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REVIEW ARTICLE

Invasive vs. endemic cichlid species: A review of Iranian cichlids with new locality records for *Oreochromis niloticus* and *O. mossambicus* (Actinopterygii: Cichlidae)

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Abstract
Freshwater ecosystems support a remarkable proportion of global biodiversity and offer crucial ecological services and economic value to society. Despite their importance, these water bodies are some of the most threatened on Earth and exhibit great vulnerability to the effects of anthropological-mediated threats including introduction of exotic species. At least 37,000 exotic species have been introduced by human activities beyond their natural range to all regions and biomes of Earth, including remote and isolated environments, and many of them have become established. Freshwater environments harbor approximately 18,915 fish species, accounting for a quarter of all vertebrate biodiversity. However, these species are experiencing declines at rates surpassing those observed in other ecosystems. Among the key drivers of this decline, biological invasions have become increasingly significant. Globally, more than 500 exotic freshwater fish species have established populations after their introduction, making them one of the most frequently introduced taxonomic groups, with significant ecological impacts such as competition with native species, habitat alteration, and the spread of diseases The United States records the highest non-native fish diversity (302 species), followed by Canada (63), Brazil (60), Russia (58), Mexico (56), and China (53). Iran, with 33 alien fish species, comprises 58.9% of the freshwater alien fish species of the Middle East, and this count positions Iran among the countries facing moderate to high biological invasion pressure in its freshwater systems, though fewer than global hotspots like the United States. The fish invasion has contributed to the biotic homogenization of freshwater fish assemblages with profound ecological, health and socio-economic consequences. The present study aims to review endemic and alien cichlids of Iran, providing current taxonomic status, distribution, morphological characteristics, identification key, introduction pathways of alien cichlids, their impacts on native fishes, and documenting first and new locality records of *Oreochromis mossambicus* and *O. niloticus* and their hybrids in the Minab River drainage (Makran basin, Hormuzgan). Understanding the distribution patterns of exotic fish species and the factors driving their establishment in specific regions are critical for developing effective management strategies and predicting future invasion risks. This is particularly important in biodiversity-rich countries such as Iran.

INTRODUCTION
Freshwater ecosystems support a remarkable proportion of global biodiversity and offer crucial ecological services and economic value to society (Dudgeon et al. 2006; Strayer 2010; Cassemiro et al. 2018). Despite their importance, these waterbodies are some of the most threatened on Earth (Saunders et al. 2002; Abell et al. 2008; Cassemiro et al. 2018) and exhibit great vulnerability to the effects of anthropological-mediated threats (Leprieur et al. 2009; Cassemiro et al. 2018; Bănăduc et al. 2024). An overview which has been provided on the water protection linked to freshwater stressors (solar ultraviolet radiation, thermal pollution, nanoparticles, radioactive pollution, salinization, nutrients, sedimentation, drought, extreme floods, fragmentation, pesticides, war and terrorism, algal blooms, invasive aquatic plants, riparian vegetation, and invasive aquatic fish), reviewed that altogether, these stressors build an exceptionally composite

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background of stressors that are continuously changing freshwater ecosystems and diminishing or even destroying their capability to create and maintain ongoing natural healthy products and essential services to humans (Bănăduc et al. 2024). The sustainable coexistence of human civilization and natural environments fundamentally depends on effective global freshwater ecosystem management, which itself requires comprehensive structural and functional understanding of prevalent stressors. Neglecting these stressors and their synergistic interactions will inevitably lead to the degradation of Earth's freshwater resources in both quantity and quality (Bănăduc et al. 2024).

Freshwater ecosystems exhibit great vulnerability to the effects of non-native species invasion (Leprieur et al. 2009). The phenomenon of biological invasion is widely studied and has become a fundamental concept in invasion biology literature. Biological invasions can occur when a species is introduced into an area where it is not native (Blackburn et al. 2011). Once the alien (or non-native/exotic) species is established and spreading in the new environment, they are classified as 'invasive', often with many documented impacts on biodiversity and society (Roy et al. 2024).

Terminology: When addressing non-native species introductions, the following terms should be incorporated: Biological invasion is a process that transports (moves) and introduces a species outside of its natural range, intentionally or unintentionally, by human activities to new regions where it may become established and spread (Roy et al. 2024). Alien species (synonyms: adventive, exotic, foreign, introduced, non-indigenous, non-native) is a species whose presence in a region is attributable to human activities that have enabled it to overcome the barriers that define its natural range. Established alien species refers to a subset of alien species that have produced a viable, self-sustaining population and may have spread. Invasive alien species reveals a subset of established alien species that spread and have a negative impact on biodiversity, local ecosystems and species. Many invasive alien species also have impacts on nature's contributions to people (embodying different concepts, such as ecosystem goods and services and nature's gifts) and good quality of life (Roy et al. 2024). More specific terms are: i) Introduction pathways including deliberate releases (aquaculture, sport fishing, research, malaria control), and accidental introductions (aquarium releases, bait bucket transfers), ii) Ecological consequences (competitive displacement, genetic contamination, and disease transmission, iii) Invasion process terms (initial introduction, population establishment, range expansion), iv) Management approaches (prevention protocols, early detection systems, and control/eradication methods, and v) Regulatory frameworks (international agreements, and national biosecurity policies), vi) Impact/consequence (any measurable change in ecological, economic, or social systems resulting from an invasive species), vii) Mechanism (the process through which an invasive species exerts its impact, viii) Biosecurity (management of risks posed by organisms to the economy, environment and human health through exclusion (the prevention of initial introduction of a species), mitigation, adaptation, control and eradication, ix) Invasiveness (the features of an alien organism, such as their life-history traits and modes of reproduction that define their capacity to invade, i.e. to overcome various barriers to invasion, x) Invasion complex (a situation where one invasive species facilitates, directly or indirectly, the establishment of one or more secondary alien species, (see Richardson et al. 2011; Ricciardi et al. 2013; Roy et al. 2024; Carneiro et al. 2025).

Global issue: Invasive alien species (IAS) represent a worldwide problem as they pose a significant threat to biodiversity and human well-being around the globe (Simberloff 2000, Wittenberg and Cock 2001: Early et al. 2016; Bradshaw et al. 2021, Hoffmann et al. 2025). IAS are also considered as one of the main causes of extinction of native species and ecosystem imbalance (Bellard et al. 2021; Hoffmann et al. 2025). There is a massive body of literature evidencing the impacts of IAS on biodiversity, and a growing concern regarding their impacts on ecosystem services and,

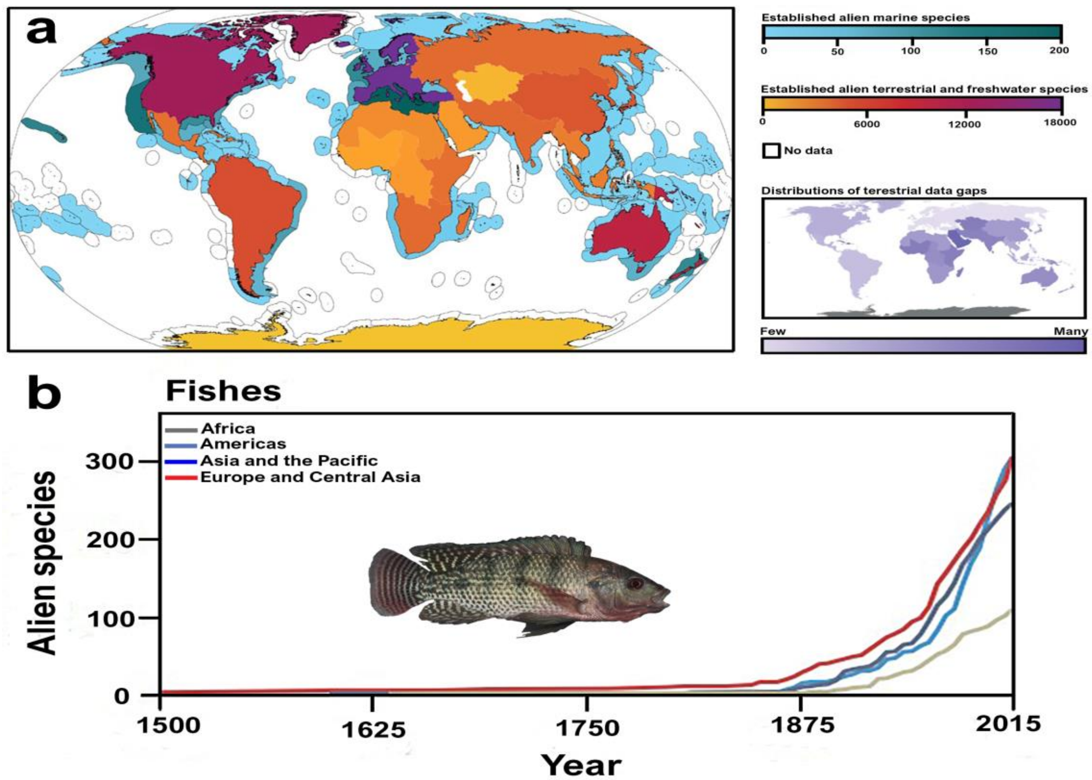

Fig.1. Global distribution and temporal trends in established alien species. Total numbers of established alien species (terrestrial and freshwater) in the regions (consisting of countries and subnational units) and marine ecoregions (marine). White denotes missing information. A gap analysis was conducted to identify data gaps for terrestrial regions, which are indicated in the inset. The data gap analysis could not be done for marine regions (white) and Antarctica (grey). The temporal trends in the number of established alien fish species from 1500 to 2015 (Roy et al. 2024).

consequently, on the support of human life (Cassemiro et al. 2018; Bănăduc et al. 2024; Hoffmann et al. 2025).

Global patterns of non-native establishment:

At least 37,000 established alien species have been introduced by human activities beyond their natural range to all regions (Fig. 1) and biomes of Earth, including remote and isolated environments (IPBES 2023; Roy et al. 2024). A subset of these established alien species becomes invasive alien taxa more than 3,500 species globally (IPBES 2023; Roy et al. 2024). Islands, and particularly remote islands with high endemism, are highly susceptible to impacts from invasive alien species, with 90% of documented global extinctions attributed mainly to invasive alien species occurring on islands. For example, brown tree snake *Boiga irregularis* (Squamata: Colubridae) caused the extinction of almost all forest birds in Guam including the global extinction of Guam flycatcher *Myiagra freycineti* (Passeriformes: Monarchidae) (IPBES 2023; Roy et al. 2024).

Global patterns of non-native fish establishment:

In a comprehensive study analyzing 14,953 freshwater fish species across 3,119 river basins globally, Xu et al. (2024) identified key invasion hotspots for both exotic and translocated non-native fishes (Fig. 2). Their research revealed that non-native species have successfully established in 1,719 basins (55.11% of those studied), with exotic species present in 1,518 basins (50.69%) and translocated species in 603 basins (19.33%). The study highlighted three river basins as particularly susceptible to invasions, the Colorado, Mississippi, and Columbia Rivers in the United States, each containing over 50 non-native fish species. Notably, three species demonstrated exceptionally wide invasion ranges including common carp *Cyprinus carpio*, rainbow trout *Oncorhynchus mykiss*, and mosquitofish *Gambusia affinis* (Xu et al. 2024). These invasive species have become established in more than 50 countries and 200

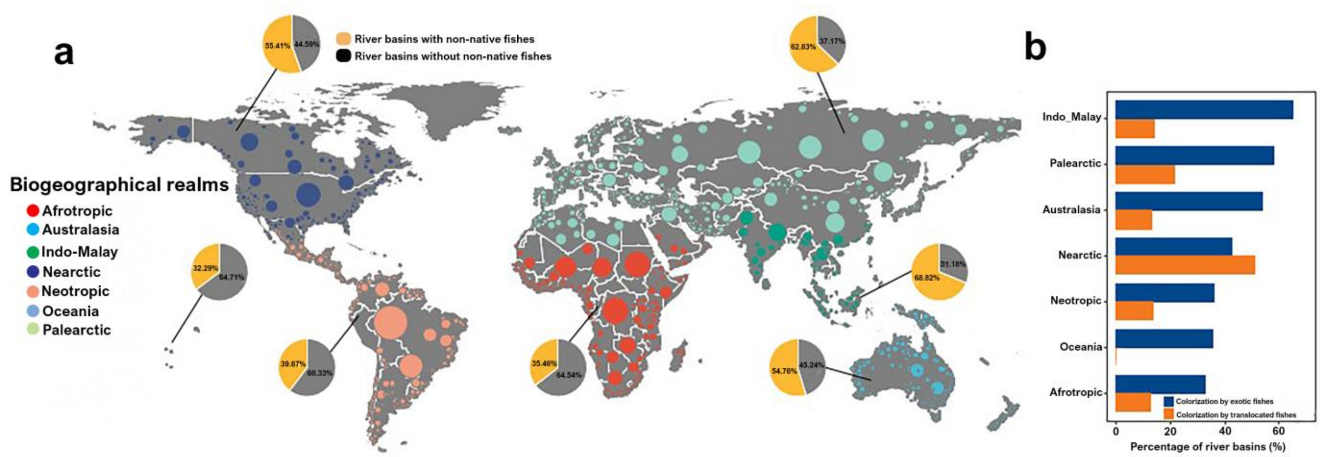

Fig.2. Sampling river basins and non-native fish colonization patterns. **a**, geographical distribution of 3,119 river basins across seven biogeographical realms and percentage of river basins colonized by non-native fish species in each realm. **b**, percentage of river basins colonized by exotic and translocated non-native fish species in each realm. The locations of river basins are represented by the median points with point size indicating basin area (Xu et al. 2024).

river basins worldwide (Xu et al. 2024).

Biogeographical distribution: Exotic fishes dominate in the Indo-Malay (64.71%), Palearctic (57.89%), and Australasia (53.52%) realms, with >30% colonization in the Nearctic, Neotropics, Oceania, and Afrotropic regions (Xu et al. 2024). Translocated fishes show lower but variable establishment rates, peaking in the Palearctic (51.01%) and ranging from 12.41-21.20% in other realms (Fig. 2). Spatially, hotspots for exotic species include southern/central Nearctic, northern/southern Neotropics, western/southern Palearctic, southern Afrotropic, northern Indo-Malay, and southern Australasia. Translocated species concentrate in the Nearctic and central Palearctic (Xu et al. 2024).

Country-level invasions: The United States records the highest non-native fish diversity (302 species), followed by Canada (63), Brazil (60), Russia (58), Mexico (56), and China (53) (Xu et al. 2024). Exotic species constitute 0.88-10.90% of national fish faunas, whereas translocated species represent 0.77-22.00% (Xu et al. 2024). Recent research by Sayyadzadeh & Esmaeili (2024) documents 33 non-native fish species (e.g., *Cyprinus carpio*, *Gambusia holbrooki*, *Pesudorasbora parva*) currently present in Iranian freshwater ecosystems which is 58.9% of freshwater alien fish species of the Middle East (Çiçek et al. 2024). This count positions Iran among the countries facing moderate to high biological invasion pressure in its freshwater systems, though fewer than global hotspots like the United States.

Given the expansion of international commerce and limited conservation funds, prevention of non-native species introductions remains the most economically viable approach for controlling biological invasions and mitigating their ecological impacts (Early et al. 2016; Cuthbert et al. 2021; Renault et al. 2022).

Alien species and fisheries: There are many malignant invasive fish species globally, including common carp (*Cyprinus carpio*), walking catfish (*Clarias batrachus*), Nile perch (*Lates niloticus*), brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), largemouth bass (*Micropterus nigricans*), and the tilapia species (Yongo et al. 2023). Global fisheries and aquaculture production surged to 223.2 million tons, with 185.4 million tons of aquatic animals and 37.8 million tons of algae in 2022. Of the total aquatic animal production, 89 percent was used for human consumption, equivalent to an estimated 20.7kg per capita in 2022. The rest went on non-food uses, mostly fishmeal and fish oil (FAO 2024). In 2022, global aquaculture production reached 130.9 million tons, valued at USD 312.8 billion, 59 percent of global fisheries and aquaculture production. Inland aquaculture contributed 62.6 percent of farmed aquatic animals, marine and coastal aquaculture 37.4 percent (FAO 2024). After carp and salmonids, tilapias are the third most widely farmed fish on a global scale. One of the main species groups, carps, barbels and other cyprinids, has shown a continuous increase, rising from around 0.7 million tons per year in the mid-2000s to almost 1.8 million tonnes in 2022, and accounts for most of the increase in catches from inland waters in recent years. Catches of tilapias and other cichlids have also increased in recent years from less than 0.7 million tons to over 0.8 million tonnes per year (FAO 2024).

At the species level, whiteleg shrimp (*Penaeus vannamei*), with 6.8 million tonnes, was the top species produced in 2022, closely followed by cupped oysters nei (*Crassostrea* spp., 6.2 million tonnes), grass carp (=white amur; *Ctenopharyngodon idellus*, 6.2 million tonnes), Nile tilapia (*Oreochromis niloticus*, 5.3 million tonnes), silver carp (*Hypophthalmichthys molitrix*, 5.1 million tons) and anchoveta (=Peruvian anchovy; *Engraulis ringens*, 4.9 million tonnes). It is worthy of note that aquaculture was the main source of production of the top five species and of eight of the top ten species of aquatic animals in 2022 (FAO 2024).

Tilapias: Tilapia is the common name of several cichlid species. The tilapia invasion has become a significant concern to ecologists and conservationists, posing severe threat to freshwater biodiversity. Tilapias are native to Africa and the Middle East but have been introduced in other regions to enhance capture fisheries and aquaculture (Canonico et al. 2005; Cishahayo et al. 2022; Yongo et al. 2022).

Some tilapia species, such as Nile tilapia (*Oreochromis niloticus*) and Mozambique tilapia (*O. mossambicus*), are most suitable for aquaculture production since they exhibit rapid growth and can tolerate a wide range of environmental parameters. They can adapt to fluctuations in salinity and dissolved oxygen concentrations, show a high reproduction rate and trophic plasticity (Coward & Little 2001; Martin et al. 2010). Although these attributes are useful for aquaculture production, they also predispose tilapias to success as invasive species (Canonico et al. 2005). Consequently, tilapias have invaded the natural waters, including lakes, of many countries and regions (e.g., the United States, Canada, Brazil, Australia, China, Southeast Asia, middle East including Iran, Oman and Central America (Grammer et al. 2012; Yongo et al. 2023; Esmaeili & Hamidan 2023; Sayyadzadeh & Esmaeili 2024). At the same time, however, the invasiveness of tilapias can vary by the species and their geographical locations (Russell et al. 2012a).

After the first record of an introduced cichlid fish, the Neotropical convict cichlid, *Amatitlania nigrofasciata* from Iran in 2013 by Esmaeili et al. (2013), the second introduced species the redbelly tilapia *Coptodon zillii*, was reported from Shadegan international wetland, Khuzestan Province, southwestern Iran (Khaefi et al. 2014). Later in 2016, first record the blue tilapia, *Oreochromis aureus* was documented from the Arvand and Karun River drainages (Persian Gulf basin) in Khuzestan province (Valikhani et al. 2016). The fourth introduced cichlid, *O. niloticus* was documented by Rafii et al. (2017) from the Dehkan River (Persis, Persian Gulf basin). There are also unofficial records of *O. mossambicus* (Rafii et al. 2017). In addition, there are two described endemic cichlids, *Iranocichla hormuzensis* and *I. persa* (Esmaeili et al., 2016; Schwarzer et al. 2016; Sayyadzadeh & Esmaeili 2024), and one undescribed population (Esmaeili et al. 2016; Schwarzer et al. 2016).

In this study, we review i) the current status of world alien species and related terminology, ii) the taxonomic status and distribution ranges of both introduced and endemic cichlids in Iran, and iii) we report a new locality record of Nile tilapia *Oreochromis niloticus* and *O. mossambicus* in the Makran basin, supported by integrated morphological and molecular analyses.

MATERIAL AND METHODS

This checklist was compiled using i) the previous and recently published articles (e.g., Esmaeili et al. 2013, 2014, 2016; Khaefi et al. 2014; Schwarzer et al. 2016; Valikhani et al. 2016; Rafii et al. 2017; Esmaeili 2021;

Sayyadzadeh & Esmaeili 2024), ii) specimen records obtained from reviewed literature and online museum databases, and iii) field-collected material was obtained during expeditions conducted by the authors in the Minab River basin, near Minab Dam, Hormozgan Province, southern Iran, part of the Makran Basin.

Molecular study

Tissue sampling: Muscle tissue from below the dorsal fin or the right pectoral fin of three specimens was carefully excised and preserved in 96% ethanol for molecular analysis. The corresponding voucher specimens were deposited in the Zoological Museum of Shiraz University (ZMSU), Iran, for future reference.

DNA Extraction and Amplification: Genomic DNA was extracted using the Sinagen Genomic DNA Extraction Kit. The standard vertebrate DNA barcode region, the COI (cytochrome oxidase subunit 1), was amplified using the primer pairs FishF1 (5' TCA ACC AAC CAC AAA GAC ATT GGC AC'3) and FishR1 (5' TAG ACT TCT GGG TGG CCA AAG AAT CA'3) (Ward et al. 2005). The following amplification protocol was used for COI primers (Fish F1 and Fish R1): Initial denaturation at 94°C for 1 minute, followed by 35 cycles of 94°C for 30 seconds, 52°C for 45 seconds, and 72°C for 45 seconds, with a final extension at 72°C for 5 minutes on a Bioer thermal cycler. The amplification was performed using a Master Mix in a total volume of 25µl, containing 12.5µl of Ready 2X PCR Master Mix (Genet bio, Cat. no. G-2000), 0.5µl of each primer (10pmol/µl), 5µl of DNA template, and 6.5µl of ddH2O. The PCR was conducted using a Bioer XP Thermal Cycler (Bioer Technology Co. Ltd., Hangzhou, China). The amplification products were confirmed by electrophoresis in 1% agarose gel in 0.5X TBE buffer. Purification and sequencing of the PCR products were carried out at Sinoh Biotechnology Company (Shiraz, Iran) using the same primer pairs. An additional 29 sequences from *Oreochromis* and *Iranocichla* were retrieved from NCBI GenBank to construct an integrative dataset for assessing the phylogenetic position of *O. mossambicus* and *O. niloticus*. The sequence of *Coptodon zillii* was used as an appropriate outgroup (Fig. 6).

Data Analysis: The mitochondrial COI sequences of the studied specimens were subjected to BLAST (Basic Local Alignment Search Tool) searches at the NCBI website (http://www.ncbi.nih.gov). Data processing and editing were performed using BioEdit 7.2.5 (Hall 1999). Sequence alignment was performed using the ClustalW algorithm in MEGA11 (Tamura et al. 2013). No unexpected stop codons or nuclear copies of mitochondrial fragments were detected in any sequence. Maximum likelihood phylogenetic trees were constructed with 1,000,000 bootstrap replicates using RAxML software 8.2.5 (Stamatakis 2006), under the GTR+G+I model of nucleotide substitution, with fast bootstrap support.

RESULTS

Morphological study: The exotic cichlid fish species introduced to Iranian inland water bodies and endemic cichlids (Fig. 3) are listed below. In total there are 8 cichlids comprising 5 exotics (3 genera: *Amatitlania*, *Coptodon*, *Oreochromis*) and 3 endemics (1 genus: *Iranocichla*). *Oreochromis mossambicus* is recorded for the first time from Iranian inland waters, *O. niloticus* (Fig. 4) is documented for the first time from Hormuzgan Province, both species from Minab Dam, Minab River drainage, Makran Basin. A putative hybrid, Taiwanese red tilapia or Mozambique tilapia × Nile tilapia (*O. mossambicus* × *O. niloticus*) is also reported from the same water body. Morphological characteristics and meristic counts of *O. niloticus* in Minab Dam are given in Table 1.

Taxonomic Account

Cichliformes (cichlids and convict blennies)

This checklist is a collection of works listed in references (see e.g., Esmaeili et al. 2013, 2014, 2016; Khaefi et al. 2014; Schwarzer et al. 2016; Valikhani et al. 2016; Rafii et al. 2017; Esmaeili 2021; Sayyadzadeh & Esmaeili 2024), and also, samples deposited in the Zoological Museum and Collection of Biology Department, Shiraz (ZM-CBSU). Genera and species are arranged alphabetically; the nomenclature

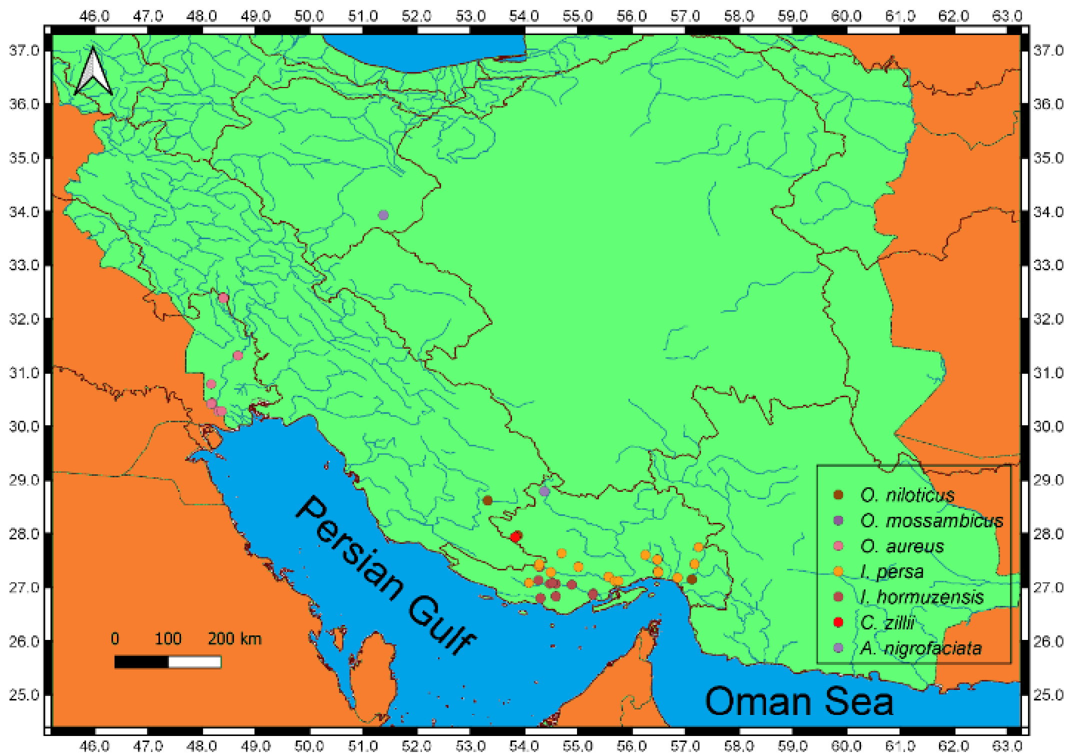

Fig.3. Distribution map of endemic and alien cichlids in inland water bodies of Iran.

Fig.4. *Oreochromis niloticus* collected from Minab Dam, Minab River drainage, Makran basin, Iran.

and authorities used for Cichliformes follow those of the online electronic version of the Catalog of Fishes (Fricke et al. 2025). English/common names are provided. The IUCN Red List of threatened species was followed to show the conservation status of each species (IUCN 2025).

The cichliform fishes comprise 1768 species, 262 genera and three families including Polycentridae (4 genera, 5 species), Cichlidae (257 genera, 1761 species in 4 subfamilies: Etroplinae, Ptychochrominae, Pseudocrenilabrinae, and Cichlinae), and Pholidichthyidae (1 genus, and 1

Table 1. Morphological and meristic characteristics of Nile tilapia from Minab Dam, Minab River drainage, Hormuzgan prov.

	Minimum	Maximum	Mean	Std. Deviation
Standard length	21.6	24.7	23.36	
In Standard length percent				
Head length	28.51	36.28	32.76	1.90
Body depth	38.63	44.44	41.40	1.41
Predorsal fin length	35.84	40.33	38.30	1.75
Postdorsal fin length	12.96	15.85	14.73	0.87
Prepectoral fin length	32.14	38.10	34.81	1.88
Preanal fin length	66.26	79.28	74.55	3.54
Postanal fin length	13.84	16.67	15.48	0.89
In Head length percent				
Eye diameter	17.86	24.64	20.58	1.79
Meristic				
Lateral line scales	30	33		
Scales in upper lateral line	5	6		
Scales in lower lateral line	9	10		
Dorsal spines	15	16		
Dorsal soft rays	11	12		
Anal spines	3	3		
Anal soft rays	9	10		
Pelvic-fin unbranched rays	1	1		
Pelvic- fin branched rays	5	5		
Pectoral-fin rays	12	13		
Gill rakers	18	28		

species) (Fricke et al. 2025). Cichliformes, particularly the cichlids of the family Cichlidae, are a highly diverse and ecologically significant order of bony fishes. They live in freshwater and occasionally in brackish waters of Central and South America (one species extending north to Texas), West Indies, Africa, Madagascar, Iran, parts of the Levant Syria, coastal India, and Sri Lanka (Nelson et al. 2016). Their unique adaptations, impressive biodiversity, and the various challenges they face in terms of conservation make them a fascinating subject of study in both ecology and evolutionary biology. Cichlids play crucial roles in their ecosystems, acting as both predators and prey. Their diverse feeding habits help maintain the ecological balance in freshwater environments. Cichlid fishes are known for their complex social behaviors and reproductive strategies (Balshine & Abate 2021). Cichlid fishes are champion caregivers that exhibit parental care and protect, clean, aerate, and sometimes even feed their young. About 1/3 of species guard young on the ground (substrate guarding) which is the ancestral form of care, and about 2/3 of the species guard young in their mouth (mouthbrooder), (Balshine & Abate 2021). The variation in sex of the caregiver includes biparental care (42% of species: the ancestral form) and female-only care (58% of species: the derived state), (Balshine & Abate 2021). Females of both endemic cichlids of Iran (*Iranocichla hormuzensis*, *I. persa*) are mouthbrooding species, where the young are carried in the female mouth for protection. Native cichlids face various threats, including habitat loss, pollution, and the introduction of invasive species. Some species are endangered or threatened due to these impacts on

Fig.5. Minab Dam, Minab River drainage, Makran basin, Iran, a new habitat for alien cichlids *Oreochromis niloticus*, and *O. mossambicus.*

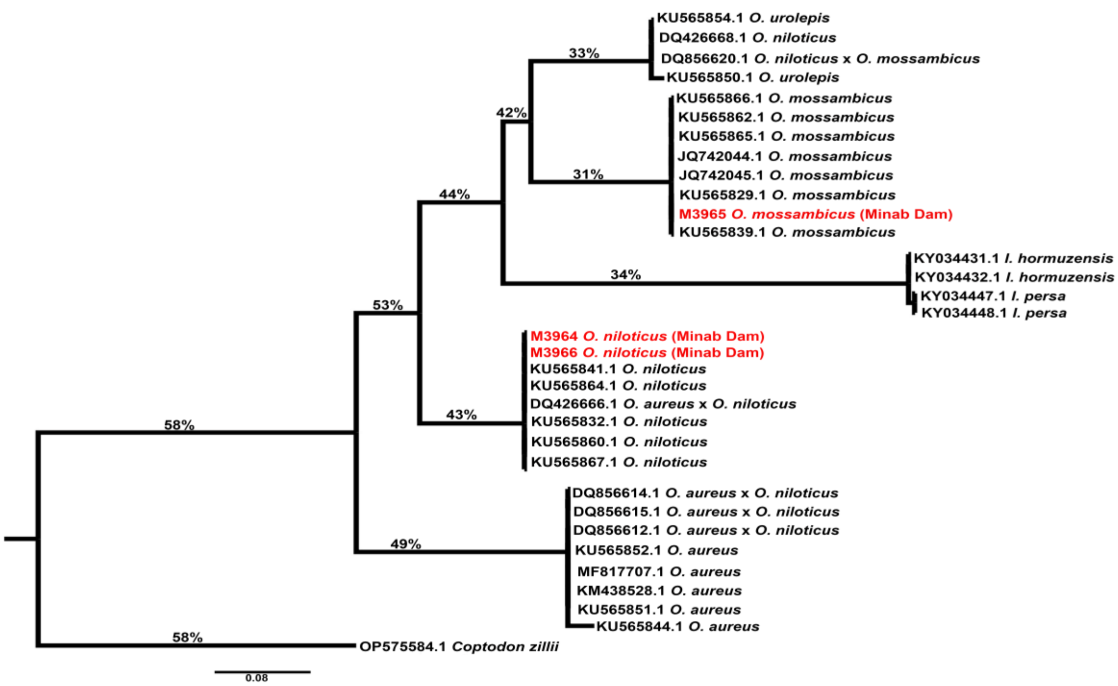

Fig.6. The maximum likelihood phylogenetic tree generated by RAxML showing the evolutionary relationships among studied cichlid species. Numbers on the tree show bootstrap values.

their natural habitats.

Cichlids are important in aquaculture for food production in some regions, and many of the species are also popular in the international aquarium trade due to their colors and behaviors which are two main reasons for global introduction and reciprocally establishment and invasion of some cichlids.

Cichlidae Bonaparte, 1835 (cichlids)

The family Cichlidae comprises 257 genera, 1,761 species in 4 subfamilies: Etroplinae, Ptychochrominae, Pseudocrenilabrinae, and Cichlinae), and Pholidichthyidae (Fricke et al. 2025), accounting for about 4.7% of all valid fish species (37,140), and about 9.3% of all valid freshwater fish species (18,915). It is one of the largest vertebrate families, with only the Cyprinidae being more speciose (Fricke et al. 2025). They are generally small, mainly freshwater fishes mainly found in East Africa (up to about 1300 species) and Central and South America (about 400 species), with smaller numbers in the Middle East and Asia (Berkovitz & Shellis 2023), although some species have been introduced worldwide. Many cichlids, particularly tilapia, are important food fishes, while others, such as the *Cichla* species, are valued game fish. The family also includes many popular freshwater fish kept by hobbyists, including the angelfish, oscars, and discus (Loiselle 1994).

1- *Amatitlania nigrofasciata* (Günther, 1867)

English Common name: Convict cichlid

Taxonomy: Original description: *Heros nigrofasciatus* Günther, 1867: 601 [Lake Amatitlán, Guatemala; lectotype: BMNH 1865.4.29.76].

Middle Eastern synonyms: *Cichlasoma nigrofasciatum* (Günther, 1867); *Archocentrus nigrofasciatus* (Günther, 1867); *Cryptoheros nigrofasciatus* (Günther, 1867).

Revisions: Schmitter-Soto (2007: 49).

Illustrations: Lee et al. (1980: 767, fig.) as *Cichlasoma nigrofasciatum.*

Distribution. *General distribution:* Central America: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama; introduced in Puerto Rico, Hawaiian Islands, Mexico, Réunion, in Middle East, Philippines and Australia.

Distribution in Iranian Freshwater Basins and adjacent regions: parts of the Levant, Iran.

Distribution in Ecoregions: 438-Jordan River, 447-Namak, 451-Northern Hormuz Drainages.

Habitat: This species prefers rocky and sandy habitats with tree branches and leaf litter, finding sanctuary in the various cracks and crevices provided by this type of environment, or among roots and debris. — Freshwater.

Economic importance: Valuable for the aquarium trade.

Reasons of introduction: Ornamental fish industry.

Conservation: Not relevant (introduced species).

Status in Iran: [Exotic]. — Cichlid-e gore khari. — First record from Iran by Esmaeili et al. (2013); listed in previous checklists from Iran by Esmaeili et al. (2017, 2018); Jouladeh-Roudbar et al. (2020); Eagderi et al. (2022); Sayyadzadeh & Esmaeili (2023). — Distribution in River Basin: 15-Namak Lake, 2-Hormuz. — Iran material: ZM-CBSU.

Status in the Levant: [Exotic]. — None. — First record from parts of the Levant by Goren (1983) as *Cichlasoma nigrofasciatum;* confirmed by Goren & Ortal (1999), Golani et al. (2022) as *Cichlasoma nigrofasciatum*; listed by Çiçek et al. (2023c). — Distribution in River Basin: 2-Dead Sea Basin. — parts of the Levant material: HUJ.

Comment: Esmaeili et al. (2013a) documented the first record of the convict cichlid, *Amatitlania nigrofasciata* specimens collected from the Golabi Spring, a fresh warm water site in the Kol River (Hormuzgan River drainage, Persian Gulf basin) in 2011 (Fig. 3). New collections in 2017 revealed that the population is still found in the same locality, and it has been established. It has also been recorded from Soleiman Spring, Namak Lake basin by Mousavi-Sabet & Eagderi (2016). *Amatitlania nigrofasciata* is native to Central America but has been introduced to some other countries causing harm to native fishes due to its aggressive and territorial behavior (Bassleer 1997; Wisenden 1994; Mrtinez 2002).

2- *Coptodon zillii* (Gervais, 1848)

English Common name: Redbelly tilapia

Taxonomy: Original description: *Acerina zillii* Gervais, 1848: 203 [Artesian well, Tuggurth, Algeria; syntypes: MNHN (lost)].

Middle Eastern synonyms: *Tilapia zillii* (Gervais, 1848); *Chromis andreae* Günther, 1865.

Revisions: Dunz & Schliewen (2013: 73).

Illustrations: Krupp & Schneider (1989: 400, fig. 52);

Esmaeili (2021:309, fig. 17.13).

Distribution. General distribution: North Africa: Morocco east to Egypt, south to Nigeria and Central African Republic; Middle East: Syria south to Israel and Jordan. Introduced elsewhere.

Distribution in the Middle East: Iran, Iraq, Israel, Jordan, Lebanon, Syria, and Türkiye.

Distribution in Ecoregions: 429-Western Anatolia, 431-Central Anatolia, 432-Southern Anatolia, 436-Coastal Levant, 437-Orontes, 438-Jordan River, 442-Upper Tigris & Euphrates.

Habitat: This species inhabits a very wide range of habitats with flowing water, from fast-flowing headwaters and reservoirs to polluted canals and large lowland rivers. It is the most environmentally tolerant of all tilapia species, tolerating lack of oxygen, pollution, salinity, etc. Low water temperatures (below 10-13ºC) limit its occurrence. — Freshwater, brackish.

Economic importance: Commercially important.

Reasons of introduction: Aquaculture/research.

Conservation: IUCN: LC (IUCN, 2023).

Threats: ABS, CON, CLI, EUT, FIT, HAB. — Low sensitivity to human activities. — Not considered a keystone species. — Decline status: Unknown. — Low priority for conservation action.

Status in Iran: [Exotic]. — Tilapia-e shekam ghermez. — It was first reported by Khaefi et al. (2014) from Shadegan Internation wetland, southwestern Iran. Listed in previous checklists from Iran by Esmaeili et al. (2017, 2018); Jouladeh-Roudbar et al. (2020); Eagderi et al. (2022), Sayyadzadeh & Esmaeili (2024). — Distribution in River Basin: 4-Tigris, 1-Persis. — Iran material: ZM-CBSU.

Status in Iraq: [Exotic]. — Bulti. — First record from Iraq by Saleh (2007) (Tigris River); Al-Saadi et al. (2012) (Euphrates River); confirmed by Jawad et al. (2019) (Shatt al-Arab River). — Distribution in River Basin: 1- Tigris, 2-Euphrates, 3-Shatt al-Arab. — Iraq materials: Fish Collection of the Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, Basrah, Iraq; Fish collection at the Marine Science Centre, University of Basrah, Basrah, Iraq.

Status in the Levant: [Native]. — Amnun matzui. — First record from Israel by Günther (1865: 490), Lortet (1883: 142) and Tristram (1884: 165) as *Chromis andreae;* confirmed by Steinitz (1953: 217) as *Tilapia zillii*, Goren (1974: 103 as *Tilapia zillii*), Goren & Ortal (1999: 4) as *Tilapia zillii*. — Distribution in River Basin: 1-Western Basin. — Israel material: HUJ.

Status in Jordan: [Native]. — Bulti mosambiki. — It is probable that this species in naturally distributed in the country. — Jordan material: None.

Status in Lebanon: [Native]. — Mesht mosambiki. — First record from Lebanon by Chervinski (1983). — Lebanon material: None.

Status in Syria: [Native]. — Mesht zili, marmour. — First record from Syria by El Bolock & Koura (1961); confirmed by Beckman (1962: 60) as *Tilapia zilli*, Saad et al. (2006), and Barakat et al. (2020). — Distribution in River Basin: 3-Desert, 4-Orontes, 5-Barada & Awaj, 6-Coastal, 7-Al-Yarmouk. — Syrian material: MNHN, MSL.

Status in Türkiye: [Exotic]. — Tilapya-parts of the Levant çipurası-Tatlı su çipurası. — Listed in previous checklists from Türkiye by Kuru (2004) as *Tilapia zillii*; Geldiay & Balik (2007) as *Tilapia zillii*; Fricke et al. (2007); Kuru et al. (2014); Çiçek et al. (2015, 2020, 2021, 2022a). — Distribution in River Basin: 8-Batı Akdeniz, 9-Antalya, 10-Burdur, 17-Doğu Akdeniz, 18-Seyhan, 19-Asi, 20-Ceyhan. — Turkish material: None.

3- *Iranocichla hormuzensis* Coad, 1982

English Common name: Hormuz cichlid

Taxonomy: Original description: *Iranocichla hormuzensis* Coad, 1982: 29, figs. 1-3 [Mehran River, Hormozdgan Province, southern Iran, 27°04'N, 54°35'E; holotype: NMC 79-0408A].

Middle Eastern synonyms: None.

Revisions: Esmaeili et al. (2016b).

Illustrations: Coad (1982: 29, fig. 1); Esmaeili et al. (2016b: 155, Fig. 11).

Distribution. General distribution: Middle East: Hormuz River drainage, Persian Gulf basin.

Distribution in the Middle East: Iran.

Distribution in Ecoregions: 451-Northern Hormuz Drainages.

Habitat: Streams are 1 to 50m wide and consist of alternating riffles and pools with occasional backwaters. The bottom is pebbles, sand, or mud. Aquatic vegetation is restricted to encrusting algae (Coad 2021). — Freshwater, brackish.

Economic importance: Esmaeili et al. (2009) note that it is eaten by local people when available in large numbers in spring. It is now an aquarium fish in Germany (Coad, 2021).

Conservation: IUCN: NE (2023).

Threats: Unknown. — High sensitivity to human activities. — Keystone species. — Decline status: Unknown. — Moderate priority for conservation action.

Status in Iran: [Endemic]. — Cichlid-e Hormuz. — Recorded from Iran in the original description by Coad (1982) and listed in previous checklists from Iran by Esmaeili et al. (2010, 2017, 2018); Jouladeh-Roudbar et al. (2020); Eagderi et al. (2022), Sayyadzadeh & Esmaeili (2024). — Distribution in River Basin: 2-Hormuz. — Iran material: NMC, ZM-CBSU.

4- *Iranocichla persa* Esmaeili, Sayyadzadeh & Seehausen, 2016

English Common name: Persis cichlid

Taxonomy: Original description: *Iranocichla persa* Esmaeili, Sayyadzadeh & Seehausen, 2016: 144, Figs. 3-5 [Hormugzan province, Shur River approx. 30 km east of Bandar Abbas, Iran, 27°17'40.10"N, 56°29'15.68"E; holotype: ZM-CBSU IP66].

Middle Eastern synonyms: None.

Revisions: None.

Illustrations: Esmaeili et al. (2016: 144, Figs. 3-5).

Distribution. General distribution: Middle East: Shur, Hasanlangi and Minab River drainages flowing to the Persian Gulf at the Strait of Hormuz (Iran).

Distribution in the Middle East: Iran.

Distribution in Ecoregions: 451-Northern Hormuz Drainages, 701-Baluchistan.

Habitat: Streams are 1 to 50m wide and consist of alternating riffles and pools with occasional backwaters. The bottom is pebbles, sand, or mud. Aquatic vegetation is restricted to encrusting algae. — Freshwater, brackish.

Economic importance: Locally commercially important. Has potential to be used as aquarium fish.

Conservation: IUCN: NE (2023).

Threats: Unknown. — High sensitivity to human activities. — Keystone species. — Decline status: Unknown. — Moderate priority for conservation action.

Status in Iran: [Endemic]. — Cichlid-e Parsi. — Recorded from Iran in the original description by Esmaeili et al. (2016) and listed in previous checklists from Iran by Esmaeili et al. (2017, 2018); Eagderi et al. (2022), Sayyadzadeh & Esmaeili (2024). — Distribution in River Basin: 3-Makran. — Iran material: ZM-CBSU.

5- *Iranocichla* sp.

English Common name: Kol cichlid

Taxonomy: Remarks. This species has yet to be identified to species level (see Schwarzer et al. 2016).

Middle Eastern synonyms: None.

Revisions: None.

Illustrations: Esmaeili et al. (2016b: 154, Fig. 10).

Distribution. General distribution: Middle East: Hormuz (Kol River drainages (Iran).

Distribution in the Middle East: Iran.

Distribution in Ecoregions: 451-Northern Hormuz Drainages.

Habitat: Streams are 1 to 50m wide and consist of alternating riffles and pools with occasional backwaters. The bottom is pebbles, sand, or mud. Aquatic vegetation is restricted to encrusting algae. — Freshwater, brackish.

Economic importance: Locally commercially important. Has potential to be used as aquarium fish.

Conservation: IUCN: NE (2023).

Threats: Unknown. — High sensitivity to human activities. — Keystone species. — Decline status: Unknown. — Moderate priority for conservation action.

Status in Iran: [Endemic]. — Cichlid-e kol. — Recorded from Iran by Esmaeili et al. (2016); Schwarzer et al. (2016); listed in previous checklists from Iran by Esmaeili et al. (2017, 2018); Eagderi et al. (2022); Sayyadzadeh & Esmaeili (2024). — Distribution in River Basin: 2-Hormuz. — Iran material: ZM-CBSU.

6- *Oreochromis aureus* (Steindachner, 1864)

English Common name: Blue tilapia

Taxonomy: Original description: *Chromis aureus* Steindachner, 1864: 229, pl. 8, fig. 5 [locality unknown; no types known].

Middle Eastern synonyms: *Tilapia aurea* (Steindachner, 1864).

Revisions: Trewavas (1965: 265) as *Tilapia aurea;* Trewavas (1982: 12).

Illustrations: Steindachner (1864: 229, pl. 8, fig. 5); Esmaeili (2021: 310, fig. 17.4).

Distribution. General distribution: Middle East and Africa. Introduced widely elsewhere.

Distribution in the Middle East: Iran, Iraq, Israel, Jordan, Lebanon, Saudi Arabia, Syria, Türkiye.

Distribution in Ecoregions: 429-Western Anatolia, 432-Southern Anatolia, 436-Coastal Levant, 437-Orontes, 438-Jordan River, 441-Lower Tigris & Euphrates, 442-Upper Tigris & Euphrates.

Habitat: This species inhabits a very wide range of flowing water habitats, from fast-flowing headwaters and reservoirs to polluted canals and large lowland rivers. It is the most environmentally tolerant of all tilapia species, tolerating lack of oxygen, pollution, salinity, etc. Low water temperatures (below 10-13ºC) limit its occurrence. — Freshwater, brackish.

Economic importance: Locally commercially important.

Reasons of introduction: Aquaculture/research.

Conservation: IUCN: NE (2023).

Threats: Unknown. — Low sensitivity to human activities. — Not considered a keystone species. — Decline status: Unknown. — Low priority for conservation action.

Status in Iran: [Exotic]. — Tilapi-e Abi. — Listed in previous checklists from Iran by Esmaeili et al. (2017, 2018); Jouladeh-Roudbar et al. (2020); Eagderi et al. (2022); Sayyadzadeh & Esmaeili (2024). — Distribution in River Basin: 4-Tigris. — Iran material: IMNRF-UT.

Status in Iraq: [Exotic]. — Bulti. — First record from Iraq by Mutlak and Al-Faisal (2009); confirmed by Al-Faisal et al. (2014); listed by Çiçek et al. (2023b). — Distribution in River Basin: 1- Tigris, 2-Euphrates, 3-Shatt al-Arab. — Iraq materials: MSCUB.

Status in the Levant: [Native]. — Amnun ha'yarden. — First record from Israel by Günther (1869) as *Tilapia aurea;* confirmed by Goren (1974: 102) as *Tilapia aurea*, Goren & Ortal (1999: 4); listed by Çiçek et al. (2023c). — Distribution in River Basin: 2-Dead Sea Basin, 3-Kinneret Basin. — Israel material: HUJ.

Status in Jordan: [Exotic]. — Bulti azrak. — It is probable that this species introduced to the country. — Jordan material: None.

Status in Lebanon: [Exotic]. — Mesht azrak. — It is probable that this species introduced to the country. — Lebanon material: None.

Status in Saudi Arabia: [Exotic]. — Balti azrak. — First record from Saudi Arabia by Al-Kahem-Al-Balawi et al. (2008); confirmed by Freyhof et al. (2020); Esmaeili & Hamidan (2023). — Saudi Arabia material: None.

Status in Syria: [Exotic]. — Mesht azrak. — According to Coad (1996), this species recorded from Syria by F. Krupp (1988) reports capture of a specimen from the Khabour River in Syria, presumably an escape from a fish farm in the basin of this tributary of the Euphrates River. Subsequently recorded Ali (2003); Saad et al. (2006); Saad (2010); listed by Saad et al. (2023). — Distribution in River Basin: 1-Dajleh & Khabour, 2-Euphrates & Aleppo, 3-Desert, 4-Orontes, 5-Barada & Awaj, 6-Coastal, 7-Al-Yarmouk. — Syrian material: MSL.

Status in Türkiye: [Exotic]. — Tilapya-parts of the Levant çipurası-Tatlı su çipurası. — Listed in previous checklists from Türkiye by Geldiay & Balik (2007); Fricke et al. (2007); Kuru et al. (2014); Çiçek et al. (2015, 2020, 2021, 2022a). —

Distribution in River Basin: 17-Doğu Akdeniz, 18-Seyhan, 19-Asi, 20-Ceyhan. — Turkish material: None.

7- *Oreochromis mossambicus* (Peters, 1852) (new record for Iran)

English Common name: Mozambique tilapia

Taxonomy: Original description: *Chromis (Tilapia) mossambicus* Peters, 1852: 681 [Zambezi River, Mozambique (East Africa); syntypes: BMNH [ex Peters] 1861.5.2.58-59 (2), FMNH 54267 [ex CM 2898] (2) Mosambique; ZMB 2805-06 (2, 1), 16035 (3), 31564 (15)].

Middle Eastern synonyms: *Tilapia mossambica* (Peters, 1852); *Sarotherodon mossambicus* (Peters, 1852); *Oreochromis mossambica* (Peters, 1852); *Oreochromis mosambica* (Peters, 1852).

Revisions: None.

Illustrations: Lee et al. (1980: 774) as *Tilapia mossambica*.

Distribution. General distribution: Southeastern Africa; introduced widely elsewhere.

Distribution in the Middle East: Israel, Saudi Arabia, UAE, Yemen, and now in Iran.

Distribution in Ecoregions: 439-Southwestern Arabian Coast, 443-Oman Mountains, 701-Baluchistan.

Habitat: This species occurs in all but fast flowing waters and thrives in standing waters. Further south in its range it is most common in blind estuaries and coastal lakes where it tolerates brackish and marine environments. It feeds on algae, especially diatoms, and detritus, large individuals also take insects and other invertebrates. — Freshwater.

Economic importance: No commercial in Israel, elsewhere commercially important.

Reasons of introduction: Aquaculture/research.

Conservation: Not relevant (introduced species).

Status in Israel: [Exotic]. — Amnun mozambiq. — First record from Israel by Golani & Lerner (2007); confirmed by Golani & Lerner (2007); listed by Çiçek et al. (2023c). — Distribution in River Basin: 2-Dead Sea Basin. — Israel material: HUJ.

Status in Saudi Arabia: [Exotic]. — Buti, mozambiki. — First record from Saudi Arabia by Al-Kahem-Al-Balawi et al. (2008); listed in previous checklists from Saudi Arabia by Freyhof et al. (2020); Esmaeili & Hamidan (2023). — Saudi Arabia material: None.

Status in UAE: [Exotic]. — Bulti, mozambiki. — First record from UAE by Freyhof et al. (2020); confirmed by Esmaeili & Hamidan (2023). — UAE material: None.

Status in Yemen: [Exotic]. — Bulti, mozambiki. — First record from Yemen by Freyhof et al. (2020); confirmed by Esmaeili & Hamidan (2023). — Yemen material: None.

Status in Iran: [Exotic]. In this study, we record it for the first time based on a single specimen collected from Minab Artificial Dam, Hormuzgan, Iran.

8- *Oreochromis niloticus* (Linnaeus, 1758)

English Common name: Nile tilapia

Taxonomy: Original description: *Perca niloticus* Linnaeus, 1758: 290 [Nile River; holotype: ?NRM LP 10].

Middle Eastern synonyms: *Perca nilotica* Linnaeus, 1758; *Tilapia nilotica* (Linnaeus, 1758); *Chromis niloticus* (Linnaeus, 1758); *Tilapia vulcani* Trewavas, 1933.

Revisions: None.

Illustrations: Ye in Pan et al. (1991: 416, fig. 248) as *Tilapia nilotica*, Teugels & Thys van den Audenaerde in Lévêque et al. (1992: 761, fig. 49.36); Esmaeili et al. (2022b: 490, fig. 46).

Distribution. General distribution: North Africa and East Africa. Widely introduced elsewhere.

Distribution in the Middle East: Iran, Iraq, Israel, Jordan, Lebanon, Oman, Saudi Arabia, Syria, Türkiye, UAE, and Yemen.

Distribution in Ecoregions: 432-Southern Anatolia, 436-Coastal Levant, 437-Orontes, 438-Jordan River, 442-Upper Tigris & Euphrates, 701-Baluchistan.

Habitat: This species inhabits a very wide range of flowing water habitats, from fast-flowing headwaters and reservoirs to polluted canals and large lowland rivers. It is the most environmentally tolerant of all tilapia species, tolerating lack of oxygen, pollution, salinity, etc. Low water temperatures (below 10-13°C) limit its occurrence. — Freshwater.

Economic importance: Locally commercially important.

Reasons of introduction: Aquaculture/research.

Conservation: Not relevant (introduced species).

Status in Iran: [Exotic]. — Tilapia-e Nil. — Listed in previous checklists from Iran by Jouladeh-Roudbar et al. (2020); Eagderi et al. (2022); Sayyadzadeh & Esmaeili (2024). — Distribution in River Basin: 1-Persis, 2-Minab River drainage. — Iran material: ZM-CBSU.

In this study, we record it for the first time based on a single specimen collected from Minab Artificial Dam, Hormuzgan, Iran.

Status in Iraq: [Exotic]. — Bulti. — First record from Iraq by Al-Faisal & Mutlak (2014); confirmed by Mohamed & Al-Wan (2020). — Distribution in River Basin: 1- Tigris, 2-Euphrates, 3-Shatt al-Arab. — Iraq materials: Fish Collection of the Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, Basrah, Iraq; Fish collection at the Marine Science Centre, University of Basrah, Basrah, Iraq.

Status in parts of the Levant: [Exotic]. — Amnun ha'yeor. — First record from Israel by Lortet (1883: 137) and Tristram (1884: 164) as *Chromis niloticus*, and by Steinitz (1953: 217) as *Tilapia nilotica exul*, Fishelson (1962) as *Tilapia nilotica;* confirmed by Goren (1974: 102) as *Tilapia nilotica*, Goren & Ortal (1999: 4); listed by Çiçek et al. (2023c). — Distribution in River Basin: 1-Western Basin. — Israel material: None.

Status in Oman: [Exotic]. — Bulti nili. — It is probable that this species introduced to the country. — Oman material: None.

Status in Saudi Arabia: [Exotic]. — Bulti nili. — Listed in previous checklists from Saudi Arabia by Freyhof et al. (2020); Esmaeili & Hamidan (2023). — Saudi Arabia material: None.

Status in Syria: [Exotic]. — Mesht Nili. — First record from Syria by El Bolock & Koura (1961); confirmed by Beckman (1962: 58 as *Tilapia nilotica*); listed by Saad et al. (2023). — Distribution in River Basin: 1-Dajleh & Khabour, 2-Euphrates & Aleppo, 3-Desert, 4-Orontes, 5-Barada & Awaj, 6-Coastal, 7-Al-Yarmouk. — Syrian materials: MSL.

Status in Türkiye: [Exotic]. — Tilapya-parts of the Levant çipurası-Tatlı su çipurası. — Listed in previous checklists from Türkiye by Geldiay & Balik (2007); Fricke et al. (2007); Kuru et al. (2014); Çiçek et al. (2015, 2020, 2022a, 2023). — Distribution in River Basin: 17-Doğu Akdeniz, 18-Seyhan, 19-Asi, 20-Ceyhan. — Turkish materials: None.

Status in UAE: [Exotic]. — Bulti nili. — Listed in previous checklists from UAE by Freyhof et al. (2020) and Esmaeili & Hamidan (2023). — UAE material: None.

Status in Yemen: [Exotic]. — Bulti nili. — Listed in previous checklists from UAE by Freyhof et al. (2020) and Esmaeili & Hamidan (2023). — Yemen material: None.

New locality records: Herein, we report for the first time presence of two cichlid fishes from Minab Dam (Minab River drainage), Minab, Hormuzgan province, Iran (Figs. 4-6).

Morphological characteristics of endemic cichlids of Iran:

Iranocichla hormuzensis

(Figs. 7-8)

Dorsal fin with 14-16 spines and 9-11 branched rays; anal fin with 3 spines and 6-9 soft rays; pectoral fin with 11-12 soft rays; vertebrae 28-30; gill rakers 14-19; upper lateral line with 17-29 pored scales, lower lateral line with 9-12 pored scales, total lateral line scale series 28-40.

Description. Dental field on lower pharyngeal bone nearly circular; teeth of lower pharyngeal bone of uniform size, not enlarged medially; cheek, operculum, belly, isthmus and area between pectoral and pelvic fin-bases naked or poorly scaled; anal and dorsal fins rounded posteriorly; pectoral fins short, not reaching vent; scales cycloid, with granular posterior circuli bearing rounded or irregular protuberances; inferior apophysis for support of swimbladder centred around 4th vertebra; mesethmoid not meeting vomer;

Fig.7. *Iranocichla hormuzensis*, upper, ZM-CBSU-IH2, male, Hormuzgan prov.: Mehran River, lower, ZM-CBSU-IH50, female, Hormuzgan prov.: Dezghan River.

median length of lower pharyngeal bone 31.8-40.9% length of head; pharyngeal blade/median length toothed area 0.6-1.0 (Coad 1982).

Iranocichla persa

(Figs. 9-10)

Dorsal fin with 14-17 spines and 9½-10½ branched rays; anal fin with 3 spines and 6½-8½ soft rays; pelvic fin with 1 spine and 5 soft rays; pectoral fin with 11-12 soft rays; gill rakers 14-17; upper lateral line with 17-24 pored scales, lower lateral line with 9-13 pored scales.

Description. A small species with greatest body depth at approximately fifth dorsal-fin spine. Dorsal body profile convex from anterior part of dorsal fin to caudal peduncle. Ventral body profile straight or slightly convex between pelvic and anal fins. Dorsal head profile straight, slightly concave between nostrils and interorbital space. Head and eyes large. Mouth terminal, tip of upper and lower jaws at same vertical line (isognathous). Upper lip noticeably thickened, buccal region enlarged ventrally, oral teeth uniform in size and not enlarged medially.

Dorsal-fin base long, its origin at a vertical of pectoral-fin base, base of last dorsal-fin ray at vertical of posterior part of anal-fin base. Posterior dorsal-fin tip reaching to a point slightly in front of caudal-fin origin when folded back. Caudal fin truncate or slightly emarginated with 8+8 or 9+8 branched rays. Upper lateral line with 17-24 pored scales, starting from posterior tip of operculum to a vertical of 3rd-4th branched dorsal-fin ray.

Fig.8. Mehran River, Hormuzgan, Iran: natural habitat of *Iranocichla hormuzensis*.

Fig.9. *Iranocichla persa*, upper, ZM-CBSU-IP66, male, holotype, 89.54mm SL; Hormuzgan prov.: Shur River, lower, ZM-CBSU-IP73, female, paratype, 76 mm SL; Hormuzgan prov.: Khorgoo Hot Spring.

Fig.10. Khorgo Hot Spring, Hormuzgan, Iran: natural habitat of *Iranocichla persa*.

Lower lateral line reaching from a vertical of 3rd-4th branched dorsal-fin rays to caudal-fin base. Scales cycloid or having very small ctenius-like structure, regularly arranged on flanks except that in a few larger individuals (≥85 mm SL; 3 out of 9 specimens), where scale rows are interspaced by irregularly set smaller scales, particularly on the upper flank. Head without scales in some individuals, dorsal and anal fin bases without scales, no scale between the pectoral and pelvic fin bases and none on the belly and isthmus anterior to the pelvic fin. Upper margin of operculum without scales or with 1-2 large scales next to each other and subopercular bone without scales or with one scale at middle. Cheek without scales or with 1-3 rows of 1-7 almost non-imbricate scales. 11-12 rows of small scales on caudal-fin base, extending distally along more than half of the fin ray length in some individuals and extending distally along equal or less than half in some others.

Nuptial males with an orange breast and lower part of head and few roundish white spots on cheek and operculum. Females have a longer head on average (33-38% SL vs. 34-37% SL), a wider interorbital distance (26-39% HL vs. 27-33% HL) and shorter pelvic fin (16-20% SL vs. 17-23% SL) as compared to males.

Iranocichla persa is distinguished from *I. hormuzensis* by its nuptial coloration in males. In *I. persa*, the lower part of the head and breast are orange (vs. black), the background colour of the flank is grey with an orange hue (vs. black), each scale is furnished with an iridescent patch and these patches take up more space (vs. less) than the space between them, a poorly developed or invisible (vs. distinctive) “Tilapia-mark” in the dorsal fin, and very clear white spots making almost wavy bars or stripes on the caudal fin (vs. without or with very few white spots). Both species are also distinguished by multiple fixed molecular characters in mitochondrial ND2, D-loop (see Esmaeili et al. 2016; Schwarzer et al. 2016).

***Iranocichla* sp.**

(Fig. 11)

The *Iranocichla* populations from the Kol River drainage (including Lar, Faryab, Gode-Gaz, Tange-Dalan, and the Kol River itself) exhibit a mosaic of phenotypic traits intermediate between *I. persa* and another congener species *I. hormuzensis*, particularly in male breeding coloration, which correlates with major drainage divisions. Mitochondrial haplotypes from these populations are either nested within

Fig.11. *Iranocichla* sp., ZM-CBSU-IH24, male, Hormuzgan prov.: Faryab Hot Spring, Kol River drainage.

the *I. persa* clade or closely related, suggesting complex evolutionary dynamics (Esmaeili et al. 2016).

Schwarzer et al. (2016) proposed two primary scenarios for allopatric speciation based on genetic evidence (haplotype networks, demographic reconstruction, low diversity, and limited haplotype sharing):

i) Pleistocene Isolation: *Iranocichla* populations persisted separately in the Mehran and Kol River systems since their initial divergence (~160-318 thousand years ago), maintaining long-term isolation.

ii) Post-LGM Colonization: The Shur and Mehran River drainages (including the Rudan River) were colonized from the Kol River during or after the Last Glacial Maximum (LGM), possibly via rare dispersal across the Strait of Hormuz. Alternatively, clade B (Shur/Kol) may have diverged earlier, with the Shur River acting as a refugium during arid LGM phases, followed by later expansion into the Rudan and recolonization of the Kol system.

A third hypothesis might be also proposed. In this case, the Shur and Kol systems were colonized simultaneously, followed by divergence due to river capture, where the eastern Kol may have once drained into the Shur, later shifting westward. This could explain the admixture of haplotypes in the western Kol and the central positioning of Shur haplotypes in the network. Subsequent bottlenecks in the eastern Kol and Shur populations may have further shaped haplotype distributions without significant sequence divergence.

Despite these insights, the taxonomic classification of Kol River populations remains unresolved, necessitating further integrative (morphological, genomic, and ecological) research to clarify their evolutionary history and species boundaries.

Distribution map of three endemic cichlid fishes is given in Figure 12.

Morphological characteristics of alien cichlids of Iran

Amatitlania nigrofasciata

(Figs. 13-14)

Dorsal fin with 17-19 spines and 7-9 soft rays; anal fin with 8-10 spines and 6-7 soft rays; vertebrae 27-28; larg gill rakers elongated, rounded or pointed, curved ventrad; scales from lateral line to base of first dorsal-fin ray modally 2.5; circumpeduncular scales usually 17-19, modally 18.

Description. Body depth 46-50 % of SL, usually less than 48 % of SL. Head profile nearly straight on orbits to convex on nape. Teeth conical, pointed. Upper symphysial teeth abruptly larger than adjacent teeth; lower symphysial teeth lower than adjacent teeth. Lips not medially narrow; lower lip often tapering, corner dorsally rounded, ventrally angled. Pectoral fins always reaching caudad beyond 2 nd anal-fin spine, pelvic fins extending beyond 3 rd anal-fin spine. Filamentous rays

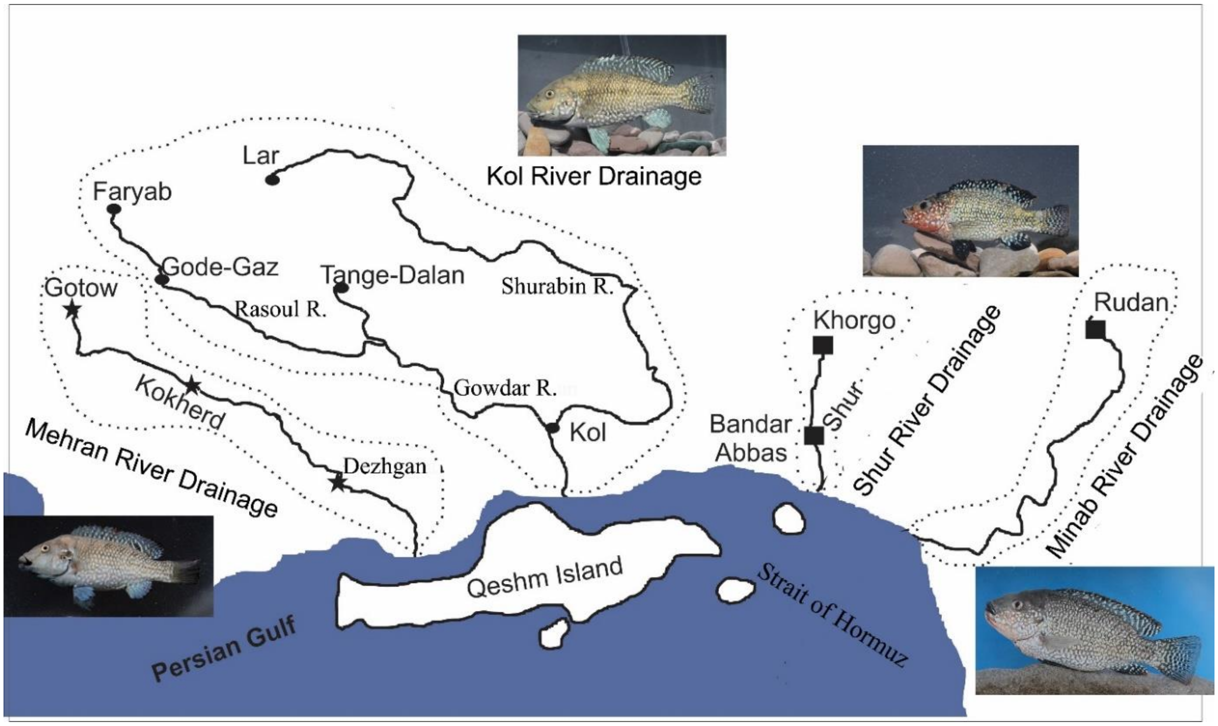

Fig.12. Geographic distribution map of endemic cichlid populations in 4 River drainages of Iran corresponding to *Iranocichla hormuzensis* (Mehran River drainage), *I. persa* (Shur and Minab River drainages), and *Iranocichla* sp. (Kol River drainage), (Esmaeili et al. 2026).

of dorsal fin to distal quarter of caudal fin. Up to two lateral-line pored scales on caudal fin, subsidiary scales usually present. Dorsal- and anal-fin interradial scale rows arranged in one or two rows, up to 8 scales long (contra Guenther 1869, who found the soft dorsal and anal fins to have "scarcely any scales on their base"). Gut simple, usually shorter than standard length of fish. Peritoneum silvery. Genital papilla tongue shaped, somewhat oval-tubular, slightly notched, tip bluntly triangular, not sunken; pigmented on margins, tip, and base on posterior (caudal) side. Suborbital streaks diffuse; stripes from snout to eye usually diffuse. Eyes bluish-green. Fourth bar on side of body I-shaped. Ocellus on spinous dorsal fin of females absent (present in 0.3 % of the specimens examined). Breast olive. Axil of pectoral fin dark; base of pectoral fin usually definitely white. Caudal blotch present as a bar on fin, not on peduncle (Schmitter-Soto 2007; GBIF 2025).

Tilapias

The word "Tilapia" is commonly used to refer to a group of relatively deep bodied African fish species that occupy lakes or slow-moving rivers, and have a generalist diet including plankton, aquatic plants, vegetative detritus and benthic invertebrates. Taxonomically speaking, all fish commonly referred to as "Tilapia" are within the family Cichlidae, an extremely diverse clade of freshwater fishes that are naturally distributed across Africa, the Middle East, the Neotropics and the Indian subcontinent. The "Tilapia" form part of the African-Middle Eastern subfamily, known as the Pseudocrenilabrinae, and are part of an evolutionary line within this subfamily called the Haplotilapiines (Genner et al. 2018). General morphology of Tilapia is given in Figure 15. The following species have been reported from Iran.

Coptodon zillii

(Figs. 16-17)

Dorsal fin with13-16 spines and 10-14 soft rays; anal fin with 3 spines and 8-10 soft rays; lower gill rakers 8-12.

Description. A large, deep-bodied species with a narrow head and small strong jaws; generally, has a bright red belly and prominent vertical barring (Genner et al. 2018). Upper profile of head not convex; lower pharyngeal bone about as long as broad, and with anterior lamella shorter than toothed

Fig.13. *Amatitlania nigrofasciata*, male (upper); female (lower); Fars prov.: Golabi Spring, Kol River drainage.

area; median pharyngeal teeth not broadened; dark longitudinal band appears on flanks when agitated; no bifurcated dark vertical bars on flanks; dorsal and caudal fins not or feebly blotched. Body brownish-olivaceous with an iridescent blue sheen; lips bright green. Chest pinkish. Dorsal, caudal and anal fins brownish-olivaceous with yellow spots, dorsal and anal fins outlined by narrow orange band; "tilapian" spot large, extending from last spine to 4th soft ray and always bordered by yellow band. Specimens of 2-14 cm standard length with completely yellowish or greyish caudal fin without dots but tend to develop a greyish caudal fin with dots of increasing size during development; above 14 cm standard length, this species has greyish caudal fins with dots on entire caudal fin. The sexes look very similar, although in a mated pair the male is usually larger (Genner et al. 2018).

The Redbelly tilapia is distinguished from other exotic cichlids of the Tigris-Euphrates by having three anal spines, outer teeth on jaws bicuspid, and 8-12 rakers on the lower part of gill arch and presence of 6-7 dark vertical bars cross two horizontal stripes.

Found in Karun, Dez, Jarahi and Mond Rivers. Also found in Shadegan and Hor Al Azim wetlands as well as Howba spring (Khaefi et al. 2014; Teimori et al. 2017; Jouladeh-Rudbali et al. 2020).

Fig.14. Invaded habitat of *Amatitlania nigrofasciata*, Fars prov.: Darab, Golabi Spring, Kol River drainage.

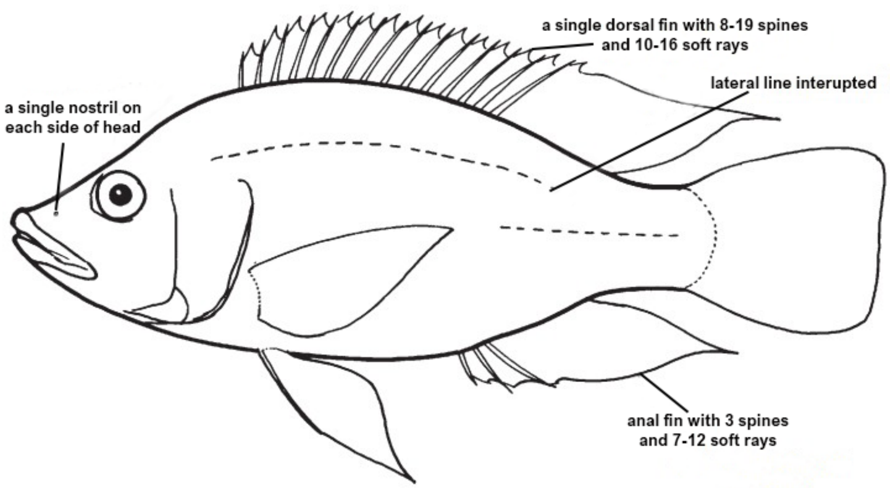

Fig.15. General morphology of a tilapia cichlid fish (Carpenter, 2001).

Oreochromis aureus

(Figs. 18-19)

Dorsal fin with 14-17 spines and 11-15 soft rays; anal fin with 3 spines and 8-11 soft rays; vertebrae 28-31; gill rakers 18-26.

Description. Adults: narrow preorbital bone (depth max. 21.5% of head length in fishes up to 21.3cm SL); lower pharyngeal jaw with short blade; no enlargement of the jaws in mature fish (lower jaw not exceeding and usually less than 36.8% head length) (Trewavas, 1983). Caudal without regular dark vertical stripes (Trewavas 1983; Teugels et al. 2003), but with a broad pink to bright red distal margin (Trewavas 1983). Breeding males assume an intense bright metallic blue on the head, a vermilion edge to the dorsal fin and a more intense pink on the caudal margin (Trewavas 1983). Breeding females with the edges of dorsal and caudal fins in a paler more orange

Fig.16. *Coptodon zillii* Khuzestan prov.: Shadegan Wetland, lower Tigris River drainage.

Fig.17. Invaded habitat of *Coptodon zillii*, Khuzestan prov.: Shadegan Wetland, lower Tigris River drainage.

color (Trewavas 1983). Juveniles: upper line of head profile running upward from snout at sharp angle; lower pharyngeal bone nearly triangular, teeth numerous but not densely crowded; dorsal and anal fin striped, with stripes running obliquely on the soft dorsal and longitudinally on the caudal fin; black Tilapia-mark on soft dorsal present; body dark; lower lip developed from beneath (Chervinski 1977).

Oreochromis aureus is distinguished from *O. niloticus* by having gill rakers 18-26 (vs. 27-33 in *O. niloticus*), dorsal-fin spines 15-16 (vs. 16-18 in *O. niloticus*), and absence of dark vertical stripes on the cauda l fin (vs. present in *O. niloticus*) (GBIF 2025).

In Iran, it was captured for the first time from the Arvand and Karun River drainages (Persian Gulf basin) in Khuzestan province by Valikhani et al. (2016).

Fig.18. *Oreochromis aureus*, 160 mm SL: Khuzestan prov.: Dezful, Dezful fish market, collected from lower Tigris River drainage.

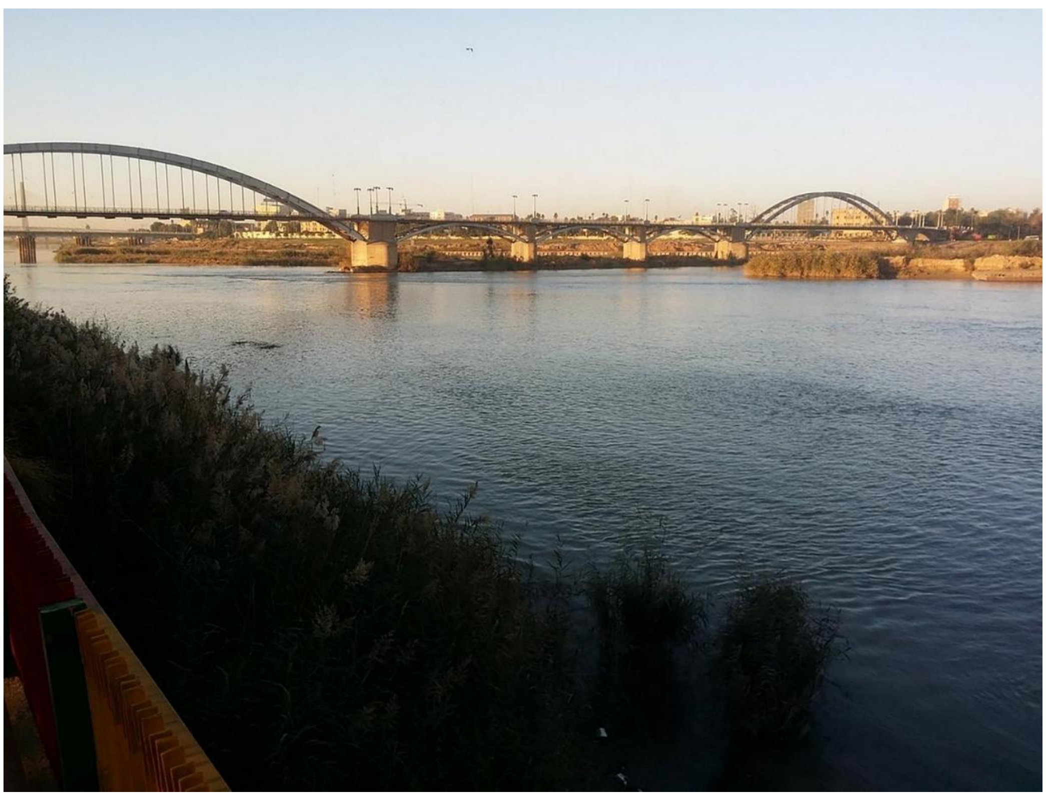

Fig.19. Karun River, lower Tigris River drainage. Khuzestan prov.: invaded by *Oreochromis aureus*.

Oreochromis mossambicus
(Figs. 5, 21)
Dorsal fin with 15-18 spines and 10-13 soft rays; anal fin with 3 spines and 7-12 soft rays; vertebrae 28-31; lower gill rakers 14-20 (modally 17 or 18).

Description. Snout long; forehead with relatively large scales, starting with 2 scales between the eyes followed by 9 scales up to the dorsal fin (Lamboj 2004). Adult males develop a pointed, duckbill-like snout due to enlarged jaws, often causing the upper

Fig.20. *Oreochromis mossambicus*, male, Zimbabwe (FishBase): https://www.fishbase.se/photos/PicturesSummary.php?resultPage=2&ID=3&what=species).

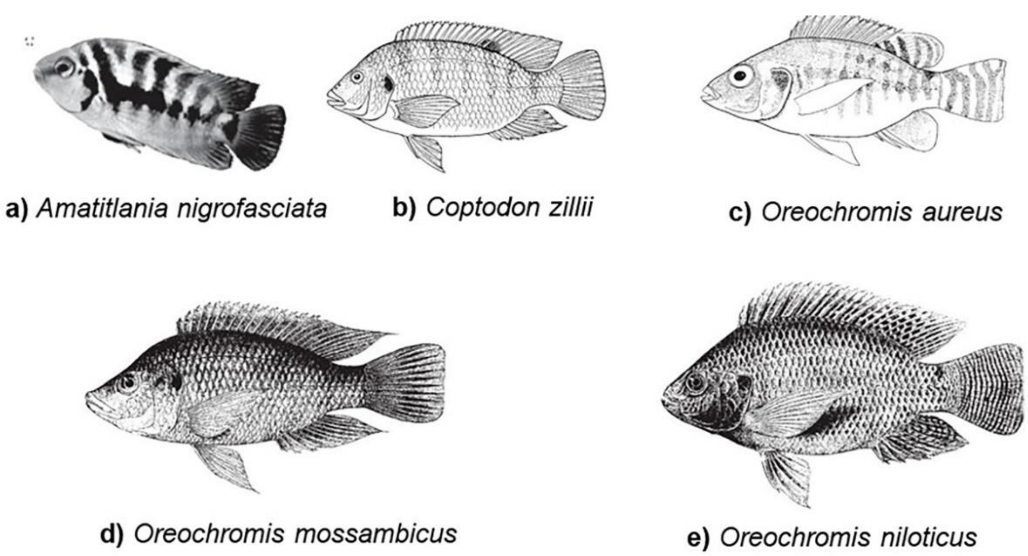

Fig.21. Schematic pictures of Tilapias (see key to species).

profile to b ecome concave (Trewavas 1983), but upper profile convex in smaller specimens. Pharyngeal teeth very fine, the dentigerous area with narrow lobes, the blade in adults longer than dentigerous areagenital papilla of males simple or with a shallow distal notch; caudal fin not densely scaled; female and non-breeding male silvery with 2-5 mid-lateral blotches and some of a more dorsal series; breeding male black with white lower parts of head and red margins to dorsal and caudal fins (Trewavas 1983).

It is recorded for the first time based on a single mtDNA sequence (Fig. 6) of collected specimen from Minab Dam, Minab River drainage, Hormuzgan, Iran.

Oreochromis niloticus

(Figs. 4-5)

Dorsal fin with 15-18 spines and 11-13 (15 in some) soft rays; anal fin with 3 spines and 9-11 soft rays; pectoral fin with 14-16, pelvic fin with 1 spines and 5 soft rays; vertebrae 30-32; lower gill rakers 18-24 (Trewavas 1983); upper lateral line with 21-23 pored

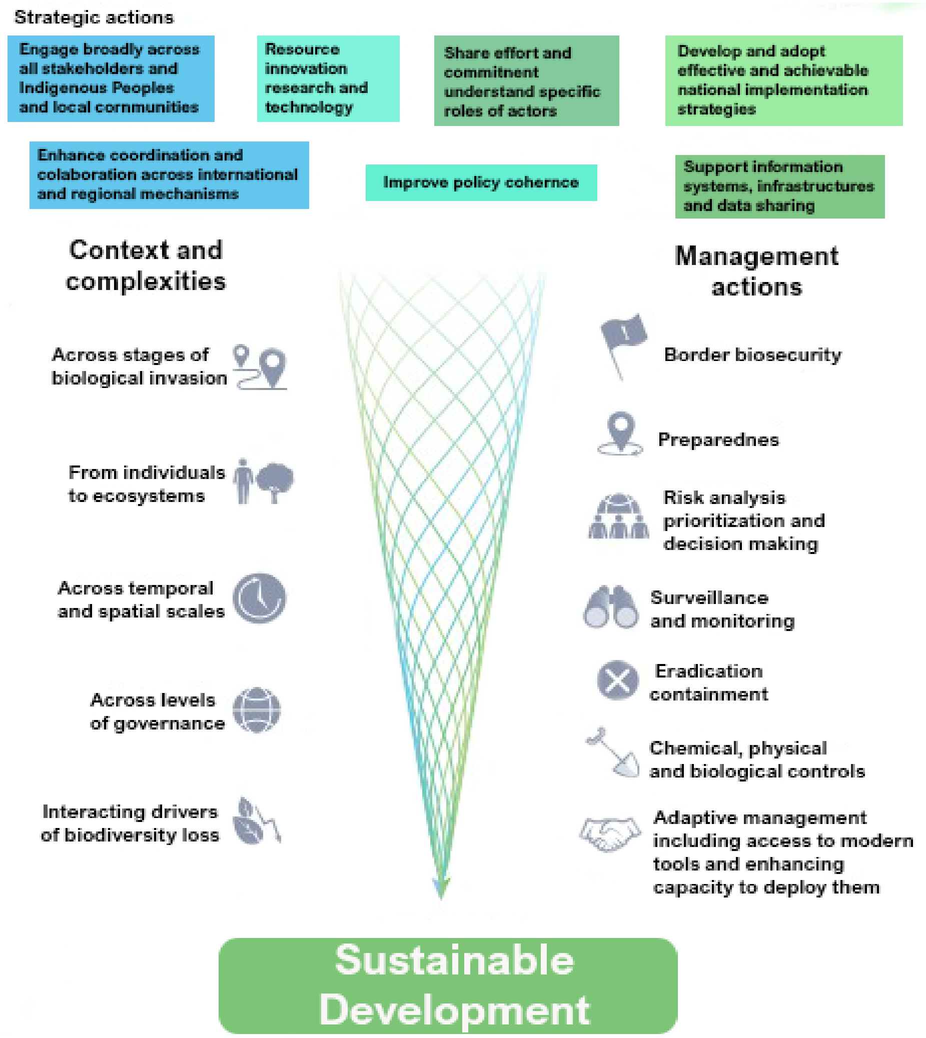

Fig.22. Integrated governance for the management of biological invasions (Roy et al. 2024).

scales, lower lateral line with 13-16 pored scales and longitudinal series with 30-35 scales, transversal series above upper lateral line with 4-5 scale rows and below lower lateral line with 8-12 scale row.

Description. A large deep-bodied tilapia, with a relatively small head (Genner et al. 2018). Mouth terminal; premaxilla and dentary with three or more teeth rows. Jaws of mature male not greatly enlarged, length of lower jaw 29-37% of head length; genital papilla of breeding male not tessellated (Trewavas 1983). Body depth 36-50% of SL (Bailey 1994). Most distinguishing characteristic is the presence of regular vertical stripes throughout depth of caudal fin (Eccles 1992; Teugels et al. 2003; Genner et al. 2018). In smaller fishes, these are relatively wide and form an arc and start at the base of the caudal fin (Genner et al. 2018). Ground color greyish to pale brown; black rounded blotch on posterior margin of opercle; dark-brown transverse bars on flank. Dorsal, anal and pelvic fins hyaline and scattered with dark-brown spots; caudal fin with dark-brown spots united forming transverse stripes. Maximum standard length. 200.0 mm (GBIF 2025). Males are bluish pink, sometimes with a dark throat, belly, anal and pelvic fins; females are usually brownish, silvery/white beneath with around 10 thin vertical bars (Genner et al. 2018).

Oreochromis niloticus is distinguished from *O. aureus* by having gill rakers 27-33 (vs. 18-26 in *O. aureus*), dorsal-fin spines 16-18 (vs. 15-16 *O.*

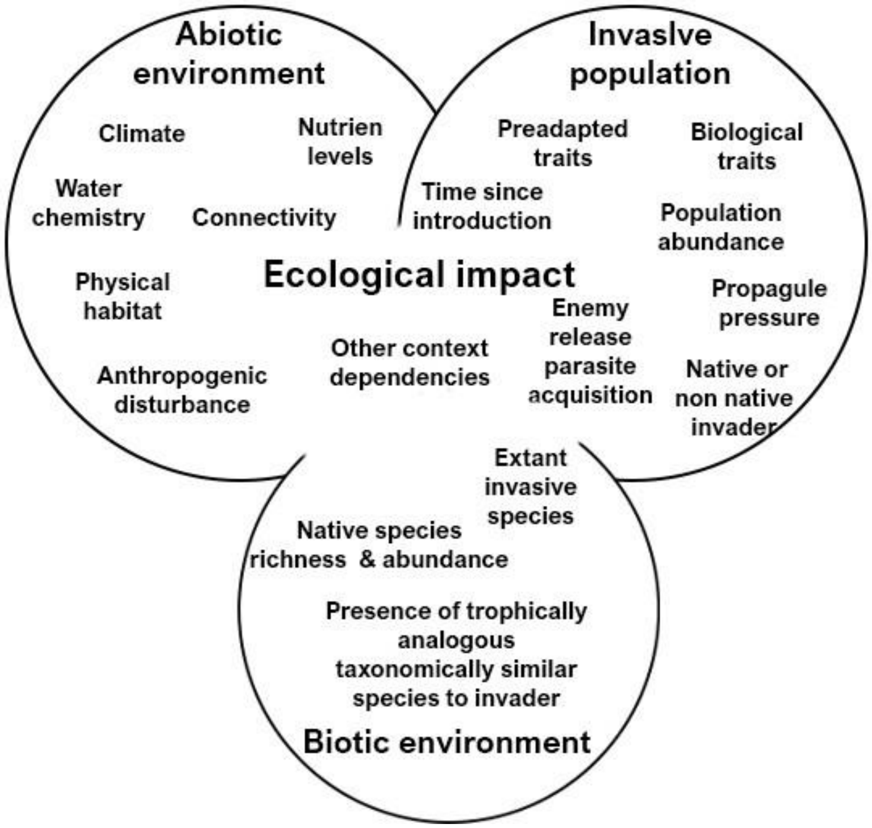

Fig.23. Summary of how the interactions between invasive fish populations and the abiotic and biotic elements of the receiving environment affect the ecological impact of the invaders (Britton 2023).

aureus), and presence of dark vertical stripes on the caudal fin (vs. absent in *O. aureus*) (GBIF 2025).

Key to alien cichlids of Iran

1a. Anal fin with 8-10 spines (Fig. 21a)....................................*Amatitlania nigrofasciata*

1b) Anal fin with 3 spine.......…...……………………….……………2

2a 8-12 gill rakers on lower limb of the gill arch: tilapia mark persisting into adulthood (Fig. 2)….…………………………….......*Coptodon zillii*

2b 19-28 gill rakers on lower limb of the first gill arch; tilapia mark lost in adulthood………………………3

3a Lower limb of first gill arch with 14 to 20 (modally 17 or 18) gill rakers; caudal fin without distinct dark narrow bars (Fig. 2)……..*Oreochromis mossambicus*

3b Lower limb of first gill arch with 18 to 28 (modally greater than 20) gill rakers; caudal fin with or without distinct narrow barsn……………………………………………..4

4a Caudal fin without prominent narrow dark bars, with a broad pink distal margin (Fig. 21c)……………….……………*Oreochromis aureus*

4b Caudal fin with distinct narrow dark bars, without a broad pink distal margin (Fig. 21e) ……………………….………*Oreochromis niloticus*

Molecular study: The maximum likelihood phylogenetic tree generated by RAxML elucidates the evolutionary relationships among Tilapia species, incorporating COI sequences from specimens collected from Minab Dam, Minab River drainage (Makran Basin). Based on the constructed tree (Fig. 6) three main clustering groups are shown. i) Oreochromis mossambicus cluster: Specimens from Minab Dam (e.g., M3965) group closely with from GenBank sequences of *O. mossambicus* (e.g., KU565866.1, JQ742044.1), confirming their taxonomic assignment. High consistency within this clade suggests minimal genetic divergence among *O. mossambicus* populations. ii) *Oreochromis niloticus* and hybrids cluster. Minab Dam samples (M3964, M3966) cluster with pure sequences *O. niloticus* from GenBank (e.g., KU565841.1, DO426668.1),

Fig.24. A putative hybrid, Taiwanese red tilapia or Mozambique tilapia × Nile tilapia (*O. mossambicus* × *O. niloticus*) from Minab Dam.

Table 2. Comparison of Mozambique tilapia×Nile tilapia with parental species.

Feature	*O. mossambicus*	Hybrid (*O. mossambicus* × *O. niloticus*)	*O. niloticus*
Body shape	Deep, robust	Intermediate	Streamlined
Color	Dull gray/pink	Olive-gray with faint bars	Brighter, distinct bars
Vertical bars	Absent or faint	Moderate (intermediate)	Prominent
Growth rate	Slow	Fast (closer to *O. niloticus*)	Very fast

validating their identification. Hybrids (*O. niloticus* x *O. mossambicus*, DQ856620.1; *O. aureus* x *O. niloticus*, DQ856614.1-DQ856612.1 form distinct subclades, reflecting intermediate genetic signatures. iii) *Oreochromis aureus* group: Sequences (e.g., KU565852.1, MF817707.1) form a monophyletic clade, separate from *O. niloticus* and hybrids, underscoring species-specific divergence. *Iranocichla hormuzensis* and *I. persa* (KY034431.1-KY034448.1), present evolutionary distinctions within tilapias.

The tree supports the presence of O. mossambicus and *O. niloticus* and hybrid tilapias in the Minab Dam, with implications for aquaculture management and biodiversity conservation. This phylogenetic analysis contributes to the understanding of speciation, genetic diversity, and hybridization in the *Oreochromis* lineage. Hybrid clusters suggest potential introgression, warranting further study to assess ecological impacts. It also provides a framework for future studies on evolutionary relationships, ecological adaptations, and conservation strategies for these crucial freshwater species.

DISCUSSION

Freshwater ecosystems harbor approximately 18,915 fish species, accounting for a quarter of all vertebrate biodiversity. However, these species are experiencing declines at rates surpassing those observed in other ecosystems (Dudgeon et al. 2006; Su et al. 2021; Xu et al. 2024). Among the key drivers of this decline, biological invasions have become increasingly significant (Xu et al. 2024). Globally, more than 500 non-native freshwater fish species have established populations, making them one of the most frequently introduced taxonomic groups (Bernery et al. 2022; Xu et al. 2024). Their proliferation has contributed to the biotic homogenization of freshwater fish assemblages (Villéger et al. 2011; Su et al. 2021; Xu et al. 2024), with profound ecological and socio-economic consequences (Cuthbert et al. 2021). Understanding the global distribution patterns of these non-native species and the factors driving their establishment in certain regions is critical for developing effective management strategies and predicting future invasion risks especially it is significant in the countries harboring great biodiversity including Iran.

Iran possesses a rich freshwater ichthyofauna in terms of diversity and endemism, and its ichthyofauna is characterized by i) having elements from Palearctic, Oriental, and Ethiopian ecoregions with exotics from the Nearctic and Neotropical origins (Sayyadzadeh & Esmaeili 2024), ii) being parts of two of the 36 world hotspots (Irano-Anatolian and Caucasus) with a high diversity of endemic species, iii) facing several natural and anthropological threats, and iv) having several taxonomic complex groups. In total, more than 300 species, belonging to 110 genera, 38 families, 23 orders, and three classes were recognized from Iranian basins, with the presence of 11 reported species that need confirmation by specimens (Sayyadzadeh & Esmaeili 2024). A total of 104 species (34.6% of the whole ichthyofauna) are endemic to Iran (Sayyadzadeh & Esmaeili 2024). Although the Iranian freshwater ichthyodiversity has been well documented, new fish are still being described e.g., *Carasobarbus doadrioi*, *C. hajhosseini* and *C. saadatii* (Jouladeh-Roudbar et al. 2024), and new records are being documented e.g., *Glossogobius laticeps* (Zarei et al. 2025).

Iran has also experienced the introductions of non-native fish. Currently, there are 33 (10.9% of all freshwater fish fauna) alien species introduced intentionally or accidentally. Some of them, viz., *Carassius auratus*, *C. gibelio*, *Pesudorasbora parva*, and *Gambusia holbrooki*, are considered invasive species posing a serious threat to the native fauna and freshwater ecosystems (Sayyadzadeh & Esmaeili 2024).

Alien freshwater species of Iran have already been listed and discussed in detail (e.g., Esmaeili et al., 2010; 2013; 2014, 2017; Mousavi-Sabet & Eagderi, 2016; Valikhania et al., 2016; Radkhah & Eagderi, 2019; 2020; Esmaeili, 2021; Sayyadzadeh & Esmaeili 2024). Several alien fish species originated from Neotropical (*Piaractus brachypomus*, *Poecilia latipinna*, *P. reticulata*, Nearctic (*Atractosteus spatula, Gambusia holbrooki, Xiphophorus hellerii*), and Africa (*Coptodon zillii*, *Oreochromis niloticus*) as documented by Esmaeili et al. (2017).

Here, in this study we list 5 exotic cichlid species belonging to 3 genera (*Amatitlania*, *Coptodon*, and *Oreochromis*).

Amatitlania nigrofasciata

The convict cichlid *A. nigrofasciata* is native to Central America (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama), but had been introduced in Puerto Rico, Hawaiian Islands (U.S.A.), Mexico, La Réunion, Middle East (Iran, and parts of the Levant), Philippines and Australia. It is one of the most important aquarium species in the ornamental fish industry.

Introduction record of *A. nigrofasciata* in Iran dates back to 2013 when Esmaeili et al. (2013) recorded it for the first time from headwaters of Kol River drainage. Mousavi-Sabet & Eagderi (2016) reported the second presence of *A. nigrofasciata* in Sulaymaniyah Spring (Namak Basin, Iran) and suggested potential negative impacts on native species such as *Capoeta aculeata* through competition, habitat alteration, and the introduction of parasites or diseases. Notably, several native fish species, including *Esmaeilius darabensis*, *Capoeta saadii*, *Carasobarbus luteus*, *Cyprinion microphthalmus*, *Garra hormuzensis*, *Mystus cyrusi*, and *Paraschistura sargadensis*, coexist with *A. nigrofasciata* in Golabi Spring (Kol River drainage), alongside two other exotic species, *Carassius auratus* and *Gambusia holbrooki* (Esmaeili et al. 2013, 2014b, 2022). Given these observations, native fish assemblages in this spring may face ecological pressures from non-native species, including the convict cichlid (Esmaeili et al. 2013; Radkhah & Eagderi 2019).

Research studies indicate that the convict cichlid exhibits invasive traits, including broad environmental tolerance, the ability to thrive in degraded habitats, rapid growth, opportunistic feeding, and parental care (Radkhah & Eagderi 2019; 2020; CABI 2025). Notably, this species has been documented to adversely affect native fish populations in various regions (CABI 2025). For instance, Tippie et al. (1991) reported that *A. nigrofasciata* contributed to the decline of native species such as the White River springfish (*Crenichthys baileyi*). Similarly, Contreras-MacBeath et al. (1998) observed negative impacts on Mexican fishery species, including *Amphilophus istlanus* and *Ictalurus balsanus*. Further supporting these findings, Mendoza et al. (2015) highlighted that the convict cichlid's omnivorous diet, aggressive behavior, and territoriality enable it to outcompete native fish. Laboratory studies by De La Torre Zavala et al. (2018) demonstrated that the Mexican mojarra (*Cichlasoma istlanum*) exhibited increased refuge use, reduced swimming activity, and decreased feeding in the presence of convict cichlids compared to interactions with conspecifics or when alone. Based on these behavioral changes, the authors suggested that convict cichlids may negatively influence the fitness of *C. istlanum* in habitats where the two species co-occur (De La Torre Zavala et al. 2018). Collectively, these studies suggest that introducing *A. nigrofasciata* into non-native freshwater ecosystems poses substantial ecological risks. Given the detrimental ecological impacts caused by introduced non-native and invasive species, implementing effective management strategies is critical to mitigate further spread and protect native ecosystems.

Besides *A. nigrofasciata*, herein, we report 3 alien cichlids (tilapias) in the Iranian inland waters.

Coptodon zillii

The redbelly tilapia *Coptodon zillii* (Cichlidae: Pseudocrenilabrinae) is distributed in North Africa (Morocco east to Egypt, south to Nigeria and Central African Republic); Middle East (Syria south to Israel and Jordan) and introduced elsewhere, including some southern U.S.A. states, Iran, Iraq, and Türkiye (Çiçek et al. 2024; Fricke et al. 2025). Translocation of this species has increased remarkably, and its range is expanding continuously. The geographical distribution of this species in Iran includes the Shadegan International wetland and the Dez River, both from Tigris-Karoun drainages in southwest Iran, the Mond River drainage, Persian Gulf basin (Khaefi et al. 2014; Roozbehfar et al. 2014; Rafiee et al. 2017; Teimori et al. 2017). The Aquatic Species Invasiveness Screening Kit (AS-ISK) assessment indicated that this species poses a potential invasion risk to the other Iranian waterbodies including the Anzali Wetland if introduced to this ecosystem (Moghaddas et al. 2020).

The redbelly tilapia is a predominantly herbivorous fish, with over 80% of its diet consisting of aquatic macrophytes, terrestrial plant matter, filamentous algae, and diatoms (Geletu et al. 2024). This substrate-spawning species forms monogamous pairs during breeding seasons and exhibits bi-parental guarding behavior (Geletu et al. 2024). It possesses several advantageous aquaculture traits, including low-trophic-level feeding, high fecundity, tolerance to salinity and cold temperatures, and adaptability to shallow vegetated waters. However, these traits also contribute to its competitive dominance, often displacing native fish by monopolizing habitat and breeding grounds (Geletu et al. 2024). Additionally, hybridization with related tilapia species (e.g., *C. guineensis*, *C. rendalli*) poses risks to local genetic diversity (Adépo-Gourène et al. 2006; Nico et al. 2019; Geletu et al. 2024). Translocations of *C. zillii* into natural waterbodies have frequently led to unintended ecological consequences. For example, its introduction in California, USA, as a biocontrol agent for aquatic weeds proved ineffective, as it only consumed vegetation seasonally and was implicated in the decline of native killifish (*Fundulus lima*) and desert pupfish (*Cyprinodon macularius*) due to competition for resources (Andreu-Soler & Ruiz-Campos 2013; Geletu et al. 2024). Similarly, after accidental establishment in a North Carolina reservoir, it eradicated Brazilian waterweed (*Egeria densa*) within two years and became a dominant fish species within three, disrupting native fish breeding habitats (Crutchfield 1992; Cassemiro et al. 2018; Geletu et al. 2024).

Documented ecological impacts of invasive *C. zillii* include water quality deterioration and declines of native fish populations across several regions, including Iran (Bavali et al. 2022), Iraq (Mohamed & Al-wan, 2020), Japan (Ishikawa & Tachihara 2008), and China (Gu et al. 2016; Xiong et al. 2022). In southwestern Iran, redbelly tilapia now dominates local fishery catches. However, its low market value has significantly reduced fishermen's income, creating substantial socio-economic challenges for affected communities (Tabasian et al. 2021).

In summary, broad environmental tolerance, dietary flexibility, and high reproductive success of *C. zillii* facilitate its invasive spread, often at the expense of native species and ecosystem integrity (Geletu et al. 2024). Notwithstanding, it is a species of invasion concern that requires continuous monitoring and implementation of mitigation actions in non-native regions. Compilation of information regarding the environmental requirements, feeding, and reproductive biology of *C. zillii* may serve as a starting ingredient for further research and management of its invasiveness, which is highly required in the face of freshwater ecosystem modifications as a result of climate change.

Originating in Africa, tilapia now has worldwide distribution and are both a prime model system for evolutionary biology and an important aquaculture species in over 135 countries (Sunarto et al. 2023). Tilapia culture has expanded worldwide, initially with Mozambique tilapia, *Oreochromis mossambicus*, and then the more productive Nile tilapia, *O. niloticus* (Sunarto et al. 2023). Tilapia, also known as the 'aquatic chicken' because they offer affordable and high-yield source of protein, exhibit high value aquaculture traits including high fecundity, rapid growth rate, tolerance to adverse water quality, and relative resistance to disease and other stressors (De Silva et al. 2004). Because they can be raised in a wide range of production systems, from subsistence backyard ponds to high intensity farms, they have made a significant contribution to food production, poverty alleviation and livelihood support in Asia and the Pacific nations (De Silva et al. 2004; Sunarto et al. 2023). Previous studies that evaluating the negative impacts of tilapias on recipient ecosystems consistently reveal the impacts on native communities, species diversity, food web structure and ecosystem function, which have consequently affected sustainable fisheries development (Xiong et al. 2022).

Oreochromis mossambicus

Mozambique tilapia, *Oreochromis mossambicus* (Cichlidae: Pseudocrenilabrinae) is native to eastward flowing rivers of central and southern Africa, but from the early 1930s it has been introduced widely elsewhere including Israel, Saudi Arabia, UAE, Yemen (Russell et al. 2012; Esmaeili & Hamidan 2023; Çiçek et al. 2024; Fricke et al. 2025), for aquaculture and for biological control of weeds and insects (Russell et al. 2012). Self-sustaining populations now exist in almost every region to which they have been imported (Russell et al. 2012). It is listed in the top 100 of the world's worst invasive alien species and has been documented to have severe impacts on freshwater ecosystems primarily through displacement of native species and habitat alteration (Sunarto et al. 2023). They are maternal mouthbrooders (Trewavas 1982 a, b) and are considered a "model invader" because they are aggressive, have extraordinary environmental adaptability, phenotypic plasticity, high hybridization capacity and rapid reproduction (Sunarto et al. 2023). Till date there is no record of Mozambique tilapia from inland waters of Iran (Rafii et al. 2017; Çiçek et al. 2024; Sayyadzadeh & Esmaeili 2024). Here we document its presence in Iran for the first time from the Minab artificial dam (Hormuzgan) based on mtDNA sequencing (Fig. 5). The Minab Dam (27°09′N, 57°03′E), constructed on the Minab River in Hormuzgan Province, southern Iran, serves as a critical water reservoir for agriculture, drinking water, and flood control in this arid region. Its reservoir supports local fisheries but has also experienced ecological changes, including shifts in fish community structure due to invasive species introductions and altered hydrological regimes. Recent studies highlight the dam's vulnerability to siltation and water quality degradation emphasizing the need for sustainable management in this ecologically sensitive area adjacent to the Persian Gulf.

There is remarkable evidence that invasive *O. mossambicus* populations are directly or indirectly impacting native fauna at many locations where they have been introduced *Oreochromis mossambicus* was responsible for the disappearance of native species in Venezuela (Pe´rez et al. 2006a), the decline of native cichlid populations in Lake Nicaragua, probably due to competitive displacement (McKaye et al. 1995), damage of indigenous fauna in Florida and Columbia (Philippart & Ruwet 1982), negatively impacted on a species flock of endemic pupfish *Cyprinodon* spp. (Fuselier, 2001) by competitively excluding them from optimal habitats, resulting in declines in the abundance in four out of the five flock members (Russell et al. 2012), and aquaculture collapsing of milkfish (*Chanos chanos*) in the island's mangrove lagoons and ponds (Fortes 2004; Russell et al. 2012) and in the Philippines (Philippart & Ruwet 1982).

Many *O. mossambicus* populations established outside of their natural range are not of a 'pure' strain but are rather hybrids. Hybridizations of *O. mossambicus* with *O. aureus* for aquaculture to improve cold tolerance, with *O. niloticus* for biomass gain, with *O. hornorum* for production of all male progeny which are better suited for intensive aquaculture, *O. urolepis* have already been reported (Russell et al. 2012). The hybridization of *O. mossambicus* in its natural range with *O. niloticus* is of concern to the extent that finding a pure strain of *O. mossambicus* is challenging (Russell et al. 2012; Mpanza 2022).

There are two major potential pathways for the inter-catchment dispersal of established populations of *O. mossambicus*:

i) Natural dispersal via oceanic corridors or across catchment boundaries. The Mozambique tilapia, being a euryhaline species, has the physiological ability to cross saline/ oceanic barriers, potentially moving between estuaries, particularly during flood events (Lobel 1980; Philippart & Ruwet 1982; Russell et al. 2012). This pathway cannot be considered for dispersal of Mozambique tilapia in Iran. Additionally, dispersal between catchments or drainage systems may occur via flooding that breaches watershed boundaries or through the diversion of irrigation water (Russell et al. 2012; O'Mara et al. 2025). While this species has been only introduced into Minab Dam, such an introduction could become feasible following its initial establishment in this waterbody, become invasive in a new habitat, particularly during the expansion phase of its invasive spread.

ii) Human-mediated dispersal through intentional and/or unintentional movement. Introductions of tilapia species, including *O. mossambicus*, outside Africa were originally made for a variety of reasons including for aquaculture and for intentional stocking of natural habitats (as a food fish), constructed water bodies and for the control of aquatic vegetation (Philippart & Ruwet 1982; Russell et al. 2012). Human mediated dispersal is the most plausible mechanism for most new introductions and the spread of *O. mossambicus* throughout the world (Russell et al. 2012) including Iran.

Oreochromis niloticus

The Nile tilapia, *O. niloticus* is native to north and northeast Africa, but it is widely introduced elsewhere including Iran (Sayyadzadeh & Esmaeili 2024; Fricke et al. 2025). The Nile tilapia is a highly invasive fish species that poses significant ecological threats, particularly in tropical ecosystems. Its highly efficient mouthbrooding reproductive strategy enables rapid population growth, leading to the overcrowding of native species. Additionally, its feeding and nesting behaviors contribute to water column disturbance, increased turbidity, and nutrient imbalances, further destabilizing aquatic habitats (GISD 2025).

Nile tilapia ranks among the most extensively cultivated and researched aquaculture species globally, accounting for its substantial contribution to global tilapia production. As a microphagous omnivore, this species demonstrates selective feeding behavior, primarily consuming phytoplankton and algal resources (Getabu 1994; Zengeya & Marshall 2007; Zengeya et al. 2011, 2013: Mojekwu & Hoareau 2024). The species exhibits remarkable environmental adaptability, thriving in both freshwater and brackish environments within an optimal thermal range of 28-42°C (Teichert-Coddington et al. 1997). *Oreochromis niloticus* demonstrates considerable growth potential, reaching up to 60 cm standard length, 4.3 kg body weight, and a maximum lifespan of 10 years (GISD 2025). Several biological traits contribute to its aquaculture success and invasive potential: rapid growth rates and early sexual maturation (5-6 months), extended reproductive season with multiple brooding cycles, high fecundity correlated with large body size, and intensive parental care behavior (Ojuok et al. 2007; Mbewe et al. 2023; Handago et al. 2024; Mojekwu & Hoareau 2024). The species' competitive dominance is particularly evident in reproductive contexts, where larger males aggressively exclude other species from limited spawning habitats (Lowe-McConnell 2000; Mojekwu & Hoareau 2024). These biological characteristics, combined with frequent escape events from aquaculture facilities, have established *O. niloticus* as a significant invasive threat. Post-establishment of the species negatively impacts native ichthyofauna through resource competition (food and habitat) and reproductive interference (Zengeya et al. 2011, 2013; Stauffer et al. 2022; Shuai et al. 2023; Mojekwu & Hoareau 2024). Research by Stauffer et al. (2022) warns that Nile tilapia establishment in Lake Malawi could trigger severe ecological and socioeconomic consequences including biodiversity Impacts (potential extirpation or complete extinction of native fish species), genetic threats (hybridization risk with endemic *Oreochromis* species), and fisheries disruption (significant harm to the local fishing communities and their livelihoods).

Alien vs. native/endemic species

There are many sympatric native and endemic species with the alien cichlids of Iran:

Minab River drainage: *Paracapoeta anamisensis* (Zareian, Esmaeili & Freyhof, 2016), *Iranocichla persa* Esmaeili, Sayyadzadeh & Seehausen, 2016, and *Paraschistura hormuzensis* Freyhof, Sayyadzadeh, Esmaeili & Geiger, 2015 are endemic fishes of this region.

Golabi spring (upstream of Kol River drainage): *Aphaniops darabensis*, *Capoeta saadii*, *Carasobarbus luteus*, *Cyprinion microphthalmus*, *Garra hormuzensis*, *Mystus cyrusi*, and *Paraschistura sargadensis*, coexist with *A. nigrofasciata* in Golabi Spring (Kol River drainage).

Shadegan Wetland: In Shadegan wetland where *C. zillii* has been introduced, 33 native and alien fish species have been listed by Esmaeili (2021b). The alien species, *Carassius auratus*, *Hemiculter leucisculus*, *Heteropneustes fossilis, Coptodon zillii*, and *G. holbrooki* have established breeding populations in this wetland (Esmaeili 2021b).

Lower Tigris River drainage (Khuzestan): Peymani et al. (2024) reported, 31 species from 15 families, including eight alien species from the lower part of Tigris River drainage (Karun, Dez, Kharkhe, Zohreh, Jarahi, Bahmanshir, Arvan, and Shaver Rivers, Khoramshar canal, and Hoor-Al-Azim Wetland) where either *C. zillii*, *O. aureus* or both species have been introduced.

The significant diversity of native and endemic fish species in Iranian water bodies invaded by alien cichlids necessitates an integrated governance approach for effective management of biological invasions (Fig. 22).

Numerus research has indicated that biological invasions have emerged as a critical element of global change, resulting in serious ecological and economic impacts worldwide (Shuai & Li 2022). It has been shown that the invasion of non-native fish poses a significant global risk to freshwater biodiversity. Therefore, it is essential to understand how these invasive species can impact ecosystem functions for effective management. Fish species are introduced for various reasons, including aquaculture, enhancing fishery stocks, sport fishing, research, aquarium trade, demonstrating in national and international fairs, and biological control (Canonico et al. 2005; Esmaeili et al. 2014; Lin et al. 2015; Mutethya & Yongo 2021). Additionally, humans intentionally introduce fish through religious animal release activities (e.g., Agoramoorthy & Hsu 2005; Fuoco 2001; Liu et al. 2012, 2013; Yongo et al. 2023). Aquaculture remains the primary reason for fish introductions in many areas

(Gozlan & Newton 2009; Yongo et al. 2023). While non-native fish species have contributed positively to aquaculture and capture fisheries, they have also posed significant threats to native ecosystems. Exotic invasive species can harm aquatic ecosystems and diminish biodiversity (Canonico et al. 2005; Cucherousset & Olden 2011; Yongo et al. 2023). They often lead to ecological and economic issues due to competition, predation, parasitism, hybridization, and habitat alteration (Giannetto et al. 2012; Mutethya et al. 2020; Yongo et al. 2021, 2023).

For instance, Nile tilapia has been introduced to more than 100 countries for aquaculture and is now recognized as one of the most destructive invasive species in tropical and subtropical areas. This invasion disrupts the trophic structure of native species (Shuai & Li 2022), resulting in lowered trophic status, shortened food chains, and diminished isotopic diversity among native fish populations (Shuai & Li 2022). These observations highlight that invasive Nile tilapia can destabilize recipient ecosystems by modifying the trophic structures and food webs of native communities (Shuai & Li 2022). A similar scenario may unfold in the Iranian freshwater ecosystems impacted by alien cichlids. Therefore, understanding the impact of invasive species on aquatic systems is essential for effective management.

Threats: In freshwater ecosystems, invasive fish species cause several conservation problems and it can alter ecosystem processes, modify community structure through competition with, and predation on native species (due to share habitat and food resources) and can alter the structure and function of the invaded system, leading to displacement, decline and, hybridisation with the congeneric native species, and in some cases, extinction of the native fish species. Furthermore, invasive fish species can clog waterways and introduce pathogens that may pose threats to human health (Bellard et al. 2016; Britton 2023; IPBES 2023; Burnett et al. 2023; Roy et al. 2024). Threats of alien species on freshwater fishes of Iran have been presented by Esmaeili et al. (2010, 2013, 2014, 2017), and Esmaeili (2021a). The listed general threats are: Competing for food and habitat utilized by native fish species and wildlife, directly preying on native fish species, hybridizing with indigenous fish species leading to genetic introgression and the loss of genetically pure stocks, changing selection pressures transmission of parasites and diseases that were not historically present in those habitats, altering habitat which includes degradation of water quality, modifying energy and nutrient flow and the food web within the aquatic ecosystem, and extirpating endemic and native faunal and floral elements.

Dispersal Pathways of Alien Freshwater Fishes: Mechanisms and Vectors

Alien freshwater fishes, defined as species introduced outside their natural range, pose significant ecological and economic challenges. Understanding their dispersal pathways is crucial for effective management and mitigation of their impacts on native ecosystems. The dispersal of these species occurs primarily through human-mediated pathways, which can be classified into intentional and unintentional introductions, followed by secondary spread.

1. Primary introduction pathways: i) Intentional releases including stocking for fisheries/aquaculture (Nile tilapia and common carp, are commonly introduced to enhance fishing opportunities or for aquaculture production which can outcompete local species and alter ecosystems); ornamental trade releases (e.g., *Amatitlania nigrofasciata*, *Carassius auratus*, *Xiphophorus helleri*, and *Poecilia reticulata* that are frequently released into natural water bodies as a result of being released by hobbyists and can establish wild populations, contributing to biodiversity loss); and biological control introductions (species such as *Gambusia holbrooki* are introduced for pest control, notably for mosquito suppression, but has led to unforeseen ecological consequences), ii) Unintentional Introductions which often occur due to human activities, including ballast water discharge (e.g., the round goby *Neogobius melanostomus* that can be introduced into new habitats via ballast water from ships due to its ability to find suitable habitats in newly colonized waters, leading to rapid population establishment); bait bucket releases (anglers releasing unused bait species like the Eurasian perch *Perca fluviatilis* in areas where they are not native contribute to unintentional introductions, often facilitating colonization of local ecosystems); and escape from aquaculture facilities (the brown trout *Salmo trutta*, if escaped from farms, can interact and compete with wild populations, thereby disrupting local aquatic ecosystems.

2. Secondary dispersal mechanisms: After their initial introduction, alien fish species can further spread through various mechanisms, including i) natural expansion (some species, such as silver carp *Hypophthalmichthys molitrix* , may naturally expand along river networks, enhancing their range and local dominance in ecosystems like the Mississippi Basin, ii) human-facilitated transport (canals and man-made waterways often facilitate the movement of species like topmouth gudgeon *Pesudorasbora parva*, which can spread through European waterways due to human activities, and iii) climate-driven range shifts (changes in climate can drive species such as pumpkinseed *Lepomis gibbosus* northward, as they adapt to warming waters, increasing their geographic distribution).

3. Anthropogenic drivers enhancing spread: Several human actions enhance the spread of alien freshwater fishes, including i) dam/reservoir construction (infrastructure projects can facilitate species invasions; for instance, African sharptooth catfish *Clarias gariepinus* has invaded Brazilian waterways and *Oreochromis niloticus* in Minab River drainage due to damming projects that connect new habitats, and ii) pollution-tolerant invasives (species such as the bleak *Alburnus alburnus* thrive in eutrophic waters, often resulting from agricultural runoff and urban pollution, allowing them to outperform native species).

Conservation of biodiversity

The introduction and establishment of invasive alien species in Iran's freshwater ecosystems, particularly the Minab River drainage system, poses significant threats to both ecological integrity and human welfare. These biological invasions could lead to i) ecological impacts (decline in native/endemic fish populations, potential local extirpation or global extinction of indigenous species e.g., *Iranocichla persa*, *Paracapoeta anamisensis*, and *Paraschistura hormuzensis*), ecosystem alterations through resource competition e.g., food and habitat, physical habitat modification, and introduction of novel pathogens and parasites, and ii) socioeconomic consequences (disruption of traditional fisheries and income of local communities). Hence, the following scientific and suitable conservation management strategies should be implemented:

1. **Background knowledge:** i) identification of native fish species, and ii) identification of invasive species.

2. Prevention measures including i) strict biosecurity policies (enforce regulations on the import, transport, and release of exotic fish species, ii) public awareness campaigns (educate aquaculturists, anglers, and pet traders about the ecological risks of releasing non-native fish, and iii) risk assessment protocols (mandate ecological impact assessments before approving new fish introductions).

3. Early detection and rapid response (EDRR): i) regular monitoring of freshwater ecosystems using new methods including eDNA analysis especially in vulnerable water bodies e.g., endemic-rich rivers and lakes to detect exotic fish early, ii) citizen science initiatives (engage local communities in reporting sightings of invasive species), and iii) containment measures (isolate and remove exotic fish populations before they establish).

3. Control and eradication of established exotics: i) selective removal (use targeted fishing, electrofishing, or trapping to reduce invasive fish numbers), ii) biological control (cautiously) (introduce natural predators or sterile males where ecologically justified), and iii) habitat restoration (modify habitats e.g., restoring natural flow regimes to favor native species over invasive).

4. Legal and policy frameworks: i) national invasive species legislation (implementation of laws prohibiting unauthorized introductions, ii) protected areas for native fish (designation of fish sanctuaries where exotic species are actively managed), and iii) international cooperation (collaboration with neighboring countries to control transboundary invasions).

5. Research and adaptive management: i) genetic studies (assessing hybridization risks between exotic and native fish), ii) ecological impact studies (investigating how invasives alter food webs and habitats), iii) biological studies (studying food and feeding habits, reproductive biology, population dynamics of both native and exotic species, and iv) climate-resilient strategies (considering how climate change may favor exotic over native species).

Implementing regulations like the ballast water management (BWM) and convention sets guidelines to mitigate the risk of introducing invasive species via maritime activities, employing environmental DNA (eDNA) techniques which can enhance early detection of invasive species, allowing for quicker response measures, and regulatory frameworks, such as the EU's invasive species regulation, that can help prevent the introduction of potentially harmful species through the ornamental trade are highly recommended. In overall, a combination of strict prevention, active management, and habitat protection/restoration is essential to safeguard native fish biodiversity. Adaptive strategies should be tailored to regional ecosystems, with continuous monitoring to assess effectiveness.

Tilapia hybridization in natural conditions and aquaculture

Specimens of Mozambique tilapia×Nile tilapia (*O. mossambicus* × *O. niloticus*) recognized as Taiwan red with higher salinity tolerance were found in Minab Dam (Fig. 24). Taiwan red hybrid exhibits intermediate morphological traits from both parent species including blending the deeper body of *O. mossambicus* and the more streamlined shape of *O. niloticus*; head profile intermediate between the slightly concave shape of *O. niloticus* and the more robust head of *O. mossambicus*; lips thicker than *O. niloticus* but not as pronounced as in some *O. mossambicus*; dorsal fin with 15-18 spines, similar to both parent species; caudal fin moderately forked, less than *O. niloticus* but more than *O. mossambicus*; anal fin with 3 spines, with slight differences in spotting patterns; lateral line scales 28-32 (intermediate between the two species); gill rakers fewer than *O. niloticus* but more developed than *O. mossambicus*; typically, grayish or olive, with variations depending on dominance of parental genes; faint to moderate vertical bars (fewer and less distinct than in *O. niloticus*); caudal fin may show some striping but usually less pronounced than in *O. niloticus*; reddish or pinkish hue on the operculum and fins (more common in *O. mossambicus* hybrids); and dorsal fin may have a reddish or black margin (a trait from *O. mossambicus*). Taiwan red tilapia grows faster than *O. mossambicus*, exhibits greater salinity tolerance than *O. niloticus* (a trait inherited from *O. mossambicus*), and demonstrates better hardiness than pure *O. niloticus* in certain environments (Table 2).

Hybridization occurs widely in fishes under natural conditions and is observed in fish more commonly than in other vertebrate animal groups. Several factors have been suggested as contributing to the high incidence of natural hybridization among closely related fish species, including external fertilization, weak behavioral isolating mechanisms, unequal abundance of the two parental species, competition for limited spawning habitat, and decreasing habitat complexity. Over the years, various attempts have been made to enhance aquaculture and food security, including introductions of tilapias from their native distribution ranges in Africa to other parts of Africa and the world (Tibihika et al. 2020; Diedericks et al. 2021). Hybridization between congeneric tilapia species has been observed under natural, post-introduction conditions and has occurred when introducing *O. niloticus* into the habitats of *O. mossambicus*, *O. aureus*, *O. andersonii*, *O. macrochir*, *O. esculentus*, *O. jipe* and *O. korogwe* (Bradbeer et al. 2019, Tibihika et al. 2020; Blackwell et al. 2021; Diedericks et al. 2021).

Intentional hybridization of tilapia species has been widely practiced in aquaculture to enhance desirable traits. Key hybrid crosses and their characteristics include: i) Hybrids of some strains of Nile tilapia×blue tilapia (*Oreochromis niloticus* × *O. aureus*) yield all-male offspring with superior growth. Some hybrids are fertile with increased cold and salinity tolerance. Reciprocal cross gives 50% males and females. ii) Nile tilapia×long-finned tilapia (*O. niloticus* × *O. macrochir*) hybrid yields predominately male offspring, but strain of Nile tilapia is important for good fry production. iii) Nile tilapia×Wami tilapia (*O. niloticus* × *O. hornorum*) hybrid produces predominately male offspring with some strains producing red-skinned fish with salt tolerance. iv) Mozambique tilapia×Nile tilapia (*O. mossambicus* × *O. niloticus*) recognized as Taiwan red with higher salinity tolerance; progeny of these hybrids displays a variety of different skin colors. v) Mozambique tilapia × Wami tilapia (*O. mossambicus* × *O. hornorum*) hybrid brings in predominately male offspring and are fertile. Certain strains produce Florida red tilapia with salinity tolerance and good growth (see Rahman et al. 2018).

Many farmed tilapia populations likely represent hybrid lineages rather than pure species, displaying intermediate morphological traits). This may explain observed phenotypic variations in introduced tilapia for aquaculture purposes.

CONCLUSION

Freshwater ecosystems, despite their ecological and economic importance, face severe threats from biological invasions, particularly by non-native fish species. Iran, with 33 recorded alien fish species (58.9% of the Middle East's total), is experiencing moderate to high invasion pressure, though less severe than global hotspots like the United States. Among these invaders, cichlids pose significant risks due to their potential to disrupt native biodiversity, alter ecosystems, and contribute to biotic homogenization. This study highlights the taxonomic status, distribution, and impacts of alien cichlids in Iran, with new records of *Oreochromis mossambicus* and *O. niloticus* in the Minab River drainage. Understanding their spread and establishment mechanisms is crucial for developing effective management strategies, particularly in biodiverse regions like Iran, where preventing further invasions is key to conserving native freshwater ecosystems.

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مقاله مروری

سیکلید ماهیان مهاجم و بومزاد: مروری بر سیکلید ماهیان ایران با گزارش‌های جدید از تیلاپیای نیل و تیلاپیای موزامبیک (شعاع‌بالگان: سیکلید ماهیان)

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چکیده: سیستم‌های آب شیرین نقش قابل توجهی در نگهداری بخش بزرگی از تنوع زیستی جهانی دارند و خدمات اکولوژیک حیاتی و ارزش اقتصادی مهمی را برای جامعه ارائه می‌دهند. علی‌رغم اهمیت فراوان آنها، این منابع آبی جزء یکی از در معرض تهدیدترین زیست‌بوم‌ها در کره زمین بوده و به‌شدت در معرض اثرات تهدیدات بشر-محور قرار از جمله معرفی گونه‌های غیربومی دارند. تاکنون حداقل ۳۷ هزار گونه غیربومی از طریق فعالیت‌های انسانی فراتر از دامنه طبیعی خود به تمامی مناطق و بوم‌سازگان زمین از جمله محیط‌های دورافتاده و انزوا یافته وارد شده‌اند، و بسیاری از آنها جمعیت‌های پایدار تولیدمثلی را به‌وجود آورده‌اند. اکوسیستم‌های آب شیرین حدود ۱۸،۹۱۵ گونه ماهی را شامل می‌شوند که یک چهارم از کل تنوع گونه‌های مهره‌داران را تشکیل می‌دهند. با این حال، این گونه‌ها در حال تجربه کاهش‌هایی با نرخ‌هایی بیش از آنچه در سایر اکوسیستم‌ها مشاهده شده، هستند. یکی از عوامل اصلی این کاهش، گونه‌های مهاجم بیولوژیک است که در حال حاضر اهمیت فزاینده‌ای یافته است. در سطح جهان، بیش از ۵۰۰ گونه ماهی آب شیرین غیربومی پس از معرفی، جمعیت‌های پایداری را به‌وجود آورده‌اند، که آنها را یکی از رایج‌ترین گروه‌های تاکسونومیک معرفی‌شده می‌سازد و اثرات اکولوژیک قابل توجهی از جمله رقابت با گونه‌های بومی، تغییرات زیستگاه و گسترش بیماری‌ها دارند. ایالات متحده بیشترین تنوع گونه‌های ماهی غیربومی (۳۰۲ گونه) را ثبت کرده است، پس از آن کانادا (۶۳)، برزیل (۶۰)، روسیه (۵۸)، مکزیک (۵۶) و چین (۵۳). ایران، با ۳۳ گونه ماهی غیربومی، ۵۸/۹ درصد از گونه‌های ماهی غیربومی آب شیرین در خاورمیانه را تشکیل می‌دهد و این تعداد، ایران را در دسته کشورهایی قرار می‌دهد که فشار نسبی متوسط تا بالا تهاجم زیستی در سیستم‌های آب شیرین این کشور را نشان می‌دهد، هرچند کمتر از مناطق بحرانی جهانی مانند ایالات متحده آمریکا است. معرفی ماهی‌های غیربومی به همگن‌سازی زیستی مجموعه‌های ماهی آب شیرین کمک کرده است که تبعات زیستی، بهداشتی و اقتصادی اجتماعی عمیقی در پی دارد. هدف مطالعه حاضر، مروری بر گونه‌های سیکلید بومی و غیربومی ایران است، که وضعیت تاکسونومیکی جاری، پراکنش جغرافیایی، ویژگی‌های ریخت‌شناختی، کلید شناسایی، راه‌های ورود گونه‌های غیربومی، تأثیرات آنها بر ماهی‌های بومی و بومزاد، و اولین گزارش دو گونه *Oreochromis mossambicus* و *O. niloticus* و هیبریدهای آنها در حوضه رودخانه میناب (حوضه مکران، هرمزگان) را ارائه می‌دهد. درک الگوهای پراکنش گونه‌های ماهی غیربومی و عوامل مؤثر بر تثبیت آنها در مناطق خاص، برای توسعه استراتژی‌های مدیریت مؤثر و پیش‌بینی ریسک تهاجمی آنها در آینده حیاتی است. این موضوع به‌ویژه در کشورهای غنی از تنوع زیستی مانند ایران اهمیت ویژه‌ای دارد.

کلمات‌کلیدی: تنوع زیستی جهانی، گونه‌های غیربومی، گونه‌های مهاجم، تهدیدات انسان‌محور، ماهی‌های آب شیرین