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# First records of small juveniles of the red drum *Sciaenops ocellatus* (Linnaeus, 1766) in a subtropical mangrove habitat of China

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## Abstract

The red drum *Sciaenops ocellatus* (Linnaeus, 1766) was introduced into China from Texas, United States for mariculture purposes nearly three decades ago. The present study provides the first evidence of small red drum juveniles living in a mangrove habitat of the Pearl River Estuary, Southern China. Twenty-eight specimens (4.5–8.0 cm standard length) were caught using traps in February 2016 and April 2016; identification was further confirmed by *COI* gene analyses. As a large marine predatory fish, the impact of the red drum on native species in Chinese waters is unknown, and the mechanisms of invasion and population establishment in the wild merit further investigations.

**Key words:** Sciaenidae, invasion, mangrove habitat, Pearl River Estuary, Chinese waters, mariculture

## Introduction

The red drum *Sciaenops ocellatus* (Linnaeus, 1766) is a marine fish (maximum size 160 cm total length (TL)) in the family Sciaenidae. It naturally inhabits the estuaries and coastal waters of the United States and Mexico in the West Atlantic from Long Island to Eastern Florida and in the Gulf of Mexico from Western Florida to at least Laguna Madre (Chao 2002) (Figure 1). The larvae are transported into estuarine nursery grounds via tidal currents where they settle in seagrass meadows, marsh-edge habitats or un-vegetated habitats and remain through the juvenile phase (Holt et al. 1983; Rooker and Holt 1997; Adams and Tremain 2000).

The red drum was introduced into China from Texas (United States) for mariculture purpose nearly three decades ago (Figure 1). It was first introduced into Taiwan in 1987 by the Taiwan Fishery Research Institute (Liao et al. 2010). In mainland China, 43 red drum larvae at an average size of 0.8 cm standard length (SL) were introduced into Shandong Province by

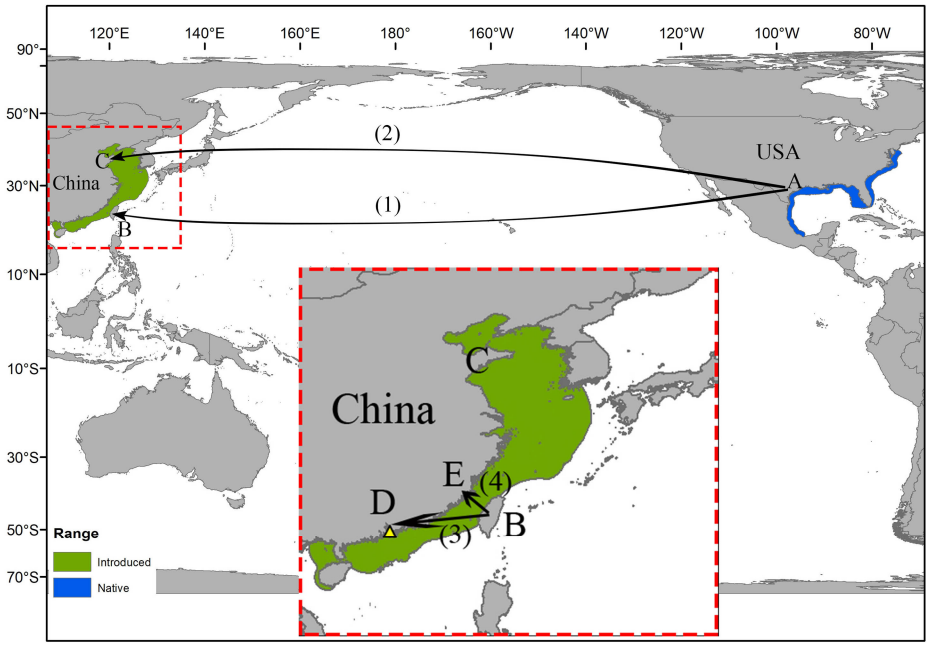


**Figure 1.** Native and introduced distributions of the red drum *Sciaenops ocellatus* based on the species assessment by the IUCN-SSC Sciaenidae Red List Authority. (1) introduction from Texas (A) to Taiwan (B) in 1987; (2) introduction from Texas (A) to Shandong Province (C) in 1991; (3) re-introduction from Taiwan (B) to Guangdong Province (D) in 1994; (4) re-introduction from Taiwan (B) to Fujian Province (E) in 1997. Yellow triangle: the sampling site in Guangdong Neilingding-Futian National Natural Reserve, the Pearl River Estuary, Southern China.

the First Institute of Oceanography in 1991 and reared in captivity until sexual maturation; two females and one male survived and were selected as broodstock in 1995 (Wang and Ji 1996; Liu et al. 1998). The species was re-introduced from Taiwan into Guangdong Province in 1994 at the juvenile phase and into Fujian Province in 1997 at the adult phase (Zou and Wu 2002; Su 2003). The red drum has become an important mariculture fish species in China, ranking third in terms of its culture production (68,253 t) in 2018, and contributed 4.57% to the total national marine fish culture production (1,495,088 t) (MOA 2019). The fish are mainly grown in intertidal ponds and floating net cages of nearshore waters in China (Xue 2008; Liao et al. 2010). The high culture production in current grow-out systems suggests that the red drum can adapt well in Chinese waters and are able to survive in the wild if individuals escape.

After two decades of mariculture practice, the red drum is now commonly caught using hook-and-line and gill nets along the entire coastal waters of China, including the Bohai Sea, Yellow Sea, East China Sea, both sides of the Taiwan Strait, northern South China Sea and the Beibu Bay, indicating it is the most widely spread non-native marine fish species in China (Figure 1). As a large marine predatory fish, the impact of the red drum on native species diversity of Chinese waters is unexplored. Mature females and males of the red drum are reported in Chinese waters (Xue 2008; Liao et al. 2010); however, the mechanisms of invasion and population establishment are still uncertain because of a lack of small juveniles in catches.

The present study provided the first records of small red drum juveniles (less than 10 cm SL and less than half a year in age) caught in a subtropical mangrove habitat of the Pearl River Estuary, Southern China. Morphological identification was subsequently confirmed by molecular barcoding analyses with the mitochondrial cytochrome *c* oxidase subunit I gene (*COI* gene).

## Materials and methods

Surveys were conducted using metal cylindrical minnow traps (mesh size 1.5 cm) in July 2015, October 2015, January 2016, February 2016 and April 2016 in a subtropical mangrove habitat located on the Guangdong Neilingding-Futian National Natural Reserve of China (22°31′26.84″N; 114°00′39.05″E) of the Pearl River Estuary, Southern China (Figure 1). Traps were deployed in the intertidal zone of the mangrove habitat, in water less than 5 m depth over muddy and sandy bottom. The red drum specimens were identified based on the external morphology of adult phase with a distinguishable feature, i.e. one to several black spots on the base of the caudal fin (Chao 2002). All specimens were measured in body length and weight, photographed and preserved in 95% ethanol.

Considering the variations in coloration between the juvenile and adult phases of the red drum, and the difficulties of sciaenid taxonomy due to their similar external morphology (Chao et al. 2019), an additional molecular tool, DNA barcoding using 630 bp *COI* gene sequences, was applied to confirm the species identification (Hebert et al. 2003; Ward et al. 2005). A small piece of dorsal muscle was dissected from each specimen, and the DNA was extracted using Chelex® 100 Resin (Bio-Rad Laboratories, Inc., the United States). A polymerase chain reaction (PCR) was conducted, and the *COI* fragment was amplified using a universal *COI* gene primer pair (VF1_t1 and VR1_t1) (Ward et al. 2005) to obtain the expected 630 bp long *COI* gene fragment. Amplicons of the expected size were purified and sequenced (Sangon Biotech, China). Then, 14 *COI* gene sequences from 13 sciaenid species (representing all 13 genera occurring in Chinese waters) and one red drum were retrieved from GenBank, and aligned by MAFFT (version 7.222) with the default settings of the E-insi algorithm. The selection of an optimal evolutionary model was constructed for the aligned sequences based on the Akaike Information Criterion using ModelTest (Posada and Crandall 1998) from the MEGA 6.06 software (Tamura et al. 2013). The HKY+G+I model was selected for the subsequent maximum likelihood (ML) phylogenetic analysis. A ML tree was inferred using MEGA 6.06 with 1,000 bootstrap pseudo-replications. The *COI* gene sequences of the 28 juveniles have been deposited in the National Center for Biotechnology Information (NCBI) GenBank database (accession numbers: MN485775–MN485802).


**Figure 2.** External morphology of the red drum *Sciaenops ocellatus*. (A) A small juvenile (6.9 cm SL) with coloration on the body collected in the present study; (B) A large juvenile (26.3 cm SL) collected from a wet market in Xiamen (China) for morphological comparison. Scale bars: 1 cm. Photographs by Min Liu (A) and Bai-an Lin (B).

## Results and discussion

A total of 28 small juveniles of red drum were caught in February 2016 and April 2016. Besides the coloration on the body, all specimens had one black spot on the base of the caudal fin above the lateral line, a distinguishable feature also present in large individuals that sometimes may have several black spots (Chao 2002) (Figure 2). The specimens were 4.5–8.0 cm SL (5.95 ± 1.02, mean ± SD) and 5.3–10.7 cm TL (7.40 ± 1.36), and had body weights of 2.0–7.0 g (3.43 ± 1.53), suggesting that they were less than 6 months old (Peters and McMichael 1987; Ross et al. 1995).

To our knowledge, these are the first recorded small juveniles of the red drum caught in Chinese waters. The sampling site (Pearl River Estuary of Guangdong Province) is similar to its native estuarine habitat in the United States that the species uses as a juvenile nursery (Holt et al. 1983; Rooker and Holt 1997; Adams and Tremain 2000). The main difference in the habitats are that the non-native locations (China) have mangrove systems where temperature and salinity are 10–32 °C and 3–24 respectively (Niu et al. 2018). In comparison, the seagrass and marsh meadows or un-vegetated beds in native waters (USA) have similar temperatures (10–33 °C) but much broader salinity ranges (1–38) (Adams and Tremain 2000). The *COI* phylogeny ML tree further confirmed the red drum juvenile identification with all 28 juveniles grouping together with one confirmed red drum (MF004315) (Figure 3).

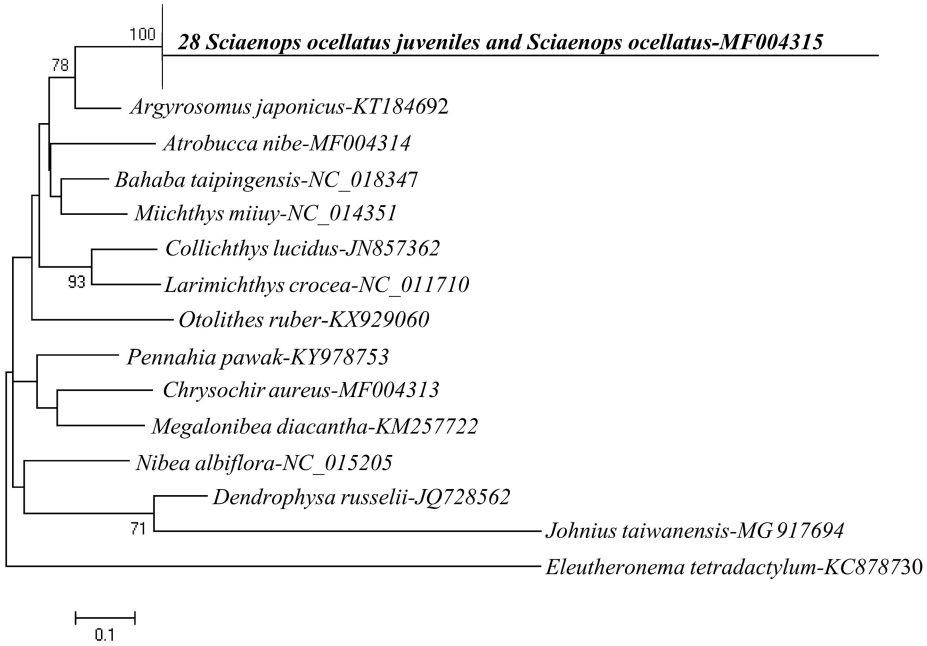


**Figure 3.** Phylogenetic relationship of the 28 small juveniles of the red drum *Sciaenops ocellatus*, 13 representative species from each of the 13 genera in Sciaenidae from Chinese waters, and one red drum individual (Figure 2B) based on maximum likelihood (ML) analyses of the *COI* gene sequences. *Eleutheronema tetradactylum* (Polynemidae) was selected as the outgroup. Nodes are supported by bootstrap values of distance matrix. Only bootstrap values ≥ 50% are presented.

The accelerating risks of marine fish species invasions and associated ecological impacts have aroused much attention (Chiesa et al. 2019). Approximately 110 fish species (marine and freshwater) from 11 orders were introduced internationally into China for aquaculture purposes, with the introduction peaking in the 1980s–2000s (Lin et al. 2015). Risks, known and potential, associated with the introduction and use of non-native marine species for aquaculture in China have been discussed (Xiong et al. 2017). The red drum currently ranks third in terms of the national marine fish culture production, indicating its great importance in the mariculture sector of China, and the suitable climate and aquatic environment for species growth in Chinese waters. Based on the high mariculture productions along coastal provinces of China and the open mariculture systems for the red drum, it is not surprising that the species is able to escape from net cages and survive in Chinese waters. The same situation occurs in the Mediterranean Sea; the red drum was introduced from USA for mariculture propose in the 1990s, and has escaped into the wild (Chiesa et al. 2019).

As a large marine predatory fish, red drum caught in the coastal waters of China feed on a diversity of prey items, including representatives of Pisces, Macrura, Brachyura, Cephalopoda, Stomatopoda and Polychaeta (Jin et al. 2008). About 20 fish species have been found in their stomachs including some species from the same family Sciaenidae (e.g. *Collichthys lucidus*, *Larimichthys polyactis*, *Miichthys miiuy* and *Johnius belangerii*), all

of which are commercial important food fishes in China. The red drum also feeds on other commercially important food fishes (e.g. Scorpaenidae, Sparidae, and Trichiuridae), shrimps (e.g. *Acetes* spp.), crabs (e.g. *Portunus sanguinolentus* and *P. trituberculatus*) and mantis shrimps (e.g. *Oratosquilla oratoria*). The red drum also consumes pelagic species (e.g. Engraulidae). Considering the high diet diversity of the red drum in Chinese waters, the impact of escaped red drum on native species merits further evaluation.

In coastal fisheries of China, the weight of commonly caught red drum ranges from 0.5 kg to 10 kg per fish, and includes both immature and mature individuals (Xue 2008; Liu and Sadovy de Mitcheson 2009; Liao et al. 2010). Together with the important observations of small juveniles (< 10 cm SL and < 6 months old) in mangrove and estuarine habitats found in this study, we believe that the red drum has established breeding populations in Chinese waters. Future efforts should focus on the mechanisms of invasion and population establishment for the red drum, especially in the estuarine habitats along the Chinese coast.

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## References

Adams DH, Tremain DM (2000) Association of large juvenile red drum, *Sciaenops ocellatus*, with an estuarine creek on the Atlantic coast of Florida. *Environmental Biology of Fishes* 58: 183–194, https://doi.org/10.1023/A:1007614930445

Chao NL (2002) Sciaenidae. In: Carpenter KE (ed), The living marine resources of the Western Central Atlantic. Volume 3: Bony fishes part 2 (Opistognathidae to Molidae), sea turtles and marine mammals. FAO Species Identification Guide for Fishery Purposes and American Society of Ichthyologists and Herpetologists Special Publication No. 5. Rome, FAO, pp 1583–1653

Chao NL, Chang CW, Chen MH, Guo CC, Lin BA, Liou YY, Shen KN, Liu M (2019) *Johnius taiwanensis*, a new species of Sciaenidae from the Taiwan Strait, with a key to *Johnius* species from Chinese waters. *Zootaxa* 4651: 259–270, https://doi.org/10.11646/zootaxa.4651.2.3

Chiesa S, Azzurro E, Bernardi G (2019) The genetics and genomics of marine fish invasions: a global review. *Reviews in Fish Biology and Fisheries* 29: 837–859, https://doi.org/10.1007/s11160-019-09586-8

Hebert PDN, Cywinska A, Ball SL, deWaard JR (2003) Biological identifications through DNA barcodes. *Proceedings of the Royal Society B: Biological Science* 270: 313–321, https://doi.org/10.1098/rspb.2002.2218

Holt SA, Kitting CL, Arnold CR (1983) Distribution of young red drums among different sea-grass meadows. *Transactions of the American Fisheries Society* 112: 267–271, https://doi.org/10.1577/1548-8659(1983)112<267:DOYRDA>2.0.CO;2

Jin H, Xu H, Xu W, Xue L (2008) Study on feeding habits of the escaped red drum *Sciaenops ocellatus* in Zhejiang sea area. *Marine Fisheries Research* 29(1): 103–108 [in Chinese with English abstract]

Liao YC, Chen LS, Shao KT (2010) The predatory Atlantic red drum, *Sciaenops ocellatus*, has invaded the western Taiwanese coast in the Indo-West Pacific. *Biological Invasions* 12: 1961–1965, https://doi.org/10.1007/s10530-009-9642-x

Lin Y, Gao Z, Zhan A (2015) Introduction and use of non-native species for aquaculture in China: status, risks and management solutions. *Reviews in Aquaculture* 7: 28–58, https://doi.org/10.1111/raq.12052

Liu M, Sadovy de Mitcheson (2009) Exploitation history, mariculture and trade status of the threatened Hong Kong grouper (*Epinephelus akaara*) throughout its geographic range. Ocean Park Conservation Foundation of Hong Kong, Hong Kong, 181 pp

Liu H, Mao X, Wang W, Wang B (1998) A preliminary study on technique for fully artificial breeding of red drum *Sciaenops ocellatus*. *Journal of Fishery Sciences of China* 5(4): 114–116 [in Chinese]

MOA (2019) Ministry of Agriculture. China Fishery Statistical Yearbook 2019. China Agriculture Press, Beijing, China [in Chinese]

Niu ZY, Shen XX, Cai WM, Xu HL, Li RL, Qiu GY (2018) Characteristics of water quality changes in the Futian Mangrove National Natural Reserve. *Acta Scientiarum Naturalium Universitatis Pekinensis* 54(1): 140–148 [in Chinese with English abstract]

Peters KM, McMichael RH (1987) Early life history of the red drum, *Sciaenops ocellatus* (Pisces: Sciaenidae), in Tampa Bay, Florida. *Estuaries* 10: 92–107, https://doi.org/10.2307/1352173

Posada D, Crandall KA (1998) Modeltest: testing the model of DNA substitution. *Bioinformatics* 14: 817–818, https://doi.org/10.1093/bioinformatics/14.9.817

Rooker JR, Holt SA (1997) Utilization of subtropical seagrass meadows by newly settled red drum *Sciaenops ocellatus*: patterns of distribution and growth. *Marine Ecology Progress Series* 158: 139–149, https://doi.org/10.3354/meps158139

Ross JL, Stevens TM, Vaughan DS (1995) Age, growth, mortality, and reproductive biology of red drums in North Carolina waters. *Transactions of the American Fisheries Society* 124: 37–54, https://doi.org/10.1577/1548-8659(1995)124<0037:AGMARB>2.3.CO;2

Su P (2003) Studies on artificial propagation and seed production of red drum, *Sciaenops ocellatus*. *Journal of Shanghai Fisheries University* 12(2): 135–139 [in Chinese with English abstract]

Tamura K, Stecher G, Peterson D, Filipski A, Kumar S (2013) MEGA6: Molecular Evolutionary Genetics Analysis Version 6.0. *Molecular Biology and Evolution* 30: 2725–2729, https://doi.org/10.1093/molbev/mst197

Ward RD, Zemlak TS, Innes BH, Last PR, Hebert PDN (2005) DNA barcoding Australia's fish species. *Philosophical Transactions of the Royal Society B* 360: 1847–1857, https://doi.org/10.1098/rstb.2005.1716

Wang B, Ji B (1996) On techniques for rearing fries of *Sciaenops ocellatus*. *Shandong Fisheries* 13(5): 21–23 [in Chinese with English abstract]

Xiong W, Shen C, Wu Z, Lu H, Yan Y (2017) A brief overview of known introductions of non-native marine and coastal species into China. *Aquatic Invasions* 12: 109–115, https://doi.org/10.3391/ai.2017.12.1.11

Xue L (2008) Elementary study on the influence of the escaping net breeded *Sciaenops ocellatus* on natural zoology of Zhejiang sea area. MSc Thesis, Ocean University of China, Qingdao, China, 46 pp [in Chinese with English abstract]

Zou J, Wu G (2002) The status and prospects of propagation and aquaculture of marine fish in Guangdong. *Transactions of Oceanology and Limnology* 4: 83–93