

who had obtained the fish from a source in New York (Robert H. Howells, personal commun., 2001). The distributor was an aquaculture facility that had imported northern snakeheads for sale to retailers in Texas, and agents confiscated the fish (Howells and others, 2002).

Florida also prohibits possession of live snakeheads. Following the discovery of the bullseye snakehead, *Channa marulius*, that was established in Tamarac, Broward County, Florida, in spring 2001, agents of the FFWCC raided two live-food fish markets, one in Miami, Miami-Dade County, and another in Pembroke Pines, Broward County. They confiscated several live *C. argus* (Florida Fish and Wildlife Conservation Commission, 2001). *Channa argus* was also confiscated from a live-food fish market in Orlando, Orange County, by FFWCC agents in July 2002.

Despite Florida's prohibition, one of the authors (JDW) purchased a live northern snakehead from a fish market in Orlando, Orange County, in March 2002. The tank in which the fish was found was labeled "Chinese catfish," although the proprietor explained to the buyer that the fish was not a catfish but "a very special fish." The Center for Aquatic Resources Studies of the USGS Florida Integrated Science Center has a permit to possess certain restricted fishes including snakeheads. This purchase was made to prove that illegal fish can be purchased in Florida. FFWCC agents confiscated four live northern snakeheads from this market on July 16, 2002.

The FFWCC licenses pet dealers, importers of restricted and tropical fishes, and retailers and wholesalers of non-native aquatic species. This last item includes markets that sell live-food fishes (Kyle Hill, personal commun., 2002). The Division of Aquaculture of the Florida Department of Agriculture and Consumer Affairs certifies and inspects fish culture facilities, and deals with permits for restricted species to fish farmers (Paul Zajicek, personal commun., 2002) but does not license retailers or wholesalers that sell live-food fishes. Restricted fishes can only be sold to people who possess a valid Aquaculture Certificate from Department of Agriculture and Consumer Affairs. Moreover, a retailer of live-food fishes who does not apply for a license becomes an illegal "unknown" to regulatory agencies. The markets in Miami, Pembroke Pines, and Orlando that were selling northern snakeheads did not have licenses to possess or sell live freshwater fishes (Kyle Hill and Barry Cook, personal commun., 2002). Clearly, there have been sources other than aquarium fish dealers from which live snakeheads could be purchased, raising the probability of introductions that could become established, as occurred in Crofton, Maryland, with *Channa argus*.

Snakeheads are also prohibited in Washington. At 11:35 a.m. on April 30, 2001, a driver for a Canadian fish wholesaler declared a shipment of live ling cod in Blaine, Washington. The shipment was bound for a seafood distributor in Seattle. Wildlife Inspector Michael Williams, U.S. Fish and Wildlife Service, inspected the shipment to find three open boxes containing fish he thought were "unusual looking." When he asked the driver what they were, his reply was that they were snakeheads that had been pond raised in China and shipped without water to Canada, adding this was the first time his employer had made such a shipment. Upon examining one box, Williams noticed the fish moved and, on further investigation, found that most were alive and some "capable of vigorous movement." Williams informed the driver that possession of live snakeheads was in violation of Washington State regulations. The driver was asked to kill the fish and began striking them with a board. Williams notified the Washington Department of Fish and Wildlife and, after returning to the truck, found that the fish were still alive despite the driver's attempt to kill them. He seized the 80 fish at noon and placed them in a freezer. Washington Department of Fish and Wildlife authorities arrived about 12:30 and removed the fish from the freezer. Most were still alive. State authorities took possession of the fish to proceed with penalties against the companies involved (Mike Williams, personal commun., 2003). The shipping invoice listed the fish as "Fresh Snakehead Fish–Product of China." The fish were subsequently identified as northern snakeheads (Ted Pietsch, personal commun., 2001).

Discovery of an established population of northern snakeheads in Maryland, catches by anglers of two verified and three unconfirmed specimens from the St. Johns River in east-central Florida, and others from a California reservoir, a pond in central Massachusetts, and two from a reservoir in North Carolina, coupled with proof of their availability in live-food fish markets at or near a size when they are reproductively mature, were reasons for substantial environmental concern.

Despite the fact that snakeheads are now prohibited from importation, several live specimens of northern snakehead were confiscated in California in July 2003.

Comments: The diploid chromosome number of *Channa argus* is 48 (Lee and Lee, 1986; Wu and others, 1986).

Distribution of *Channa argus* in the Eastern Hemisphere

Channa asiatica (Linnaeus, 1758)
Chinese Snakehead

UF 127103, 135 mm standard length. Specimen purchased in an Asian market in Kansas, October 2002. Photo by Buck Albert, USGS, Gainesville, Florida.

Original description: *Gymnotus asiaticus* Linnaeus, 1758:246. Systema Naturae, ed. 10. Holmiae, 1:i-ii + 1-824. Type locality: Asia. Holotype: ZIU 171.

Synonyms: (?)*Ophicephalus miliaris* Cuvier, 1831:439.

Channa ocellata Peters, 1864:392.

Channa fasciata Steindachner, 1866:480.

Channa sinensis Sauvage, 1880:58.

Channa orientalis Karoli, 1882:147.

Channa formosana Wu, 1929:73; Myers and Shapovalov, 1932:36.

Cuvier (1831) described *Ophicephalus miliaris* based on a description by Jean-Jacques Dussumier of a snakehead from Canton (Guangzhou), China. Dussumier's descriptions were made from live or fresh specimens and were considered quite accurate by Cuvier (Bauchot and others, 1990). Figure 10 in Bauchot and others (1990), an illustration of a snakehead lacking pelvic fins and based on Dussumier's description, appears to be *Channa asiatica*. Therefore, we have treated *O. miliaris* as a possible synonym of *C. asiatica*. Nevertheless, Peter Ng (personal commun., 2003) noted that a closely related species, *C. nox*, that has very similar markings to *C. asiatica*, is available for sale in live-food fish markets in Ghangzhou, raising the possibility that *O. miliaris* might be a synonym of that species. Resolution of this situation is complicated because there are apparently no types of *O. miliaris.*

Common names: **Chinese snakehead**; chi hsing yü (Yangtze River basin, China); hua-t'sai-yü (Tungting Lake on Chang Jiang [Yangtze] River); kôtal (Japan; Uyeno and Akai, 1984; Hosoya, 2002).

Native range: China, middle and lower Chang Jiang (Yangtze) basin, and Xun River basin in Guangxi and Guangdong provinces (Kimura, 1934; Pearl River Fisheries Research Institute, 1991). Also reported from Hainan Island, China (Kimura, 1934) where it is likely native rather than introduced.

Introduced range: Taiwan (Musikasinthorn, 2000); Japan, Ishigaki Shima Island in the Ryukyu Islands (Uyeno and Akai, 1984; Hosoya, 2002). Klee (1963) reported that this species was "occasionally found in Florida waters," but we have found no evidence that it is established.

Size: Up to 34 cm (Daiqin and others, 1999). By studying annual ring development on scales, they noted a linear relationship between scale length and body length for this species. They also commented that growth is rapid during the first 2 years of life and slows thereafter. They recommended regulating a minimal harvestable age of this species at 2.6 years for resource conservation purposes.

Habitat preference: No information available. Probably a riverine species.

Temperature range: No information available. Nevertheless, distribution within native range (32-22º N) indicates a warm temperate to subtropical species.

Reproductive habits: No information found concerning reproduction in natural habitats. Hosoya (2002) stated this species does not build a nest but provides parental care in Japan where the species was introduced. Breder and Rosen (1966) summarized this

species, in aquaria, as producing floating eggs, the eggs about the "size as that of the head of a pin." Reproductively active females become paler with a pink cast, with dark brown markings becoming darker and silver markings becoming brighter. Reproductively active males also become darker. The prespawning female rises to the surface of an aquarium, gulps air, and rolls from side to side. The male then rises, circles the female, and they embrace, rising to the surface with the male squeezing the female. They are reported to have rolled once, then sank, releasing themselves, repeating the sequence after a few minutes. In aquaria, spawning can occur every 6 to 10 days. Reproductive activities appear to occur at night. Hatching in aquaria occurs in about 24 hours at 28 ºC. There are some indications that the male may be a mouthbrooder. Both male and female are reported to aggressively protect against anything introduced into an aquarium when eggs or fry are present.

Feeding habits: No information found, but likely a thrust predator.

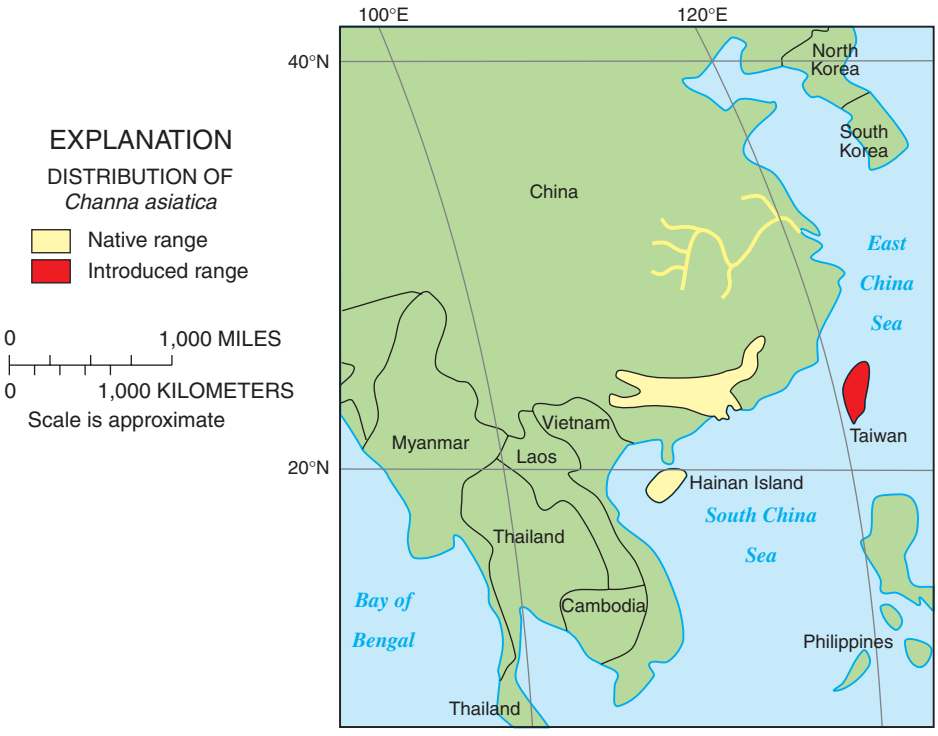
Characters: Gular region of head without patch of scales. Pelvic fins absent. Dorsal fin with 44 rays; anal fin 26 rays; pectoral fin 14 rays. Lateral line scales 57; predorsal scales 12; rows of scales between dorsal origin and lateral line 5; scale rows between lateral line and midline of belly 16. Color pattern distinct among snakeheads with dark chevrons on sides and large ocellus centered on caudal peduncle. The center of the ocellus is not round but more quadrangular in shape (Bureau of Aquatic Products Industry, 1988; Lee and Ng, 1991), unlike that illustrated in Pearl River Fisheries Research Institute (1991). The most closely related snakehead is *Channa nox*, which has 47-51 dorsal fin rays, 31-33 anal fin rays, and is black on the upper half of the body. Like *C. asiatica*, *C. nox* also lacks pelvic fins and has a large black ocellus on the caudal peduncle.

Commercial importance in the United States: Ross B. Socolof (personal commun., 2003) reported *Channa asiatica* as the first snakehead to have been imported to the contiguous United States for the aquarium fish trade. Subsequent accounts of this species in the aquarium fish literature (Innes, 1920, 1955; Armstrong, 1923; Stoye, 1935; Axelrod and Schultz, 1955) are indicative of its availability through much of the early to mid-1900s. Typically not listed on aquarist-oriented websites.

Commercial importance in native range: Nichols (1943) commented that it was never seen for sale in China. Nevertheless, it is sold in the aquarium fish trade outside its native range in Singapore (Ng and Lim, 1990). Daiqin and others (1999) recommended restricting the legal harvestable age to 2.6 years, a clear indication that the species is being fished commercially in China. Ping Zhuang (personal commun., 2002) noted that this species is now common in aquaculture in China.

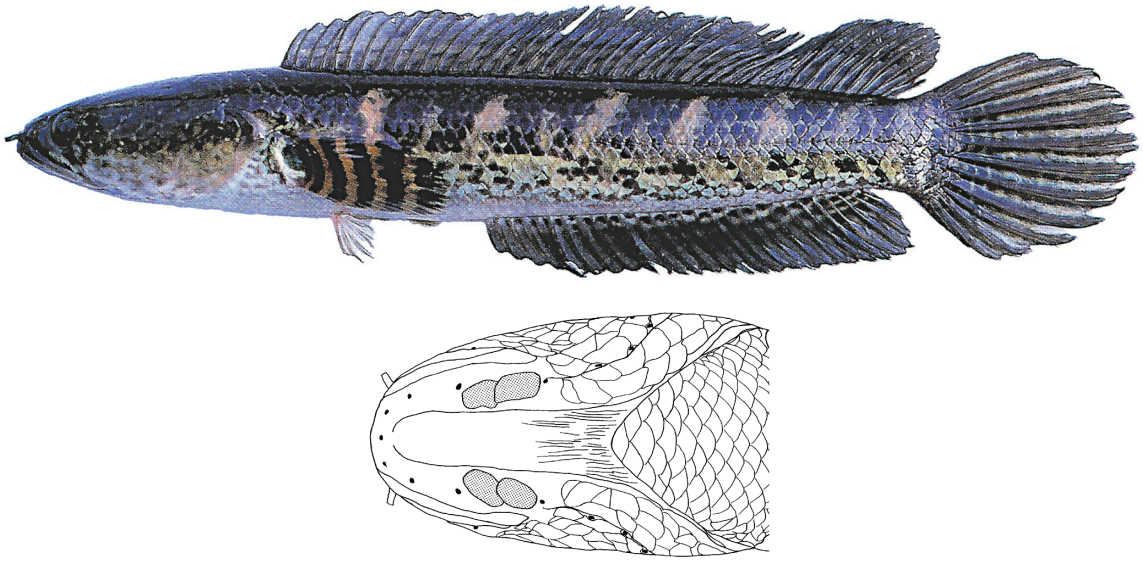
Environmental concerns: Probably a thrust predator on other fishes and invertebrates like many other snakeheads. According to Ross B. Socolof (personal commun., 2003), this was the first snakehead imported into the U.S. for the aquarium fish trade, the earliest imports occurring in the late 1800s or early 1900s.

Comments: The diploid number of chromosomes of *Channa asiatica* is 46 (Wu and others, 1986).



Channa asiatica

Channa aurantimaculata Musikasinthorn, 2000
Orangespotted Snakehead



Upper image: holotype, KUMF 3135, 190.8 mm standard length. **Lower image:** ventral view of head showing enlarged scales on lower jaw, paratype, KUMF 3136, 163.7 mm standard length. Reprinted with permission from Prachya Musikasinthorn, author, and Tomoki Sunobe, Secretary of the Ichthyological Society of Japan, from: Musikasinthorn, Prachya. 2000. *Channa aurantimaculata*, a new channid fish from Assam (Brahmaputra River basin), India, with designation of a neotype for *C. amphibeus* (McClelland, 1845). Ichthyol. Res. 47(1):27-32.

Original description: *Channa aurantimaculata* Musikasinthorn, 2000:27-32. *Channa aurantimaculata*, a new channid fish from Assam (Brahmaputra River Basin, India), with designation of a neotype for *C. amphibeus* (McClelland, 1845). Ichthyological Research, 47(1):27-37, figs. 1-5. Type locality: Dibrugarh town, Digrugarh, Assam, India. Holotype: KUMF 3135. Paratypes: KUMF 3136; NSMT-P 55735; ZSI uncataloged, collected with KUMF 3136.

Synonyms: No synonyms.

Common names: **orangespotted snakehead**; naga-cheng (Assam, India).

Native range: Endemic to middle Brahmaputra River basin, northern Assam, India (Musikasinthorn, 2000).

Introduced range: No introductions known.

Size: To about 40 cm.

Habitat preference: Forest streams, ponds, and swamps adjacent to the Brahmaputra River in subtropical rainforest conditions (Musikasinthorn, 2000).

Temperature range: Unknown, except preferred habitat and known range is subtropical.

Reproductive habits: No specific information, but probably a nest builder with pelagic eggs like the majority of channid fishes.

Feeding habits: No information, but more than likely a carnivorous predator as adults.

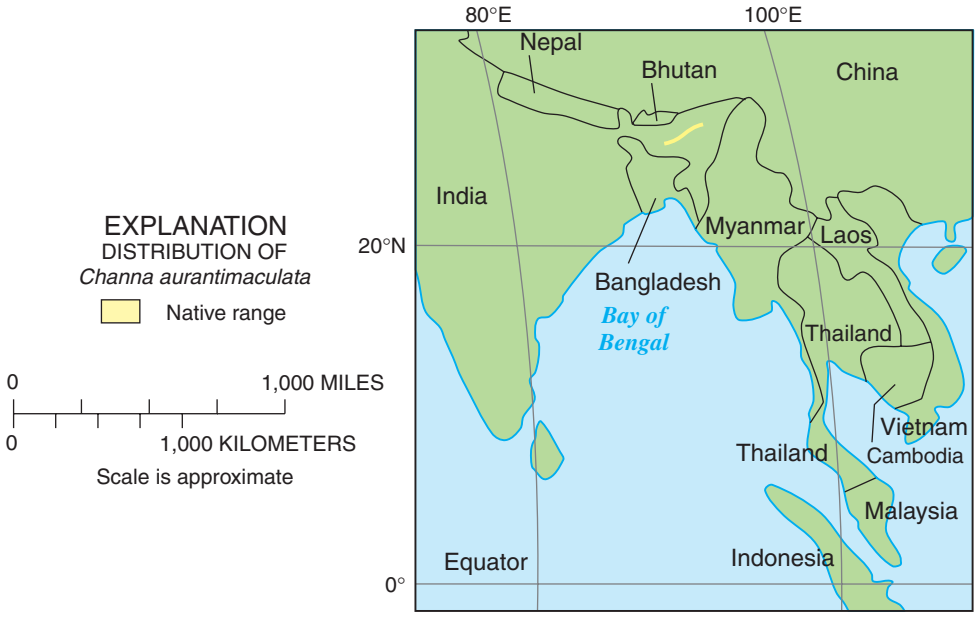
Characters: Patch of scales on gular part of head absent. Head elongated, mouth large, interorbital region almost flat. Dorsal fin rays 45-47; anal rays 28-30; lateral line scales 51-54; cheek scales 8-12; predorsal scales 13-15; total vertebrae 50-52; two large scales on each side of undersurface of lower jaw; pelvic fin

length less than 50 percent of pectoral fin length; cephalic sensory pores single without satellite openings. Small conical teeth in premaxilla with an additional series of somewhat larger conical teeth anteromedially; small teeth and 3 large conical teeth on prevomer; a row of conical teeth with 5 or 7 large canines on each side of palatine; dentary with medium-sized conical teeth on each side, also with 5 to 6 large canine-like teeth (Musikasinthorn, 2000).

Commercial importance in the United States: None known. Recently described species, not listed on aquarist-oriented websites and unknown for sale in live-food fish markets.

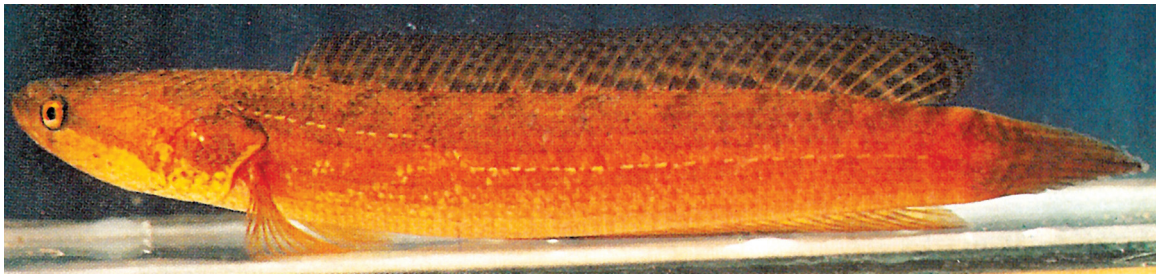
Commercial importance in native range: No specific information, but reported in markets in Assam, India (Musikasinthorn, 2000).

Environmental concerns: Unknown, but probably a predator on other fishes and invertebrates.

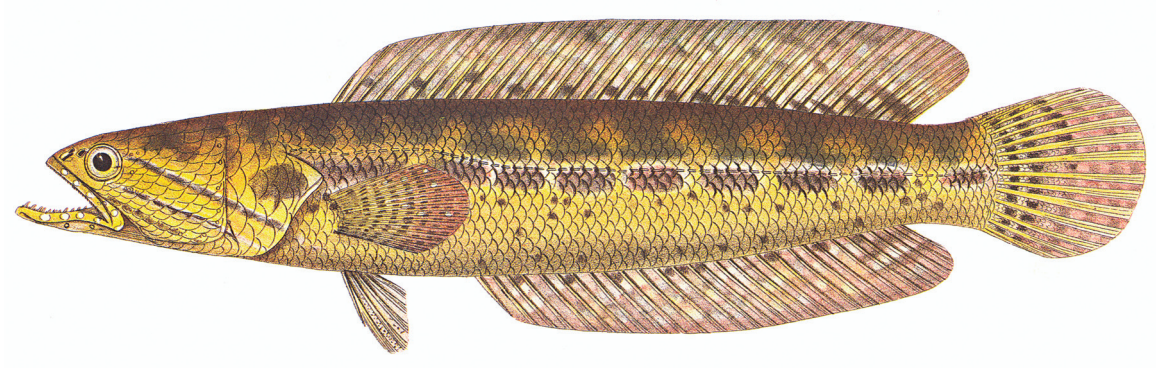


Channa aurantimaculata

Channa bankanensis (Bleeker, 1852)
Bangka Snakehead



Reprinted with permission from P.K.L. Ng from: Lee, P.G., and P.K.L. Ng. 1991. The snakehead fishes of the Indo-Malayan region. Nature Malaysiana 16(4):112-129.



After Bleeker, 1878

Original description: *Ophiocephalus bankanensis* Bleeker, 1852:726. Nieuwe bijdrage tot de kenne der ichthyolische fauna van het eiland Banka. Natuurkd. Tijdrschr. Neder. Indië 3:715-738. Type locality: Bangka Island, Malaysia. Locality of holotype unknown.

Synonyms: No known synonyms (Ng and Lim, 1990).

Common names: **Bangka** (or Banka) **snakehead**; runtuk (Kalimantan).

Native range: Sumatra: southeastern rivers (Hari and Musi basins) of mainland; Bangka Island; rivers of central, southern, and western Kalimantan (southern Borneo; Roberts, 1989; Ng and Lim, 1991; Kottelat and others, 1993); peat swamps of Selangor, peninsular Malaysia (Lee and Ng, 1991).

Introduced Range: No introductions known.

Size: No specific information; Musikasinthorn (2000) examined specimens up to 14 cm standard length.

Habitat preference: Prefers submerged vegetation in tannin and humic acid enriched backwaters (pH 2.8-3.8) and moderately fast-flowing streams in peat swamps (Lee and Ng, 1991; Ng and Lim, 1991). Also found in mouths and middle reaches of rivers (Lee and Ng, 1994).

Temperature range: Preferred range 26-30 ºC (Lee and Ng, 1994).

Reproductive habits: No specific information, but likely a nest builder with pelagic eggs.

Feeding habits: No specific information, but probably a carnivorous predator.

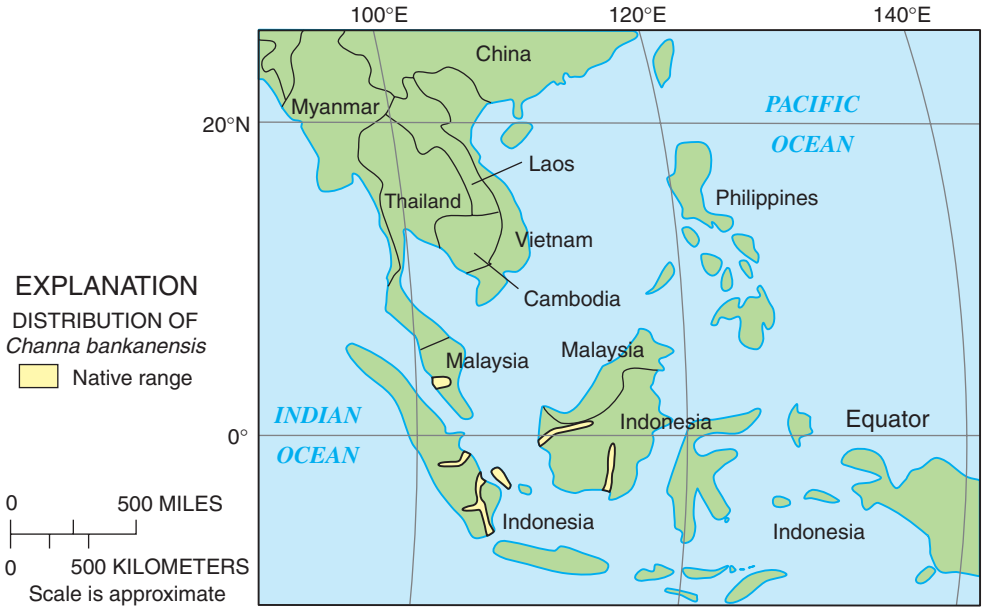
Characters: Patch of scales present on gular part of head. Large canine-like teeth on prevomer and palatines. Lateral line scales 55-68; scale rows between lateral line and dorsal origin 4½; scale rows below lateral line and anal fin origin 7-9; preopercular scales 5-10.

Dorsal fin rays 31-45, anal fin rays 20-31. Superficially resembles *Channa lucius*, head taller and more blunt in *C. bankanensis* (see Ng and Lim, 1990, p. 142, fig. 5C, D), and body more compressed in *C. lucius* (Lee and Ng, 1991). Somewhat rounded, dark blotch on operculum of adult, not elongated as in *C. lucius* (Ng and Lim, 1990).

Commercial importance in the United States: Not listed on aquarist-oriented websites.

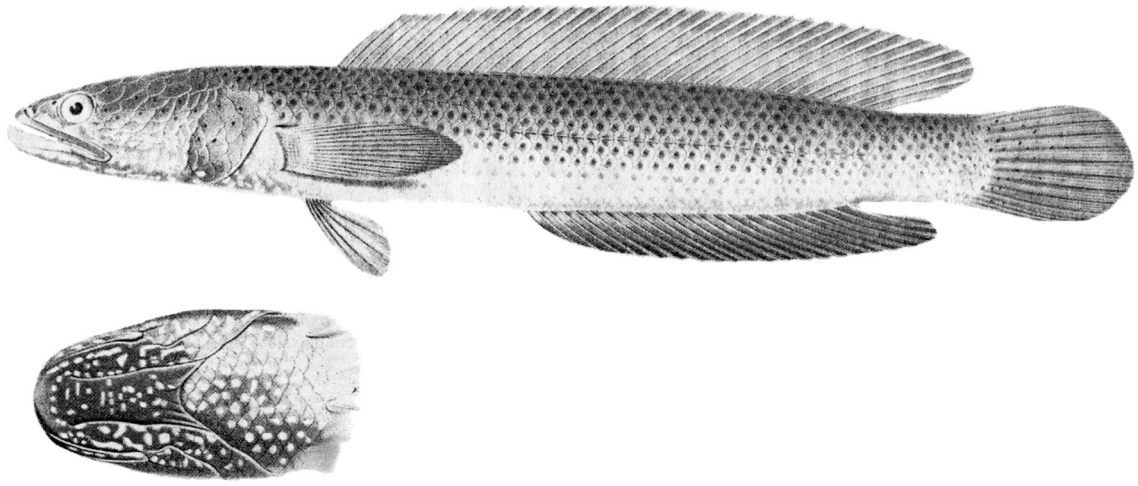
Commercial importance in native range: Probably not of commercial importance due to habitat preferences. Lee and Ng (1991) stated that this species is not popular with local anglers due to its small size.

Environmental concerns: Unknown, but probably a predator on other fishes and invertebrates. Habitat preferences indicate the species might only become problematic in highly acidic waters. Stoye (1935) mentioned availability of this species as an aquarium fish.

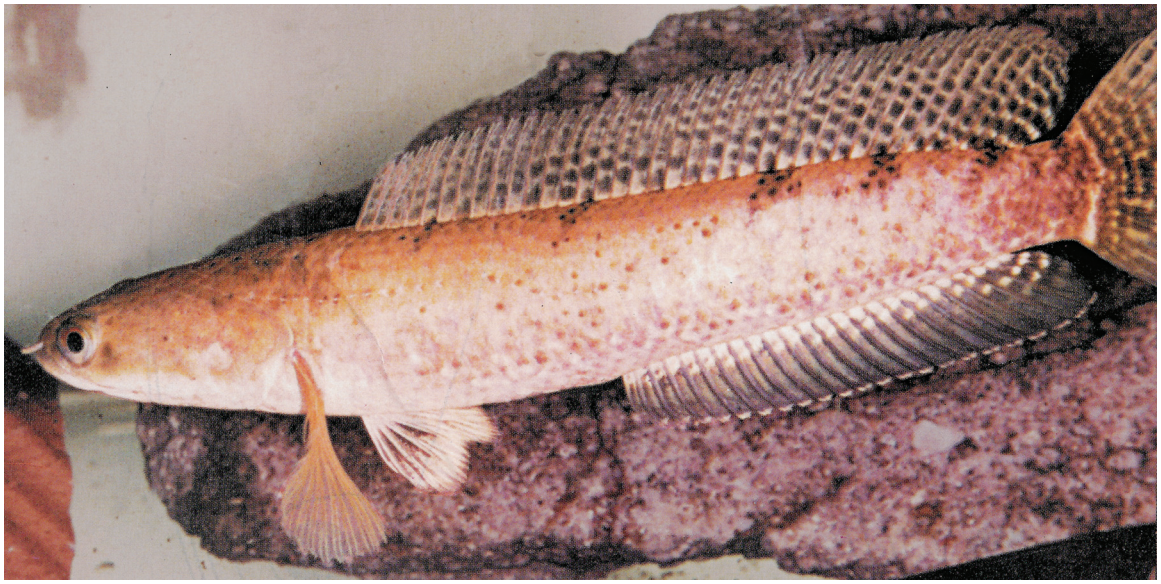


Channa bankanensis

Channa baramensis (Steindachner, 1901)
Baram Snakehead



After Steindachner, 1901



Live coloration (14.7 cm)

Reprinted with permission from H.H. Ng and P.K.L. Ng from: Ng, H.H., and others, 1996. Revalidation of *Channa baramensis* (Steindachner, 1901), a species of snakehead from northern Borneo (Teleostei: Channidae). Sarawak Mus. J. 48(69 n.s.):219-226.

Original description: *Ophicephalus baramensis* Steindachner, 1901:435, pl. 17. Kükenthal's Ergebnnisse einer zoologischen Forschungriese in den Molukken und Borneo. Abh. Senckenb. Naturforsch. Ges. 25:409-464, pls. 17-18. Type locality: Baram River, northern Sarawak (northern Borneo). Syntypes: SMF 860; SMF 8473.

Synonyms: *Ophicephalus melasoma* (Bleeker, 1851) *fide* Weber and de Beaufort (1922); Myers and Shapovalov (1932); Roberts (1989); Ng and Lim (1990); and Rainboth (1996). Ng and others (1996) revalidated the species and Musikasinthorn (2000) also recognized the species as valid.

Common names: **Baram snakehead**; barama snakehead.

Native range: Northern Sarawak, Brunei, and western Sabah (northern Borneo). Also occurs in the Sadong basin, southern Sarawak, and the Segama basin, eastern Sabah (Martin-Smith and Hui, 1998).

Introduced range: None.

Size: To about 22 cm.

Habitat preference: Known from blackwater swamps (Ng and others, 1996) and small to moderate-sized streams, clear or turbid, in secondary growth or forest areas (Inger and Kong, 1962).

Temperature range: No specific information, but native range is tropical (about 3-6º N).

Reproductive habits: Habits can be inferred from those of its closest relative, *Channa melasoma*. Doubtlessly a nest builder like other channids with probably only one parent guarding eggs and young. Likely a nocturnal species.

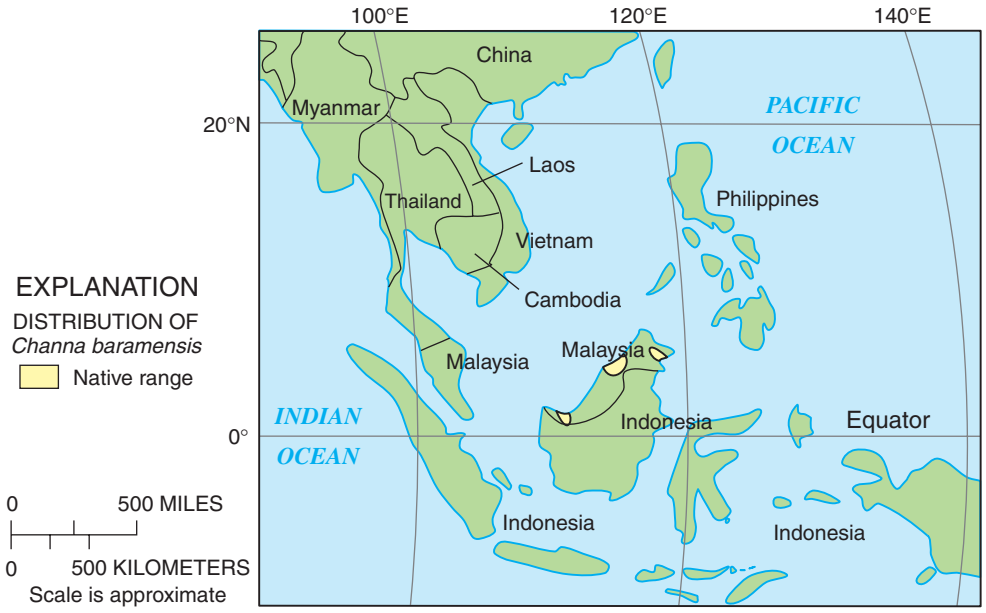
Feeding habits: Like *Channa melasoma*, probably a nocturnal thrust predator that feeds on other fishes, small reptiles, crabs, insects and insect larvae.

Characters: No patch of scales on gular region. Dorsal fin rays 38-40; anal rays 23-26. Predorsal scales 8-9; lateral line scales 51-52. This species appears to be most closely related to *Channa melasoma*, and some characters overlap in both species (Ng and others, 1996). Nevertheless, adults (120 mm or more standard length) can be separated as follows: Lateral head profile of *C. melasoma* distinctly sharper. Postorbital depth greater in *C. baramensis* than in *C. melasoma* (33.3-34.1 percent of head length versus 27.9-31.8 percent of head length in *C. melasoma*) (Ng and others, 1996). There are also distinct differences in coloration. In closely related *C. melasoma* and *C. cyanospilos*, black pigment (melanin) appears as evenly spread over each scale, whereas in *C. baramensis*, melanin is concentrated in the central part of most scales in adults and most specimens smaller than 120 mm standard length. Moreover, there is a distinct barred pattern on the caudal fin in adult *C. baramensis* that is absent in *C. melasoma* and *C. cyanospilos* of similar lengths. This character, however, cannot be used to identify specimens smaller than about 120 mm standard length (Ng and others, 1996).

Commercial importance in the United States: Unknown to have been imported for any purpose.

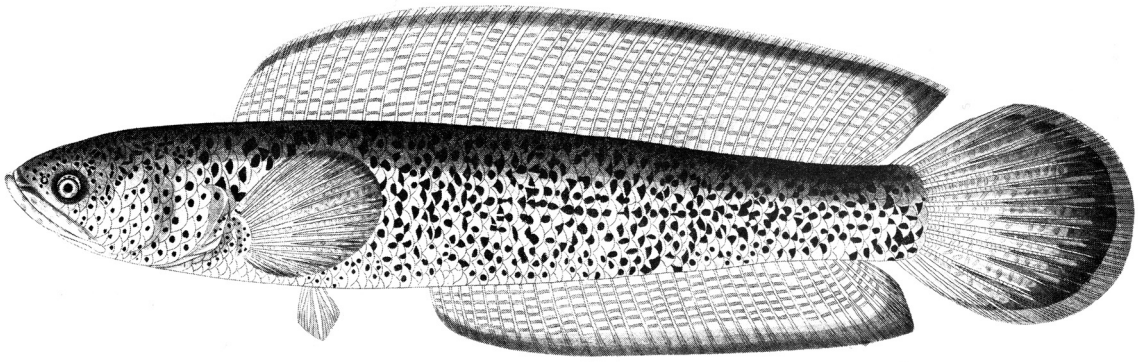
Commercial importance in native range: Reported as caught by anglers, indicating use as a food fish (Ng and others, 1996). Probably only of minor commercial importance.

Environmental concerns: This species is probably a nocturnal thrust predator. Its limited range in the tropics would restrict its ability to establish in all but the warmest waters of the U.S.



Channa baramensis

Channa barca (Hamilton, 1822)
Barca Snakehead



After Hamilton, 1822

Original description: *Ophiocephalus barca* Hamilton, 1822:67, pl. 35, fig. 20. An account of the fishes found in the River Ganges and its branches. Edinburgh and London. i-vii + 1-405, pls. 1-39. Type locality: Brahmaputra River, near Goalpara, Assam, India. Types unknown.

Synonyms: *Ophicephalus nigricans* Cuvier, 183:431.

Common name: barca snakehead.

Native range: Endemic to Ganges and Brahmaputra River basin, India and Bangladesh (Musikasinthorn, 2000). Bhuiyan (1964) cited its presence in eastern and some areas of western Pakistan but this may be a misidentification.

Introduced range: No introductions known.

Size: To 90 cm (Talwar and Jhingran, 1992).

Habitat preference: Large rivers (Talwar and Jhingran, 1992).

Temperature range: No specific information. Nevertheless, its native range is located between about 25-27º N, suggesting it is a warm temperate species.

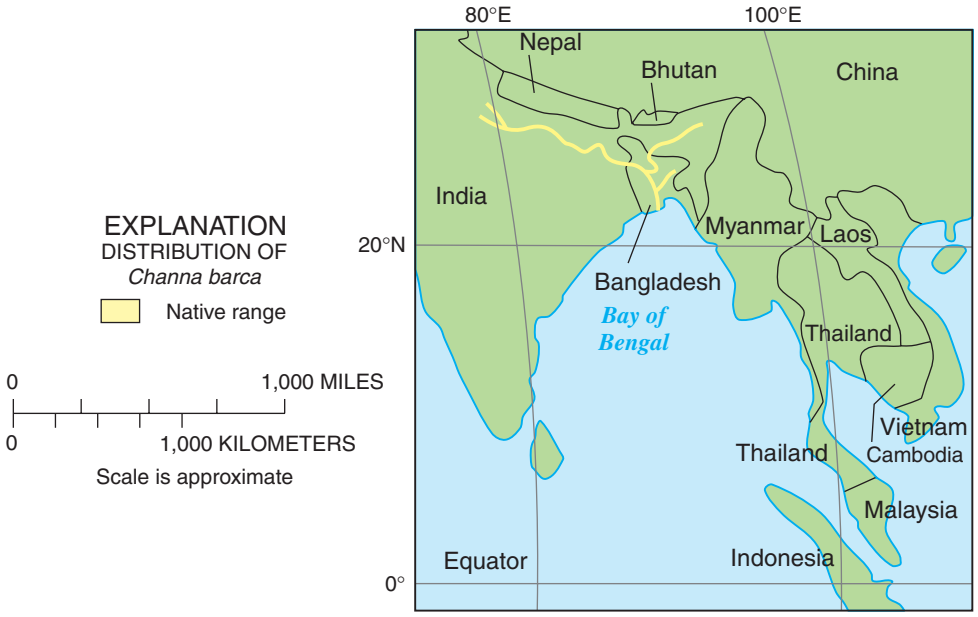
Reproductive habits: No detailed information, but like other snakehead species, it is assumed to clear a nest in nearshore vegetation, lay pelagic eggs which, following fertilization, rise to the surface where they are guarded vigorously by one or both parents until hatching.

Characters: Body elongated, mostly rounded. Mouth large; lower jaw with a few canines behind a single row of villiform teeth that widen to 5 or 6 rows at jaw symphysis; 2 or 3 large teeth on vomer and some on palatines. Scales on top of head large; 9 scale rows between preopercular angle and posterior border of orbit; predorsal scales 15; 60 to 65 scales in longitudinal series. Dorsal fin rays 47-52; anal fin rays 34-36; pectoral rays 16; pelvic fin rays 6. Life colors violet on back fading to dull white with purple cast on sides; back and sides with large black blotches, as are dorsal, anal, and caudal fins; fin edges red; pectoral fins red with numerous black spots.

Commercial importance in the United States: Typically not listed on aquarist-oriented websites. Likelihood of being imported for sale in aquarium fish trade or live-food fish markets has been low to probably nonexistent.

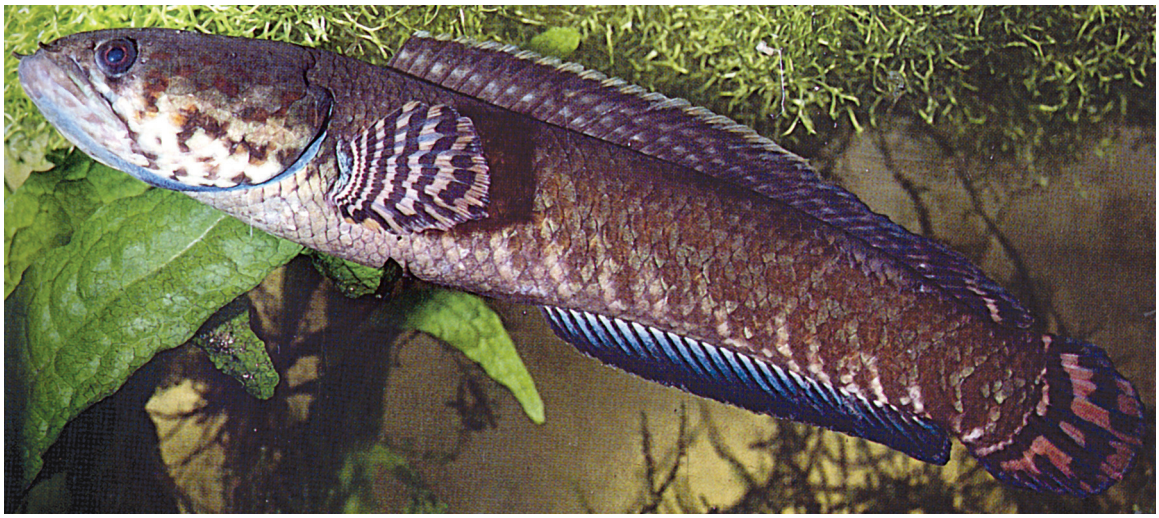
Commercial importance in native range: While reported as common in the Brahmaputra River, Assam, India, it is said to be of minor importance as a fishery resource. Nevertheless, it is considered an excellent food fish (Talwar and Jhingran, 1992).

Environmental concerns: Like other snakeheads, adults are carnivorous predators, most preferring other fishes as food.



Channa barca

Channa bleheri Vierke, 1991
Rainbow Snakehead



Reprinted with permission from Jörg Vierke from: Vierke, Jörg. 1991a. Ein farbenfroher neuer schlangenkopffish aus Assam *Channa bleheri* spec. nov. Das Aquarium 259:21.

Original description: *Channa bleheri* Vierke, 1991a:20-24. Ein farbenfroher neuer Schlangenkopffisch aus Assam *Channa bleheri* spec. nov. Das Aquarium 259:20-24. Type locality: upper part of Dibru River, near Guijan, Brahmaputra River basin, northeastern Assam, India. Holotype: ZFMK 16555. Paratype: ZFMK 16556.

Synonyms: No synonyms.

Common name: rainbow snakehead.

Native range: Endemic to the Brahmaputra River basin, Assam, India (Musikasinthorn, 2000).

Introduced Range: No introductions known.

Size: To about 20 cm.

Habitat preference: Forest streams, ponds and swamps in tropical rainforest conditions (Musikasinthorn, 2000).

Temperature range: Unknown, except preferred habitat and known range is subtropical.

Reproductive habits: No specific information concerning wild populations. Vierke (1991b), however, described reproductive behavior in aquaria in detail. He noted that females are smaller than males of the same age, and that males grow faster than females. A male selects the nesting site, but it is the female that appears to initiate courtship behavior. Two days prior to spawning, there is frequent body contact between male and female, with the two wrapping around each other. This behavior increases at spawning, near the surface, and the spawning act can last up to 30 seconds.

The eggs released are transparent and float to the surface. They are small, round, and 0.9-1.1 mm in diameter. An oil globule, about 0.6-0.7 mm in size, is present in each egg. The egg mass, with eggs close together, appears to be made of foam. Both the male and female initially tend the egg mass and display an interesting behavior. They take the eggs into the oral cavity and expel them through the gills, presumably to remove materials that may settle on egg surfaces. The eggs adhere to each other at the surface. Following hatching, both parents guard the larvae.

The young remain around the parents, often with body contact between them. Young can often be found on the heads of parents, appearing to be feeding on mucus.

They appear to nip the parents, and removal of young from parents at this stage seems to slow growth of the separated individuals.

Feeding habits: No information concerning wild populations, but likely a carnivorous predator as an adult. Vierke (1991b) noted that in aquaria, rainbow snakeheads will feed on worms similar to bloodworms. When fed guppies (*Poecilia reticulata*), they will eat guppies they can easily catch, but typically tire of chasing this prey, eventually tolerating their presence.

Characters: No area of scales in gular region. No pelvic fins. Dorsal rays 36-37; anal rays 24; predorsal scales 6-7; lateral line scales 45-46. One or 2 large scales on undersurface of lower jaw.

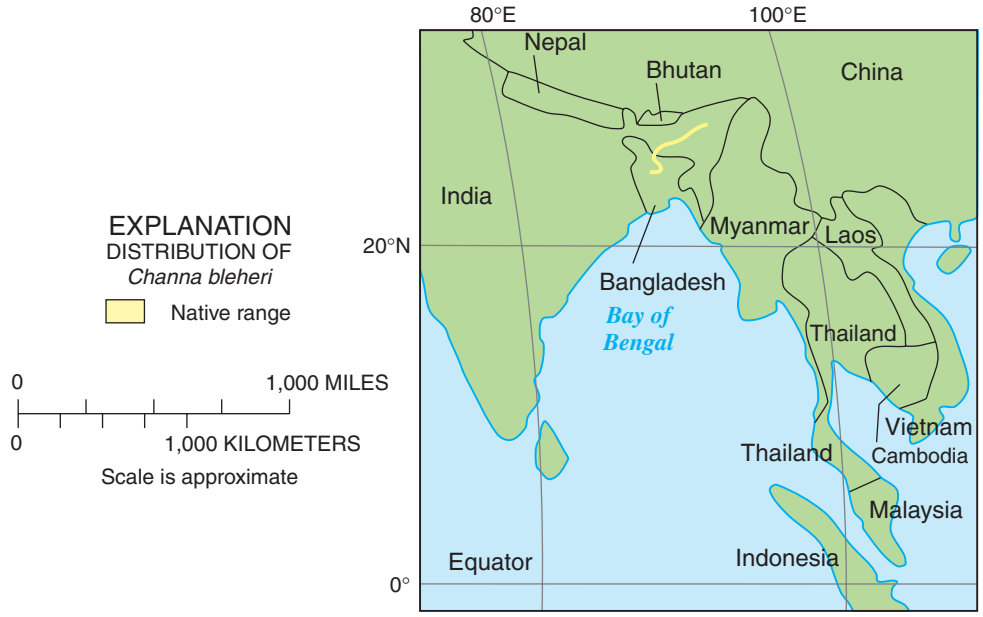
Live adults have large irregular red or orange spots (white in preserved specimens) that sometimes coalesce (Musikasinthorn, 2000). This is the most colorful of all snakehead species. Newly hatched larvae are colorless. When they reach a length of 1 cm, the dorsum and sides of the body becomes "canary" yellow, with a dark bar on the head, angled from the tip of the lower jaw, through the eye, to the upper margin of the operculum; the ventral side is colored smoke gray to black. As young continue to grow, their color becomes more pale and an ocellus appears on the posterior part of the dorsal fin. Later they begin to change to adult coloration (Vierke, 1991a).

This species appears to be most closely related to *Channa burmanica* (Peter Ng, personal commun., *in* Vierke, 1991b). They differ in several characters. *Channa burmanica* has 51 lateral line scales, 28 anal rays, and 8 predorsal scales, whereas these counts in *C. bleheri* are 45-46, 24, and 6-7, respectively. The rainbow snakehead also has a longer caudal peduncle than *C. burmanica* with 9 scales from the posterior end of the anal fin to the caudal fin base in *C. bleheri* and 4+2 in *C. burmanica* (Vierke, 1991b).

Commercial importance in the United States: This species is sometimes listed on aquarist-oriented websites and has been available for sale through aquarium fish retailers. Because of its attractive coloration, it appears to have been increasing in popularity as an aquarium species. An aquarium fish dealer in Kentucky was found to be selling this species illegally, having imported them from a supplier in Atlanta, Georgia, where snakeheads are also illegal (Major David Casey, personal commun., 2002).

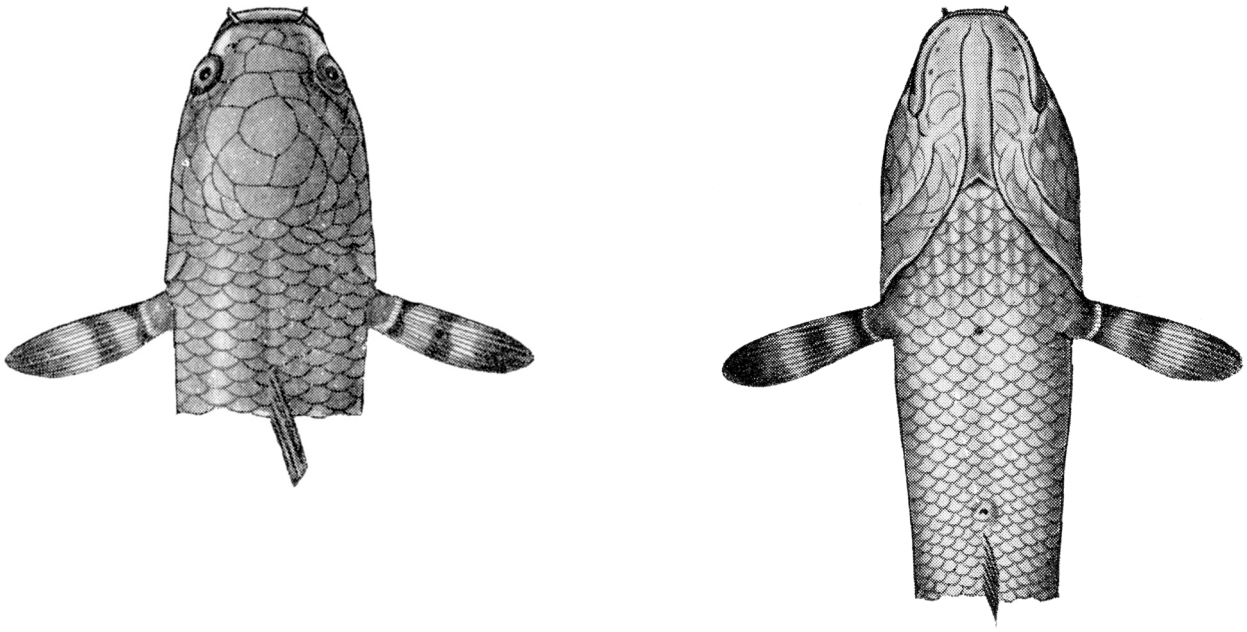
Commercial importance in native range: This species is caught commercially for the aquarium fish trade (Ralf Britz, personal commun., 2002) and is not known to be cultured for this purpose.

Environmental concerns: If released into U.S. waters, it could become established in subtropical Florida, Hawaii, perhaps southeastern Texas, and thermal springs and their outflows in western states. Probably predacious on other fishes.



Channa bleheri

Channa burmanica Chaudhuri, 1919
Burmese Snakehead



After Chaudhuri, 1919

Left: dorsal view; **Right:** ventral view

Original description: *Channa burmanica* Chaudhuri, 1919:284-286, fig. 4. Report on a small collection of fish from Putao (Hkamti Long) on the northern frontier of Burma. Records of the Indian Museum 16:271-287. Type locality: Putao Plains of northern Myanmar, river Sen-Ben-Ti. Holotype: ZSI F9755.

Synonyms: Synonyms unknown.

Common name: **Burmese snakehead.**

Native range: Endemic to headwaters (Kiu River, perhaps Lang basin) of the Ayeyarwaddy (=Irrawaddy) River in northern Myanmar, between the Kumon and Shan-ngaw mountain ranges.

Introduced range: No introductions known.

Size: Maximum size unknown. Chaudhuri's (1919) largest specimen (one of four) was 106 cm total length. The species doubtlessly reaches a greater length, but cannot be considered as one of the moderate-to-large snakehead species.

Habitat preference: No specific information in Chaudhuri's (1919) publication.

Temperature range: No specific information. The type locality (Putao Plains) is about 27º N, indicating a subtropical to warm temperate species.

Reproductive habits: No specific information. The Burmese snakehead may show reproductive habits similar to its closest relative, *Channa bleheri*.

Feeding habits: No specific information. Perhaps similar to that of *Channa bleheri*.

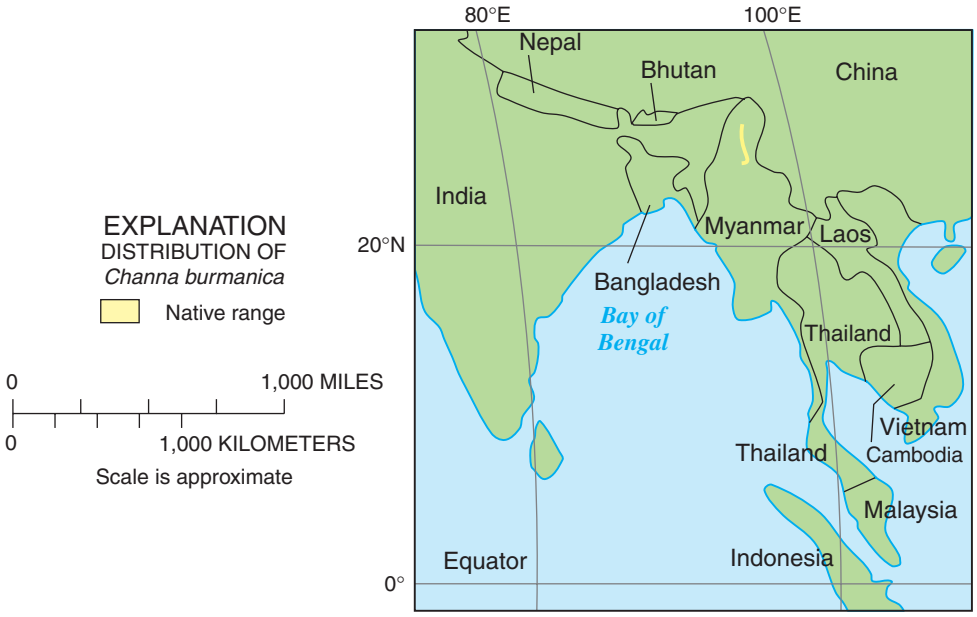
Characters: No area of scales in the gular region. No pelvic fins. Dorsal rays 38; anal rays 28. Lateral line scales 51 (50 pored scales), with lateral line dipping ventrally after the 12th scale (scale in disjunction without pore). Predorsal scales 8.

This species appears to be most closely related to *Channa bleheri* (Peter Ng, personal commun., *in* Vierke, 1991b). See account for *C. bleheri* for species differences.

Commercial importance in the United States: None known.

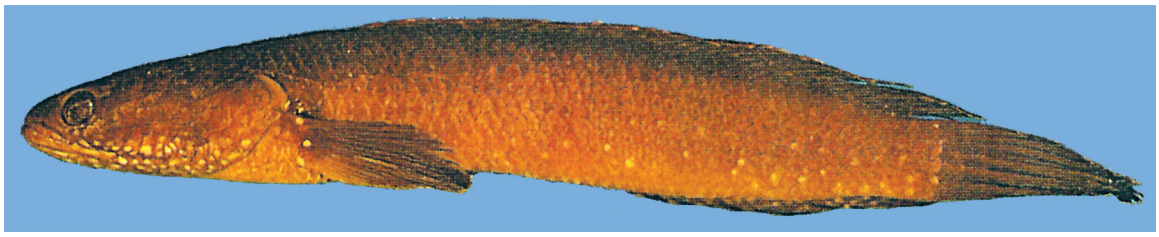
Commercial importance in native range: Unknown.

Environmental concerns: Doubtlessly a predator and likely feeding on other fishes. Like *Channa bleheri*, this species has potential to establish in much of peninsular Florida, Hawaii, perhaps southern Texas, and thermal springs and their outflows in the American west if introduced.



Channa burmanica

Channa cyanospilos (Bleeker, 1853)
Bluespotted Snakehead



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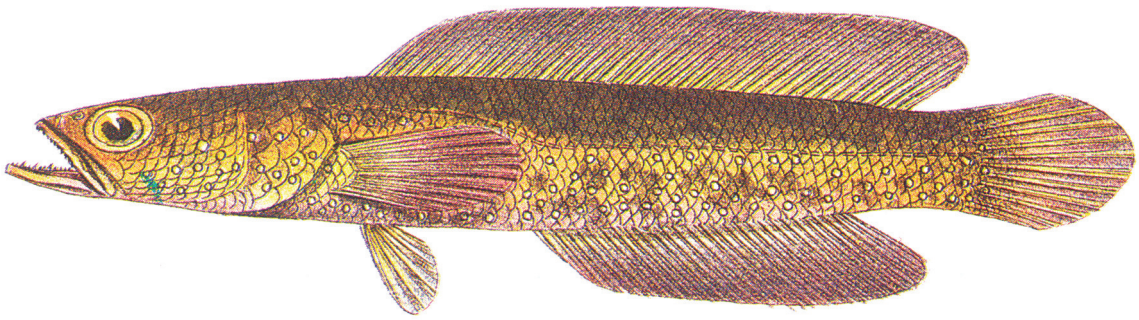


After Bleeker, 1878

Original description: *Ophicephalus cyanospilos* Bleeker, 1853:256. Bleeker, P. Disgnostiche beschrijvingen van nieuwe of weining bekende vischsoorten van Sumatra. Tiental V-X. Tijdrschr. Neder. Indië 4:243-302. Type locality: Telok Betong (presently Bandar Lampung), southern Sumatra, Indonesia. Holotype locality unknown.

Synonyms: (?)*Ophiocephalus striatus* Weber and de Beaufort, 1922.

Channa sp. Ng and Lim, 1990.

(?)*Channa striata* Ng and Lim, 1990.

Common names: None known. The authors propose **bluespotted snakehead** as this character remains obvious in preserved specimens and is unknown in other channids from Indonesia or Malaysia (Ng and Lim, 1991).

Native range: Sumatra and probably peninsular Malaysia and Kalimantan (Kapuas basin, western Borneo; Ng and Lim, 1991). Also found during 1995-1996 in Riau and Jambi, central Sumatra (Peter Ng, personal commun., 2003).

Introduced range: No introductions known.

Size: To at least 20 cm (Ng and Lim, 1991).

Habitat preference: No specific information, but known from a tributary in the Sungei Alas (Alas River) basin, northern Sumatra.

Temperature range: No specific information. The known native range of this species is between 3º N and 6º S, indicating a tropical, equatorial taxon.

Reproductive habits: No information located. Probably a nest builder that guards its eggs and young like other snakeheads.

Feeding habits: No information found. Likely a thrust predator as other snakeheads.

Characters: No patch of scales in gular region of head. Dorsal fin rays 38-43; anal fin rays 24-26.

Lateral line scales 51-55; predorsal scales (posterior to cephalic shields) 8. Small canines present on lower jaw. Pale blue spots on the lower half of the body from gill cover to caudal peduncle, remaining visible in preserved specimens.

Weber and de Beaufort (1922) listed this species as a possible synonym of *Channa striata*, a practice followed for many decades. Ng and Lim (1990) cited the species in this same manner. Ng and Lim (1991), however, recognized the species as valid as did Kottelat and others (1993) and Musikasinthorn (2000). Ng and Lim (1991) allied *C. cyanospilos* with *C. melasoma*, rather than *C. striata*, based on morphological features, particularly with regard to the shapes of the throat region and ventral surfaces of the gill cover.

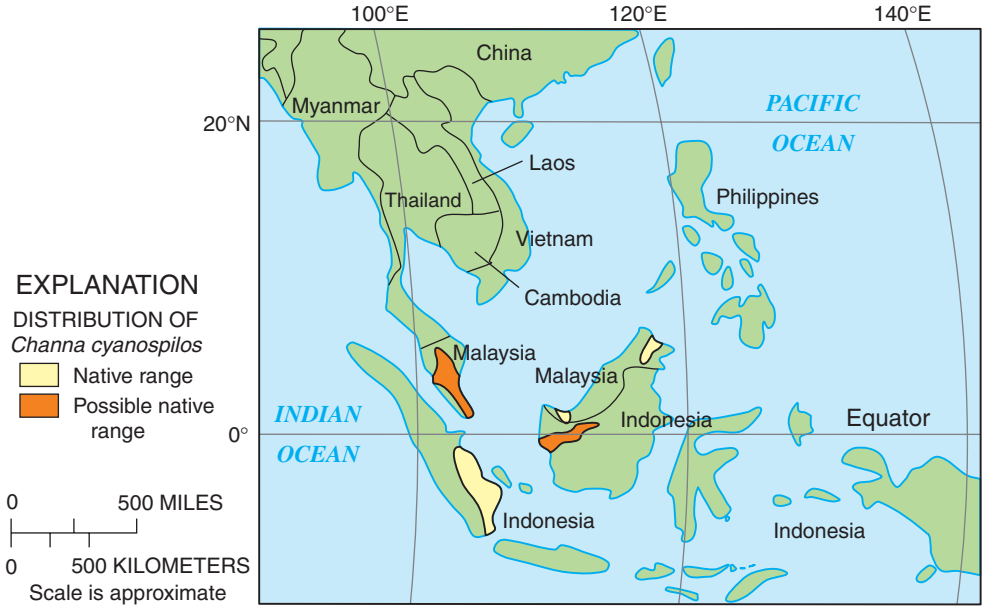
Channa cyanospilos can be separated from *C. melasoma* by lower jaw length (5 percent standard length in *C. cyanospilos*, 12-13 percent in *C. melasoma*). Both species also have 8 predorsal scales behind the cephalic shields (7 in *C. striata*).

Pale blue spots or blotches in the throat region of *C. cyanospilos* are similar to those in *C. melasoma*, but in the latter species the spots and blotches form a marbled pattern; *C. striata* lacks any blue spots in the throat region but has brown streaks and spots (Ng and Lim, 1991).

Commercial importance in the United States: Not listed on aquarist-oriented websites and probably has been unavailable in the aquarium fish trade. Not known to have been imported or available in live-food fish markets.

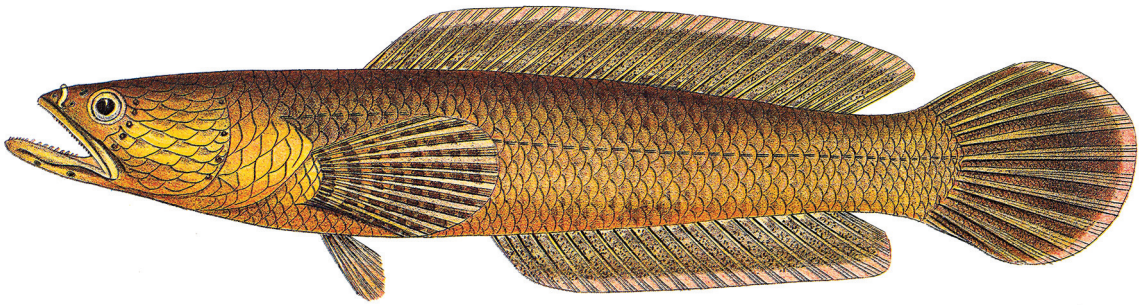
Commercial importance in native range: No information found. Probably occasionally caught by angling.

Environmental concerns: Likely a thrust predator with a diet that includes fishes. Nevertheless, this species is tropical and probably would survive only in extreme southern Florida, Hawaii, and thermal springs and their outflows if introduced.



Channa cyanospilos

Channa gachua (Hamilton, 1822)
Dwarf Snakehead



After Munro, 1955

Upper image: ZRC 41100, 107.7 mm standard length, from Perlis, Malaysia. **Lower image:** ZRC 41656, 46.5 mm standard length, from Kerala, India. Reprinted with permission from P.K.L. Ng from: Ng, H.H., P.K.L. Ng, and Ralf Britz. 1999. *Channa harcourtbutleri* (Annandale, 1918): a valid species of snakehead (Perciformes: Channidae) from Myanmar. J. South Asian Nat. Hist. 4(1):57-63.

Original description: *Ophicephalus gachua* Hamilton, 1822:68, 367. An account of the fishes found in the river Ganges and its branches. Edinburgh and London, i-xii + 1-405. Type locality: ponds and ditches of Bengal, India. Type specimens unknown.

Synonyms: *Ophiocephalus aurantiacus* Hamilton, 1822:69, 368, pl. 23, fig. 22.

Ophicephalus marginatus Cuvier, 1829:230, *fide* Roberts, 1993:38, Menon, 1999, and Ng and others, 1999:57.

Ophicephalus limbatus Cuvier, 1831, no p., pl. 201, *fide* Roberts, 1993:40, Menon, 1999:275, and Ng and others, 1999:57.

Ophicephalus marginatus Cuvier, 1831, no p., pl. 201, *fide* Roberts, 1993:38, Menon, 1999:275, and Ng and others, 1999:57.

Ophicephalus coramota Cuvier, 1831:414, *fide* Menon, 1999:275 and Ng and others,1999:57.

Ophicephalus fuscus Cuvier, 1831:414, *fide* Menon, 1999:275 and Ng and others, 1999:57.

Ophicephalus montanus McClelland, 1842:583, *fide* Menon, 1999:275, and Ng and others, 1999:57.

Philypnoides surakartensis Bleeker, 1849:19, *fide* Menon, 1999:275, and Ng and others, 1999:57.

Ophiocephalus apus Canestrini, 1861:77, pl. 4, fig. 7.

Ophiocephalus kelaartii Günther, 1861:472, *fide* Talwar and Jhingran, 1991;1019, Menon, 1999:275, and Ng and others, 1999:57.

Ophiocephalus guachua [sic] var. *malaccensis* Peters, 1868.

Ophicephalus gachna [sic] Jordan and Seale, 1907.

Ophiocephalus gachua kelaarti Günther: Munro, 1955:100.

Species is in need of revision; status of many synonyms uncertain (Ng and Lim, 1990; Ng and others, 1999). Roberts (1989), Lim and others (1990), Talwar and Jhingran (1992), and Rainboth (1996) treated this species as a synonym of *Channa orientalis*, but Ng and others (1999) disagreed with this conclusion. Day (1889), Coad (1981), Lim and others (1990), Kottelat (1998), Musikasinthorn (2000), and others considered *C. gachua* to be valid. For purposes of this report, we follow the most recent authorities in recognizing the species as valid, but also realizing that it doubtlessly represents a species complex.

Common names: **dwarf snakehead**; frog snakehead; brown snakehead; dolli or dauli (Pakistan); dheri dhok (Hindu); para korava (Tamil); doarrah (Punjab, India); chen-gah (Assam, India); cheng (West Bengal, India); dheridhok, chainga (Bijar Province, India); chenga (Orissa Province, India); malamatta-gudisa, erramatta, tatimatta-gudisa (Andrah Pradesh Province, India); koravu, vattudi (Kerala Province, India); mohkorava, mottu (Karnataka Province, India; Talwar and Jhingran, 1992), parandal kanaya (Sri Lanka; Pethiyagoda, 1991); bakak (Malay; Lim and Ng, 1990).

Native range: Bampur-Haliri basin and Mashkel River, southeastern Iran (Coad, 1979); Kabol (Kabul) drainage of Afghanistan (Coad, 1981); eastern and western Pakistan (Qureshi, 1965); India, Sri Lanka, Bangladesh, Myanmar, Thailand, Laos, Cambodia, Malaysia, Indonesia (Borneo), Java, southern China (Mukerji, 1933; Mendis and Fernando, 1962; Fernando and Indrassna, 1969; Roberts, 1989; Pearl River Fisheries Research Institute, 1991; Pethiyagoda, 1991; Talwar and Jhingran, 1992; Kottelat, 1998, 2001a; Musikasinthorn, 2000). Kullander and others (1999), citing Das and Nath (1971), recorded this species from the Punch Valley, in a tributary of the Jhelum River, in the Kashmir Valley of northeastern Pakistan/western Kashmir. Peter Ng (personal commun., 2003) reported its occurrence in the Toba area of northern Sumatra, and Riau and Jambi in central Sumatra in 1996, as well as in Yunnan Province, China, in 2000.

Introduced range: There may have been introductions that went unrecorded, but Kottelat's (1985) reference to *Channa orientalis* from the Greater Sunda Islands doubtlessly refers to some species of the *C. gachua* complex. Myers and Shapovalov (1932) cited a specimen of *C. gachua* from Formosa (=Taiwan) that lacked both pelvic fins. Because pelvic fins were absent, they tentatively identified the specimen as *C. orientalis* but noted other specimens of *C. gachua* from India that also lacked pelvics based on reports by earlier scientists. They suggested that this fish may have been introduced to Taiwan. This snakehead can be easily transported for great distances with significant altitude and temperature changes (Day, 1877). Peter Ng (personal commun., 2003) found this snakehead in Bali in 2000, perhaps within its native range or an introduction.

Size: This species is often referred to by authors as the smallest snakehead, reaching a length of about 17 cm (Kottelat, 1998). Lee and Ng (1991) stated that it rarely exceeded 20 cm. The smallest snakehead, however, is *Channa orientalis*, a species that rarely exceeds 10 cm in length (Pethiyagoda, 1991).

Habitat preference: Appears to prefer clear pools, shallow streams, and swamps, particularly in forested areas. Nevertheless, Pethiyagoda (1991) noted that it is common "in streams and ponds," but is tolerant of "very stagnant, poorly oxygenated, turbid water." Deraniyagala (1929) stated that it "flourishes in ponds rendered so stagnant as to prove toxic to most fishes."

Said to be largely a nocturnal fish. Habitat destruction, due to deforestation near Singapore, is considered a threat to this species (http://www.sci-ctr.edu.sg/ssc/imglib/vertebra/channa.html). Kottelat (1998, 2001a,b) reported this species from hill streams in Laos, Thailand, Cambodia, and Vietnam. Lim and others (1990) recorded finding it in forest streams in peninsular Malaysia. This snakehead is reported to tolerate a wide range of pH levels with 100 percent survival over 72 hours from pH 3.10 to 9.6 (Varma, 1979).

Lee and Ng (1994) reported the species "from rivers, lakes, ponds, well-shaded, small forest streams less than 20 cm deep, hillstreams not continuous to mountain ranges and in the upper zone of rivers." They indicated that it is found from sea level to an altitude of 1,520 m in India and up to 1,430 m in Malaysia, in waters with flow rates from stationary to rapids with a pH range of 3.1-9.6. Lee and Ng (1991) stated that the species is also found in mountain brooks up to 3,600 m above sea level. Mukerji (1931) reported capture of two specimens from the Billigirirangan Hills of southern India at an altitude of 751 m. The species has been reported surviving in brackish water, but this is doubted by Lee and Ng (1991). Srivastava and others (1980) noted decreasing body weight of this species in salinities as low as 5 ppm. They are capable of overland migrations (Lee and Ng, 1991), and Deraniyagala (1929) commented that it is "exceedingly active on land, pregressing by a series of leaps."

Temperature range: Lee and Ng (1994) indicated that this species can tolerate temperatures in hot springs in Sri Lanka to as low as 13 ºC. The species complex, however, is reported from as far north as Afghanistan (with cold winters) to Borneo and Java (equatorial tropical). Pethiyagoda (1991) cited Deraniyagala (1932) as having recorded this species from hot springs at 36.5 ºC.

Reproductive habits: This species has been cited as a mouthbrooder (Lee and Ng, 1991, 1994; Kottelat, 2001a) and confirmed by Ralf Britz (personal commun., 2003). An interesting factor here is that other authors (for example, Munro, 1955) made no mention of oral brooding of fertilized eggs and young for the dwarf snakehead. Based on Kahn (1924) and Deraniyagala (1929), Breder and Rosen (1966) stated that spawning in India occurs with the female swimming upside-down under the male, with eggs being released and fertilized in groups of 200-300 every minute or two. Females in Indonesia and Malaysia, however, are reported to produce from 20 to 200 eggs per spawning, with the male orally brooding developing eggs and fry (Lee and Ng, 1991, 1994), further evidence that *Channa gachua* is a species complex. This is one of three species of snakeheads known to spawn in ponds lacking vascular aquatic plants (Parameswaran and Murugesan, 1976b).

Bhuiyan and Rahman (1982) measured fecundity from 30 female *Channa gachua* collected near Rajshahi, Bangladesh, which ranged from 487 (94 mm specimen) to 4,482 (164 mm specimen). Mean fecundity of the 30 specimens was 2,307 oöcytes for a specimen having a mean length of 132 mm. The relationship between fecundity and length is largely linear, as is the relationship between fecundity and length of ovaries.

Mishra (1991) described mature (stage V) oöcytes as ranging from 2.1 to 2.6 mm in diameter with the highest percentage of stage V oöcytes in July from specimens collected near Berhampur, Orissa, India. The highest gonadosomatic index was 6.8 and occurred in June. Estimated fecundity ranged from 2,539 to 7,194 in 15 mature specimens ranging from 13.4 to 17.2 cm in length. Again, the relationship between fecundity and length, as well as fecundity and body weight, was largely linear.

Feeding habits: Lee and Ng (1994) summarized food preferences as including "mouse, rat, frog, tadpole, fish, Ephemerophtera and other insects, mosquito larvae, prawn (*Macrobrachium* sp.), crab (*Irmengardia johnsoni*), and other crustaceans." They cited the species as a nocturnal predator living at or near the substrate and quite capable of migrating overland.

Characters: No patch of scales in the gular region. Pelvic fins present, although Talwar and Jhingran (1992) stated that pelvics may be present or absent. Lateral line scales 39-47; 3½ scales between lateral line and base of anterior dorsal rays. Dorsal rays 32-37; anal rays 20-23. Lower jaw with 10-20 canines posterior to a single row of villiform teeth, the latter expanding to about 7 rows at the jaw symphysis. Dorsal, anal, and caudal fins with white (translucent in preserved specimens) margin; ocellated spot often present near posterior end of dorsal fin. The ocellated spot, however, may appear only in juveniles and females as occurs in *Channa orientalis*. Lim and others (1990) noted that while the fish is alive the dorsal, anal, and caudal fins are margined with red or yellow, and that the pectoral fins have semiconcentric rings and a dark area at the base.

Commercial importance in the United States: This species is occasionally mentioned on aquarist-

oriented websites and has been available for sale from certain aquarium fish dealers. Its small size makes it more appealing as an aquarium species. Too small to be sold in live-food fish markets.

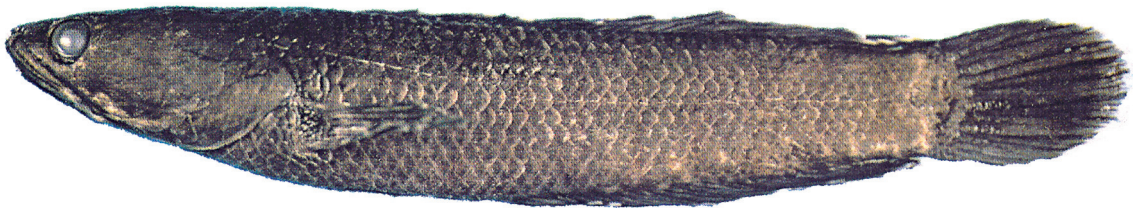
Commercial importance in native range: Talwar and Jhingran (1992) cited the species as of minor importance in India. According to comments on aquarist-oriented websites and in Ng and Lim (1990), members of this species complex appear to be of importance in the aquarium fish trade with individuals captured from the wild for sale or export. Ng and Lim (1990) cited individuals being sold for S$30-60 in Singapore, although Lim and Ng (1990) listed the species as endangered there. Pethiyagoda (1991) noted that it is largely unused as food or in the aquarium trade in Sri Lanka. Deraniyagala (1929) commented that this snakehead is utilized as food by "only the poorest classes" in Sri Lanka, adding that it is used as live bait to catch larger species, such as *Channa striata* and *C. marulius*.

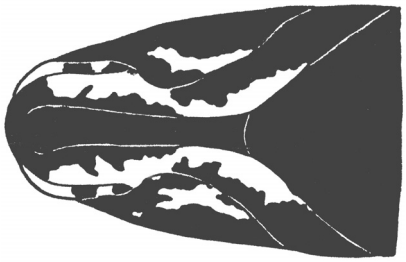
Environmental concerns: Like other channids, this species is a thrust predator, capable of breathing atmospheric oxygen. This species is noted by many authors as migrating overland.

Comments: The diploid number of chromosomes for *Channa gachua* is 78 from India (Banerjee and others, 1988) and 112 for specimens from Thailand (Donsakul and Magtoon, 1991), a strong indication that this represents a species complex.

Channa gachua

Channa harcourtbutleri (Annandale, 1918)
Inle Snakehead





Upper image: ZRC 42556, 111.3 mm standard length, Myanmar: Inle Lake. **Lower image:** ventral view of head illustrating pigmentation, ZRC 42556, 111.3 mm standard length. Reprinted with permission from P.K.L. Ng from: Ng, H.H., P.K.L. Ng, and Ralf Britz. 1999. *Channa harcourtbutleri* (Annandale, 1918): a valid species of snakehead (Perciformes: Channidae) from Myanmar. J. South Asian Nat. Hist. 4(1):57-63.

Original description: *Ophiocephalus harcourtbutleri* Annandale, 1918:54, pl. 2, fig. 7; pl. 4, figs. 16-17. Fishes and fisheries of the Inlé Lake. Rec. Indian Mus. (Calcutta), 14:33-64, pls. 1-7. Type locality: southern Shan State, Myanmar (Burma). Holotype: ZSI F9439/1.

Synonyms: (?) *Ophioceplahus gachua* (non-Hamilton, 1822) Boulenger, 1899:199.
Ophiocephalus harcourt-butleri Annandale, 1918:54.
(?) *Ophicephalus gachua* (non-Hamilton, 1822) Hora and Mukerji, 1934:135.
Ophiocephalus harcourtbutleri Tint Hlaing, 1971:517.
Channa orientalis Kottelat, 1989:20; Talwar and Jhingran, 1991:1019.
Channa harcourtbutleri Ng and others, 1999.

Common name: Inle snakehead.

Native range: Yawnghwe and nearby areas of Myanmar, particularly Inlé Lake in southern Shan State (Ng and others, 1999).

Introduced range: Not known to have been introduced.

Size: To about 16 cm.

Habitat preference: Annandale (1918) noted that the species occurred in Inlé Lake on "muddy bottom in sluggish streams … hiding as a rule among weeds."

Temperature range: No specific information in literature. Nevertheless, Inlé Lake lies at about 20.7º N, indicating that *Channa harcourtbutleri* is a tropical/subtropical species. Inlé Lake is at an altitude of about 1,000 m (Kullander and others, 2000).

Reproductive habits: No specific information in literature. Ralf Britz (personal commun., 2003) indicated that it is unknown if this species is a nest builder or mouthbrooder.

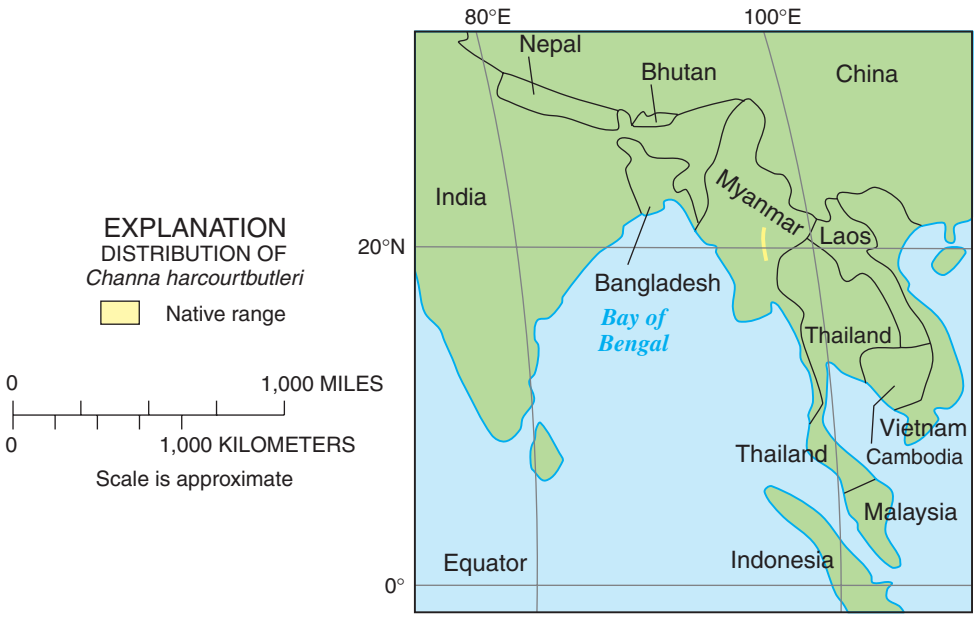
Food preferences: No specific information in literature. Likely a thrust predator as are other snakeheads (Ng and others, 1999).

Characters: No patch of scales in gular region of head. Lateral line curves downward between scales 15-16. Lateral line scales 44-45; transverse scales 4; predorsal scales 4. Dorsal fin rays 34-38 (mode 36); anal fin rays 23-26; pectoral fin rays 14-15 (mode 14) (Ng and others, 1999). This species is most closely related to *Channa gachua* from which it can be distinguished as follows: Head profile of *C. harcourtbutleri* flatter and less convex than in *C. gachua* resulting in a smaller postorbital head depth (30.9-35 percent head length versus 39.8-44 for *C. gachua*), its length 32-34 percent standard length versus 26.8-31.9 percent, and width 16.9-19 percent standard length versus 18.6-21.7 percent. Moreover, the snout of *C. harcourtbutleri* is more convex when viewed dorsally (Ng and others, 1999, figs. 3b,4a). The two species also differ in coloration (Ng and others, 1999) with *C. harcourtbutleri* never having an ocellus at the posterior end of the dorsal fin (occurring in subadult *C. gachua*).

Commercial importance in the United States: Not known to have been imported for any purpose.

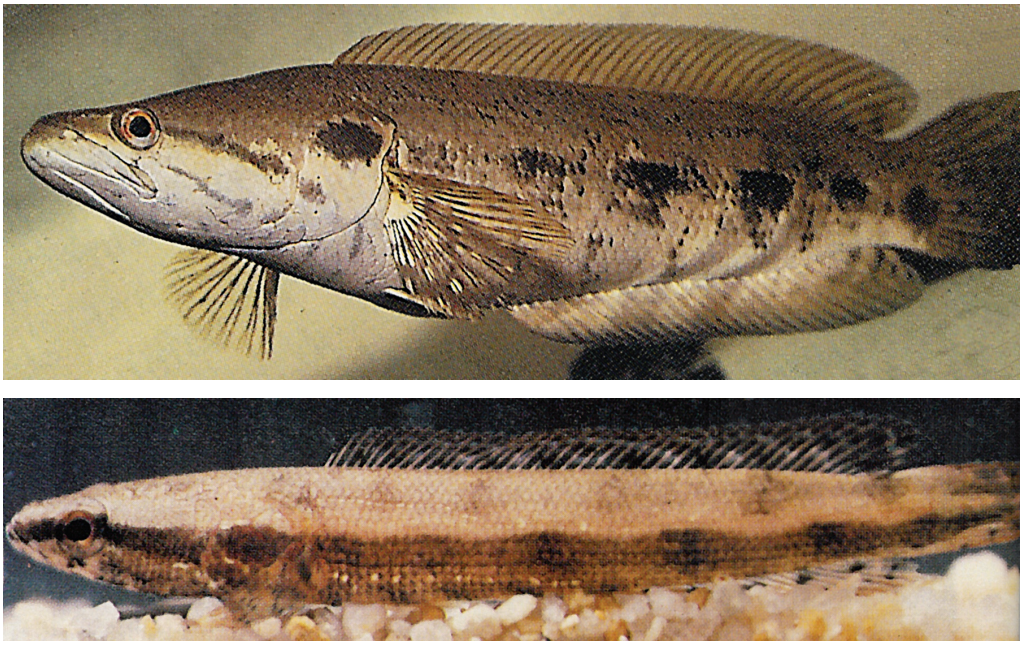
Commercial importance in native range: Sold in live-food fish markets in the vicinity of Inlé Lake, Myanmar (Ng and others, 1999).

Environmental concerns: Although this species is tropical/subtropical and could potentially establish if released in southern Florida, Hawaii, and warm thermal springs and their outflows, its food habits are largely unknown (Ralf Britz, personal commun., 2003). Like other snakeheads, it may be a predator (Ng and others, 1999).



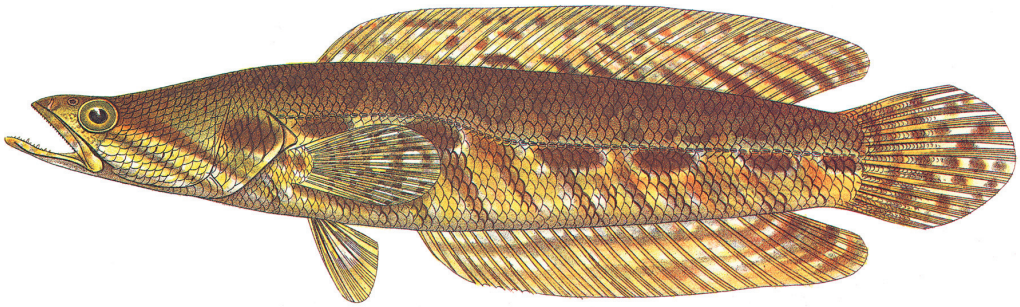
Channa harcourtbutleri

Channa lucius (Cuvier, 1831)
Splendid Snakehead



Upper image: adult. **Lower image:** juvenile.

Reprinted with permission from P.K.L. Ng from: Lee, P.G., and P.K.L. Ng. 1991. The snakehead fishes of the Indo-Malayan region. Nature Malaysiana 16(4):112-129.



After Bleeker, 1878

Original description: *Ophicephalus lucius* Cuvier *in* Cuvier and Valenciennes, 1831:416. Histoire naturelle des poissons 7:i-xxix + 1-537, pls. 170-208. Type locality: Java. Holotype: RMNH, whereabouts unkown.

Synonyms: *Ophiocephalus polylepis* Bleeker, 1852:578.

Ophiocephalus bistriatus Weber and de Beaufort, 1922.

Ophiocephalus bivittatus Károli, 1822. Name preoccupied by *Ophiocephalus bivittatus* Bleeker, 1845, changed to *Channa bistriata* by Weber and de Beaufort, 1922.

Ophicephalus siamensis Günther, 1861 (Musikasinthorn and Taki, 2001).

Channa bistriata Weber and de Beaufort, 1922 (young of *C. lucius* [Alfred, 1964]).

Common names: **splendid snakehead;** forest snakehead; ikan bujok or ikan ubi (Malaysia), runtuk (Kalimantan), trey kanh chorn chey (Cambodia); bujok (Mayay; Lim and Ng, 1990).

Native range: Rivers of southeastern Sumatra and the Kapuas basin of western Kalimantan (southern Borneo; Roberts, 1989); Mekong basin of Laos (Kottelat, 2001a). Kottelat (1985) and Ismail (1989) included China, Vietnam, Laos, Thailand, Malaysia, Kalimantan, Java, and Sumatra in the native range. Peter Ng (personal commun., 2003) collected this species during November 1999 and April 2000 in central Sumatra, southern Sarawak, and the Mahakam and Kayan basins of eastern Kalimantan.

Introduced range: No introductions known.

Size: To 40 cm.

Habitat preference: Kottelat (2001a) stated preference for streams in forested areas where the species lives among vegetation. Lim and Ng (1990) indicated a preference for forest streams and peat swamps. Lee and Ng (1994) said the species occurs in lakes, ponds, shaded forest streams, peat swamps, and mid-depths of rivers, showing a preference for faster moving waters. pH range is 5.5-6.0 and the species is said to be crepuscular or nocturnal (Lee and Ng, 1994). Rainboth (1996) cited preferred habitat as "slowly moving streams and rivers as well as lakes, ponds, and reservoirs from Thailand to Indonesia. Usually found in areas with much aquatic vegetation as well as submerged, woody plants…"

Temperature range: Lee and Ng (1994) recorded the fish in waters between 24-29 ºC, indicating a tropical/subtropical species.

Reproductive habits: A nest builder like other channids, with both parents guarding developing eggs and larvae (Lee and Ng, 1994). No information located on fecundity.

Food preferences: Lee and Ng (1994) cited the species as "a midwater or surface predator relying on camouflage to ambush its prey, mainly fish." Rainboth (1996) stated that this species preys "on fishes, prawns, and crabs and slightly less on shrimps."

Characters: Patch of scales present on gular region of head. Large canine teeth present on prevomer and palatines. Upper profile of head somewhat concave. Lateral line scales 58-65; 5½ scales between lateral line and base of anterior dorsal rays. Dorsal rays 38-41; anal rays 27-29. Sides of body with series of distinct, dark "porthole" blotches, oblique bars on belly, and slightly elongated, dark blotch on operculum (Ng and Lim, 1990; Lee and Ng, 1991). Juveniles with three dark stripes from head to caudal fin base.

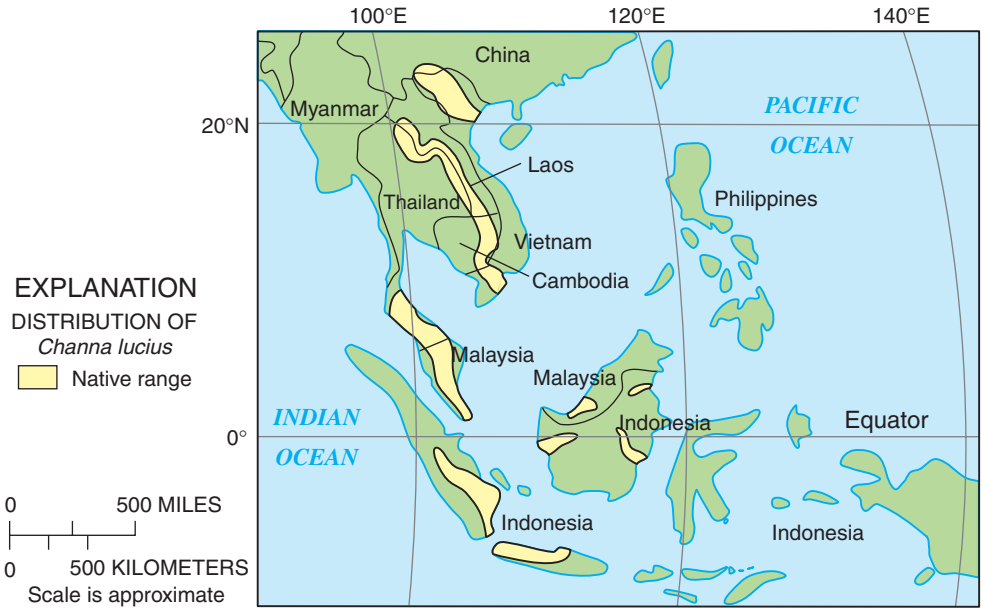
Ismail (1989) stated that this species has one or two rows of primarily canine teeth on the prevomer and palatines.

Commercial importance in the United States: Rarely mentioned on aquarist-oriented websites and probably of little or no importance in the domestic aquarium fish trade. No information on its past availability in live-food fish markets.

Commercial importance in native range: Ng and Lim (1990) listed this species as the third most highly prized food fish in southeastern Asia, where channids bring S$10-20/kg when fresh. Only *Channa micropeltes* and *C. striata* are more popular in live-food fish markets. It is also sold in the Singapore aquarium fish trade (Ng and Lim, 1990). It is sold fresh, frequently alive, in Cambodia (Rainboth, 1996).

Environmental concerns: This species is known to be a nocturnal thrust predator, with a preference for other fishes. Its natural range includes tropical and subtropical climate zones, indicating that if introduced, this species could establish only in similar climates or thermal springs and their outflows.

Comments: The diploid number of chromosomes of *Channa lucius* is 48 (Donsakul and Magtoon, 1991).



Channa lucius

Channa maculata (Lacepède, 1802)
Blotched Snakehead

Original description: *Bostrychus maculatus* Lacepède, 1801:140, 143. Histoire naturelle des poissons 3:i-lxvi + 1-558, pls. 1-34. Type locality: none designated. No type specimens.

Synonyms: *Ophicephalus guentheri* Sauvage and Dabry de Thiersant, 1874:4.

Ophicephalus lucius Koller, 1927:41, pl. 1, fig. 7.

Ophicephalus tadianus Jordan and Evermann, 1902:1289.

Ophiocephalus marmoratus Brind, 1914:11.

Common names: **blotched snakehead**. No other English names known; hei-yü (Tungting Lake, China; Nichols, 1943); tai wan li (Mandarin); lê-hî (Taiwan; Shen and Tzeng, 1993); Taiwan-dojô (Japan and Taiwan; Uyeno and Arai, 1984; Hosoya, 2002); fibata (Madagascar; Paul V. Loiselle, personal commun., 2003).

Native range: southern China, south of the Chang Jiang (Yangtze) basin and Hainan (Nichols, 1943; Okada, 1960; Hay and Hodgkiss, 1981; Uyeno and Arai, 1984); northern Vietnam (Kotellat, 2001a).

Introduced range: Taiwan (established); introduced into Japan beginning in 1916 from Taiwan, established in Nara, Hyôgo, Hiroshima, Mie, and Shiga prefectures, Japan, as of 1960 (Okada, 1960; Liang and others, 1962; Hay and Hodgkiss, 1981; Uyeno and Arai, 1984; Shen and Tzeng, 1993); Philippines (Uyeno and Arai, 1984), and Madagascar (misidentified as *Channa striata*; Raminosoa, 1987; Welcomme, 1988; Reinthal and Stiassny, 1991; Stiassny and Raminosoa, 1994; Lever, 1996; Lévèque, 1998). Brind (1914) described a snakehead, *Ophiocephalus marmoratus*, from specimens supposedly acquired in Singapore and Malacca, Malaysia. "About 60 specimens, from 3 to 6 inches in length, were caught by a sailor of a merchant vessel and brought to New York direct" (Brind, 1914). There are no records of *C. maculata* having been introduced to either locality. The illustration that accompanied his description of this fish, although somewhat poor, appears to be of *C. maculata* and most certainly is not of any snakehead native to Singapore or Malaysia. Moreover, Brind (1914) commented that this fish "can stand cold water." Therefore, we have included *O. marmoratus* as a synonym of *C. maculata* and conclude that either the localities from which these specimens were obtained were in error or that they were acquired from Chinese traders in those two cities. A somewhat similar situation involving a bagrid catfish, *Hemibagrus elongatus*, the holotype of which was supposedly from Singapore, was reported (Kottelat and others, 1998) where the actual type locality

is believed to be China. Those authors also noted that although the type of *H. elongatus* might have come from Singapore, there had been active trade in Singapore of fishes imported from China for purposes of "food, aquaculture or accidentally" that would explain its Chinese origin. There are no type specimens of *O. marmoratus*.

This species may be one of the most widely introduced snakeheads in the Indian and Pacific Ocean basins. As of August 2002, it was becoming apparent that many reports of introductions and established populations of *Channa striata* in such places as Hawaii and Madagascar were based on misidentifications of *C. maculata* (Ralf Britz, personal commun., 2002). We have confirmed (October 2002) that the snakehead species recorded from Hawaii since the late 1800s is indeed *C. maculata* and not *C. striata.* See comments under **Introduced range** in the account for *C. striata*.

Channa maculata was introduced into Madagascar about 1978 by former President Didier Ratsiraka who had seen snakeheads at an aquaculture facility during an earlier visit to North Vietnam. The species he saw in North Korea was likely *C. argus*, but the species that was shipped to President Ratsiraka from China was *C. maculata.* The shipment was divided equally, one group stocked into ponds at the presidential summer residence near Antananarivo, adjacent to the headwaters of the Betsiboka River. The remaining fish were stocked into ponds at Ratsiraka's home near Vatomandry on the east coast. Subsequent floods from monsoons washed snakeheads out of ponds in both localities and into adjacent natural waters. By 1986, *C. maculata* was well established in floodplain lakes of the Betsiboka basin. Nearly the same occurred on the east coast of Madagascar. There is an extensive canal system (Pangalanes Canal) that includes many inland lakes along the Indian Ocean coast of Madagascar that extends for hundreds of kilometers north to south. Snakeheads entered this canal system from ponds near Vatomandry and spread rapidly, being recorded about 200 km north of Vatomandry near Toamasina, the northern terminus of the Pangalanes Canal, several years later. It also dispersed southward to the Mangoro River. The species apparently was also moved to other areas of Madagascar by Sino-Malagasy merchants (Paul V. Loiselle, personal commun., 2003). It was initially misidentified as *C. striata* beginning with Raminosoa (1987). Reports of *C. striata* from Mauritius are also possible misidentifications of *C. maculata*.

Size: To 33 cm (Okada, 1960) but reaches a length of more than 1 m when fully mature (William S. Devick, personal commun. to Paul L. Shafland, 2002).

Habitat preference: Streams, lakes, ponds and ditches in southern China; prefers shallow waters with vegetation (Okada, 1960; Hay and Hodgkiss, 1981).

Temperature range: Native range is subtropical to warm temperate. Nevertheless, Okada (1960) reported that in Japan, this species tolerated "seven days in 7 ºC air temperature out of water." Atkinson (1977), however, cited it as a "tropical" species. Nevertheless, this snakehead has become established far north of its native range and assumed climate tolerances in Japan, following its introduction there.

Reproductive habits: Builds a circular, open nest in vegetation. Eggs float to surface and are guarded by parents. Spawns in Japan in early summer (Okada, 1960).

Feeding habits: Reported to feed on crustaceans, large insects, frogs, and fishes (Okada, 1960; Hay and Hodgkiss, 1981); described as a "fierce predatory fish" that "hides among rocks or aquatic plants until its prey approaches, then it quickly attacks, kills, and swallows its victim" (Hay and Hodgkiss, 1981).

Paul V. Loiselle (personal commun., 2003) reported that a fisherman in Madagascar had observed young blotched snakeheads slithering onto land, allowing their bodies to be covered by ants, then returning to the water where the ants floated at the surface and were devoured by the juvenile snakeheads. He also commented that amphibian populations in Madagascar are probably being negatively affected by the introduced blotched snakehead. Historically, frog tadpoles in the central highlands were preyed upon to some extent by native eels (Anguillidae), but now those same waters contain considerable numbers of *Channa maculata*.

Characters: No patch of scales on gular region. Head profile slightly depressed. Dorsal rays 40-46; anal rays 26-30. Lateral line scales 41-60 with lateral line continuous; transverse scales below lateral line 11; 9 scale rows between posterior rim of orbit to upper edge of operculum. Color pattern similar to that of *Channa argus*; dark stripe from tip of snout through orbit extending to almost above anterior base of pectoral fin; second dark stripe from posteroventral corner of orbit to posteroventral edge of operculum; sides of body with two rows of large, dark blotches extending posteriorly to anterior caudal peduncle; blotches in the form of two bar-like markings on caudal peduncle;

dark markings toward mid-dorsal part of back extending up onto proximal part of dorsal fin. A key character for separating this species from *C. argus* are the bar-like markings on the caudal peduncle. In *C. maculata*, the most posterior dark bar (usually complete) is preceded and followed by pale bar-like areas, whereas in *C. argus* such pale markings are absent and the final dark marking is irregular, often blotch-like.

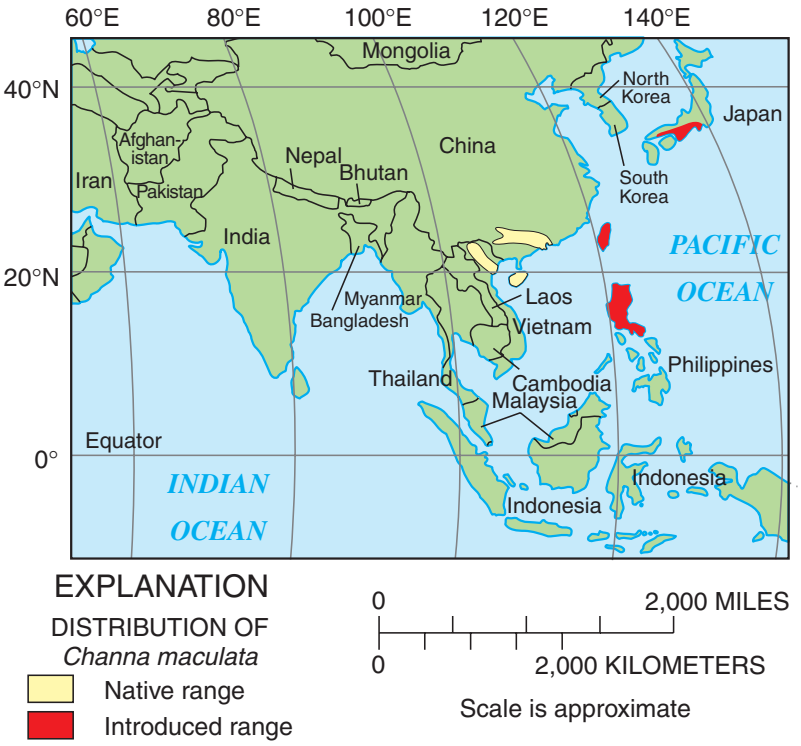
Commercial importance in the United States: Rarely mentioned on aquarist-oriented websites. Because it is a valuable food fish in southern China and Taiwan, we believed it could be available for sale in live-food fish markets. Ralf Britz (personal commun., 2002) confirmed that this species was one of the two snakeheads purchased from a live-food fish market in Boston, Massachusetts, in November 2001. A reexamination of the second specimen confirmed that it was also *Channa maculata*. We also noted from Federal records that imports of snakeheads from Guangdong Province, China, had increased during 2001. Because most culture of blotched snakeheads occurs in that province, the likelihood of availability of this northern snakehead "look-alike" in U.S. markets was increased. Ralf Britz (personal commun., 2002) also confirmed that the blotched snakehead has been present in Hawaii since before 1900, misidentified as *C. striata,* based on specimens in the U.S. National Museum of Natural History. We have learned that the species presently in culture in Hawaii as of 2002 is *C. striata* (Pam Fuller, personal commun., 2002), apparently imported in the early 1990s (Domingo Cravalho, Jr., personal commun., 2002).

Commercial importance in native range: Considered an important and valuable food fish in China (Nichols, 1943; Atkinson, 1977; Hay and Hodgkiss, 1981). It is the second most important snakehead species cultured in China with most culture activity located in Guangdong Province, southeastern China (Fang Fang, personal commun., 2002). Liang and others (1962) commented that it is only sold alive as a food fish within its introduced range in Taiwan.

Environmental concerns: This species is known to be a thrust predator feeding on large invertebrates and fishes. Moreover, its temperature tolerance indicates a species that could live in subtropical to temperate areas in the United States if introduced. That it is established throughout much of central Japan, an area located generally between 34-37º N, and its southernmost range in China is Hainan Island (about 19º N), is indicative of a species that has potential to establish from extreme southern Florida to North Carolina on the Atlantic Coast or central California on the Pacific Coast.

Comments: The diploid number of chromosomes of *Channa maculata* is 42 (Wu and others, 1986).

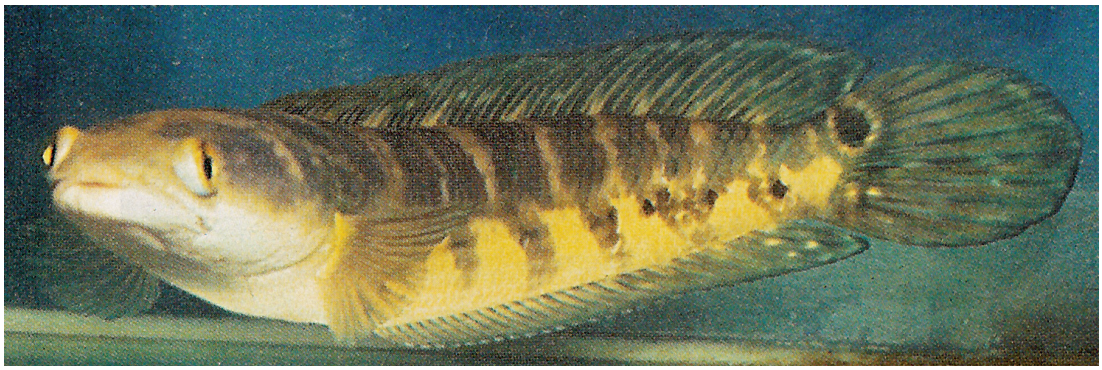
See map on following page



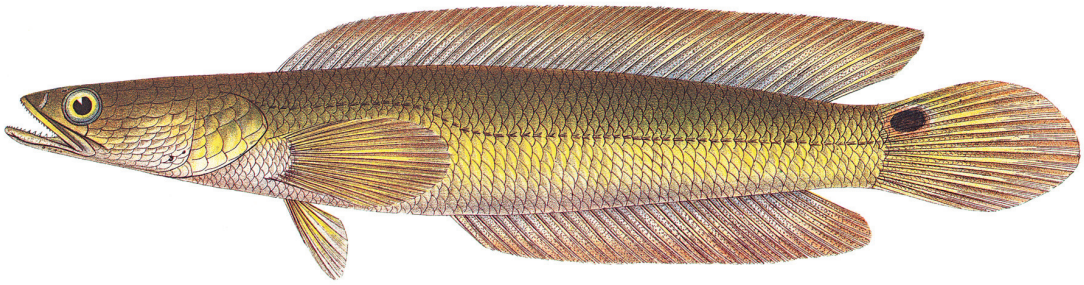
Distribution of *Channa maculata* in the Western Pacific basin

This species is also established on Oahu, Hawaii, and may prove to be a more widely introduced snakehead in the Indian and Pacific Ocean basins than previously known. See comments above and under **Introduced range** in the account for *Channa striata*.

Channa marulioides (Bleeker, 1851)
Emperor Snakehead



Reprinted with permission from P.K.L. Ng from: Lee, P.G., and P.K.L. Ng. 1991. The snakehead fishes of the Indo-Malayan region. Nature Malaysiana 16(4):112-129. Adult; photo by J. Vierke.



After Bleeker, 1878

Original description: *Ophicephalus marulioides* Bleeker, 1851:424. Vijfde bijdrage tot de kennis der ichthyologische fauna van Borneo, met bescrijving van eeinige nieuwe soorten van zoetwatervisschen. Natuurkd. Tijdschr. Neder. Indië 2:415-442. Type locality: Sambas, Kalimantan (southern Borneo), Indonesia. Whereabouts of holotype unknown.

Synonyms: No known synonyms (Roberts, 1989; Ng and Lim, 1990).

Common names: **emperor snakehead**; darkfin snakehead; ikan jaloi (Malay); toman bunga (=flower snakehead; Malaysia).

Native range: Rivers (Musi, Hari, Indragiri, and others) of southeastern Sumatra; Kapuas basin of western Kalimantan (southern Borneo; Roberts, 1989, Kottelat, 1994); Bangka (Banka) and Belitung (Billiton) (Roberts, 1989). Peter Ng (personal commun., 2003) collected this species in Samarinda, eastern Kalimantan, in November 1999. In peninsular Malaysia, occurring mostly toward the center of the peninsula in Pahang (Lee and Ng, 1994). Often confused with *Channa melanoptera* (Lee and Ng, 1994). Also recorded from southern Thailand (Malay Peninsula) by Herre and Myers (1937) and reported as the only record from that country (Smith, 1945). Kottelat and others (1993) did not list Thailand within its native range, although it is possible that its range extends northward into extreme southern Thailand. Ismail (1989) included Thailand within native range but added that the species was “quite rare” in peninsular Malaysia.

Introduced range: No introductions known.

Channa marulioides, caught and released from jungle of Perak State, Malaysia, January 2003. Photo courtesy of Jean-Francois Helias, Fishing Adventures Thailand.

Size: To 65 cm (Lee and Ng, 1994).

Habitat preference: A riverine species (Kottelat, 1994), also found in lakes, appearing to be an inland species (Lee and Ng, 1994).

Temperature range: No specific information found. The native range is equatorial/tropical.

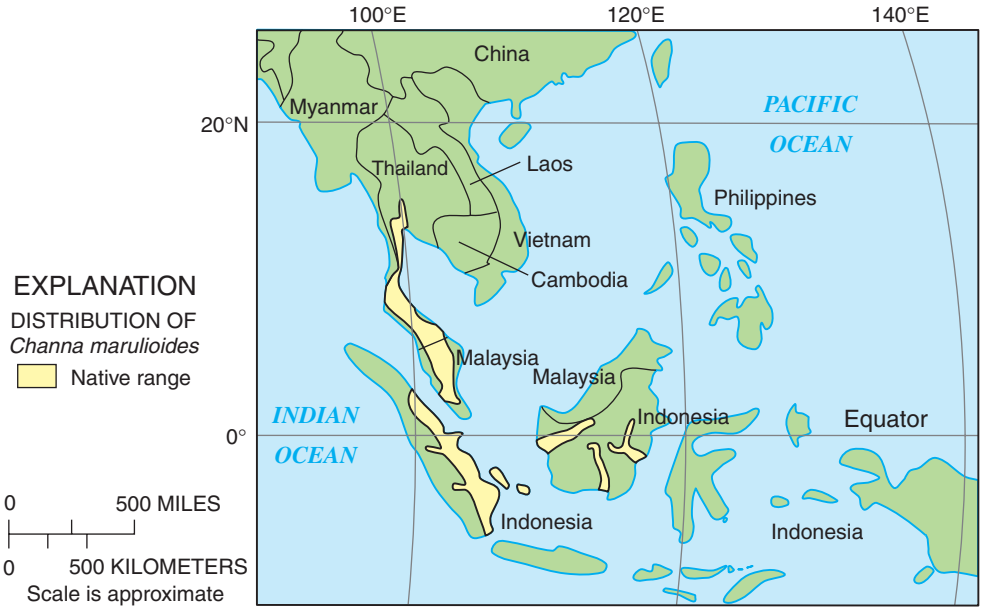
Reproductive habits: No specific information found. Likely a nest builder with adults guarding fertilized eggs and larvae.

Characters: No patch of scales on gular region of head. Dorsal fin rays 45-47; anal fin rays 30-31. Lateral line scales 55-58; predorsal scales 13-15. Scales between lateral line and anterior rays of dorsal fin 3½. Lateral line curves downward abruptly at lateral line scales 17-20. Preopercular scales 5-7. No canines on prevomer or palatines (Smith, 1945; Kottelat and others, 1993). These characters overlap those of *Channa melanoptera*. Lee and Ng (1994) stated that the only way to separate these two species is by coloration. *Channa marulioides* possesses an ocellated spot on the upper part of the caudal fin base, similar to that in *C. marulius*. In live specimens, the margin of the ocellus is orange; the margin appears white in preserved specimens. *Channa marulioides* often has a series of dark patches of scales, the posterior and posterodorsal scales each margined by white, along the sides of the body, a character that is absent in *C. melanoptera* (Kottelat and others, 1993; Lee and Ng, 1991, 1994) and *C. marulius*, and may disappear with growth. The iris of the eye is orange or red as in *C. marulius*.

Commercial importance in the United States: Rarely mentioned in aquarist-oriented websites. This species is colorful and has perhaps been found periodically for sale in the aquarium fish trade. Not known from live-food fish markets.

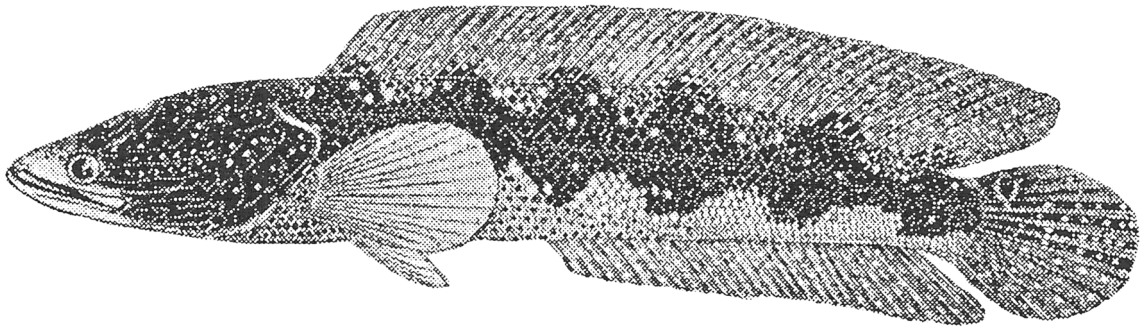
Commercial importance in native range: Ng and Lim (1990) stated that this snakehead is sold in the aquarium fish trade in Singapore, costing up to S$100 per individual. This market likely precludes this species as available in live-food fish markets as a food species.

Environmental concerns: Likely a thrust predator. This is an equatorial/tropical species that, if introduced, might establish only in areas with a similar climate.

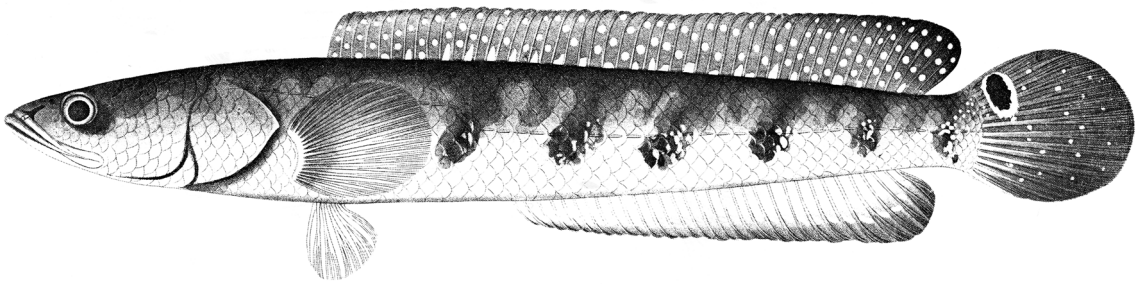


Channa marulioides

Channa marulius (Hamilton, 1822)
Bullseye Snakehead



After Munro, 1955



After Hamilton, 1822; juvenile

Original description: *Ophiocephalus marulius* Hamilton, 1822:65, 367, pl. 17, fig. 19. An account of the fishes found in the river Ganges and its branches. Edinburgh and London, i-vii + 1-405, pls. 1-39. Type locality: "Gangetic provinces," India. No types known.

Synonyms: *Ophicephalus sowara* Cuvier, 1831:426.

Ophicephalus grandinosus Cuvier, 1831:434.

Ophiocephalus leucopunctatus Sykes, 1839:158.

Ophiocephalus theophrasti Valenciennes, 1840:pl. 13, figs. 1-1a.

Ophicephalus pseudomarulius Günther, 1861:478.

Ophiocephalus aurolineatus Day, 1870:99.

Channa marulius ara Deraniyagala, 1945:24, pl. 24.

Common names: **bullseye snakehead**; giant snakehead; great snakehead; cobra snakehead; Indian snakehead; soal (Pakistan); haal (Assam, India); sal, gajal (West Bengal, India); pumurl, bhor (Bijar, India); kubrah, sawal, dowlah (Punjab, India); saal (Orissa, India); poomeenu, phoola-chapa, phool-mural (Andra Pradesh, India); aviri, puveral (Tamil Nadu, India); chaeru-veraal, curuva, bral (Kerala, India); hoovina-murl, madinji, aviu (Karnataka, India); ara, gangara, kalumaha (Sinhalese, Sri Lanka); iru viral (Tamil, Sri Lanka); ara (Sri Lanka); trey raws (Cambodia).

Smith (1945) noted that near Bankok, Thailand, the common name pla chon ngu hao is used for this species; ngu hao means cobra. Talwar and Jhingran (1992) listed a common name of kubrah, used in Punjab, India. This perhaps explains the use of "cobra snakehead" for this species in the U.S. aquarium fish trade.

Native range: Pakistan (Kabul and Indus Rivers; Mirza, 1999); many drainages of India, Sri Lanka, Bangladesh, southern Nepal (Gandaki, Koshi, and Karnali River basins), Myanmar, Thailand, Mekong basin of Laos and Cambodia, and southern China (Day, 1877, Nichols, 1943; Mendis and Fernando, 1962; Qureshi, 1965; Fernando and Indrassna, 1969; Pethiyagoda, 1991; Talwar and Jhingran, 1992; Rainboth, 1996; Kottelat, 2001a). Smith (1945) cited this species as "one of the rarest of the serpent-heads found in Thailand." It is not reported from Malaysia or Indonesia where it appears to be replaced by a somewhat lookalike species, *Channa marulioides*. Nichols (1943) recorded the species from the Yangtze drainage, China. Maurice Kottelat and Tyson Roberts (personal commun. to J.D. Williams, 2001) indicated that *C. marulius*, as currently recognized, is possibly a species complex.

Introduced range: Introduced into residential lakes and adjoining canals in Tamarac, Broward County, Florida, and established as a reproducing population (Florida Fish and Wildlife Conservation Commission, 2001; Howells and others, 2002; Paul L. Shafland, personal commun., 2002).

Size: This species is reported to be the largest of the family Channidae, reaching a length of 120-122 cm (Bardach and others, 1972; Talwar and Jhingran, 1992). Talwar and Jhingran (1992) reported that it grows to 180 cm and a weight of 30 kg in Maharashtra State, western India, noting that a length of 30 cm can be attained in 1 year. Rohan Pethiyagoda and Prachya Musikasinthorn (personal commun., 2002) stated they doubted that any snakehead would reach such a length and were unaware of any specimens of that size. Murugesan (1978) reported a maximum size of 52.8 cm at 8 months from fish stocked at an average length of 37 mm in a tank in Karnataka State, south-western India, with lengths of 38.6 to 48 cm typical in 1 year. He recorded growth of 2.5 to 4 mm/day for the first 3 months and 0.8 to 1.3 mm/day thereafter, with an average growth rate of 7 cm/month. Johal and others (1983) reported that bullseye snakeheads grow faster than *Channa argus, C. punctata*, or *C. striata*, but also noted that growth decreases with increasing age, with the greatest increase in weight occurring during the second year. Their specimens were obtained from River Ghagger, Rajasthan State, northwestern India. Ahmad and others (1990) also reported decreasing growth rate

Adult *Channa marulius* guarding young. Photographed April 23, 2003, in Tamarac, Broward County, Florida, by Ianaré T. Sevi.

Channa marulius, from Khao Laem Reservoir, Kanchanaburi Province, Thailand, June 2002. Photo courtesy of Jean-Francois Helias, Fishing Adventures Thailand.

with increasing age in specimens from River Kali in northern India. Wee (1982) cited *C. marulius* and *C. micropeltes* as the two fastest growing snakeheads.

Habitat preference: Lakes and rivers; deep, clear water with sand or rocky substrate (Talwar and Jhingran, 1992); "rivers usually in the vicinity of mud or fine sands" (Sen, 1985); "deep pools in rivers and occasionally in lakes" (Pethiyagoda, 1991). Jhingran (1984) noted presence of this species in swamps, tanks (=small reservoirs), and ponds, but that it also "prefers deep, clear stretches of water with sandy or rocky bottom." Rainboth (1996) listed preferred habitat as "sluggish or standing water in canals, lakes, and swamps from India to China, south to Thailand and Cambodia." He added that it is often found with submerged aquatic vegetation.

Temperature range: No specific information in literature. Native range of the species is from about 34º N to 7º N, indicating a species that can exist in temperate to tropical conditions. Preliminary temperature testing on individuals from the established southeastern Florida population indicated the lower range to be about 10 ºC (Paul L. Shafland, personal commun., 2002), suggesting that this population did not originate from northern reaches of the native range of this species.

Reproductive habits: Breder and Rosen (1966) summarized brood size from Chacko and Kuriyan (1947) as being about 500 young with parents guarding them until they reached about 10 cm in length. Eggs are pale red-yellow and 2 mm in diameter, hatch in 54 hrs at 16-26 ºC and 30 hrs at 28-33 ºC. Parameswaran and Murugesan (1976a) reported brood sizes of 357 to over 3,600 in swamps in Karnataka State, India. Talwar and Jhingran (1992) remarked that this species lays eggs in a nest and guards them, and that breeding occurs through most of the year. Day (1875) supported this guarding habit by stating, "Colonel Puckle observes 'that they are very savage, protecting their young with great boldness'." Pethiyagoda (1991) noted that males are territorial. In river basins of southern Nepal, it is said to spawn from June until August (Shrestha, 1990). Parameswaran and Murugesan (1976a) indicated spawning occurs in all but the months of December and January in Karnataka State, India, peaking during the rainy season. Jhingran (1984) stated that fecundity of this species is "2,000-40,000 ova." Mirza and Bhatti (1993) indicated a spawning period in Pakistan of April to June with parental protection of eggs and larvae for 6 weeks. Sriramlu (1979) reported two spawning periods (May-June and November-December) for *Channa marulius* in Andhra Pradesh, southeastern India, at altitudes ranging from 548 to 670 m above sea level.

A Mozambique tilapia (*Oreochromis mossambicus*), an introduced species in Thailand, bitten in half by a giant snakehead (*Channa micropeltes*). Photo courtesy of Jean-Francois Helias, Fishing Adventures Thailand.

Srivastava (1980) also reported two spawning peaks (May and January) for this species from a lake at Gorakhpur, in Uttar Pradesh, northern India. This species is one of three snakeheads known to spawn in the absence of vascular aquatic plants (Parameswaran and Murugesan, 1976b).

Food preferences: Regarded as predacious (Jhingran, 1984; Talwar and Jhingran, 1992), especially on other fishes (Schmidt, 2001). The few aquarist-oriented websites that list this species warn that it cannot coexist in aquaria with other fishes once a length of 25 cm is reached. Schmidt (2001) goes further to recommend that two individuals of the same species or mixed with others should not remain in the same aquarium after they reach 25 cm, concluding that "at that stage…they will establish a species aquarium in their own way." He described the species as a "thrust predator", noting that it is rarely found in the aquarium trade and, if found, individuals are juveniles.

Dasgupta (2000) reported stomach contents of *Channa marulius* collected from several localities in West Bengal, India, as consisting primarily of fishes (40 percent), followed by crustaceans (30 percent), “macrophyte tissue” (15 percent), larval insects (10 percent), and algae (5 percent). Ahmad and others (1990) stated the diet of *C. marulius* in the River Kali, northern India, was more than 60 percent fishes and the remainder crustaceans, gastropods, insects, and larval chironomids.

Characters: No patch of scales on gular region of head. Dorsal fin rays 45-55; anal fin rays 28-36; pectoral rays 16-18; pelvic fin rays 6. Lateral line scales 60-70; predorsal scales 16. Lateral line scales drop two rows between the 16th and 18th perforated scale. Scale rows between posterior margin of orbit and preopercular angle 10. Scales on top of head moderate-sized with a rosette of head scales between the orbits, with the frontal head scale in the center of the rosette; two scales between rosette and the basal head scale; 10 scale rows between preopercular angle and posterior border of orbit. Pectoral fin length about half head length. Mouth large, lower jaw with 7 to 18 canines behind a single row of villiform teeth that widen to 5-6 rows at jaw symphysis. Teeth present on prevomer but absent on palatines (Talwar and Jhingran, 1992), and Smith (1945) indicated that canine teeth were absent from both prevomer and palatines.

Talwar and Jhingran (1992) provided information on life colors for both young and adults, commenting that there is a “pale-edged ocellus” toward the

upperside of the caudal fin base that "fades with growth," but provided no information as to size when that happens. Kottelat (2001a), however, stated that the ocellus occurs only in individuals less than 40 cm in standard length. Juveniles often with a series of dark blotches (usually five) bordered posteriorly and posterodorsally by a series of white scales forming a white margin to the blotches (Prachya Musikasinthorn, personal commun., 2002).

The only other species of *Channa* having an ocellus on the upper lobe of the caudal fin near its base is *C. marulioides*. The geographic ranges of the two species do not overlap. In contrast to *C. marulius*, *C. marulioides* has 55-58 lateral line scales, 13-15 predorsal scales, and 5-7 preopercular scales. The lateral line drops abruptly between the 17th and 20th scale in *C. marulioides*, and there is a two row drop of the lateral line in *C. marulius* between the 16th to 18th scale. Juveniles of *C. marulius* may have a series of dark blotches along the sides, margined posteriorly and posterodorsally by a series of white scales; late juveniles and adults of *C. marulioides* also have a series of dark blotches on the sides, but the posterior and posterodorsal scales of these blotches are dark, usually black, and margined with white (Lee and Ng, 1991).

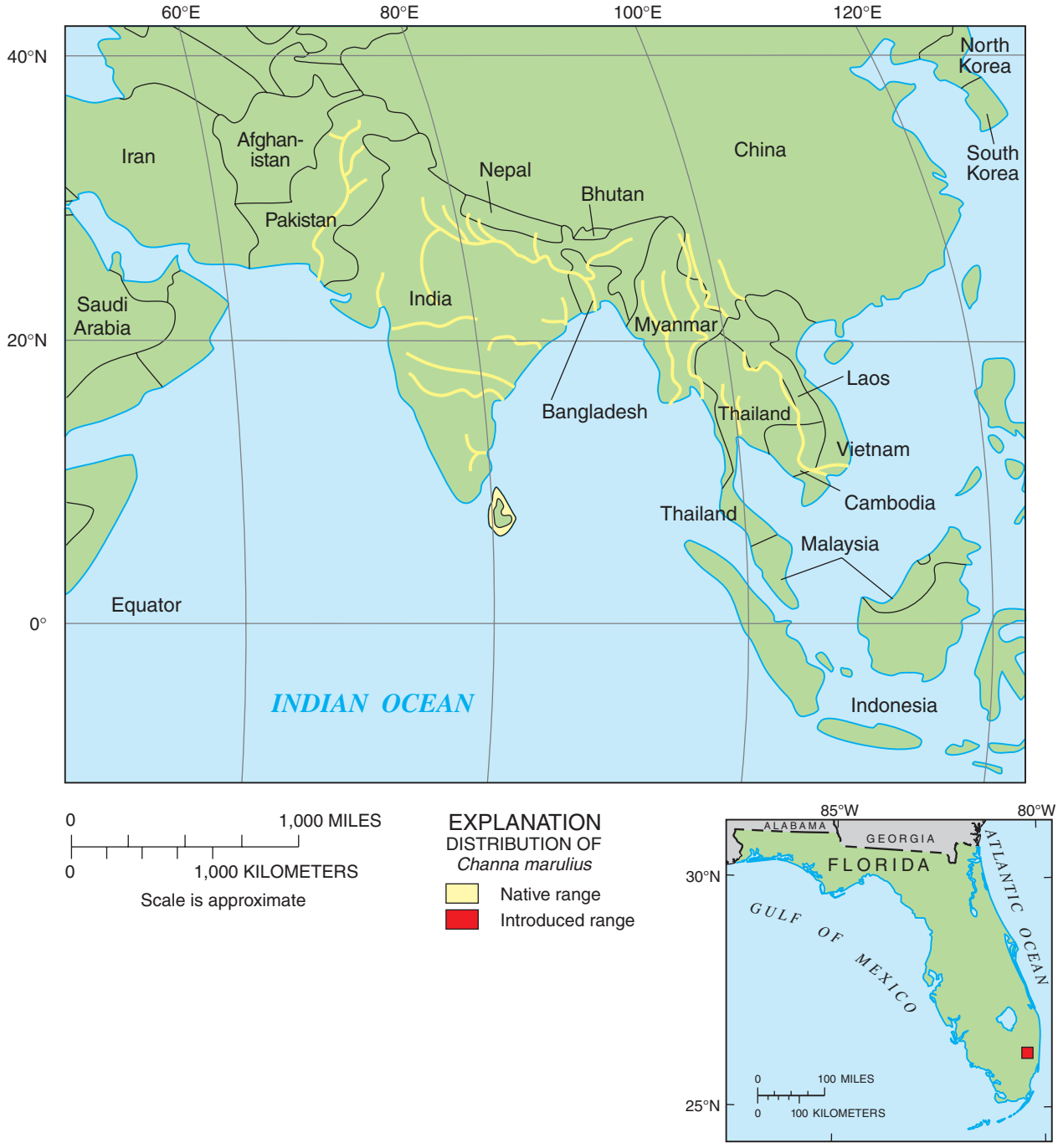
Commercial importance in the United States: Other than occasional mention on aquarist-oriented websites and Schmidt's (2001) statement that "giant snakehead" are rare in the aquarium trade, we found that it was being marketed under the name cobra snakehead as an aquarium fish in the U.S. Aquarist-oriented chat rooms on the Internet suggest it may be second in popularity to *Channa micropeltes*. Its introduction into southeastern Florida may have resulted from an intentional release of aquarium fish by hobbyists. Nevertheless, we recently learned of its availability in live-food fish markets in New York City (Leo Smith, personal commun., 2002) and, therefore, cannot rule out the live-food fish trade as having been the source of this introduction. Nevertheless, its popularity as a game species in Thailand (http://www.fishingasia.com) may have prompted someone to illegally introduce this fish for sport purposes. Using a special permit from the FFWCC to import restricted and prohibited aquatic species, the USGS purchased a young bullseye snakehead from an aquarium fish dealer in Rhode Island in early 2002. In May 2002, law enforcement personnel of the California Department of Fish and Game confiscated a bullseye snakehead from an aquarium fish dealer in the Los Angeles area (Richard Feeney, personal commun. 2002).

Commercial importance in native range: This species is considered an important food fish in India, and it is a significant component of the freshwater fishery in Andhra Pradesh State (Talwar and Jhingran, 1992). Rao and Durve (1989) reported this species as one of three snakeheads fished commercially in Lake Jaisamand, the oldest reservoir in India. Sriramlu (1979) listed this species and *Channa striata* as the most preferred fish in two regions of Andhra Pradesh, India. Bardach and others (1972) noted that it was under culture in India and Pakistan in ponds and ricefields, and irrigation wells that do not support other fishes. Wee (1982) listed the species as being reared in monoculture ponds in India where it is fed tilapia. Nevertheless, Mirza and Bhatti (1993) stated that this species is unsuitable for aquaculture in Pakistan because it is piscivorous. Rainboth (1996) noted that it is "marketed fresh and sometimes alive" in Cambodia. It is touted as an important sport species in Thailand (http://www.fishingasia.com).

Environmental concerns: The native range of this species indicates a temperate to tropical species that, if introduced, has the potential to establish into southern states of the contiguous United States as well as Hawaii. This species is regarded as a predator, particularly on other fishes (Schmidt, 2001). That it has become established as a reproducing population in southeastern Florida indicates the likelihood that it could establish elsewhere if introduced into areas with a suitable temperature regime.

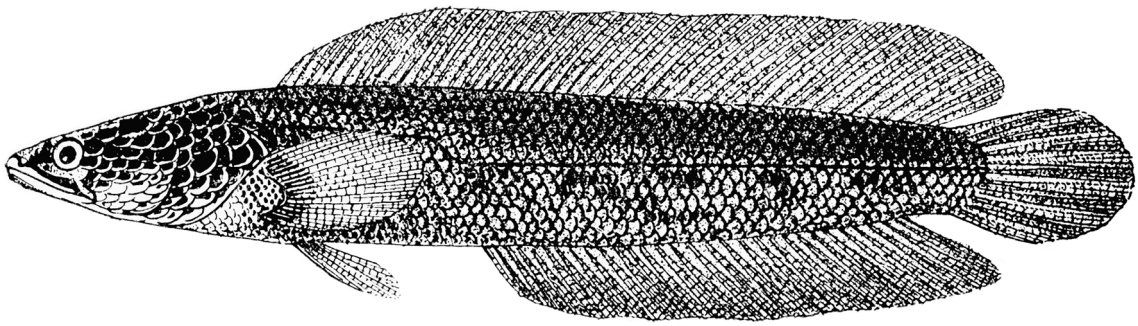
Comments: The diploid number of chromosomes of *Channa marulius* is 44 (Donsakul and Magtoon, 1991).

See map on following page

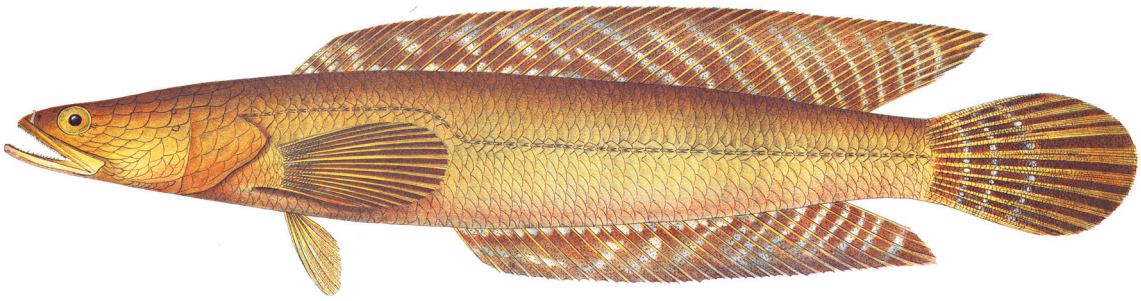


Channa marulius

Channa melanopterus (Bleeker, 1855)
Blackfinned Snakehead



After Weber and de Beaufort, 1922; image reversed from original



After Bleeker, 1878

Original description: *Ophicephalus melanopterus* Bleeker, 1855:420. Negende bijdrage tot de kennis der ichthylogische fauna van Borneo. Zoetwaterfischen van Pontianak en Banjdermasin. Natuurkd. Tijdschr. Neder. Indië 9:415-430. Type locality: Kapuas River, Pontianak, Borneo, Indonesia. Location of holotype reported as unknown, but located by Musikasinthorn (2000) as RMNH 6416.

Synonyms: No known synonyms (Ng and Lim, 1990). Often confused with *Channa marulius* (Ng and Lim, 1990; P. Musikasinthorn, personal commun., 2002), and *C. marulioides* (Lee and Ng, 1994).

Common name: blackfinned snakehead.

Native range:Kapuas River basin of Kalimantan (western Borneo) and possibly the southern tip of Sumatra (Roberts, 1989; Lee and Ng, 1994). These latter authors stated that records of this species from central Sumatra are misidentifications of *Channa marulioides*.

Introduced range: No introductions known.

Size: To at least 65 cm (Lee and Ng, 1994).

Habitat preference: No specific information, but appears to be a riverine species.

Temperature range: No specific information. Native range is equatorial to about 3º S.

Reproductive habits: No information located, but likely a nest builder that provides parental protection of eggs and fry.

Feeding habits: No information found. Likely a thrust predator as other snakeheads.

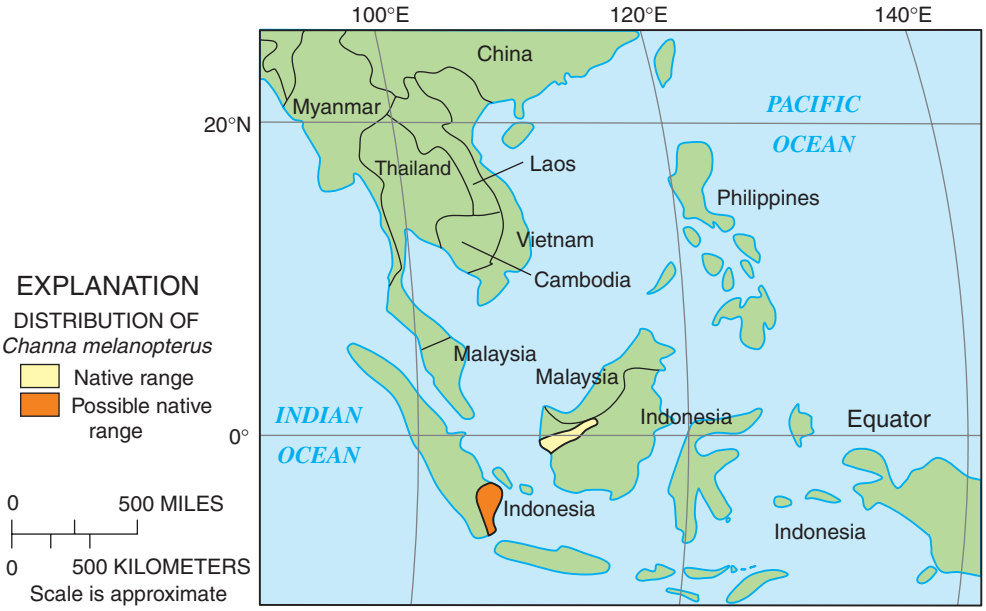
Characters: No patch of scales on gular region of head. Dorsal fin rays 44-48; anal fin rays 28-32. Lateral line scales 54-57; predorsal scales 13-15. Lateral line curves downward at lateral line scales 16-18.

Preopercular scales 5-8. Unfortunately, these characters are about equal to those of *Channa marulioides*. Lee and Ng (1994) stated that the only way to separate these two species is by coloration. *Channa marulioides* possesses an ocellated spot on the upper part of the caudal fin base, similar to that in *C. marulius*, and *C. melanopterus* lacks this ocellus. There are also differences in coloration of live individuals (Lee and Ng, 1994). *Channa marulioides* also differs from *C. melanopterus* in that the former often (but not always) possesses several patches of dark scales rimmed by white margins along the sides of the body (Lee and Ng, 1994).

Commercial importance in the United States: Rarely mentioned in aquarist-oriented websites and probably has been rarely, if ever, available for sale in the aquarium fish trade. Unknown from live-food fish markets.

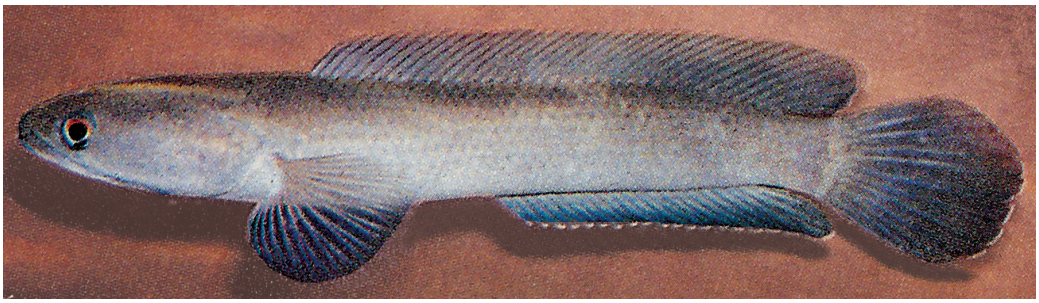
Commercial importance in native range: No information found. Considering its moderate size, it is probably available at local live-food fish markets.

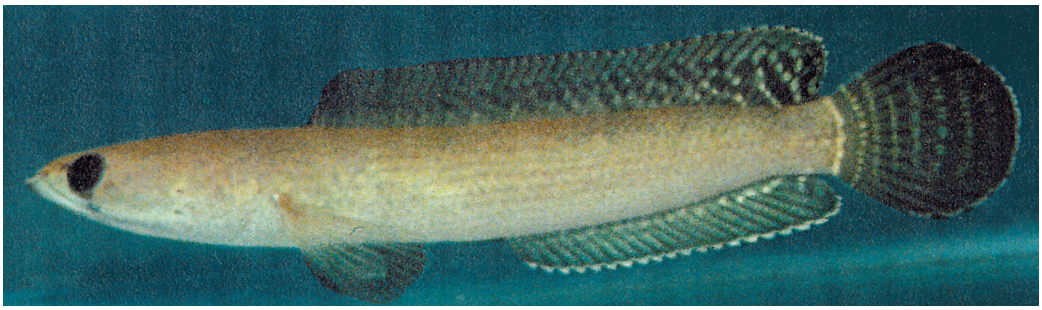
Environmental concerns: Likely a thrust predator. This is a strictly tropical species that could only establish in extreme southern Florida, Hawaii, or warm thermal springs and their outflows if introduced.



Channa melanopterus

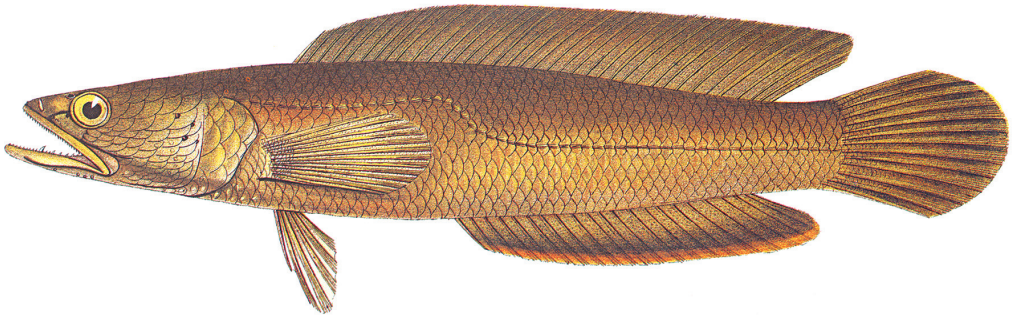
Channa melasoma (Bleeker, 1851)
Black Snakehead





Upper image: adult; photo by K.K.P. Lim. **Lower image:** subadult.

Reprinted with permission from P.K.L. Ng from Lee, P.G., and P.K.L. Ng. 1991.
The snakehead fishes of the Indo-Malayan region. Nature Malaysiana 16(4):112-129.



After Bleeker, 1878

Original description: *Ophicephalus melasoma* Bleeker, 1851:424. Vijfde bijdrage tot de kennis der ichthyologische fauna van Borneo, met beschrijving van eeinige nieuwe soorten van zoetwatervisschen. Natuurkd. Tijdschr. Neder. Indië 2:415-442. Type locality: Sambas, western Borneo. Whereabouts of holotype unknown.

Synonyms: *Ophicephalus rhodotaenia* Bleeker, 1851:425.

Ophicephalus mystax Bleeker, 1853:188.

Ophicephalus melanosoma Bleeker, 1856:214.

Ophiocephalus melanosoma Günther, 1861:473.

Ophiocephalus baramensis Steindachner, 1901:3435, *fide* Roberts, 1989, Ng and Lim, 1990, and Rainboth, 1996. Species revalidated by Ng and others, 1996.

Note: Frequently misspelled *melanosoma* (Ng and Lim, 1990).

Common names: **black snakehead**; ikan bakak (Malay).

Native range: Chao Phraya River, near Bangkok, Thailand (misidentification?); Mekong River in Cambodia (Rainboth, 1996; misidentification?); rivers of southeastern Sumatra; rivers of western Kalimantan, particularly the Kapuas basin (southern Borneo); Bangka and Belitung (Billiton) islands; Palawan Archipelago, Philippines (Inger and Kong, 1962; Roberts, 1989; Ng and Lim, 1990; Lee and Ng, 1991). Bean and Weed (1912) reported the species from Java, later challenged by Weber and de Beaufort (1922), and there is no evidence that it occurs there (Ng and Lim, 1990). Smith (1945) reported this species as rare in Thailand, and Lee and Ng (1994) stated that because of its preference for acidic waters, the species is more common toward the southern part of the Malay Peninsula. It is present but apparently rare in the North Selangor Peat Swamp Forest of the Malaysia Peninsula (Ng and others, 1992). Peter Ng (personal commun., 2003) reported occurrence of this species in the Golok area of southern Thailand. Records of this species from northern Borneo (Sarawak, Brunei, and Sabah) are misidentifications of the endemic *Channa baramensis* (Ng and others, 1996).

Introduced range: Uncertain. Presence of this species on Palawan (Kottelat, 1985; Roberts, 1989) may have resulted from an introduction. The same may be true in the Chao Phraya River, Thailand, and Mekong River, Cambodia, unless misidentified.

Size: To 35 cm (Inger and Kong, 1962).

Habitat preference: Prefers shaded, clear water forest streams with mud bottom and leaf litter, but is also found in turbid waters.
Reported to burrow into mud bottom when disturbed (Lee and Ng, 1991). Seems to prefer waters of pH 5-5.3 (Lee and Ng, 1994). Also occurs in middle parts of rivers. Capable of locomotion on land (Lee and Ng, 1994). Rainboth (1996) stated that it prefers "sluggish or standing waters" in the Mekong River basin.

Temperature range: No specific information, but native range of *Channa melasoma* is tropical (Borneo) to subtropical (Thailand).

Reproductive habits: A nest builder like other channids; only one parent guards eggs and young (Ng and Lim, 1990).

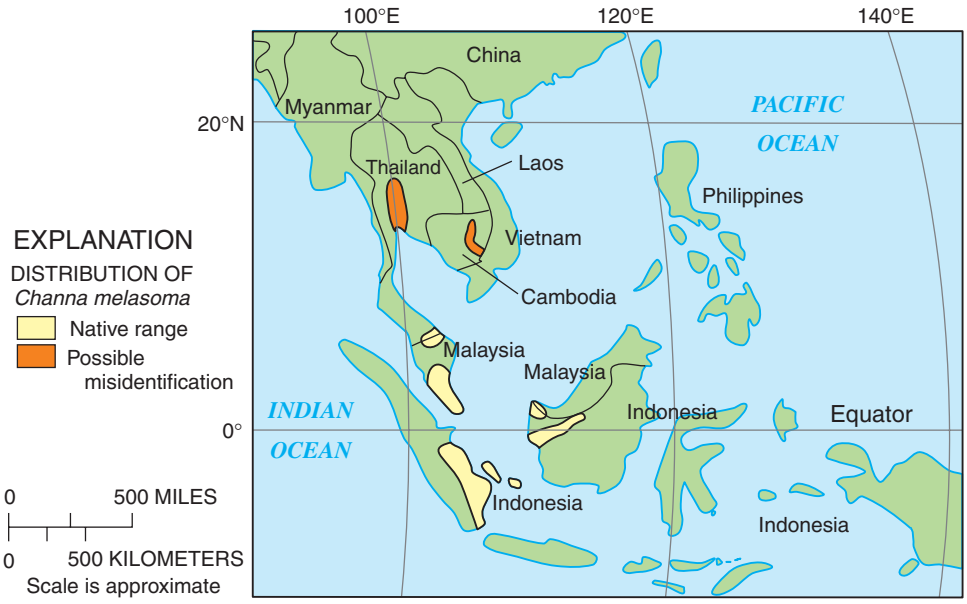
Feeding habits: A nocturnal thrust predator (Ng and Lim, 1990; Lee and Ng, 1991, 1994). Feeds on other fishes, lizards, crabs, insects and insect larvae (Inger and Kong, 1962; Ng and Lim, 1990; Rainboth, 1996).

Characters: No patch of scales on gular region. Dorsal fin rays 37-40; anal fin rays 22-25; pectoral rays 14-17. Lateral line scales 50-54; transverse scale rows from lateral line to dorsal fin origin 4-5½; transverse scale rows from lateral line to anal fin origin 7½. Color in preservative dark brown above, pale below, with fins dusky or dark and caudal fin usually barred. Many lateral scales with dark central spots (Inger and Chin, 1962). See account of *Channa baramensis* for characters that separate *C. melasoma* from this closely related species.

Commercial importance in the United States: Rarely mentioned on aquarist-oriented websites. Not known to have been imported as a live-food fish species.

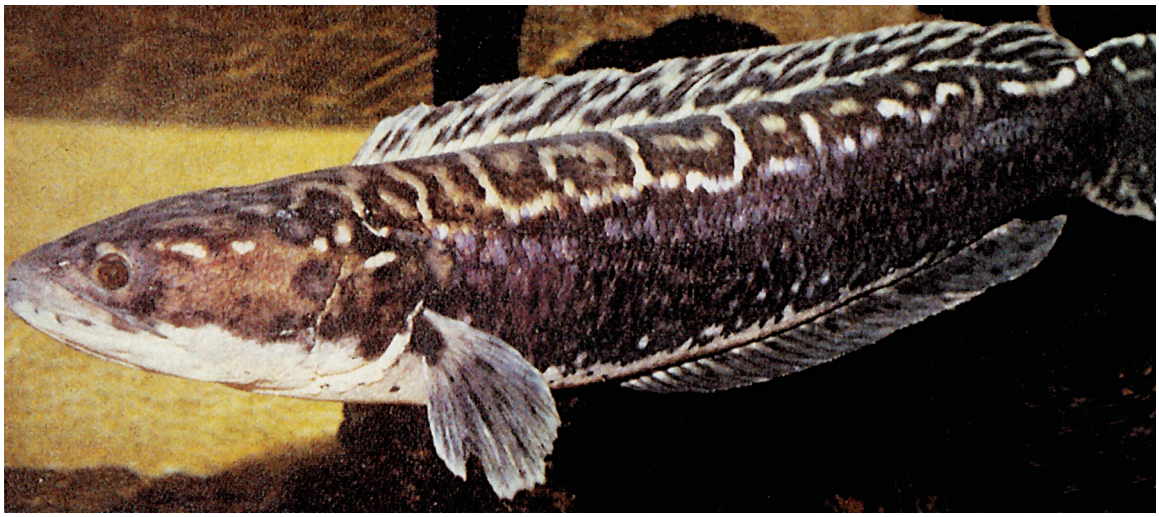
Commercial importance in native range: Probably nil. This species is primarily nocturnal and reported to be difficult to capture (Lee and Ng, 1991). Rainboth (1996) noted that it is not found in markets in Cambodia.

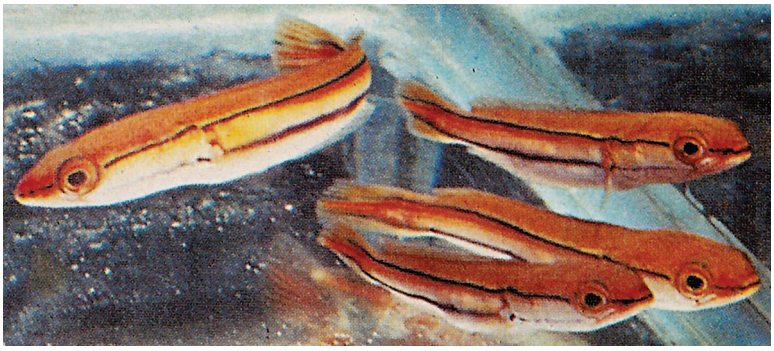
Environmental concerns: This species is a nocturnal thrust predator, known to feed on other fishes as well as lizards, crabs, and insects (Lee and Ng, 1991).



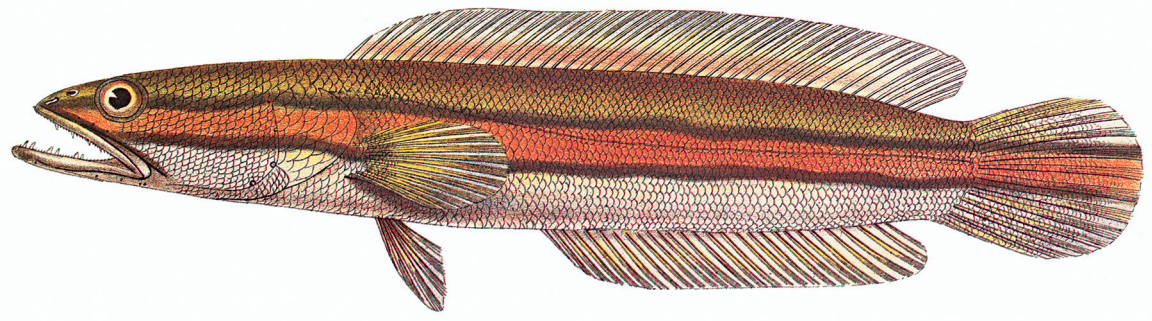
Channa melasoma

Channa micropeltes (Cuvier, 1831)
Giant Snakehead





Upper image: young adult; photo by P.R. Sweet. **Lower image:** young juveniles. Reprinted with permission from P.K.L. Ng from: Lee, P.G., and P.K.L. Ng. 1991. The snakehead fishes of the Indo-Malayan region. Nature Malaysiana 16(4):112-129



After Bleeker, 1878; juvenile

Original description: *Ophicephalus micropeltes* Cuvier *in* Cuvier and Valenciennes, 1831:427. Histoire naturelle des poissons 7:i-xxix +1-537, pls. 170-208. Type locality: Java, Indonesia. Syntypes: RMNH D2318; possible syntypes: RMNH D1131, RMNH D1132.

Synonyms: *Ophiocephalus serpentinus* Cuvier, 1831:429.

Ophicephalus bivittatus Bleeker, 1845:519.

Ophiocephalus stevensii Bleeker, 1853:444.

Ophiocephalus diplogramma Day, 1865a:36.

Ophiocephalus diplogramme [sic] Day, 1865b:147.

Ophiocephalus studeri Volz, 1903:555.

Common names: **giant snakehead**; red snakehead, redline snakehead; Malabar snakehead; Mala; ikan toman, toman (Malaysia); pla chado (Thailand), pla melang pu (Bangkok, Thailand); trey diep (juvenile) and trey chhdaur (adult; Cambodia); toman, anak toman, gabus tobang (Kalimantan). The name red or redline snakehead is commonly applied to juveniles of this species in the aquarium fish trade.

Native range:This snakehead has a markedly disjunctive distribution. Rivers of the Malabar (southwestern) Coast of India (restricted to Kerala State, southwestern India *fide* Roberts, 1989; Talwar and Jhingran, 1992); Myanmar (?); Thailand; Mekong basin of Laos; Vietnam; Malaysia; southeastern Sumatra; Kalimantan, particularly the Kapuas basin (southwestern Borneo; Roberts, 1989; Rainboth, 1996); Bangka and Belitung (Billiton) islands; northern Java (Day, 1877; Mohsin and Ambak, 1983; Roberts, 1989; Lee and Ng, 1991, 1994; Kottelat, 1985, 2001a). Its presence in Myanmar (Burma) is questionable. Ismail (1989) stated that it is "quite common in peninsular Malaysia."

We found it most puzzling that a species described from southeastern Asia (Java) could have a disjunctive distribution between a reported range in southwestern India (Kerala State) and Thailand, its westernmost confirmed range in southeastern Asia, a distance of about 2,500 km. Such a distribution gap indicates that the form in Kerala State, India, is either a different species or perhaps a very early introduction from its native range. We believe the latter interpretation is correct.

Day (1865a) described *Ophiocephalus diplogramma* based on one specimen, about 42 mm in length, collected in October 1863 near the port city of Cochin in southwestern India. Day (1865b) provided a species account for *O. diplogramme* [sic], his entry based on the same juvenile specimen collected in 1863 near the "mouth of the Cochin River." The characters he provided in that original description closely match those of *Channa micropeltes*, and his description of the life coloration appears to be that of a juvenile giant snakehead.

We believe that the description of *Ophiocephalus* (=*Channa*) *diplogramma* was based on a juvenile *C. micropeltes* and that its presence in Cochin, Kerala State, India, was the result of one or more introductions from southeastern Asia that occurred prior to the mid-1800s. Cochin has been a major trading port for several centuries. Moving an airbreathing snakehead, even on sailing ships from its native range to a new locale some 2,500 km or greater distance away, would have been an easy task. The progeny from this introduction, resulting from a small founder population, would be expected to exhibit some small degree of character divergence when compared to the source population within its native range.

Introduced range: This species was reported from Maine, Massachusetts, and Rhode Island, without evidence of reproduction (Courtenay and others, 1984; Fuller and others, 1999). A review of photographs of snakeheads captured from open waters of Maryland, undertaken by Maryland Department of Natural Resources personnel during Summer 2002, revealed two specimens of giant snakeheads that had been caught on separate occasions in different drainages during the two previous years. On September 6, 2002, a specimen about 56 cm long, was found struggling near the surface in shallow water of the Inner Harbor, Baltimore, Maryland, and captured by dipnet. All captures of this species appear to be of released pet fish. Two specimens, about 46 cm in length, were confiscated from an aquarium fish dealer in Los Angeles, California, in 2000 (Camm Swift, personal commun., 2002). California is one of fourteen states where snakeheads were prohibited before summer 2002.

Size: To 1 m and weight of over 20 kg (Roberts, 1989; Lee and Ng, 1991; Talwar and Jhingran, 1992). Peter Ng (personal commun., 2003) noted that this snakehead is known to reach a length of 1.5 m. Wee (1982) cited this species and *Channa marulius* as the two fastest growing snakeheads.

Habitat preference: Lakes, rivers, canals, and reservoirs (Mohsin and Ambak, 1983; Lee and Ng, 1991). Kottelat (1998) stated a preference for "deep water bodies." This species is nearly incapable of overland movements (Ng and Lim, 1990) except for the young (Peter Ng, personal commun., 2002), but he has observed large individuals attempting to move on dry land. Rainboth (1996) noted a preference for "standing or slowly flowing waters."

Temperature range: No specific information, but its native range is between 20º N to about 7º S, indicating a subtropical/tropical species.

Reproductive habits: Like other channids, *Channa micropeltes* clear a circular area of vegetation, spawn, and the pelagic eggs rise to the surface where they are fiercely guarded by the parents. Guarding continues after hatching (Lee and Ng, 1991), probably until young become demersal.

Feeding habits: Primarily a daytime feeder (Ng and Lim, 1990). Accounts of this species almost invariably describe it as a vicious predator on other fishes. Adult and perhaps subadult *Channa micropeltes* feed in packs, usually in midwaters or near the surface. Parents guard their eggs and young, and are reported to have attacked humans that approached a nest (Smith, 1945; Lee and Ng, 1991). Kottelat and others (1993) stated that anglers and swimmers who got too close to young were attacked, some seriously wounded, and that there have been fatalities. The report of fatalities was from local fisheries officials (Maurice Kottelat, personal commun., 2003). Peter Ng (personal commun., 2002) commented that he knew of one instance where a man was nearly castrated by an attacking giant snakehead. Prey includes other fishes, frogs, and birds (Lee and Ng, 1994). Lee and Ng (1991) commented that authorities at the Singapore Botanic Gardens planned to remove *C. micropeltes* from ponds at that facility because this snakehead was feeding on cygnets. Ng and Lim (1990) referred to this species as the "most ravenous" of snakeheads, and they, Mohsin and Ambak (1983), and Roberts (1989) noted that it is known to kill more fishes than it consumes in its natural habitat. Ng and Lim (1990) described the enlarged canine teeth of *C. micropeltes* as being knifelike, "with two cutting edges in cross-section," the edges arranged perpendicular to the body axis. This allows shearing of prey.

Beeckman and De Bont (1985) reported that the digestive system of the giant snakehead is relatively short, that young fed on crustaceans and adults are piscivorous in the Nam Ngum reservoir, Mekong basin, in northern Laos. They noted parasites in stomachs of 60 percent of all specimens captured with even more found in the intestines. Parasitism apparently begins when this species becomes piscivorous.

Cowx (1998) commented that escapes of Chinese carps, tilapias, and oscar (*Astronotus ocellatus*) from cage culture in Chenderoh Reservoir, Perak, Malaysia, failed to establish breeding populations. He attributed this failure to predation by giant snakeheads.

Characters: A patch of scales present in the gular area. Head depressed, somewhat pointed, and flattened above. Mouth large, oblique, maxillary reaching beyond posterior border of the eye. Lower jaw with several canine-like teeth behind a single row of villiform teeth, the latter expanding to about 5 rows at the jaw symphysis; large canine teeth on prevomer and palatines. Scales on top of head small; 16-17 scale rows between preopercular angle and posterior border of orbit; predorsal scales 22; 95-110 scales in longitudinal series, although Ismail (1989) reported 82-91 for specimens from peninsular Malaysia. This species obviously has smaller scales than other large *Channa,* hence the species name *micropeltes* (=small scale). Dorsal fin rays 43-46; anal fin rays 27-30; pectoral rays 15; pelvic rays 6; caudal fin rounded. Pelvic fin about 50 percent of pectoral fin length (Talwar and Jhingran, 1992; Musikasinthorn and Taki, 2001).

Commercial importance in the United States: This species frequently appears on aquarist-oriented websites. Although several sites warn that *Channa micropeltes* is only suitable for aquarium purposes as juveniles, require substantial amounts of animal food, and should not be kept with other fishes, it has been available in aquarium fish retail stores in states where snakeheads are not prohibited. One retailer who sells snakeheads via the Internet reported that he refused to sell this species to individual hobbyists (Ken Arnold, personal commun., 2002). Releases of this species into waters of Maine, Maryland, Massachusetts, and Rhode

Island were likely made to dispose of fish that grew too large for aquaria. We also know of two instances, one in 2001 and another in 2002, when juvenile giant snakeheads were confiscated from pet shops in southern California. Because it is an esteemed food fish in southeastern Asia, it has possibly been available periodically in live-food fish markets.

Commercial importance in native range: Talwar and Jhingran (1992) remarked that this species is only of minor interest to fisheries in Kerala State, India. Conversely, Lee and Ng (1991) stated that it is a highly prized food fish in Malaysia, and grown in cage culture where it is fed tilapia. It is also grown in cage culture in the lower Mekong basin of southern Vietnam where it and *Channa striata* collectively comprise the second most important fish group under culture (Pantulu, 1976; Wee, 1982). FAO (1994) listed a production of 1,490 metric tons of this species in Thailand in 1992, up from 386 tons in 1986. Rainboth (1996) noted that it is sold fresh and sometimes as live fish in Cambodian markets, and that it is cultured in cages.

In the Kapuas River of western Kalimantan, there is a hook fishery for *Channa micropeltes*, particularly within the Danau Sentarum Wildlife Reserve. About 40 percent of the fishes caught with large (sizes 5-8) hooks and 60 percent taken with medium (sizes 9-11) hooks were giant snakehead. In recent years, cage culture has developed for this species in the Reserve where large numbers of

Mark Sabaj (left) purchasing specimens of giant snakehead for the Academy of Natural Sciences, Philadelphia, caught from Khao Laem Reservoir, an impoundment of Mae Nam Khwae Noi River, in a market in Thong Pha Phum, Thailand, in 2001. Photo by Mike Hardman, Los Angeles County Museum of Natural History.

juveniles are caught with cast nets, raised in wooden cages, and fed other wild caught fish until they reach market weight of 0.8-1.5 kg. This earns about $700,000 for the communities and represents one-third of fish-related income in the Reserve. Recently recognized problems with this activity include fear of diminished populations of giant snakehead due to removal of young from the wild for culture purposes and the estimated 4,000 tons of river-caught fish needed annually to feed them (Dudley, 2000).

Environmental concerns: *Channa micropeltes* has a reputation of being the most predacious of all snakeheads, known to kill more fishes than it consumes. Its greatest threat in the U.S. would be in southern Florida and Hawaii where this subtropical/tropical species would likely establish if introduced.

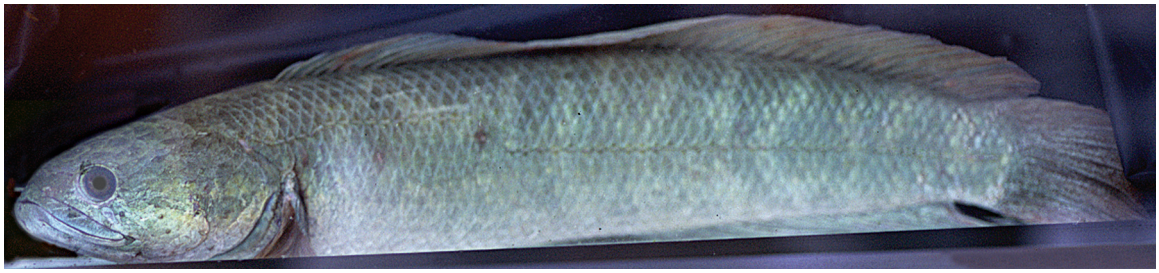
Comments: The diploid number of chromosomes of *Channa micropeltes* is 44 (Donsakul and Magtoon, 1991).

See map on following page

Channa micropeltes, caught by angler John Oatley; Khao Laem Reservoir, Kanchanaburi Province, Thailand, 2002. Photo courtesy of Jean-Francois Helias, Fishing Adventures Thailand.

Channa micropeltes

Channa nox Zhang, Musikasinthorn, and Watanabe, 2002
Night Snakehead



Purchased from a live-food fish market at Mong Kok, Hong Kong. Photograph by Heok Hui Tan.

Original description: *Channa nox* Zhang, Musikasinthorn, and Watanabe, 2002:140-146. *Channa nox*, a new channid fish lacking a pelvic fin from Guangxi, China. Ichthyological Research 49(2):140-146. Type locality: Nanliu River basin, vicinity of Hepu, Guangxi Province, China. Holotype: IOZCAS (Institute of Zoology, Chinese Academy of Sciences) 70028. Paratypes: IOZCAS 69848; IOZCAS 69849; IOZCAS 70029; IOZCAS 70039; and IOZCAS 70042.

Synonyms: No synonyms.

Common names: None in English. We propose **night snakehead** based on the dark coloration of the fish.

Native range: Southern China, near Hepu, Guangzi Province, specifically the lower Nanlui Jiang River, where its range overlaps that of its nearest congener, *Channa asiatica*. Peter Ng (personal commun., 2003) found this snakehead in live-food fish markets in Guangzhou, China, and Hong Kong in July 2000.

Introduced range: No introductions known.

Size: Reported to almost 20 cm (Zhang and others, 2002), but probably attains a larger size.

Habitat preference: Zhang and others (2002) reported the species from humid rainforest conditions. Appears to be a riverine species.

Temperature range: No information available. Nevertheless, distribution within native range (21-32º N) indicates a warm temperate to subtropical species.

Reproductive habits: No information available concerning reproduction in natural habitats, but likely a nest builder like most snakeheads. There are indications that the male of the most closely related species, *Channa asiatica* is perhaps a mouthbrooder. Whether such behavior applies to *C. nox* is unknown.

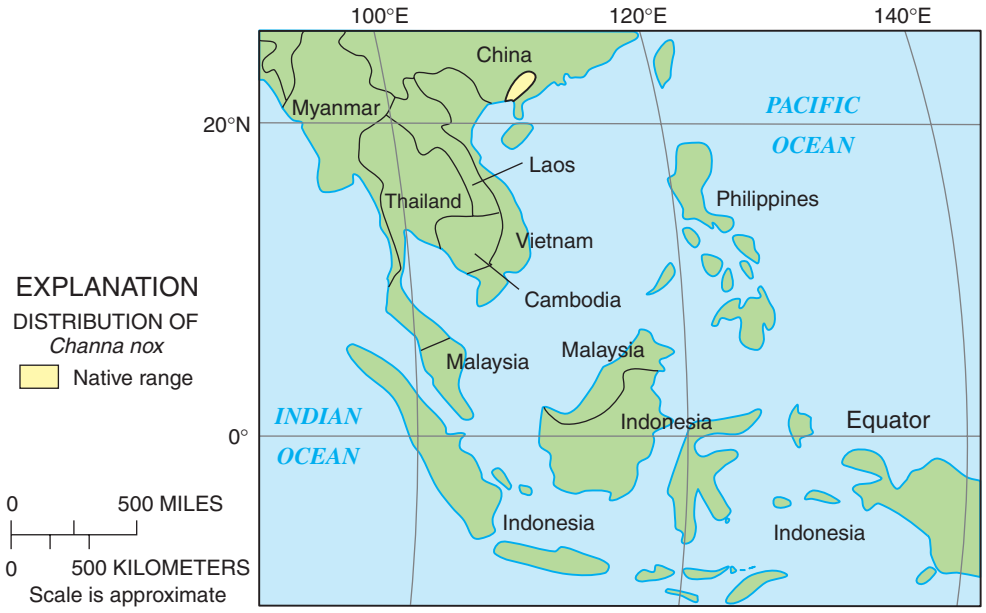
Feeding habits: No information available, but likely a thrust predator as is its closest relative, *Channa asiatica*.

Characters: Gular region of head with one to two scales on either side of underside of lower jaw. Pelvic fins absent. Head small, rounded. Dorsal fin rays 47-51; anal fin rays 31-33. Lateral line scales 55-63; 5.5-6.5 scales above lateral line; check scales 9-13. Total vertebrae 53-55. Large ocellus, black with white rim, on caudal peduncle. This species is most closely related to *Channa asiatica* which also lacks pelvic fins and has 49-53 vertebrae, 41-47 dorsal fin rays and 28-32 anal fin rays. *Channa nox* also differs in having a shorter predorsal length (26.9-28.4 percent) and snout length (3.6-5.1 percent). Live coloration also differs from *C. asiatica* in that *C. nox* is dark on the upper half of the body and the ocellus on the caudal peduncle lacks a white rim.

Commercial importance in the United States: None.

Commercial importance in native range: Available in local markets in Hepu, Guangxi Province, southern China (Zhang and others, 2002). Also reported as available in markets in Ghangzhou and Hong Kong (Peter Ng, personal commun., 2003).

Environmental concerns: Likely a thrust predator on other fishes and invertebrates like other snakeheads.


100°E
120°E
140°E
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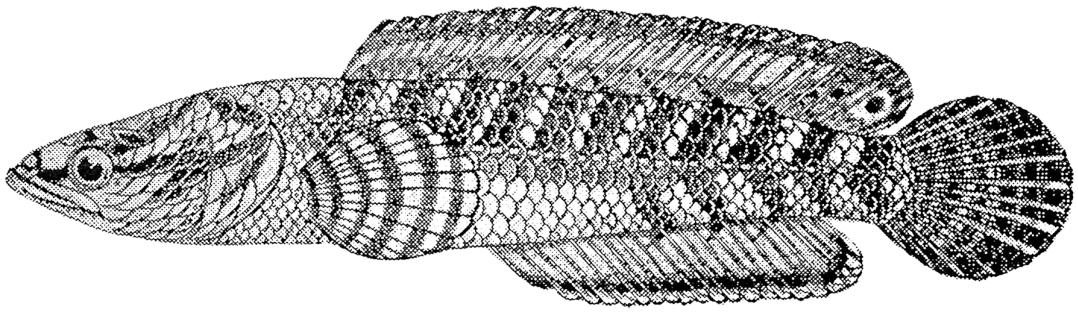
China
Myanmar
Laos
Thailand
Vietnam
Cambodia
Malaysia
Malaysia
Philippines
PACIFIC
OCEAN
INDIAN
OCEAN
Indonesia
Indonesia
Indonesia
Equator
EXPLANATION
DISTRIBUTION OF
Channa nox
Native range
0
500 MILES
0
500 KILOMETERS
Scale is approximate

Channa nox

Channa orientalis Schneider, 1801
Ceylon Snakehead

Type species of *Channa* Scopoli, 1777

Reprinted with permission from Rohan Pethiyagoda from Pethiyagoda, R. 1991. Freshwater fishes of Sri Lanka. Wildlife Heritage Trust of Sri Lanka, Colombo, Sri Lanka.



After Munro, 1955; female

Original description: *Channa orientalis* Schneider, in Bloch and Schneider, 1801:496, pl. 90. M.E. Blochii, Systema Ichthyologiae iconibus cx illustratum. Post obitum auctoris opus inchoatum absoluit, correxit, interpolavit Jo.Gottlob Schneider, saxo. Sumtibut Austoris Impressum et Bigliopolio Sanderiano Commissum, Beroloni. i-lx + 1-584, pls. 1-110. Type locality: "Habitat in India orientale" (=east India). No types known (Paepke, 1993). Paepke (1993) noted that Schneider's description was based on an illustration in Gronovius (1763).

Synonyms: There has been much confusion regarding the taxonomy of the Ceylon snakehead. Many have considered this species to be part of what we term the *Channa gachua* complex as reflected in the following synonymy, all of which are synonyms of *C. gachua* and are **invalid** for *C. orientalis* (Ralf Britz, personal commun., 2003).

Ophiocephalus auranticus Hamilton, 1822:69, 368, pl. 23, fig. 22.

Ophicephalus marginatus Cuvier, 1829:230, *fide* Menon, 1999:275.

Ophicephalus coramota Cuvier, 1831:414, *fide* Menon, 1999:275.

Ophicephalus fuscus Cuvier, 1831:414, *fide* Menon, 1999:275.

Ophicephalus limbatus Cuvier, 1831, no p., pl. 201, *fide* Menon, 1999:275.

Ophicephalus marginatus Cuvier, 1831, no p., pl. 201, *fide* Menon, 1999:275.
Ophicephalus montanus McClelland & Griffith, 1842:583, *fide* Menon, 1999:275.
Philypnoides surakartensis Bleeker, 1849:19, *fide* Menon, 1999:275.
Ophiocephalus apus Canestrini, 1861:77, pl. 4, fig. 7.
Ophiocephalus kelaartii Günther, 1861:472, *fide* Talwar and Jhingran, 1991:1019, and Menon, 1999:275.
(?)*Channa burmanica* Chaudhuri, 1919:284, pl. 22, fig. 4.
Ophiocephalus gachua kelaarti Günther: Munro, 1955:100.
Note: Although *Channa burmanica* is listed as a synonym, some authors recognize this species as valid (Peter Ng, personal commun., *in* Vierke, 1991b; Ralf Britz, personal commun., 2003).

Common names: **Ceylon snakehead**; Asiatic snakehead; smooth breasted snakehead (Munro, 1955; Pethiyagoda, 1991); green snakehead (Ettrich, 1989); kola kanaya (Pethiyagoda, 1991).

Native range: *Channa orientalis* is endemic to southwestern Sri Lanka (Pethiyagoda, 1991; Ralf Britz, personal commun., 2003), specifically to the "wet zone" and "lower south western hills" (Pethiyagoda, 1991). Mendis (1954) included both *C. orientalis* and *Ophicephalus gachua* from Sri Lanka, commenting that the former may or may not possess pelvic fins. The Ceylon snakehead, however, lacks pelvic fins (Deraniyagala, 1929; Pethiyagoda, 1991; Ralf Britz, personal commun., 2003). Talwar and Jhingran (1992) noted that *C. orientalis* lacking pelvic fins occurs in Sri Lanka, Myanmar, and Java; nevertheless, reports of this fish from Myanmar and Java refer to members of the *C. gachua* complex. DeWitt (1960) considered absence of pelvic fins in snakeheads as an anomalous character; this conclusion, however, is not supported by *C. orientalis* or other snakeheads that lack pelvics (*C. asiatica, C. bleheri, C. burmanica,* apparently some members of the *C. gachua* complex, and *C. nox*).

Munro (1955) correctly identified the snakehead species lacking pelvic fins in Sri Lanka as *Channa orientalis* and treated the taxon with pelvics as *C. gachua kelaarti*. Lim and others (1990) noted that Myers and Shapovalov (1932) synonymized *C. gachua* with *C. orientalis*, but suggested these species are separate with the latter lacking pelvic fins. Because *C. orientalis* is endemic to Sri Lanka, records from southern India and elsewhere are erroneous.

Introduced range: No introductions known, although its presence in the Greater Sunda Islands (Kottelat, 1985) would represent an introduction if the species is indeed *Channa orientalis*. More than likely, however, Kottelat's (1985) reference is to a species of the *C. gachua* complex. Pethiyagoda (1991) noted a possible introduction in the Mahaweli basin of Sri Lanka.

Size: Sometimes cited as the smallest species of snakehead (Ismail, 1989; Talwar and Jhingran, 1992), a comment often also used for *Channa gachua*. Pethiyagoda (1991) noted that this snakehead typically does not exceed 10 cm and, therefore, is significantly smaller than *C. gachua*.

Habitat preference: Deraniyagala (1929) and Munro (1955) cited "clean freshwater pools close to streams" as the preferred habitat. Pethiyagoda (1991) stated that it occurs in "shaded, clear, flowing water with a silt or gravel substrate" and "shallow rivulets barely deeper than its own body." He also predicted pollution and destruction of rainforest habitat in Sri Lanka would likely negatively affect populations of this species.

Temperature range: No specific information found. Because the species is endemic to Sri Lanka (unlikely), it is strictly tropical.

Reproductive habits: Ettrich (1989) reported this species as a mouthbrooder. He described the basic body color as brown, remarking that the flanks of males sometimes are dove gray with a violet cast, becoming paler ventrally. The dorsal and caudal fins of males are "sky-blue," black and orange, with a blue anal fin margined in black and white with black rays, and the eye red. Reproductively active females change from brown to shades of blue. During spawning, the male wraps itself around the female near the surface, after which the male broods the eggs in its oral cavity, typically remaining in an upper corner of an aquarium. Fry remain in the male parent's mouth until able to survive on their own. Females sometimes retrieve stray fry into their oral cavities, returning the young to the

parental care of the male. Fry are never ejected via the mouth but rather leave via the gill openings. This is somewhat similar to behavior observed in *Channa bleheri* (Vierke, 1991b). Both parents provide parental care with the female defending territory. It is unknown if the Ceylon snakehead is a mouthbrooder only in aquaria (Ettrich, 1989).

Ettrich (1989) assumed that there were two forms of *Channa orientalis* in Sri Lanka, one with and one without pelvic fins, but remarked that there were no hybrids known between these forms. The one with pelvic fins, however, is part of the *C. gachua* complex (Deraniyagala, 1929; Pethiyagoda, 1991; Ralf Britz, personal commun., 2003).

Feeding habits: Moyle and Senanayake (1984) determined that most gut contents consisted of terrestrial insects, the remainder comprised of trichopterans and a few fishes. Pethiyagoda (1991) noted that in aquaria, chopped steak is readily accepted by this snakehead.

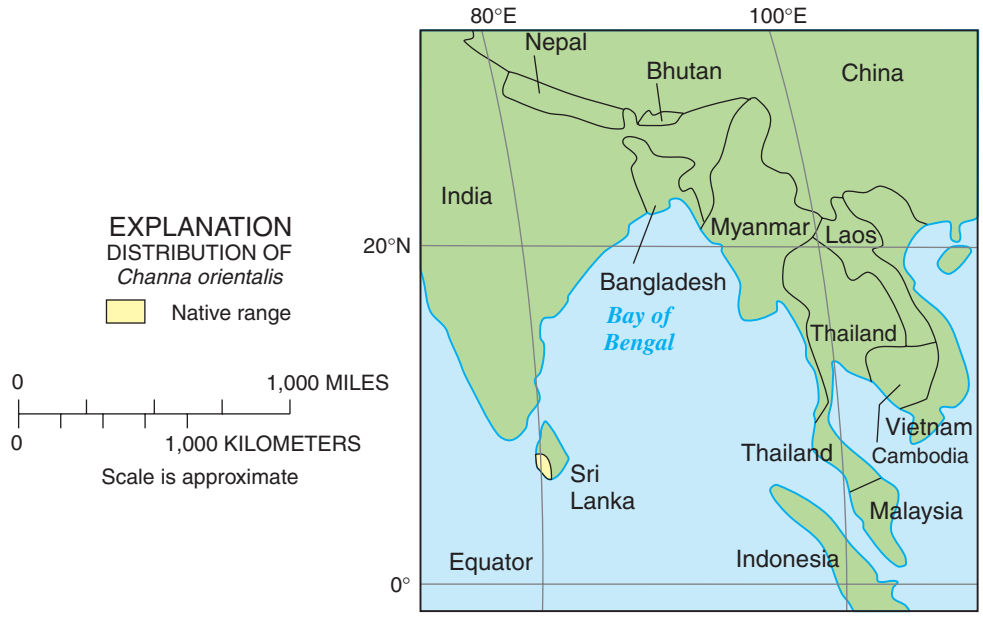
Characters: Gular part of head without patch of scales. Pelvic fins absent. Predorsal scales 6-7; scales from posterior border of orbit to posterior edge of preopercle 5-6. Lateral line scales 36-42. Anal fin rays 20-22; dorsal fin rays 30-34. Pectoral fins with 13-15 rays. Ocellated spot at posterior end of dorsal fin, above caudal peduncle, in juveniles and females. Lower jaw with 10-20 canines behind single row of villiform teeth, the latter expanding to about 7 rows at jaw symphysis; prevomer and palatines with canine-like teeth.

Commercial importance in the United States: Sometimes listed on aquarist-oriented websites, but often misidentified.

Commercial importance in native range: Pethiyagoda (1991) stated, “Small numbers are used by the aquarium fish export trade.”

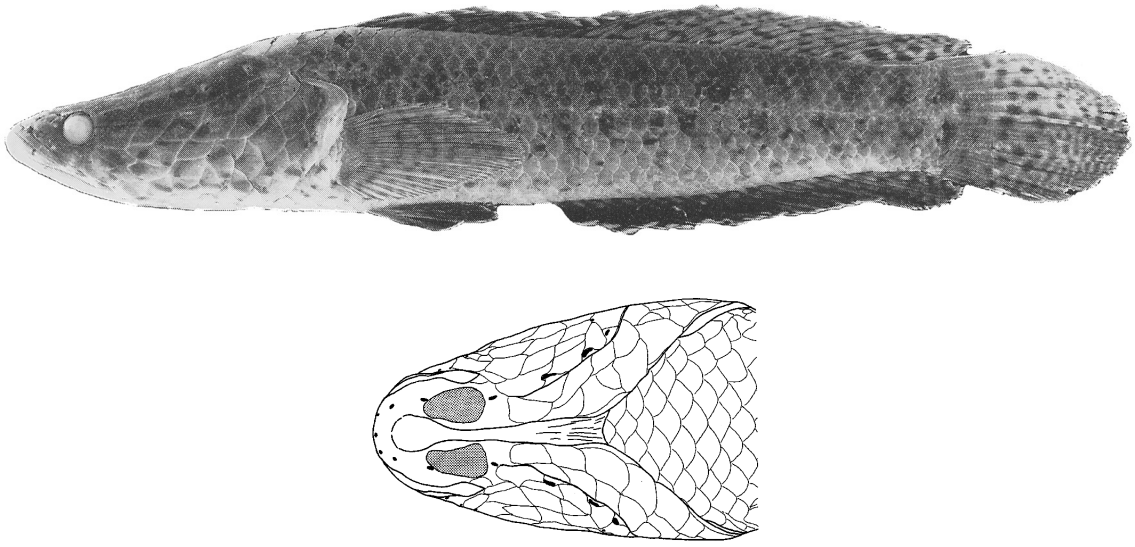
Environmental concerns: Perhaps a thrust predator like other snakeheads. Because this species is endemic to Sri Lanka, its ability to establish in North America, if introduced, would be limited to subtropical areas (extreme southern Florida, Hawaii) or warm thermal springs.

See map on following page



Channa orientalis

Channa panaw Musikasinthorn, 1998
Panaw Snakehead



Upper image: holotype, KUMF 3050, 151.7 mm standard length. **Lower image:** ventral view of head showing enlarged scales on lower jaw; paratype, KUMF 3060. Reprinted with permission from Prachya Musikasinthorn, author, and Tomoki Sunobe, Secretary of the Ichthyological Society of Japan, from: Musikasinthorn, Prachya. 1998. *Channa panaw*, a new channid fish from the Irrawaddy and Sittang River basins, Myanmar. Ichthyol. Res. 45(4):355-362.

Original description: *Channa panaw* Musikasinthorn, 1998:356. *Channa panaw*, a new channid fish from the Irrawaddy and Sitang River basins, Myanmar. Ichthyological Research 45(4):355-362, 7 figs. Type locality: Yangon fish market, Yangon, Myanmar. Holotype: KUMF 3050. Paratypes: KUMF 3051; KUMF 3060; KUMF 3061; KUMF 3062; NSMT-P 36121; NSMT-P 36129; KUMF 3052; KUMF 3053; KUMF 3054; NRM 27421; and ANSP 77016.

Synonyms: No synonyms.

Common names: **panaw snakehead**; nga panaw (Myanmar).

Native range: Ayeyarwaddy (=Irrawaddy) and Sittang River basins, Myanmar (Musikasinthorn, 1998).

Introduced range: No introductions known.

Size: No specific information in literature, but known to grow to at least 17 cm (Musikasinthorn, 1998).

Habitat preference: No specific information, but appears to prefer rivers.

Temperature range: No specific information. Native range (about 16-24º N) indicates this species to be subtropical to tropical.

Reproductive habits: No information, but probably a nest builder as are most other snakeheads.

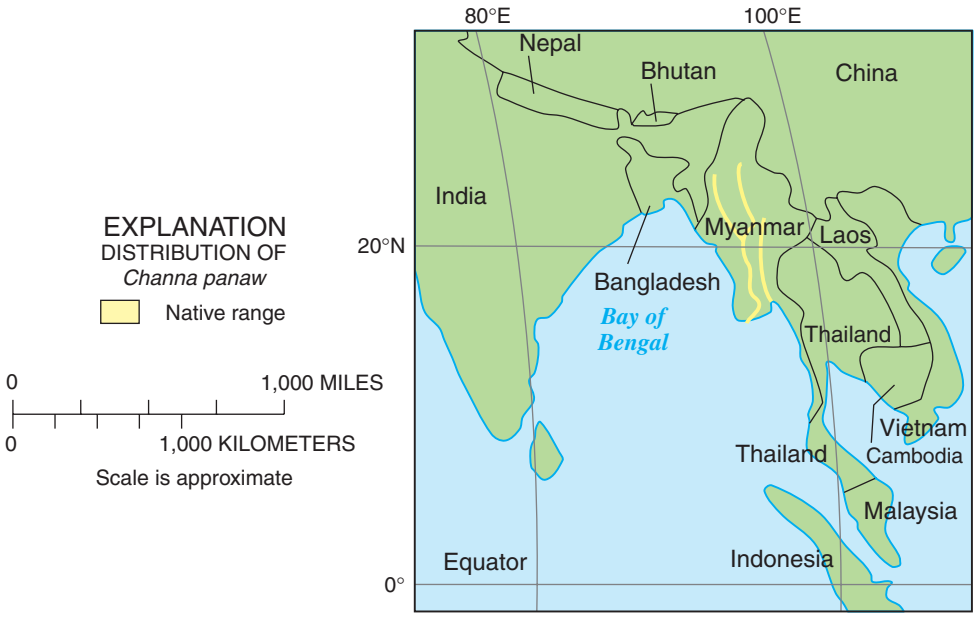
Feeding habits: No information. Nevertheless, Musikasinthorn (1998) stated this species is most closely related to *Channa punctata*, which suggests adults feed primarily on other fishes and insects.

Characters: Gular part of head without patch of scales. One large scale on either underside of lower jaw, rarely two on one side of jaw. Lateral line scales 39-41; predorsal scales 14-17. Dorsal fin rays 32-35; anal fin rays 32-35; pectoral rays 17-20. Pelvic fin length always more than 50 percent of pectoral fin length. Most similar to *Channa punctata*, but differs in having a narrow, pointed snout, pelvic fins 50 percent or more longer than the pectorals, and there is one large scale (rarely two on one side) on either underside of the lower jaw.

Commercial importance in the United States: None known. Not listed on aquarist-oriented websites.

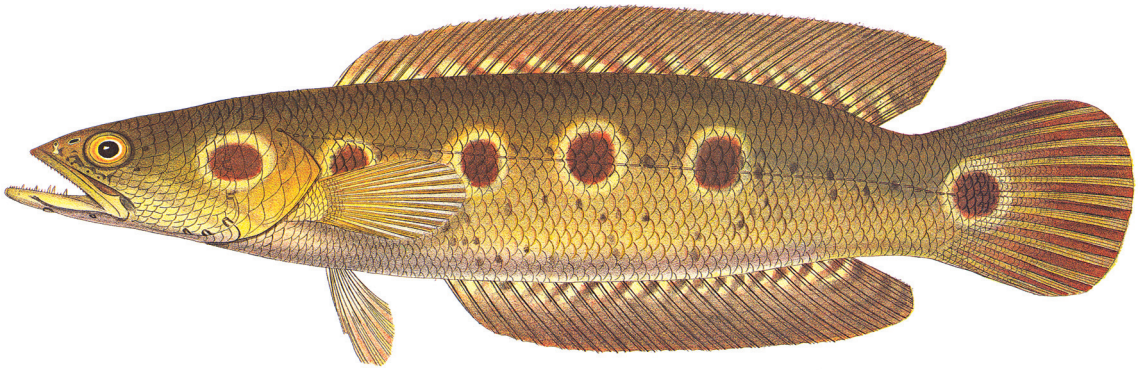
Commercial importance in native range: No information, but its presence in markets in Myanmar (Musikasinthorn, 1998) indicates that it is fished commercially.

Environmental concerns: Like the closely related *Channa punctata*, this species is probably a thrust predator on other fishes and insects.



Channa panaw

Channa pleurophthalma (Bleeker, 1851)
Ocellated Snakehead



After Bleeker, 1878

Original description: *Ophicephalus pleurophthalmus* Bleeker, 1851:270. Nieuwe bijdrage tot de kennis der ichthyologische fauna van Borneo mit beschrijving van eenige nieuwe soorten van zoetwatervisschen. Natuurkd. Tijdschr. Neder. Indië 1:259-275. Type locality: Bandjarmasin, Borneo, Indonesia. Syntype and/or Bleeker specimen: BMNH 1880.4.21.123.

Synonyms: *Ophicephalus urophthalmus* Bleeker, 1852:578.

Ophicephalus spiritalis Fowler, 1904:530, pl. 9, *fide* Roberts, 1989:170.

Common names: **ocellated snakehead**; eyespot snakehead; kerandana (Kalimantan).

Native range: Padang (?) and rivers (Hari and Musi basins) of southeastern Sumatra; Kapuas and Barito basins of Kalimantan (southern and southwestern Borneo; Roberts, 1989; Kottelat and others, 1993). Absent from peninsular Malaysia (Ng and Lim, 1990).

Introduced range: Introductions unknown.

Size: To 40 cm.

Habitat preferences: No information found, but probably a riverine species.

Temperature range: No information found. Nevertheless, native range is equatorial, indicating a solely tropical species.

Reproductive habits: No information found, but likely a nest builder as are most other snakeheads.

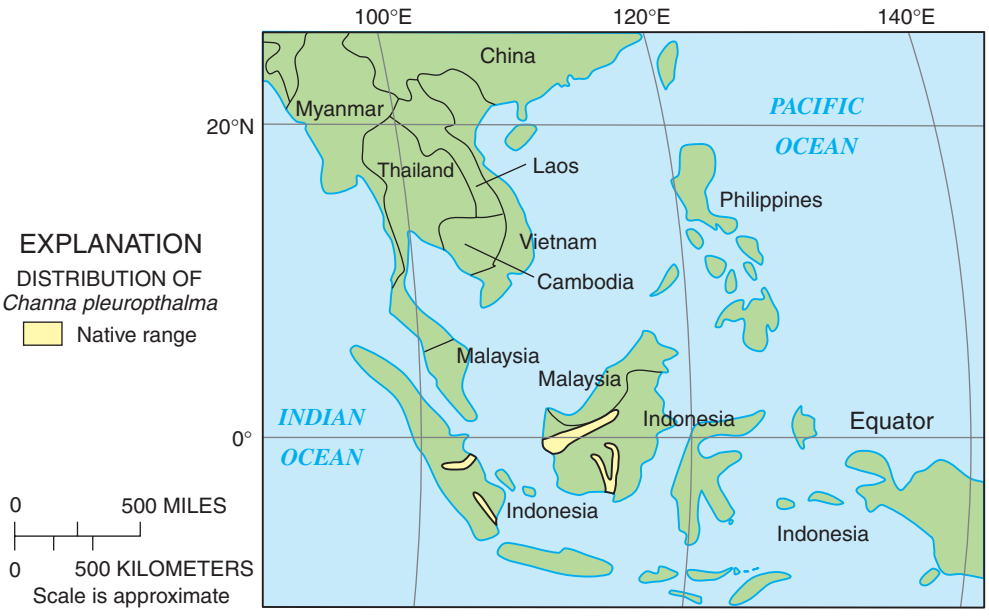
Feeding habits: No specific information, but likely a predator as are other snakeheads.

Characters: Patch of scales on gular part of head. Dorsal fin with 40-43 rays; anal fin with 28-31 rays. Lateral line scales 57-58; scale rows between lateral line and anterior base of dorsal fin 5½. Single row of canine-like teeth on prevomer; single row of small teeth and single row of 4-5 canines on palatines. Four to five prominent ocelli on sides of body, anterior-most ocellus on opercula, usually 3 to 4 on body (Kottelat and others, 1993).

Commercial importance in the United States: Often listed on aquarist-oriented websites. This species has attractive markings (red to yellow ocelli) on the body that has made it of interest to aquarists. Ng and Lim (1990) indicated it to be among the two highest-priced aquarium fishes. Not known for sale in live-food fish markets.

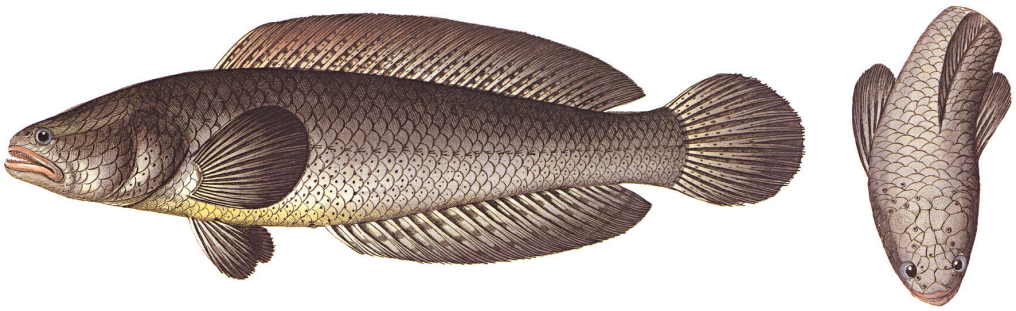
Commercial importance in native range: Kottelat and others (1993) indicated *Channa pleurophthalma* as an important food fish in Indonesia and Sumatra. Lee and Ng (1991) noted that it is sold in markets of Sumatra and Kalimantan. Dudley (2000) reported it in the fishery of Danau Sentarum Wildlife Reserve, Kapuas River, Kalimantan.

Environmental concerns: Ng and Lim (1990) stated that the aquarium fish trade is growing in Indonesia and Malaysia, indicating that this species, among others, may have become more readily available for sale in the U.S. Like other snakeheads, this species is probably a thrust predator. Nevertheless, it is an equatorial species that could probably survive in very few waters (thermal springs, perhaps extreme southern peninsular Florida, and Hawaii) if introduced into the U.S.

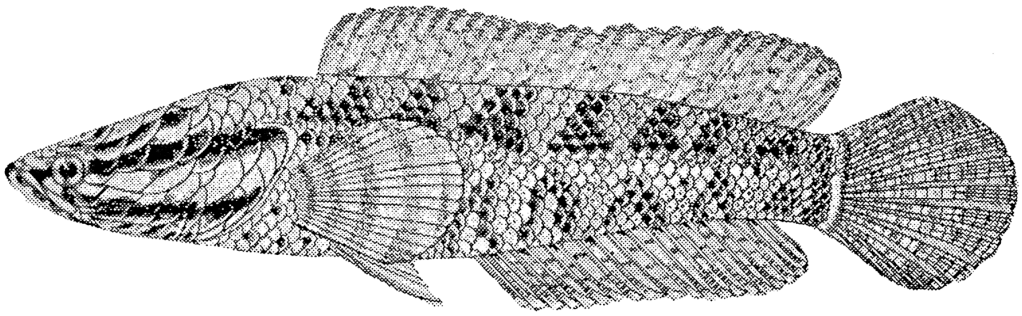


Channa pleurophthalma

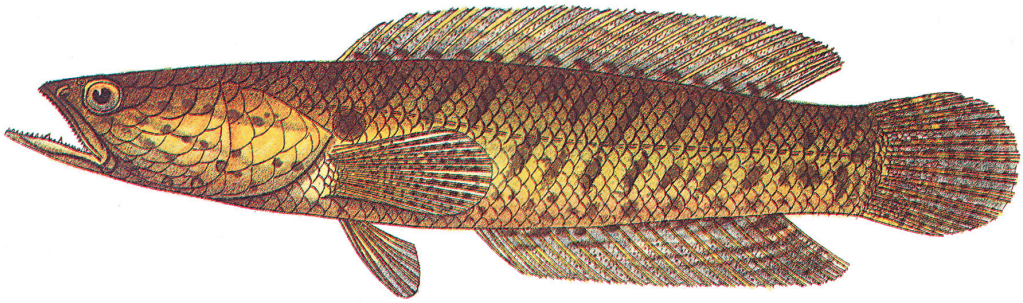
Channa punctata (Bloch, 1793)
Spotted Snakehead



After Bloch, 1793; images reversed from original pl. 358



After Munro, 1955



After Bleeker, 1878

Original description: *Ophicephalus punctatus* Bloch, 1793:139, pl. 358. Naturgeschichte der Ausländischen Fische, 7:i-xiv + 1-144, pls. 325-360. Type locality: rivers and lakes of Malabar coast, southwestern India. Syntype: ZMB 1394.

Synonyms: *Ophicephalus karruwey* Lacepède, 1801:551-552.

Ophicephalus lata Hamilton, 1822:63.

Ophicephalus indicus McClelland, 1842:583.

Ophiocephalus affinis Günther, 1861:470.

Common names: **spotted snakehead**; green snakehead; dolla or daula (Pakistan); taki, lata (West Bengal, India); phool-dhok (Bihar, India); duloora, daula (Punjab, India); soal (Jammu, India); gorissa or godissa (Orissa, India); matta-gudisa, burada-matta (Andhra Pradesh, India); korava-patti (Tamil Nadu, India); kayichal, arracan (Kerala, India); korava, juchi, belikkorava (Karnataka, India); (Talwar and Jhingran, 1992); cheng (northern Bengal, India; Shaw and Shebbeare, 1938); mada kanaya (Sri Lanka; Pethiyagoda, 1991).

Native range: Kabol (Kabul) River basin, Afghanistan, eastward through Khyber Pass into Indus River basin, Pakistan; rivers of the plains of India; Sri Lanka; southern Nepal (Edds, 1986a,b, 1993; Shrestha, 1990; Pethiyagoda, 1991); Bangladesh; Myanmar; eastward to Yunnan Province, southwestern China (Coad, 1981; Talwar and Jhingran, 1992). Musikasinthorn (1998) reported that this species is not present in Myanmar (replaced by *Channa panaw* in the Ayeyarwaddy (=Irrawaddy) and Sittang River basins), and reports from Yunnan Province, China, are probably misidentifications. He further stated that the eastern terminus of the range of *C. punctata* is the Ganges-Brahmaputra River basin. Jhingran (1984) lists this species as absent from Sri Lanka, but Pethiyagoda (1991) and Devi (1992) included Sri Lanka within its native range.

Introduced range: Smith (1950) reported this species from the vicinity of Delagoa Bay, Maputo, southern Mosambique, considered an introduction from Asia (Teugels and others, 1986). Jim Cambray, Albany Museum, Grahamstown, South Africa (personal commun., 2001) located the specimen (AM/G3714) and provided a digital photograph to us. It appeared to be a specimen of *Channa striata* rather than *C. punctata*. We borrowed the specimen through Jim Cambray and confirmed that it is *C. punctata*. Paul Skelton (Rhodes University, Grahamstown, South Africa; personal commun., 2001) reported the specimen as having come from the Museum in Lourenco Marques, Mozambique, and added that no other snakehead has been found or reported from that area since the Smith (1950) record. This indicates that snakeheads are not established in southern Africa.

Size: To 30-31 cm (Bardach and others, 1972; Talwar and Jhingran, 1992).

Habitat preference: Stagnant waters and muddy streams on plains of Pakistan and India, and abundant in muddy waters up to 600 m (Talwar and Jhingran, 1992). Shaw and Shebbeare (1938) recorded the species from "muddy or clear streams and ponds from 2,000 feet" (610 m) "downwards." Quayyum and Qasim (1962) described preferred habitat in India as ponds with "a swampy bottom" and abundant aquatic vegetation, as well as ponds with sand or gravel substrate and no vegetation; they added that "large numbers can live together in a small body of water." Kumar and Mittal (1993) found habitat preferences included open water to very dense masses of vegetation in Keoladeo National Park, Bharatpur, Rajasthan, north-central India. This species is reported to tolerate a wide range of pH levels with 100 percent survival over 72 hours from pH 4.25 to 9.4 (Varma, 1979). It is unable to tolerate salinities above 6 ppm (Mansuri and others, 1979). Nevertheless, Khora and Rao (1994) recorded this snakehead as present and of commercial importance in Bahuda Estuary, Ganjam District, Orissa, India; this estuary drains into the Bay of Bengal.

This airbreather can live indefinitely without rising to the surface if water is well oxygenated (6.0 ml/L and above), but will die within 2-3 hours at an O_2 level of 2.79 ml/L if access to the surface is prevented (Pandey and Chanchal, 1977).

Temperature range: The native range extends from about 34º N southward to about 7º N and altitudes up to 1,830 m, suggesting the species can exist in temperate (for example, Kabol River basin of Afghanistan) to tropical regions. Jain and Garg (1984) provided an upper lethal limit of 40 ºC and lower limit of 9 ºC for fish acclimated to 30 ºC, but found seasonal differences. Those collected during summer months tolerated a high of 40 ºC and a low of 2 ºC, whereas those captured in winter showed an upper limit of 36 ºC and a low of 4 ºC.

Reproductive habits: Dehadrai and others (1973) noted that snakeheads in India are sexually dichromic and dimorphic, and during the breeding season, males and females of *Channa punctata* become deep yellow ventrally up to the lateral line, with many small melanophores in the ventral area of males and black blotches in females. Moreover, females have a circular genital opening whereas in males the opening is elongated.

Said to be a prolific breeder, with pairs spawning (in India) throughout the year, peaking before and during monsoon months (Jhingran, 1984; Talwar and Jhingran, 1992). Reaches sexual maturity in 1 year. Like many other snakeheads, this species builds circular nests in nearshore vegetation, and the eggs are pelagic and guarded by both parents. Most initial guarding appears to be by the female parent. Should the young be disturbed, the female follows the young and the male parent joins her, sometimes charging an intruder and sometimes leaving and swimming into deeper water, at which point the female attacks and drives away the intruder. Feeding by parents continues during protection of the young, and when one parent leaves the young, the other guards (Quayyum and Qasim, 1962). The nest, described as cup-shaped

(Chacko and Kuriyan, 1947), is about 22-23 cm in diameter. Breeding typically occurs at night, and takes place twice each year (Raj, 1916). Kahn (1924) stated that this species builds elaborate tunnels to the nest through surrounding vegetation. Jhingran (1984) indicated that reproduction in ponds occurs through most of the year. The larger the parents, the more offspring they produce. Fecundity is between 2,300 to 29,600 eggs, with egg diameter peaking at slightly less than 0.5 mm. This information is in contrast to that presented by Kahn (1924) who recorded egg size as 2 mm. Khan (1924) also stated that hatching occurred in 54 hrs at 16-26 ºC and 30 hrs at 28-33 ºC. Protection of young continues for 15-20 days until juveniles become demersal (Quayyum and Qasim, 1962). Spawning in southern Nepal occurs from June until August (Shrestha, 1990). Lowe-McConnell (1987) gave April to July as the spawning period in Punjab Province, India, citing brood size as up to 500 individuals; guarding occurs for up to a month or until young are 10 cm long. Reddy (1979) stated that spawning occurs once per pair during July to October, with maximal spawning between July and August in Andhra Pradesh Province, southeastern India. This agrees with Bhuiyan and Rahman (1984) who reported a single annual spawning between April and August in Bangladesh. It appears that spawning season is largely correlated to active monsoonal periods. This is one of three species known to spawn in ponds lacking vascular aquatic plants (Parameswaran and Murugesan, 1976b).

Joshi and Sathyanesan (1981) reported finding stage I oöcytes in testicular tissue of 2 of over 100 specimens of *Channa punctata*, all collected in December when the species is reproductively inactive. Oöcytes were scattered through the testis and the gonads appeared to be a normal testis externally.

Feeding habits: Young (1.5-3.0 cm) feed primarily on zooplankton, with rotifers, insect, and crustacean larvae constituting most of the diet. Adults consume fishes, insects, and aquatic vegetation (Quayyum and Qasim, 1962), the latter probably ingested in the process of capturing animal prey.

The species is an opportunistic feeder. In canals and irrigation ponds near Guntur, Andra Pradesh State, India, stomach contents consisted of 13 species of small fishes with young of *Channa punctata* (one each) found in only three individuals, indicating that cannibalism is rare. Fish bones, scales, fin rays, etc., were common. Insects comprised the second tier of ingested food, followed by crustaceans, tadpoles, and an annelid worm. No algae were found, but parts of leaves and seeds were occasionally observed. By far, the most common food item was fishes (Reddy, 1980). In contrast, in polluted Hussainsagar Lake, Hyderabad, Andra Pradesh State, insects and their larvae were preferred (59.5 percent), followed by fishes and fish larvae (12.5 percent), annelids, algae, leaves, crustaceans, amphibians, and gastropods (Reddy and Rao, 1990). In ponds, tanks, and canals in the central delta area of River Godavari, Andra Pradesh, only 24 percent of the diet consisted of fishes, but 41.6 percent were crustaceans. Dutta (1994) found insects dominant (up to 100 percent) in young (3.1-4.5 cm in length) followed by crustaceans (up to 25 percent) and fishes, except for the months of June, July, and November when no fishes were found. All individuals above a length of 5 cm contained fishes. This study was conducted on specimens captured from Gadigarh Stream, Jammu, northern India.

Wee (1982) cited a study by Panday and Dwivedi (1974) in which it was shown that *Channa punctata* has well-developed olfactory organs in the nasal sacs and taste buds extending into the esophagus, concluding that this species locates food by odor. He also cited Gerald (1976b) as reporting maximal feeding activity of this species occurs at 28 ºC. Food absorption efficiency was reported as 95.5 percent (Gerald, 1976a). Larger fish have a lower feeding rate than young (Gerald, 1976a).

Characters: Body elongated, mostly rounded; 4 or 5 scales between orbit and angle of preopercle, 12 or 13 predorsal scales; pelvic fins more than half the length of pectoral fins, extending to anal fin; pectoral fins plain, no vertical bands, 15-16 rays, about 75 percent of pectoral fin length; anal fin rays 28-37; dorsal fin rays 28-32, rarely 33; caudal fin rounded. Mouth large; lower jaw with 3 to 6 canines behind a single row of villiform teeth that widen to 5 or 6 rows at jaw symphysis. Predorsal scales 12; scales in lateral series 37-40; scales on top of head large, arranged in a rosette between orbits, the frontal scale of which has an open lateralis pit, forming the center of the rosette (Talwar and Jhingran, 1992; Jayaram, 1999). Life colors vary from black to pale green on dorsum and sides, ventral sides white to pale yellow, sometimes with red tinge; several dark blotches on lower sides; occasionally black spots on body and dorsal, anal, and caudal fins. Dorsal, anal, and caudal fins dark gray, sometimes with reddish edge; pectoral and pelvic fins pale orange (Talwar and Jhingran, 1992).

Commercial importance in the United States: Although occasionally listed on aquarist-oriented websites and in aquarium fish books, this species does not appear to have been important to the aquarium fish trade in North America. It is not known to have been imported for culture or live-food fish market sale.

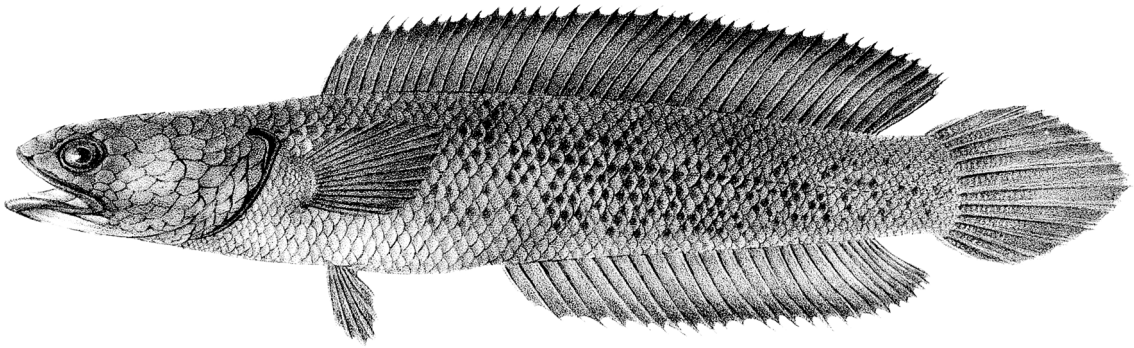
Commercial importance in native range: Snakehead fishes in general are regarded as important fishery resources in India and elsewhere, fished commercially and some species utilized in aquaculture. Quayyum and Qasim (1962) reported this species as "the main bulk of pond fishery in the plains of northern India." Rao and Durve (1989) reported *Channa punctata* as one of three snakehead species fished commercially in Lake Jaisamand, the oldest reservoir in India. They are considered to be a delicacy and demand high prices (Talwar and Jhingran, 1992). Pethiyagoda (1991) noted that it is popular as a food fish in Sri Lanka and is also used as bait for catching larger snakeheads.

Environmental concerns: Because of their voracious, carnivorous feeding habits, snakeheads are regarded as pests in India due to their devastation of other fishes (Talwar and Jhingran, 1992), apparently in pond or culture situations where other desired species exist.

Comments: Banerjee and others (1988) recorded the diploid chromosome number of *Channa punctata* as 32. Dhar and Chatterjee (1984), however, found two groups, one with 32 and another with 34, indicating a species complex.

Channa punctata

Channa stewartii (Playfair, 1867)
Golden Snakehead



After Playfair, 1867

Original description: *Ophiocephalus stewartii* Playfair, 1867:14, pl. 3. On the fishes of Cachar. Proc. Zool. Soc. Lond. 1867(1):14-17, pl. 3. Type locality: Cachar, Assam, India. Syntypes: BMNH 1867.2.14.19-20.

Synonyms: None known.

Common names: **golden snakehead**; Assamese snakehead; sengalee (Assam, India; Talwar and Jhingran, 1992); helae (Nepal).

Native range: Endemic to Brahmaputra (upper, middle, lower) River basin of India and Bangladesh, and the Ganges River basin from southern Nepal southeastward (Sen, 1985; Talwar and Jhingran, 1992; Musikasinthorn, 2000). In southern Nepal, it occurs in the Kamala, Bagmati, Koshi, Gandaki, and Karnali River basins (Shrestha, 1990).

Introduced range: Introductions unknown.

Size: To 25.4 cm (Sen, 1985).

Habitat preference: Flowing and standing water (Talwar and Jhingran, 1992); marshes and estuaries, and tolerant of limited salinity (Sen, 1985). Sen and Dey (1984) recorded this species from altitudes above 1,500 m in Meghalaya, a plateau north of Bangladesh and south of the Brahmaputra River, India.

Temperature range: No specific information. Native range is about 22-27º N, indicating a warm temperate to subtropical species.

Reproductive habits: No specific information, but probably a nest builder providing eggs and young with parental care.

Feeding habits: No specific information, but likely a thrust predator like other snakeheads.

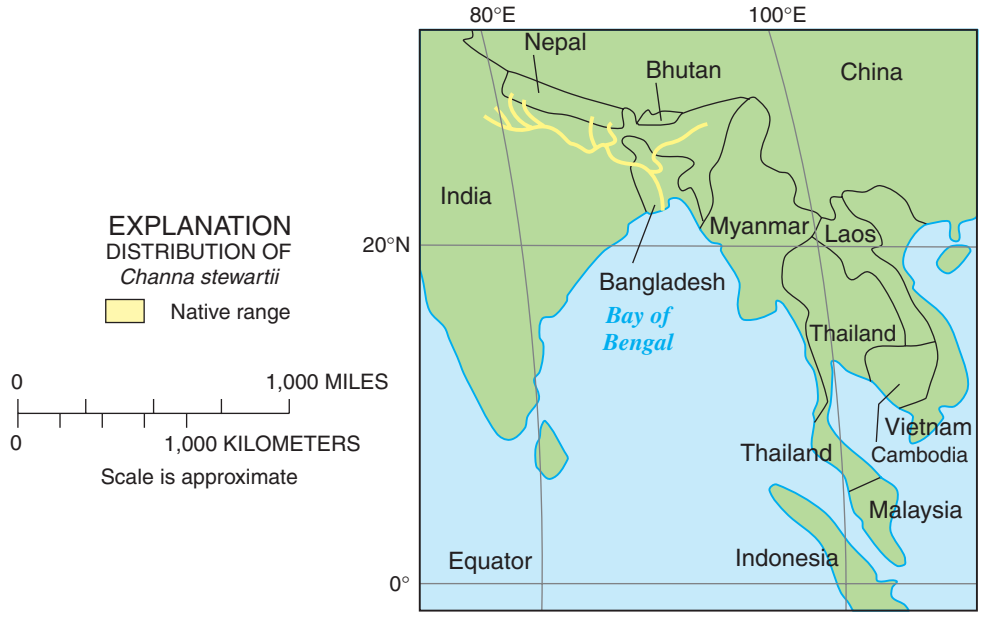
Characters: No patch of scales on gular region of head. Dorsal fin with 39-40 rays; anal fin rays 27. Pelvic fin about one-third as long as pectoral. Lateral line scales 47-50; scale rows between preopercular angle and posterior border of orbit 4-5; predorsal scales 13. Dorsal fin originates above base of pectoral fin. Black spots on many body scales.

Commercial importance in the United States: Rarely mentioned in aquarist-oriented websites but available through aquarium fish trade. Not known to be available in live-food fish markets.

Commercial importance in native range: Talwar and Jhingran (1992) stated that this species is of only minor fishery interest.

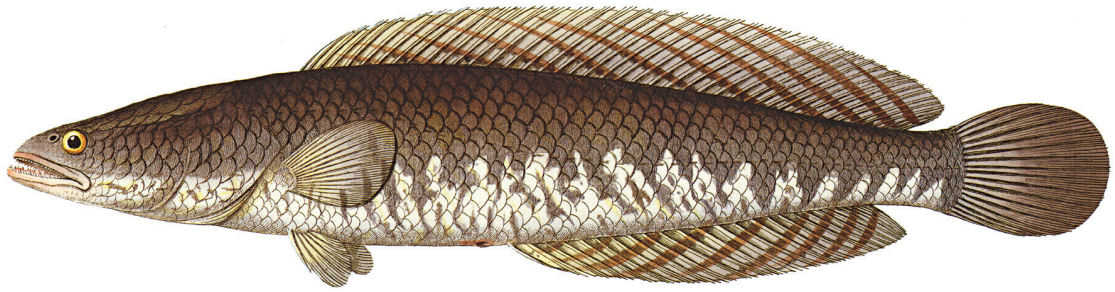
Environmental concerns: Likely a thrust predator, feeding on other fishes and invertebrates.

Comments: The diploid chromosome number of *Channa stewartii* is 104 (Rishi and Haobam, 1984).

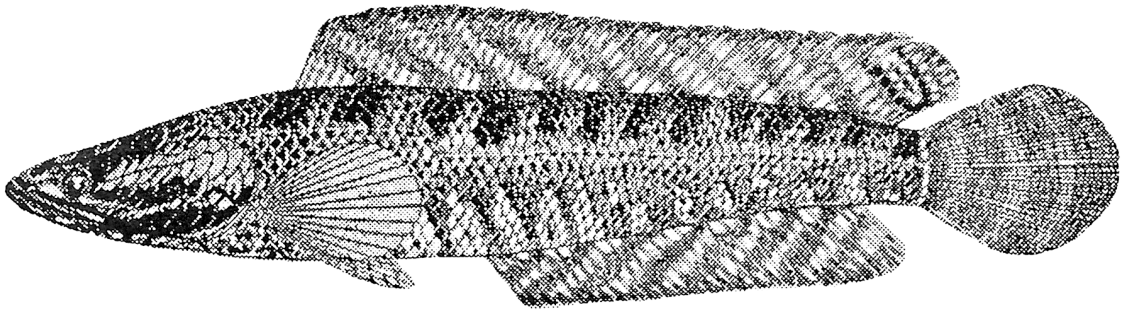


Channa stewartii

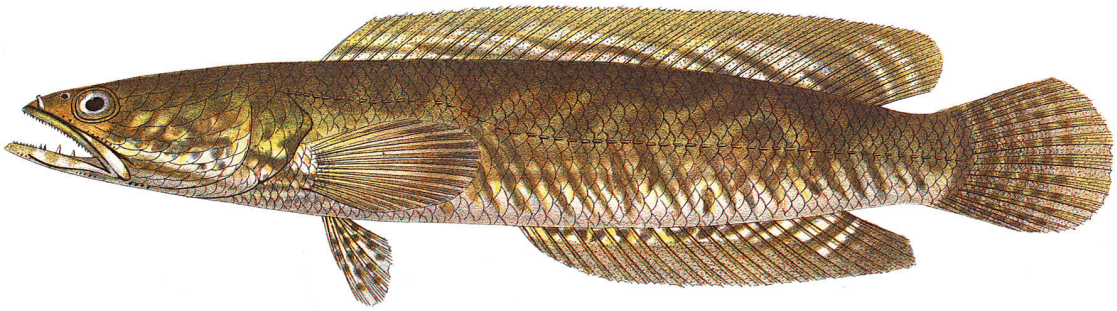
Channa striata (Bloch, 1793)
Chevron Snakehead



After Bloch, 1793; image reversed from original pl. 359



After Munro, 1955; juvenile
Note “pseudo-ocellus” on posterior lobe of dorsal fin, a juvenile characteristic (Lee and Ng, 1991).



After Bleeker, 1879

Original description: *Ophicephalus striatus* Bloch, 1793:141, pl. 359. Naturgeschichte der Ausländischen Fische, 7:I-xiv + 1-144, pls. 325-360. Type locality: Malabar, southwestern India. Syntypes: ZMB 1400; ZMB 6522.

Synonyms: *Ophiocephalus wrahl* Lacepède, 1801:552.
Ophiocephalus wrahl Hamilton, 1822:60, 367, pl. 31.
Ophiocephalus chena Hamilton, 1822:62, 367.
Ophicephalus planiceps Cuvier, 1831:424.
Ophicephalus sowarah Bleeker, 1845.
Ophiocephalus vagus Peters, 1868:260.
Ophiocephalus philippinus Peters, 1868:262.
(?)*Ophiocephalus melanopterus* Smith and Seale, 1906.

Common names: **chevron snakehead**; striped snakehead; banded snakehead; common snakehead; soali (Pakistan); murrel (India); haal, shawl, shol (Assam, India); shol (West Bengal, India); morrul, morl, soura (Bihar, India); sowl, dhoali, carrodh (Punjab, India); dolla (Jammu, India); sola (Orissa, India); korramennu, korra-matta (Andhra Pradesh, India); sowrah, veralu, kaunan (Kerala, India); pooli-kuchi, koochinamarl (Karnataka, India); sohr, dekhu (Mararashtra, India); hal path maha, lulla (Sinhalese, Sri Lanka); viral (Tamil, Sri Lanka); pla chon or pla chorn (Thailand); trey phtuok (juveniles) and trey raws (adults; Cambodia); ikan aruan, haruan, ruan, tomam paya (Malaysia); gabus (Java); delak, gabus, telak (Kalimantan), cá lóc (Vietnam); dalag, dalak (Tagalog or Moro, Philippines); bakule or bulig (young; Tagalog or Moro, Philippines); pongee (Hawaii, although that name is a general name for snakeheads; Mike Yamamoto, personal commun., 2003).

Native range: Pakistan (Indus River basin; Mirza, 1975), most drainages of India, southern Nepal (Koshi, Gandaki, and Karnali River basins; Shrestha, 1990), Sri Lanka (Mendis and Fernando, 1962; Fernando and Indrassna, 1969; Pethyagoda, 1991); Bangladesh, Myanmar, Thailand, Cambodia, southern China, Malay Archipelago including Malaysia, Sumatra, Borneo (Pethiyagoda, 1991; Rainboth, 1996; Jayaram, 1999); Sabah (Inger and Kong, 1962); western Java (Giltay, 1933; Roberts, 1993); Vietnam, Laos (Yên and others, 1992; Kottelat, 2001a,b). This is an amazingly extensive "native" distribution for any freshwater fish, indicating that *Channa striata* is quite probably a species complex.

Introduced range: *Channa striata* has been considered the most widely introduced species of snakehead. Various reports indicate it was released into Hawaii before 1900, established (Jordan and Evermann, 1903; Cobb, 1905; Smith, 1907; Tinker, 1944; Brock, 1952, 1960); Madagascar, in 1978, established (Raminosoa, 1987; Reinthal and Stiassny, 1991; Stiassny and Raminosoa, 1994; Lévêque, 1998); Philippines, date unknown (Seale, 1908; Herre, 1924, 1934; Conlu, 1986); Vogelkop Peninsula, Papua, Indonesia, probably during 1970s or 1980s, established (Allen, 1991) and identification confirmed by photographs provided by Gerald Allen (personal commun., 2002); Sundaland, Sulawesi, Lesser Sundas, Moluccas, date unknown, established (Welcomme, 1981; Kotellat and others, 1993; Lever, 1996); Fiji, establishment questionable (Maciolek, 1984; Eldredge, 1994); Mauritius, established (Parameswaran and Goorah, 1981; Welcomme, 1988; Lever, 1996); New Caledonia, establishment questionable (Maciolek, 1984); Guam, introduction unsuccessful (Maciolek, 1984; Eldredge, 1994). Herre (1924) recorded the source of introduction into Hawaii as southern China. Kottelat and others (1993) reported some populations in China to have been introduced but gave no specific locations. Its introduction into the Philippines probably occurred in the early to mid-1800s, indicated by two synonyms (*Ophiocephalus vagus* and *O. philippinus*) described from the Philippines by Peters (1868). Although Jayaram (1999) included Borneo in the native range of this species, Roberts (1989) hinted that its presence in western Borneo may have resulted from introductions.

Ralf Britz (personal commun., 2002) has advised that reports of this species from Madagascar are in error, the result of misidentification of the blotched snakehead, *Channa maculata*. He also examined a specimen labeled as *C. striata* (USNM 126588), collected by Jordan and Evermann on Oahu, Hawaii, in 1901, that was also *C. maculata*. Two specimens we borrowed from the Bernice P. Bishop Museum in Honolulu (BPBM 1759 and BPBM 3798), collected in the early 1900s on Oahu and labeled as *C. striata*, are *C. maculata*. Specimens borrowed from the California Academy of Sciences (CAS 17710, 1 specimen; CAS 108133, 3 specimens) collected on Oahu also proved to be *C. maculata* and not *C. striata*. We are convinced that all early records of *C. striata* from Hawaii are misidentifications of *C. maculata.* Although most records for Hawaii cite establishment only on Oahu, Morita (1981) reported that it also occurred on Kauai. *Channa striata* is now present and established on Oahu but confined to a fish culture facility. The first imports of this species occurred in the early 1990s. It is likely that many identifications of *C. striata* on islands of the Indian and Pacific Oceans are in error and that *C. maculata* may prove to be more widely introduced than previously thought.

Following publicity accompanying discovery of an established population in Maryland of northern snakehead, *Channa argus*, in June-July 2002, the lead investigator received an email message from an individual (Clifford Faik) in East Sepik Province, Papua New Guinea, who had seen the northern snakehead report on the CNN website. He stated that a similar snakehead was now present in rivers of Sepik Province.

Temperature regimes at that locality would preclude presence of northern snakehead, but is likely indicative that the chevron snakehead is the species involved, probably introduced from populations established in Papua, Indonesia. If so, this would be the first record of a snakehead from Papua New Guinea.

Size: To 90 cm (Bardach and others, 1972); 91.4 cm (Sen, 1985). Can attain a length of 30-36 cm in 1 year (Bhatt, 1970). Talwar and Jhingran (1992) stated that this species is sexually mature at 30 cm, but added that 2 years were required to reach that size. Murugesan (1978), however, recorded a growth rate of 1.3 to 3.0 mm/day for the first 3 months, slowing to 0.3 to 0.9 mm/day thereafter. He also reported lengths of 25-27 cm in 13½ months and 23.4-31.7 cm in 9½ months in Kerala State, India; 32 cm in 2 years in West Bengal; and 30.5l cm in 2 years in Madras. In rivers of Uttar Pradesh, chevron snakeheads grew to 32 cm in 2 years.

Habitat preference: Freshwater ponds and streams, usually in stagnant muddy waters; primarily found on plains in India (Talwar and Jhingran, 1992). It occurs in reservoirs in Sri Lanka (Fernando and Indrassna, 1969). Nevertheless, in Malaysia this species is reported to exist in rivers, lakes, swamps, rice paddies, mining pools, and roadside ditches (Mohsin and Ambak, 1983; Lee and Ng, 1991). Ng and Lim (1990) listed this species from "open country areas," adding that it is the primary snakehead in shallow waters (1 m or less) with dense vegetation. In India, it can be found in reservoirs and rice paddies (Jhingran, 1984). In Keoladeo National Park, Bharatpur, Rajasthan, north-central India, it may be found in open water to dense mats of aquatic vegetation (Kumar and Mittal, 1993). Herre (1924), Umali (1950), and Conlu, 1986) recorded it from lakes and lowland rivers in the Philippines, and its introduction to two crater lakes at an altitude about 1,050 m above sea level. Kottelat (1998) reported a preference for "standing waters." Lee and Ng (1991) noted that this species seems to be the most adaptable snakehead, tolerating "quite foul water" and able to move overland.

Channa striata is an obligate airbreather. Vivekanandan (1977a,b) stated that the breathing organ is developed in about 60 days during growth from a length of 1 to 4.5 cm at 26-28 ºC. Singh and others (1986) noted that at 28 ºC, this species breathes aquatically until 18 to 20 days following hatching when young reach a length of 1.1-1.2 cm and, thereafter, becomes a bimodal breather. They measured a decrease in oxygen uptake through the gills and skin of almost 42 percent once bimodal respiration began. Pandian (1982) reported that fingerlings of this species spend up to 15 percent of the time in surfacing and related activities.

Varma (1979) recorded a pH range for *Channa striata* of 4.25 to 9.40 with 100 percent survival over 72 hours, and 90 percent survival at pH 3.10 for the same period.

Temperature range: No specific information, but native range lies between about 32º N and 7º N, indicative of a fish that is temperate to tropical.

Reproductive habits: Lee and Ng (1991) indicated the species as solitary except during spawning seasons. In India, pairs breed during most months of the year, laying a few hundred to more than 1,000 amber-colored eggs (Parameswaran and Murugesan, 1976a; Talwar and Jhingran, 1992). Peak spawning coincides with peak rainfall (Parameswaran and Murugesan, 1976a). Howell (1913) said the eggs average about 1.25 mm and are nonadhesive, hatching in 1 to 3 days. Females mature about 30 cm in length at about 2 years of age (Talwar and Jhingran, 1992; Ali, 1999). Parents clear a shallow depression by biting off aquatic vegetation (Ling, 1977). Nevertheless, Alikunhi (1953) remarked that *Channa striata* will spawn in the absence of vegetation. Eggs float to the surface after fertilization (Lee and Ng, 1991). The pelagic eggs are guarded by both parents in the Philippines (Lowe-McConnell, 1987) and possibly throughout the native range of the species. Nevertheless, Herre (1924) stated that one or the other parent guards the nest at all times, and that if food becomes scarce, parents become cannibalistic on the young. He further indicated that in the Philippines, *C. striata* spawns throughout the year and that many, perhaps all, breed twice annually. Ali (1999) confirmed ripe females present throughout the year in ricefields in Perak, northwestern Malaysia. Peak spawning in southwestern Sri Lanka occurs between May and September, with a secondary spawning October through December (Kilambi, 1986). Jhingran (1984) cited fecundity as 3,000-30,000 ova. Lee and Ng (1991) stated that they had collected fry without seeing parents nearby. They also said that eggs hatch in 3 days in Malaysia, the fry developing a deep orange color. This pattern persists until the young reach a length of 15 mm when only an orange lateral stripe remains. At 40 mm in length, all orange color is lost but a "pseudo-ocellus" appears on the posterior lobe of the dorsal fin, a characteristic lost in adulthood. Mookerjee and others (1948) described and illustrated early development of *C. striata.*

Feeding habits: Carnivorous, feeding on worms, prawns, frogs, and especially other fishes (Mohsin and Ambak, 1983). Reported as a solitary (except during breeding season), territorial, ambush feeder (Lee and Ng, 1991). Conlu (1986) stated that young fry feed on algae and protozoans, juveniles feed on small crustaceans, and "adults are highly carnivorous, dreaded predators of other pond fish." She added that this fish is used as a predator to control tilapias in culture ponds. Jhingran (1984) cited larvae as feeding "on insects, water fleas, and fish fry," juveniles preferring "dipteran larvae, zooplankton, and fish fry," and adults as "piscivorous." Mahan and others (1978) reported that *Channa striata* (32 individuals ranging from 3.5 to 36.7 cm in length) fed almost exclusively on shrimp (47 percent by volume) in a lake in central Java. Dasgupta (2000) found that this snakehead consumed primarily insects (40 percent) followed by fishes (30 percent) and crustaceans (10 percent) in waters of West Bengal, India. Rao and others (1998) noted a preference for crustaceans and fishes from ponds and canals of East Godavari District, Andhra Pradesh, southeastern India. Ng and Lim (1990) described the enlarged canine teeth of *C. striata* as "cylindrical in cross section … ideal for gripping, killing, and tearing."

Characters: Gular region of head without patch of scales. Mouth large; lower jaw with 4-7 canines behind a single row of villiform teeth that widen to 6 rows at the jaw symphysis; villiform teeth on prevomer and palatines. Pectoral fin about half of head length. Dorsal fin with 37-46 rays; anal fin rays 23-29; pectoral rays 15-17; pelvic rays 6; caudal fin rounded. Scales on top of head large with a rosette of head scales between orbits, with frontal head scales forming central plate of rosette; 9 scale rows between preopercular angle and posterior border of orbit; predorsal scales 18-20; scales 50-57 in lateral series (Talwar and Jhingran, 1992). Coloration is quite variable in this species or species complex. The dorsum is often dark brown to black, typically obscuring the chevron-like markings dorsally. A distinguishing marking, however, is the dark stripe extending from just above the maxillary posteroventrally toward the opercular curvature.

Commercial importance in the United States: Introduced population is utilized as a food resource in Hawaii (Maciolek, 1984), although the species involved was not *Channa striata* but *C. maculata*, the result of century-old misidentifications. In addition to live fish, several thousand metric tons of frozen snakeheads are reported as being imported annually for food purposes into mainland United States. It is unknown how much of that market involves *C. striata*.

During fiscal year 1999, the U.S. Department of Agriculture Small Business Innovation Research Program funded a Phase II project to the Hawaii Fish Company of Waialua, Hawaii, $230,000 for 24 months, to develop commercial culture of *C. striata*. Phase I research had established feasibility of rearing striped snakeheads in captivity, spawning, and studies on rearing juveniles on artificial diets. Phase II was targeted to production of larvae and juveniles through induced spawning, additional studies on feeding, and cost-effective grow-out performance to marketable size. Phase III was designed to result in a commercial effort to produce farm-raised snakeheads for Hawaii, mainland U.S., and Canada, and was to be funded ($300,000) by the Wah Wah Seafood Company, Inc., of Honolulu. Phase III, however, was never funded.

In retrospect, importation of *Channa striata* to Hawaii is quite recent. Perhaps based on the belief that this species had been established in Hawaii for nearly a century, a permit was issued in the early 1990s to Arlo Fast of the University of Hawaii to import *C. striata* for culture research on Coconut Island in Kaneohe Bay. A second permit to import *C. striata* was issued to Dr. Fast in 1995 in cooperation with the person who currently cultures the species in a rockpit area at Mokuleia. The culturist had the only permit from the Hawaii Department of Agriculture to import *C. striata* with restrictions that sale to consumers must be of fresh-killed or cooked fish (Domingo Cravalho, Jr., personal commun., 2002).

This species often appears in aquarist-oriented websites and has been sometimes listed for sale by commercial aquarium websites. Interest in its use as an aquarium fish seems to be limited due to the size it attains and its aggressive nature toward other fishes.

On July 24, 2002, a specimen of *Channa striata* was purchased from a market in San Diego, California, where at least two other individuals of the same species were observed (Richard Rosenblatt and Phil Hastings, personal commun., 2002). All three were dead, on ice. The appearance of the specimen sent to us in a digital photograph seems to be of a freshly dead individual, with no cloudiness visible in the eye.

Commercial importance in native range: *Channa striata* is reported as being cultivated in Pakistan and India. There is a "tank fishery" for this species in Tamil Nadu, India. Tanks in India and Sri Lanka are

"ancient irrigation reservoirs" (Fernando and Indrassna, 1969). They stated that there were more than 1,000 tanks in Sri Lanka alone. In India, the chevron snakehead is described as a popular and highly prized fish, widely distributed, and the most economically important species of the genus (Talwar and Jhingran, 1992). *Channa striata* is one of three species of snakeheads commercially fished in Lake Jaisamand, the oldest reservoir in India (Rao and Durve, 1989). Fernando and Inrassna (1969) stated that it is the only species of snakehead in Sri Lanka of economic value, although three additional species (*C. gachua, C. marulius,* and *C. punctata*) are used as food fishes. It is also cultured in Vietnam (Pantulu, 1976; Bard, 1991), Thailand, Java (Hofstede and others, 1953), and the Philippines (Guerrero, 2000). Bard (1991) noted that this species is the most expensive fish produced by aquaculture in northern Vietnam. Ali (1999) cited it as "a popular food fish in Malaysia" remarking that ricefields have provided the largest source of this fish. Populations in Malaysia are reported to be depressed due, apparently, to overfishing, raising costs for live specimens. China is culturing *C. striata* and some of the product is being canned for sale in Malaysia (Wan Ahmad, personal commun., 2001).

Lee and Ng (1991) cited this species as the most economically important member of the snakeheads and noted that it is cultured throughout most of its range. Hofstede and others (1953) cited this species as bringing "the highest prices at the markets" in Indonesia. It is sold either fresh or alive in Cambodian markets (Rainboth, 1996). In the Danau Sentarum Wildlife Reserve of Kalimantan, chevron snakehead comprised 13 percent of the setline fish catch using small (size 12-16) hooks from the Kapuas River (Dudley, 2000).

Ng and Lim (1990) and Lee and Ng (1991) indicated that *Channa striata,* along with *C. micropeltes* and *C. lucius*, are utilized for medicinal purposes, particularly in Indonesia and Malaysia. Mention was made of use in a postnatal diet and during recuperation from illnesses or surgery (Lee and Ng, 1991). While no specifics were given as to how the fish were used following surgery, a neighbor of one of the authors (WRC), a Malaysian by birth, said that the oils from the "haruan" are used to greatly reduce scarring. She added that she had seen the results and "it is true" that scar tissue is dramatically reduced to a minimum.

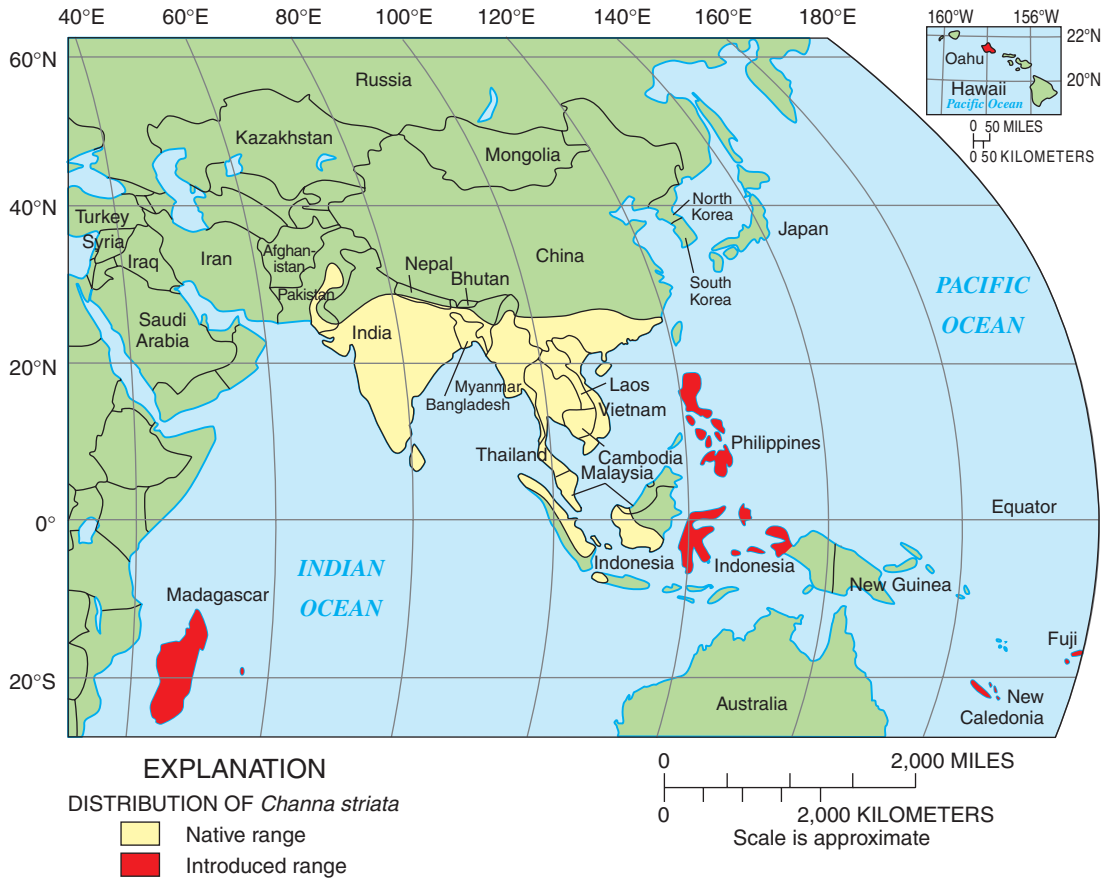
Cream extracts of haruan tissues contain high levels of arachidonic acid, a precursor of prostaglandin, essential amino acids (particularly glycine), and polyunsaturated fatty acids necessary to promote prostaglandin synthesis. Treating wounds with these extracts has been demonstrated to promote synthesis of collagen fibers better than standard use of Cetrimide, an antimicrobial quaternary ammonium compound, thus increasing tensile strength (Baie and Sheikh, 2000).

Lee and Ng (1991) indicated that the flesh of these larger snakeheads is rejuvenating following illnesses, prepared by being double-boiled with herbs, and only the soup is consumed. Nevertheless, for the soup to be effective in recovery, it is firmly believed that the fish must be killed just before cooking, dispatched with careful but firm blows to the head with a mallet. Herre (1924) reported much the same for the Philippines. Conceivably, this could be a reason that obtaining live snakeheads in live-food fish markets is considered important to some persons of southeast Asian descent living in the United States. Seale (1908) cited this species "as one of the most wholesome fishes and are given to invalids" in India.

Bard (1991) noted that *Channa striata* is cultured in Vietnam and is a highly desired and expensive fish in the markets of Hanoi, with a price/kg matching that of beef.

Environmental concerns: Adults of this species are considered to be highly predacious, ambush feeders on other fishes. In addition, their adaptability to living in turbid or clear waters, their apparent ability to tolerate subtropical to warm temperate climates, suggests the probability of establishment if introduced into waters of the extreme southern U.S. The apparent northern limit within its native range (32° N) is equivalent to a potential range from Savannah, Georgia, to just north of Ensenada, Baja California del Norte, México, in North America. Temperature regimes in the southwestern U.S. would permit establishment well north of 32º N, probably as far north as the Los Angeles basin, California; Phoenix, Arizona; or Las Cruces, New Mexico.

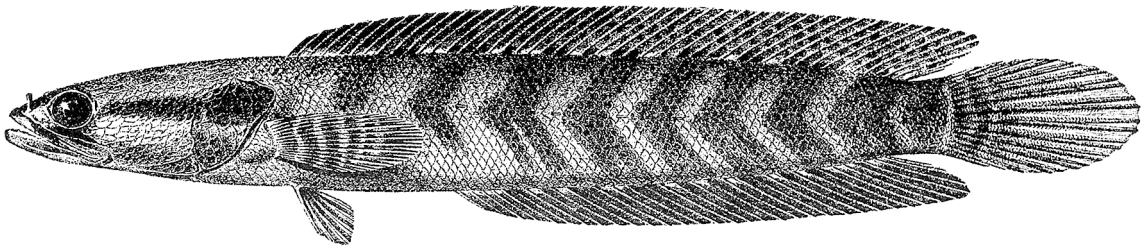
Comments: Banerjee and others (1988) recorded the diploid chromosome number of *Channa striata* from India as 40, but Donsakul and Magtoon (1991) reported a count of 44 for this species from Thailand, indicating that it represents a species complex.



Distribution of *Channa striata*

See comments above under **Introduced range**, as some reports of *C. striata* on Indian Ocean (for example, Madagascar) and Pacific Islands (for example, Hawaii) are misidentifications of *C. maculata* that require further investigation.

Parachanna africana (Steindachner, 1879)
Niger Snakehead



After Boulenger, 1916

Original description: *Ophiocephalus africanus* Steindachner 1879:31. Über einige neue und seltene Fischarten aus den zoologischen Museen zu Wien, Stuttgart und Warschau. Anz. Akad. Wiss. Wien. 16(4):29-34. Type locality: Lagos, Nigeria. Holotype: SMNS (no number provided).

Synonyms: *Channa africanus* (Steindachner, 1879).

Parophiocephalus africanus (Steindachner, 1879).

Common names: **Niger snakehead**; African snakehead.

Native range: Southern Bénin to southern Nigeria, primarily the Ouémé River and Niger basin (Bonou and Teugels, 1985; Skelton, 1988).

Introduced range: Introductions unknown.

Size: To 32 cm.

Habitat preference: Bonou and Teugels (1985) noted that there was little known of the biology of this snakehead. Daget and Iltis (1965) considered this species as a Guinean form that occupied waters in forested areas. Teugels and others (1992) commented that this species is limited to coastal sections of rivers.

Temperature range: No specific information. Nevertheless, the native range is equatorial, indicating a strictly tropical species.

Reproductive habits: No specific information located. Likely a nest builder that provides parental protection to young like other snakeheads.

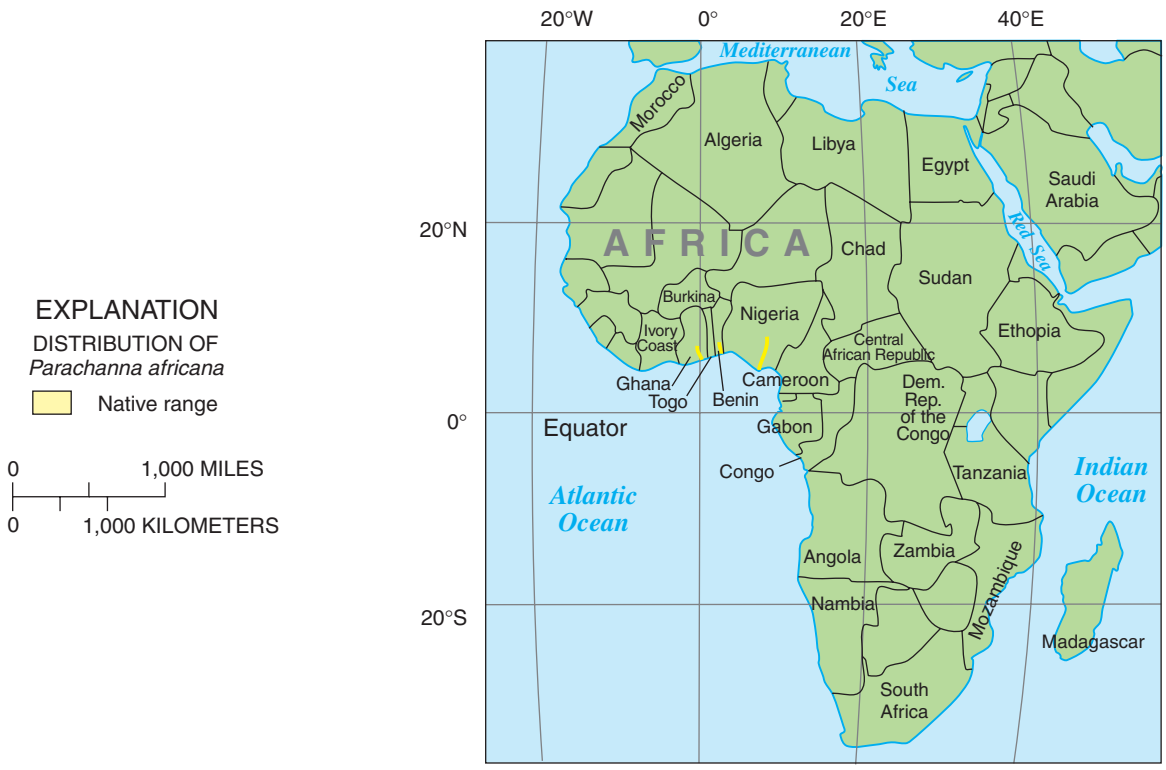
Feeding habits: No specific information. In considering this species as a game fish, Copley (1952) remarked that it ate frogs and worms, as well as fishes. Probably a thrust predator like other channid fishes.

Characters: Patch of scales present in gular region. No canines on prevomer or palatines. Transverse scales 19-24; lateral line scales 73-83. Dorsal rays 45-48; anal rays 32-35. Head slightly depressed anteriorly and covered with large scales. Lower jaw slightly longer than upper jaw with 3 to 4 large canine teeth. Coloration distinct among African snakeheads in having a series of forward-pointing chevrons on the side of the body posterior to the pectoral fins that extend upward to the base of the dorsal fin (Bonou and Teugels, 1985).

Commercial importance in the United States: Sometimes listed on aquarist-oriented websites and has been periodically sold through aquarium fish retailers. Unknown in live-food fish markets.

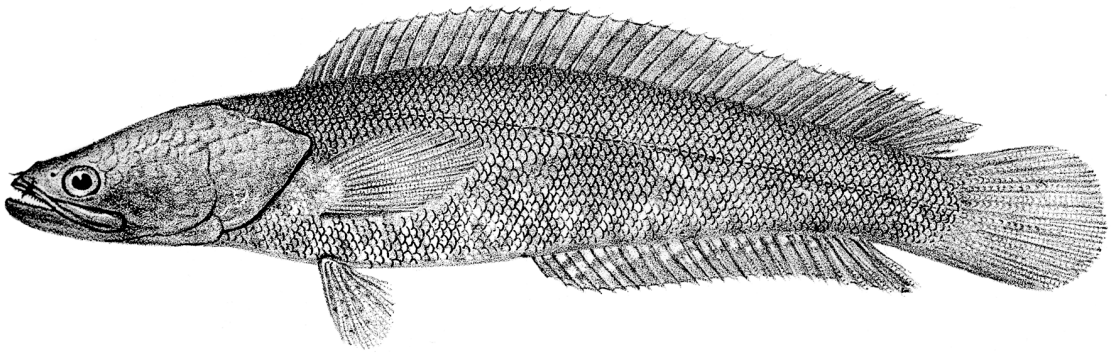
Commercial importance in native range: Unknown, but probably available in live-food fish markets.

Environmental concerns: Likely a thrust predator. Native range is equatorial indicating that if introduced this species would be restricted to tropical/subtropical waters.

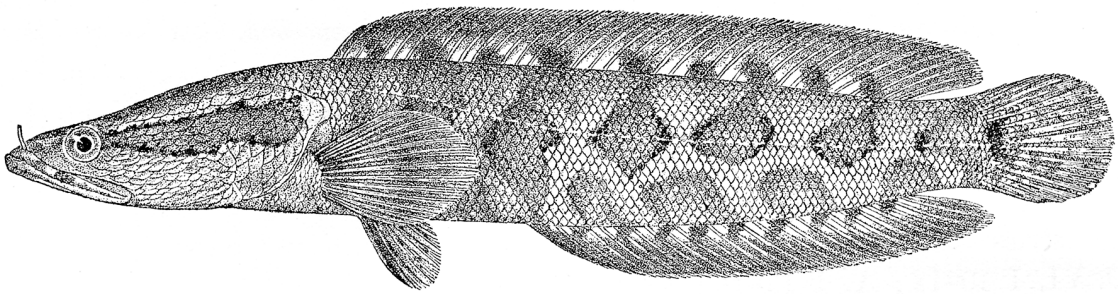


Parachanna africana

Parachanna insignis (Sauvage, 1884)
Congo Snakehead



After Sauvage, 1884



After Boulenger, 1916

Original description: *Ophiocephalus insignis* Sauvage, 1884:195, pl. 5, fig. 3. Notes sur des poissons de Franceville, Haut Ogooué. Bull. Soc. Zool. France 90, 1884:193-198. Type locality: upper Ogooué River, Gabon. Syntypes: MNHN 1844-0301 to 0305.

Synonyms: *Ophiocephalus obscurus* Poll, 1942.

Parophiocephalus insignis Daget and Stauch, 1963.

Ophiocephalus obscurus Matthes, 1964.

Common names: **Congo snakehead**; light African snakehead; ifoïfoli (juvenile; Zaire), foli (adult; Zaire).

Native range: Ogooué River basin, Gabon; Zaire River basin, Congo and Zaire. Bonou and Teugels (1985) recorded this species from above Boyoma (Stanley) Falls in the Lualaba (Congo) River. Guy Teugels (personal commun., 2002) stated that he doubted this distribution to be the result of an introduction into the upper Lualaba.

Introduced range: No introductions known.

Size: To about 45 cm.

Habitat preference: Bonou and Teugels (1985) noted that no specific studies of the biology of this species had been undertaken. General information indicates this snakehead occupies creeks, rivers, lakes, and lagoons, and sometimes in deep waters in calm areas.

Temperature preference: No specific information. Nevertheless, the native range of this species is equatorial/tropical.

Reproductive habits: Gosse (1963) commented that little is known of the reproduction of this snakehead. Nevertheless, he had observed juveniles ("de 30 à 40 mm") in groups, guarded by a large adult. He misidentified this species as *Ophiocephalus obscurus* in central Zaire.

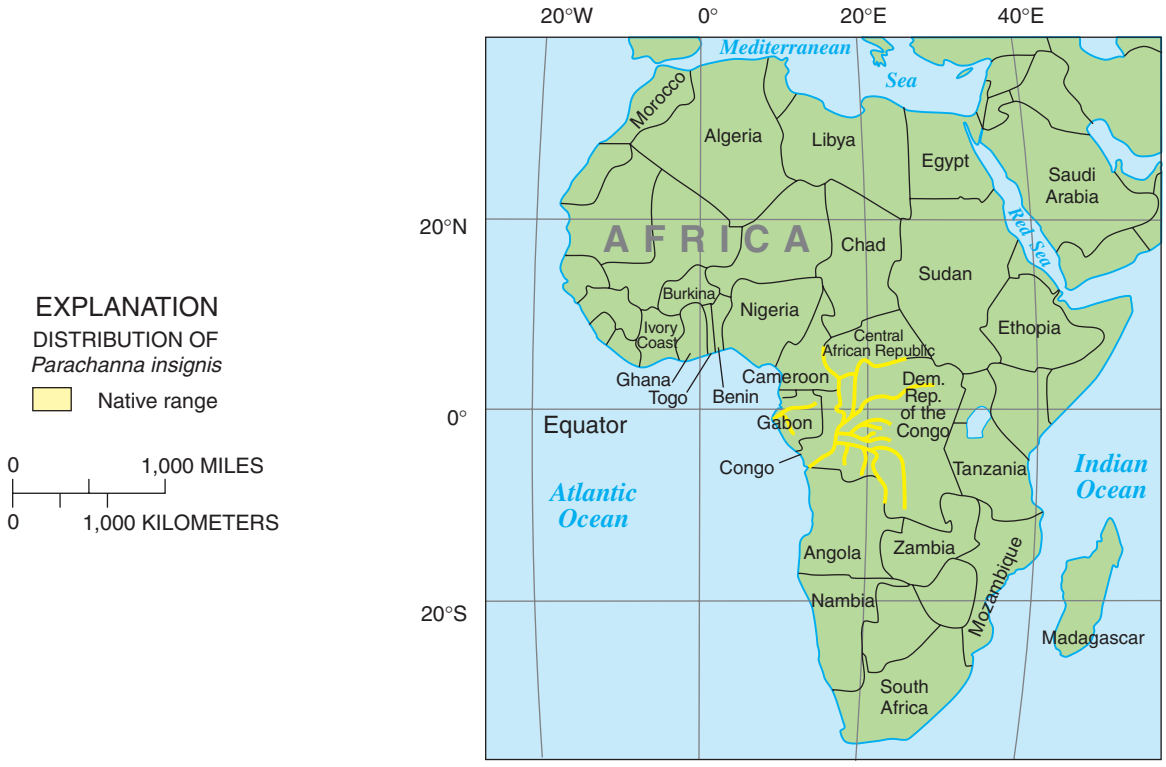
Feeding habits: Gosse (1963) described this species as "un ichthyophage typique." He noted that stomach contents of nine specimens contained primarily fishes (*Pelmatochromis, Tilapia, Hemichromis, Xenomystus*, cyprinodonts and fish remains).

Characters: Patch of scales present in gular region. No canine teeth on prevomer or palatines. Scales in a transverse line 25-33 with 7-10 above the lateral line and 16-22 below; lateral line scales 73-86. Dorsal fin rays 40-44; anal fin rays 27-31. Head slightly depressed anteriorly and covered with large scales. Lower jaw longer than upper jaw with 4-5 well-developed canine teeth on each side. Lateral line complete. Coloration is distinct among African channids in that there are chevron-shaped bars across the middle of the back that extend up onto the dorsal fin; central area of sides contain 4-5 dark blotches that are distinct from each other; lateral line passes through these blotches. Dark stripe on side of head extending from posterior rim of orbit to upper part of operculum.

Commercial importance in the United States: Rarely listed on aquarist-oriented websites. Unavailable in live-food fish markets.

Commercial importance in native range: No specific information, but probably available in live-food fish markets in the Congo basin.

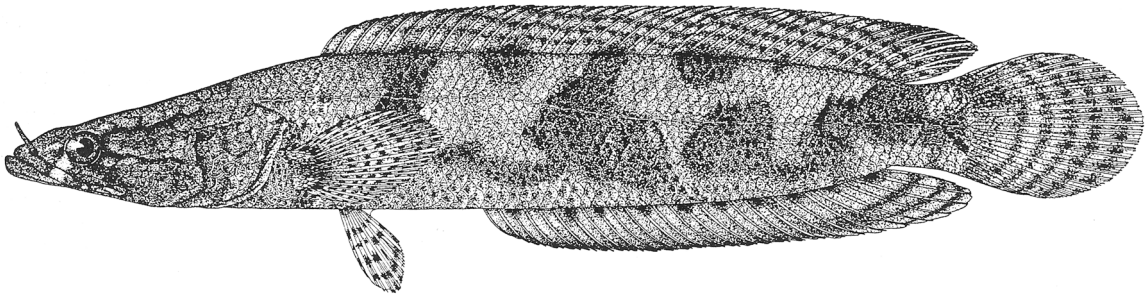
Environmental concerns: Likely a thrust predator showing a preference for fishes. If introduced, it could probably survive only in tropical/subtropical conditions.



Parachanna insignis

Parachanna obscura (Günther, 1861)
African Snakehead

Type species of *Parachanna* Teugels and Daget, 1984



Reprinted with permission from Guy G. Teugels from: Bonou, C.A., and G.G. Teugels. 1985. Révision systématique du genre *Parachanna* Teugels et Daget 1984 (Pisces: Channidae). Rev. Hydrobiol. Trop. 18(4):267-280.

Original description: *Ophiocephalus obscurus* Günther, 1861:476. Catalogue of the acanthopterygian fishes in the collection of the British Museum, 3:i-xxxv + 1-586. Type locality: West Africa. Syntypes: BMNH 1849.12.25.2-3.

Synonyms: *Ophiocephalus (Parophiocephalus) obscurus* Senna, 1924.

Channa obscura Myers and Shapovalov, 1932.

Parophiocephalus obscurus Berg, 1940.

Common names: **African snakehead**; snakehead; fakka (Arabic); ojul (Shilluk); abioth (Dinka); jul (Nuer); woroko (Zande; Bailey, 1994).

Native range:White Nile, specifically the Jebel and Ghazal systems of Sudan (Bailey, 1994) and Gambela region of Ethiopia (Golubtsov and others, 1995); Lake Chad basin; Zaire (Congo), Cross, Niger, and Senegal River basins (Boulenger, 1907, 1916; Irvine, 1947; Teugels and Daget, 1984; Bonou and Teugels, 1985; Skelton, 1988; Teugels and others, 1992). Boeseman (1957) recorded the species from Stanley Pool, Lualaba (Congo) River. Said to be "widely distributed" in Ghana and noted as both useful as food and aquarium species (Dankwa and others, 1999).

Introduced range: Not known to have been introduced.

Size: To 35 cm (Bailey, 1994).

Habitat preference: Bailey (1994) indicated a preference for marginal vegetation and floodplain habitat in the Sudan. Bonou and Teugels (1985) stated that this species occupies a wide variety of habitats including streams, rivers, lakes, lagoons and marshes. In flowing water, the species occupies calm areas. Lowe-McConnell (1988) indicated this species as "widely distributed" in marshy habitats and also found in bank vegetation of river channels. Teugels and others (1992) listed the species as common in stagnant side channels of the Cross River, Cameroon-Nigeria, and found among waterlogged fallen trees and leaf debris.

Temperature range: No specific information, but the native range is in equatorial Africa indicating a strictly tropical species.

Reproductive habits: Bonou and Teugels (1985) stated that little was known of the reproductive behavior of *Parachanna obscura*. Gosse (1963) stated that young are guarded by a large adult. Likely a nest builder like other channids. Under monoculture conditions in southern Nigeria, reproductive activity was greatest in October and November (Victor and Akpocha, 1992). Fecundity in this monoculture pond varied, with stages III, IV, and V ovaries containing 35-4,010 oöcytes. Moreover, fecundity was found not

to be correlated to length or weight, but this could result from "poor culture conditions" (Victor and Akpocha, 1992).

Feeding habits: Bonou and Teugels (1985) cited the species as feeding on other fishes, noting that in Bénin it is used to control the young of tilapias in aquaculture ponds. Citing Blache and others (1964), they recorded the food of young as copepods and insect larvae. Adults appear to prey on other fishes (Copley, 1952; Poll, 1957; Gosse, 1963; Teugels and others, 1992). Adebisi (1981) noted that juveniles fed on prawns, copepods, and aquatic insect larvae whereas adults fed only on fishes in southern Nigeria.

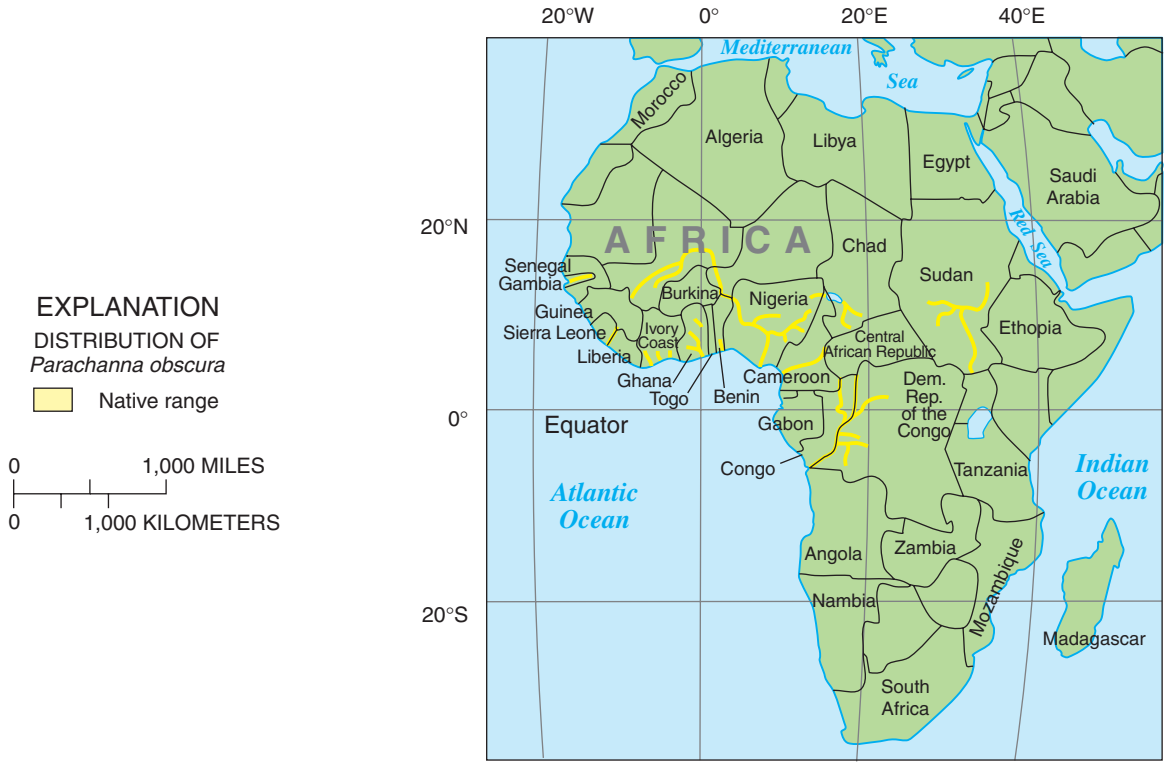
In monoculture in a Nigerian pond, young of this species (10-16 cm standard length) fed primarily on detritus and larval insects, whereas larger individuals (16-24 cm standard length) contained "fish parts" and juveniles, with insects and fish making up the bulk of the diet (Victor and Akpocha, 1992).

Characters: Patch of scales present in the gular region. No canine teeth on prevomer or palatines. Transverse scales 19-24; lateral line scales 65-78. Dorsal fin rays 39-45; anal fin rays 26-32. Head depressed anteriorly, relatively long and covered with large scales. Lower jaw slightly longer than upper jaw, with 4-6 well-developed canines. Lateral line typically complete, rarely discontinous. Coloration distinct among African snakeheads in having a series of dark blotches, some of which may coalesce, and no chevron-shaped bars across the middle of the back.

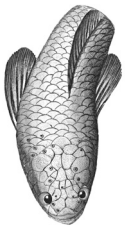
Commercial importance in the United States: Sometimes listed on aquarist-oriented websites. Not known to have been available in live-food fish markets.

Commercial importance in native range: Probably available in local live-food fish markets. This snakehead is being cultured in Ghana (Morrice, 1991), Nigeria (Ajana, 1983; Victor and Akpocha, 1992), and Bénin (Jackson, 1988), and was recommended for culture in the Central African Republic (Micha, 1974). All these localities are within the native range of this species.

Environmental concerns: Known to be a predator, particularly of other fishes (Copley, 1952; Poll, 1957; Gosse, 1963; Teugels and others, 1992).



Parachanna obscura



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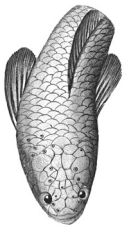

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