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EXOTIC AND INVASIVE FISH SPECIES: A MAJOR THREAT TO AQUATIC BIODIVERSITY OF PAKISTAN

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ABSTRACT

The introduction of exotic fishes in another country may be deliberate aiming to enhance fish production in natural water bodies or increase fish production in the aquaculture ponds. The alien fishes may also be accidentally released through aquarium and fish pet trade. In most cases, these fishes get adjusted to a new environment and become invasive and compete with local fauna and flora. Brown trout (*Salmo trutta***)** and rainbow trout (O*ncorhynchus mykiss***)** were the first two exotic fishes that were introduced in Khyber Pakhtunkhwa areas of Pakistan in 1928. To enhance fish production and to control of undesirable weeds in Pakistan, several exotic fishes including Mozambique tilapia (*Oreochromis mossambicus*), common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*) and grass carp (*Ctenopharyngodon idella*) were also introduced in the 1960s were but all of these species became invasive and seriously affected local fish fauna. In the 1980s, silver carp (*Hypophthalmichthys molitrix*), bighead carp (*H. nobilis*), Nile tilapia (*O. niloticus*), and blue tilapia (*Oreochromis aureus*) were also introduced whereas grass carp was reintroduced to enhance aquaculture production. All these species have also established in natural ecosystem in Pakistan affecting other fauna and flora. The source of introduction of three invasive cichlids including redbelly tilapia (*Coptodon zillii*), mango tilapia (*Sarotherodon galilaeus*), banded tilapia (*Tilapia sparmanii*) and Balon's tilapia (*Tilapia baloni*) is not known but possibly these were introduced through aquarium trade and now among important invasive whose range is extending. In the 1990s and later on, a wave of introduction of catfishes was observed. These included channel catfish (*Ictalurus punctatus)*, pangasius (*Pangasianodon hypophthalmus*), North African catfish (*Clarias gariepinus*), walking catfish (*C. batrachus*), and magur catfish (*C. magur*) to enhance fish production in natural water bodies and aquaculture ponds but these species have turned into invasive species and their range of distribution is extending. The Amazon sailfin catfish (*Pterygoplichthys pardalis*) is accidentally released into natural water bodies through aquarium trade and now turning into a pest in water bodies in lower Sindh. The source of the introduction of blunt-toothed African catfish (*C. ngamensis)* into the waters of lower Sindh is not known but this species has also become an invasive species in some parts of Sindh. Introduction of livebearers including mosquito fish (*Gambusia affinis*) and guppy (*Poecilia reticulata*) was started in the British period for controlling mosquitoes, however, these species are found in most water bodies in the country. Other livebearers including black molly (*P. sphenops*), sailfin molly (*P. latipinna*), green swordtail (*Xiphophorus hellerii*)**,** and variable swordtail (*X. variatus*) have been introduced by accidental or deliberate release through aquarium trade and now became invasive in some water bodies in Pakistan. It seems evident that most exotic fishes introduced deliberately or accidentally in Pakistan have turned into invasive species threatening biodiversity and ecosystem functioning in the aquatic environment of the country. This warrants a legislative cover to control the introduction of further exotic fish species in Pakistan which is essentially required for the ensuing higher production of natural water bodies and conservation of biodiversity.

Keywords: Exotic species, invasive, introduced species, aquaculture, mosquito control, trouts, grass carp, common carp, bighead carp, silver carp, goldfish, Nile tilapia, Mozambique tilapia, blue tilapia, redbelly tilapia, moon tilapia, pangasius, North African catfish, walking catfish, magur catfish, Blunt-toothed African catfish, Amazon sailfin catfish, mosquitofish, molly, guppy, swordtail, platyfish, biodiversity.

INTRODUCTION

Aquaculture is possibly the fastest-growing economy, at least in Pakistan. To enhance their production, fish farmers try to grow fast-growing species that consume less food, are disease-resistant, and have high market acceptability. Such features may not be found in species that were found in the natural water bodies of the area.

Therefore, to earn more profit they may consider introducing exotic fishes with a proven record of high productivity over a shorter period. The exotic which are also called introduced species or alien species may include a fish species that may be introduced outside its present range accidentally or intentionally (Kottelat, 1997; Kottelat and Freyhof, 2007; Kottelat and Whitten, 1996; Kumar, 2000). According to Kumar (2000) these fish species are generally added to local fauna in many parts of the work to enhance the production of desirable food fish in terms of quantity as well as diversity, for aquarium and pet trade, angling, and sport and biological control (mosquitoes, undesirable weeds).

Although several species of fish are introduced, only a few species survive in natural water bodies where they have been introduced and establish themselves outside their natural habitat. Some of these introduced species may turn invasive, if they compete or impact local fish and other fauna and flora and may spread in a large area There have been instances where several exotic species were introduced on the pretext of enhancing fish in the alien environment (Gozlan *et al.,* 2010; Gallardo *et al.,* 2016; Imran *et al.,* 2021; Joshi *et al.,* 2021; Mehboob, 2021). Invasive fish species may severely impact the diversity of the fish in introduced areas which may include even major impact on ecosystem functioning (Britton *et al.*, 2023; Cucherousset and Olden, 2011; Vilizzi *et al.,* 2015). In some cases, the invasive fish species may lead to a major economic impact (Cuthbert *et al.,* 2021). According to Nyman (1991), the establishment of a population of invasive species may lead to irreversible changes in the aquatic ecosystems and that may also result in the extinction of native species.

It is a fact that deliberate introductions for stocking of alien fish for enhanced aquaculture and natural water production, ecological management (mosquito control or weed control) usually lead to its release from fish farms and, aquariums to natural water bodies (Anas and Mandrak, 2021; Bobeldyk *et al.,* 2015; Mandrak and Cudmore, 2010).

According to FAO (1998), the introduction of exotic fishes is usually well planned and done with the best of intentions, however, the introduced species face new competitors, predators, and environmental conditions they are unable to withstand. However, those species that got acclimatized and developed their niche survive in the alien natural water bodies and may leave a serious effect on the indigenous aquatic biota. The invasive species may lead to ecological impacts and socio-economic impacts. The ecological impacts include the impact on biodiversity, crossbreeding with local fish fauna and genetic degradation of natural fish fauna whereas the socio-economic impact may include a reduction in natural fish production or high productivity of an undesirable species that cannot be marketed (FAO, 1998).

In Pakistan, the introduction of alien fish species started in the last century. Brown trout (*Salmo trutta fario*) was introduced in British India between 1863 and 1900 for stocking in ponds and reservoirs (Kumar, 2000). It was introduced in the territory that is now included in Pakistan in 1928, when it was first brought from Kashmir into Shinu, Kaghan. Since then, many species of fish have been introduced in Pakistan, some of which were established in natural water bodies and commercially harvested whereas there were several failures in the introduction of fish species that could not deliver the desired results and become pests for natural flora and fauna. In Pakistan, only a few studies have been undertaken on the impact of exotic species on inland water ecosystems (Khan *et al.,* 2008; 2011a, 2011b, 2016). Khan, *et al.,* (2011a) have reported that some alien species introduced in Pakistan have preyed upon local fish and invertebrate fauna and competed with local fauna for space and food. The present paper provides details of the introduction of fish in Pakistan with special reference to their impact on fisheries, aquaculture, and local habitats.

MATERIALS AND METHODS

A review of the scientific literature on fish introduction in Pakistan was made. Information on introduced species was also obtained from the Provincial Fisheries Department. In addition, monitoring of commercial landings of freshwater fishes at Karachi Fish Harbour (which is the largest market of freshwater fish) was carried out from 2003 to 2024 for the presence of exotic species. Specimens of some exotic fishes collected from Karachi Fish Harbour were photographed. Information about exotic fishes was also obtained from fishermen, fish traders, aquarium fish importers, and leading aquaculture farm operators.

RESULTS AND DISCUSSIONS

With the first introduction of an exotic fish (brown trout) in 1928, several fish species were introduced in Pakistan mainly for sport fishing in cold water streams. Other introductions in Pakistan were made for enhanced aquaculture production and aquaculture ponds, for controlling mosquitoes and weeds as well as through aquarium trade (Ahmed, 1996). Some of the alien species have adjusted to the natural aquatic habitat of Pakistan whereas a few of them could not establish themselves in the natural water bodies, however, some species have become

invasive in Pakistan. An account of introduced species along with their impacts on biodiversity and ecosystem functioning is provided in the present paper.

Trout (Order Salmoniformes)

Trout was introduced in Pakistan (also in other parts of British India) by the European residents in the 19th century as a sport fish. The first attempt to introduce trout was made by Mr. H. S. Thomas in 1863 but the consignment of ova brought from Scotland perished on the way (Day, 1876). In 1986, F. Day imported 6,000 ava and most of them died a few days after reaching Udhagamandalam (Ooty) Western Ghats mountains, the few that survived turned out to be the first trout that were introduced in British India (Day, 1876; Jones and Sarojini, 1952).

Several attempts have been made to introduce both brown and rainbow trout but no breakthrough could be obtained till the turn of the new century. The first shipment of ova of brown trout was sent in 1900 by the Duke of Bedford to Maharaja of Kashmir but the whole consignment perished because of high heat. The consignment received later on survived and spread in the waters of Kashmir. Some ova liberated in the River Kalapani near Abbottabad flourished and bred there (Jones and Sarojini, 1952). In 1903, a heavy flood swept over all the brood ponds and hatcheries and destroyed them but provided an opportunity to widely spread trout in Kashmir.

Many attempts were made to introduce brown trout in Shinu, Kaghan in the last century but without any success. Its introduction was also attempted in Swat and Chitral in 1930 but these attempts also did not succeed. In 1946, about 120 adult brown trout were stocked in the Lutkoh River, Chitral which reproduced, and a good population was ultimately established in Gilgit (Yaqoob, 2002). Presently, there is a well-established trout fishery in the Khyber Pakhtunkhwa, Gilgit-Baltistan, and Azad Kashmir. In these areas, exotic trout brown trout (*Salmo trutta***)** and rainbow trout (O*ncorhynchus mykiss*) have successfully established themselves in rivers, streams, and other natural water bodies. Brown trout have established in many cold water bodies including River Panjkora, Upper Dir (Akhtar *et al*., (2014b).

The introduction of rainbow trout in Gilgit Baltistan dates back to 1906-1908 when aged ova were carried to Gilgit. In 1909, Henry. C. Wilson successfully introduced rainbow trout from New Zealand to Southern India but these could not survive. By that time rainbow trout was already established in Kashmir India from where it was taken to Southern India for reintroduction, in 1920 (Mackay, 1945). Brown trout was also introduced to Quetta, Balochistan from Kaghan in 1953. Now Karez Reservoir and other waters bodies have been regularly stocked with fry and fingerling obtained from the trout hatchery established at Urruk near Quetta.

Trout fishery contributed substantially to the economy of local communities in the Khyber Pakhtunkhwa, Gilgit-Baltistan, and Azad Kashmir as a part of the tourist industry. In addition, trout farming is also established in some of these areas. Trout fish is mainly cultured in these areas in flow-through concrete raceways constructed at places where sufficient water is available throughout the year.

The benefit is trout as sport and farmed fish usually outweigh the negative impact on the ecosystem functioning. Usually, the introduction of trout is considered to be non-problematic (Kumar, 2000), however, trout are reported to compete with a natural stock of cold-water fishes found in streams, lakes, and rivers. There have been reports of the elimination of natural cold-water fishes and even hybridization with genetically similar indigenous species (Rinne, 1995). Rainbow trout is known to be a major predator of the eggs and young ones of the native species (Blinn *et al.*, 1993).

The biodiversity of the water bodies is severely affected due to the introduction of alien brown trout they feed upon grazing invertebrates, which results in increased algal biomass which may affect the production dynamics of sensitive cold water streams (Townsend, 1996). In most cases, the ecological consequences of the introduction of brown trout are irreversible, and the natural ecosystem of cold water habitat cannot be restored. Similarly, rainbow trout are considered as worst invasive species. The rainbow trout is known to displace native species and also affect invertebrates found in the cold water ecosystem, including the depletion of food of native fauna.

Attempts were also made to introduce coho salmon (*Oncorhynchus kisutch*) in Swat based on imported fertilized eggs from the USA which initially got a good growth rate achieving ½ kg in less than 3 months but then all introduced salmon died. A similar attempt to introduce brook *trout* (*Salvelinus fontinalis*) in Gilgit-Baltistan in the 1980s also failed as imported fertilized eggs did hatch in a Government hatchery but all the fingerlings died within 20 days after hatching possibly because of improper feed.

Genus Salmo Linnaeus, 1758

Salmo trutta Linnaeus, 1758

(Fig. 1)

This species is commonly known as brown trout which is introduced in Pakistan in the 19th century from India. The details of introduction in India have been described by Howell (1916), Mitchell (1918) and Jones and Sarojini (1952).

Fig. 1. *Salmo trutta* (a) cultured brown trout; (b) brown trout at raceway culture in Swat

Brown trout has a fusiform body and pointed head. Its mouth is large, extending mostly after the eye, and has well-developed teeth. Its caudal peduncle is thick and rounded. The body is grey-blue with numerous spots which are also present below the lateral line. The spots are blackish on the upper part of the body, usually orange on the sides which are surrounded by pale halos. Adipose fin has a red margin.

Brown trout is originally found in parts of Europe and Asia including the Atlantic, North, White, and Baltic Sea basins, from Spain to Chosha Bay (Russia), Iceland and the northernmost rivers of Great Britain and Scandinavia, and the upper Danube, Volga, and Rhône drainages (Froese and Pauly, 2024). This species has been introduced widely in cold water environments in several countries.

This species is considered for culture in water bodies at about 1,000 m altitude. In Saif-ul-Maluk Lake (Kaghan Valley) the fish is known to attain 7 kg. It is a carnivorous fish that feeds upon a variety of aquatic animals including native fishes and invertebrates, and thus, may have negative impacts on the cold water biodiversity of Pakistan (Ahmad and Niazi, 1988).

Oncorhynchus mykiss (Walbaum 1792)
(Fig. 2)

It is commonly known as rainbow trout. The body of this fish is elongated, but compressed. Its coloration may vary with habitat, size, and maturity. Breeding males does not have a hump; juveniles do not have parr marks. It usually has a wide pink-to-red stripe from the head to the caudal base.

This species naturally occurs in the Pacific Slope from Kuskokwim River drainage in Alaska to Otay River drainage in California, USA, and Eastern Pacific including the Kamchatkan Peninsula, Sea of Okhotsk as far south as the mouth of the Amur River (Froese and Pauly, 2024). This species is introduced in many countries including Pakistan. It is also farmed in some areas of Khyber Pakhtunkhwa, Gilgit-Baltistan, and Azad Kashmir.

Fig. 2. *Oncorhynchus mykiss.* Photographed in Karachi (Metro Stores)

Carps (Order Cypriniformes)

Pakistan has vast marine, brackish and freshwater (both cold and warm waters) which is known to have rich fish fauna. However, to enhance fish production, carp culture in ponds used to be the most common form of fish farming in the country. Indian major carp including *Labeo rohita* (Hamilton, 1822), *Labeo catla* (Hamilton, 1822) and *Cirrhinus mrigala* (Hamilton, 1822) used to be the most preferable species for farming. These carp species are known to be slow-growing, therefore, exotic carp have been introduced in Pakistan to enhance aquaculture production. These included *Cyprinus carpio* Linnaeus 1758, *Hypophthalmichthys molitrix* (Valenciennes, 1844), *H. nobilis* (Richardson, 1845) and *Ctenopharyngodon idella* (Valenciennes 1844).

The introduction of alien carp has resulted in increased freshwater fish production but these species have also been established in natural water bodies including large rivers, reservoirs, lakes, dams, and other water bodies almost throughout the countries. The introduction of alien species including carp may result in competition with the native species in the freshwater habitat (Pullin *et al.,* 1997). Asian carp species that have been introduced in Pakistan and other regional countries are known to have high fecundity and are fast-growing as compared to native Indian major carp therefore, have outcompeted native species not only in terms of numbers but also consume the bulk of the food that used to be eaten by native carp species (IUCN Bangladesh, 2000; Welcomme and Chavalit, 2003).

According to Mahboob and Sheri (997) and Khan (2011a), all exotic carp species have been established in major rivers and reservoirs and other warm water habitats in the country in general and in Punjab in particular. There are incremental evidence that alien carp species may destroy the habitat of native species and seriously impact native fish fauna. Muhammad *et al.,* (2017 and Ahmad, *et al.,* (2022) reported silver carp, goldfish and grass carp from the River Indus at Taunsa Barrage indicating their establishment in the river system. Imran *et al.,* (2021) reported a preponderance of exotic carp in the Head Qadirabad, Head Baloki, Islam Headworks, and Rasul Barrage, replacing native Indian major and minor carp.

Through introductions, common carp now occur globally except in the Poles and northern Asia (Lowe *et al.,* 2000; Nelson, 1984) and ecologically most harmful freshwater invasive species (Hume *et al.,* 1983, Pallewatta *et al.,* 2003; Zambrano *et al.,* 2001; Koehn, 2004). Being fast-growing and omnivorous, common carp are capable of dominating the freshwater ecosystem and can cause environmental degradation of the water body (Roberts *et al.,* 1995, Zambrano *et al.,* 1999, Barton *et al.,* 2000). Its high abundance in the River Ganges and other water bodies in India is a major threat to indigenous fish fauna (Singh *et al.,* 2008).

Common carp was introduced in Pakistan from Thailand in 1964 to enhance aquaculture production (Khan *et al.,* 2016) but now it is well established in most natural and man-made water bodies in the country. Within a short period, it became the most dominating species of carp found in inland waters and among the most popular cyprinid species being farmed in Pakistan. The species is known to populate water bodies and compete with space with cyprinids and other species. Its presence in a water body may impact some other fish species because of the occupation of their spawning and rearing habitat, altering water quality (Durocher *et al.,* 1984; Paukert *et al.,* 2002, Lougheed *et al.,* 1998; Parkos *et al.,* 2003). Because of having similar feeding habit, common carp was reported to compete with native some observed that the feeding niche overlaps among alien *Cyprinus carpio* and native omnivorous fishes including *Tor putitora* and *Barilius pakistanicus* from Swat River, Khyber Pakhtunkhwa (Said *et al.,* 2022).

Latif *et al.,* (2016) reported *Cyprinus carpio, Ctenopharyngodon idella*, and *Hypophthalmichthys molitrix* from Head Qadirabad, River Chenab. Altaf *et al.,* (2011a) observed grass and silver carps to be important at Head Qadirabad and Head Khanki, Chenab River whereas Altaf *et al.,* (2011b) grass common and silver carp among the

list of species found at Head Qadirabad, River Chenab. Basharat *et al.,* (2024) observed goldfish, common carp, grass carp, silver carp, and bighead carp from Qadirabad, Malara and Khanki Headworks, River Chenab. Khan *et al.,* 2011a) and Mirza *et al.* (2011) observed the negative impact of alien species on the local fish fauna at the Headworks Balloki (River Ravi) and Trimmu (River Jhelum and Chenab) whereas Ullah *et al.,* (2016) reported invasive carps (grass carp, silver carp, and bighead carp) have established in Muzaffargarh and Taunsa Punjab Link Canals.

Cyprinus carpio was observed to be the most dominating species in large water reservoirs in Punjab such as Chashma Barrage whereas it is among the most dominating species in Taunsa Barrage where this and other species have seriously affected fish diversity (Khan *et al.,* 2008). In addition, Hussain *et al.,* (2016) reported common carp from dhands along the River Indus at Ghazi Ghat whereas Ashraf *et al.* (2022, 2023) reported common carp from various parts of the Ravi River.

Common carp was also introduced in reservoirs of Mirani Dam, Makran, Balochistan along with other local and exotic carp. Within two decades, *Cyprinus carpio* became the most dominating species in the reservoir and adjacent areas which was known to be the abode of several endemic species of carp. Zugmeyer (1912) reported *Labeo macmahoni* and *Labeo gedrosicus* (=*Bangana gedrosicus*) from the Dashat and Kech River systems which feed rivers of the Mirani Dam. However, these species were not observed in the area in a recent survey (unpublished report).

From Khyber Pakhtunkhwa, Common carp is reported from Rhound Stream, District Lower Dir (Ullah 2014), Baran Dam of District Bannu (Ullah *et al.,* 2014), Sharki Dam, District Karak (Hasan *et al.,* 2015a), River Swat (Hasan *et al.,* 2013), Changhoz Dam, District Karak (Khan and Hasan, 2011), Khuram Dam, Karak (Younas *et al.,* 2016), Rhound Stream at District Dir Lower (Ullah *et al.,* 2015), Barganat Dam, North Waziristan Agency (Rehman, *et al.,* 2016b), Timergara, District Dir Lower Khyber (Ullah *et al.,* 2014), River Panjkora, District Dir Lower (Hasan *et al.,* 2015b), Gomal Ghandiali Dam, District Kohat (Rehman *et al.,* 2015d), Gomal Zam Dam, South Waziristan Agency (Rehman *et al.,* 2016d), Konhaye Stream, district Dir Lower (Ullah *et al.,* 2020), Dandy Dam North Waziristan Agency (Rehman *et al.,* 2016a), River Harrow at Kharala and Rambala (Usman *et al.,* 2018), Khaisari (Ghundi Shahbaz Khan) Dam, District Karak (Junaid *et al.,* 2017), Muhabbt Khel Dam (Lake Kana) District Karak (Younas *et al.,* 2017), River Khiali at District Charsadda (Iqbal and Lubna, 2023), Gandiali Dam, District Kohat (Ullah *et al.,* 2022), River Swat at Charsadda (Yousafzai *et al.,* 2013) and Khuram Dam (Younas *et al.,* 2017). From Balochistan, Mengal *et al.,* (2015) also reported common carp from the Khanozai Dam of Pishin.

Grass carp are known to eliminate aquatic plants in introduced habitats altering trophic structure and inflicting widespread detrimental effects on ecosystems (Standish and Wattendorf, 1987). They may also feed selectively on softer plants thereby enhancing the development of tougher plants which may have a serious ecological impact on the aquatic floral composition of the water body. They compete with native invertebrates and vertebrates (fish and amphibians) for food and other important resources. Grass carp also impact waterfowl by reducing aquatic vegetation which is food for aquatic birds (Gertzen *et al.,* 2017). It is widely known from Punjab and established in most rivers and water bodies (Khan *et a*l., 2011a). Although it is farmed in Sindh but not found in natural water bodies (Mahar, 2016).

From Khyber Pakhtunkhwa, Common carp is reported from Khuram Dam, District Karak (Younas *et al.,* 2016), River Panjkora, District Dir Lower (Hasan *et al.,* 2015b), Tanda Dam, District Kohat (Haseeb *et al.,* 2015, 2016a), Gomal Zam Dam, South Waziristan Agency (Rehman *et al.,* 2016d), Darwazai Dam Tehsil Lachi, District Kohat (Rehman *et al.,* 2015a), Dargai Pal Dam South Waziristan Agency (Rehman, 2016), Dandy Dam North Waziristan Agency (Rehman *et al.,* 2016a), Bahawal Gorh River, District Kohat (Azeem *et al.,* 2019), River Khiali at District Charsadda (Iqbal and Lubna, 2023), Zebi Dam, Karak District (Rehman, *et al.,* 2015b), Darmalak Dam, Tehsil Lachi, District Kohat (Rehman, *et al.,* 2015c), Gomal Ghandiali Dam, District Kohat (Rehman *et al.,* 2015d), Talai Dam, Bajaur Agency (Rehman *et al.,* 2015e), Barganat Dam, North Waziristan Agency (Rehman, *et al.,* 2016b), Kandar Dam, District Kohat (Haseeb *et al.,* 2016b), Gandiali Dam, District Kohat (Ullah *et al.,* 2022), Khuram Dam (Younas *et al.,* 2017) and Dandi Idhar Khel Lake, District Karak (Zaryab *et al.,* 2017).

Silver carp (*Hypophthalmichthys molitrix*) was introduced in Pakistan in 1970 to increase fish production of aquaculture ponds and natural water bodies. This species is now widely established in Pakistan and is among the popular species for farming. It, however, competes for food and space in aquaculture ponds and may compete with species of similar habit such as *Labeo catla.* Munawar, *et al.,* (2023) reported that silver carp compete with common carp in Head Malara (Silakot) and Mangla Dam. Ashraf *et al.* (2022, 2023) reported silver carp from the Ravi River.

It is widely established in Khyber Pakhtunkhwa including Baran Dam, District Bannu (Asmat-Ullah *et al.,* 2014), Changhoz Dam, District Karak (Khan and Hasan, 2011), Tanda Dam, District Kohat (Haseeb *et al.,* 2016a), Zebi Dam, Karak District (Rehman *et al.,* 2015b), Chambai Dam District Karak (Yousaf *et al.,*2016). Sarki

Lawaghar Dam, District Karak (Rehman *et al.*, 2015f), Muhabbt Khel Dam (Lake Kana) District Karak (Junaid *et al.*, 2016; Younas *et al.*, 2017)), Ghol Dam Bahadur Khan, District Karak (Azeem *et al.*, 2016), Shnebaye Stream, Karak District (Rehman *et al.*, 2016c), River Harrow at Akhora and Kharala (Usman *et al.*, 2018), Khaisari (Ghundi Shahbaz Khan) dam located in District Karak (Junaid *et al.*, 2017), Naryab Dam, District Hangu (Haseeb *et al.*, 2016c), Timergara, District Dir Lower)Ullah *et al.*, 2014), Darwazai Dam Tehsil Lachi, District Kohat (Rehman *et al.* 2015a), Gomal Zam Dam, South Waziristan Agency (Rehman *et al.*, 2016d), Dandy Dam North Waziristan Agency (Rehman *et al.*, 2016a), Gomal Ghandiali Dam, District Kohat (Rehman *et al*., 2015e), Kandar Dam, District Kohat (Haseeb *et al.*, 2016b), Gandiali Dam, District Kohat (Ullah *et al.*, 2022) and Talai Dam, Bajaur Agency (Rehman *et al*., 2015d),

Bighead carp (*Hypophthalmichthys nobilis*) was introduced in Pakistan in 1982-1983 from Nepal and China (Khan *et al.*, 2011a; Mahboob and Sheri, 1997). Imran *et al.*, (2021) reported that bighead carp may compete with native species for food and shelter. Bighead carp is known to have been established in major water bodies in Punjab and Khyber Pakhtunkhwa but has not been reported to be established in Sindh. Mahar (2016) studied the fish fauna of water bodies in Sindh and did not observe the presence of bighead carp in the waters of Sindh. From Khyber Pakhtunkhwa it is reported from Tanda Dam, District Kohat (Haseeb *et al.*, 2016a), Naryab Dam, District Hangu (Haseeb *et al.*, 2016c), Barganat Dam, North Waziristan Agency (Rehman *et al.*, 2016b), Baran Dam, District Bannu (Asmat-ullah *et al.*, 2014), Dargai Pal Dam South Waziristan Agency Rehman, 2016) and Gomal Zam Dam, South Waziristan Agency by Rehman *et al.*, 2016d). It is not reported from Balochistan.

Goldfish is one of the oldest domesticated (Balon, 2004) and most widely introduced freshwater fishes globally (GISD-Global Invasive Species Database 2005). Once introduced, it can rapidly establish and become a dominant species, particularly in still or slow-flowing water bodies (Lorenzoni *et al.*, 2010a, 2010b; Morgan and Beatty, 2007; Beatty and Morgan, 2013). There is limited information about the ecological impact of goldfish (Beatty *et al.*, 2016; Corfield *et al.*, 2008), however, being a benthic omnivore, its feeding activity disrupts the sediment, it can potentially impact aquatic macrophytes, water quality, and may reactivate cyanobacteria through its gut processes (Copp *et al.*, 2010; Corfield *et al.*, 2008; Kolmakov and Gladyshev, 2003; Richardson *et al*, 1995, Beatty and Morgan, 2013). It is also known to be a vector for the introduction of parasites and diseases (Corfield *et al.*, 2008; Lymbery *et al.*, 2014; Trust *et al.*, 1980). It is considered to be an invasive species as it competes with other native fish species of Pakistan for food and space (Khan *et al.*, 2011a). Goldfish have also been known to prey upon the eggs, larvae, and adults of native fishes (Morgan *et al.*, 2004), as well as depleting aquatic vegetation (Richardson *et al.*, 1995).

Goldfish (*Carassius auratus*) is an indigenous fish species of eastern Asia but does not occur naturally in Pakistan. It was introduced in Pakistan in 1961 for use in ornamental and aquaculture purposes (Khan *et al.*, 2011a; Mirza, 2003, 2004). This species is now established in water bodies in various parts of Pakistan including Punjab, Khyber Pakhtunkhwa, Sindh, Balochistan, and Azad Kashmir (Mirza, 2003). Mirza (2003) reported its population from the River Indus up to Tarbela and Khalabat Pocket. It is also reported from most water bodies in Punjab including the River Indus, the River Ravi and other major water bodies of Punjab (Khan *et al.*, 2008; Hussain *et al.*, 2015). In most cases, it may not be a dominating species but still it is now established in freshwater habitats (Ashraf *et al.*, 2022; Ahmad *et al.*, 2022). Ashraf *et al.* (2022, 2023) reported goldfish from the Ravi River.

It is also widely distributed in Khyber Pakhtunkhwa including River Swat (Hasan *et al.*,2013), Charsadda (Yousafzai *et al.*, 2013), Bajaur Agency (Hasan *et al.*, 2014), District Malakand (Ali *et al.*, (2020), River Panjkora, District, Upper Dir (Akhtar *et al.*, 2014b; Muhammad *et al.*, 2014), the Zebi Dam, Karak District (Rehman *et al.*, 2015b), the Gandiali Dam, District Kohat (Rehman *et al.*, 2015d; Ullah *et al.*, 2022), River Swat at Manglawar Valley (Akhtar *et al.*, 2014a) and the River Jindi at District Charsadda (Rehman *et al.*, 2019). Rehman *et al* (2015e) reported it from Talai Dam, Bajaur Agency. From Balochistan, it was reported from the Khanozai Dam of Pishin by Mengal *et al.*, (2015). Goldfish was reported to occur in Sindh, however, not been reported from water bodies in Sindh (Mahar, 2016).

Cyprinus carpio Linnaeus 1758

(Fig. 3-6)

Fig. 3. *Cyprinus carpio*-Scaly carp

Common carp has a long dorsal fin. Its caudal fin is deeply emarginated. Its mouth is large and has two pairs of barbels, one pair on the upper lip and the other pair at the corners of the mouth. The colour of its body varies from grey, silver to bronze and with a yellowish or reddish belly. This species is highly variable in form, proportions, squamation, development of fins, and colour.

The body of native forms and improved strains may vary from elongated to deep oval. There are only two basic forms of common carp: *Cyprinus carpio morpha hungaricus* and *C. carpio morpha acuminatus*. *Morpha hungaricus* has an elongated torpedo-like body, while the body of *morpha acuminatus* is short and stocky. Jhingran and Pullin (1985), Pintér (1989), and Kuznetsov *et al.*, (2011) have identified four subspecies of common carp namely *Cyprinus carpio carpio* (European Transcaucasian common carp), *Cyprinus carpio aralensis* (Aral common carp), *Cyprinus carpio haematopterus* (Amur common carp) and *Cyprinus carpio viridiviolaceus* (North Vietnamese common carp) whereas, Balon (1995) reported only two subspecies, *C. carpio carpio*, and *C. carpio haematopterus.* Froese and Pauly (2024) do not recognize any subspecies of this carp. Common carp is one of the most variable freshwater fish species in body shape and several varieties that differ in the size and colour of their scales are known which include:

- Common carp are typical fully scaled fish (Fig. 3 and Fig.4).
- Mirror carp have relatively few large, shiny scales (Fig. 5).
- Linear carp have scales only along the lateral line (not noticed to occur in Pakistan during the present study).
- Leather or naked carp have very few scales (not noticed to occur in Pakistan during the present study).
- Koi carp are colourful varieties imported for ornamental ponds. Koi carp naturally occurs in the Aral, Caspian, and Black Seas, however, in Pakistan koi do not occur in nature, however, sometimes crossbreeds may be found especially in lower Sindh (Fig. 6).

Common carp is known from Europe to Asia including the Black, Caspian, Aral Sea basins and the River Danube (Froese and Pauly, 2024; Kottelat, 1997; Kottelat and Freyhof, 2007). This species is introduced globally including Pakistan. It is considered to be a widely distributed carp species in Pakistan. In nature, common carp live in the middle and lower sections of rivers and in areas where the water is shallow and the bottom is muddy.

Fig. 4. Deep-body common carp commonly found in Pakistan

Fig. 5. Cyprinus carpio: Mirror carp

Fig. 6. Koi type (crossbreed) common carp collected from Thatta (landed at Karachi Fish Harbour).

Genus *Ctenopharyngodon* Steindachner, 1866
Ctenopharyngodon idella (Valenciennes, 1844)
(Fig. 7)

Fig. 7. *Ctenopharyngodon idella*

Grass carp have elongated, laterally compressed, and torpedo-shaped bodies. The terminal mouth is slightly oblique, terminally located on a wide head and the eyes are small and lack barbels. It has a short caudal peduncle. Its body is dark olive, shading to brownish-yellow on the sides, with a white belly and large, slightly outlined scales. This species can be differentiated from goldfish and common carp in having a shorter dorsal fin (only 7-8 rays) and from bighead and silver carp in having fewer anal rays (9 or fewer) and fewer but larger lateral scales.
This species is known from Eastern China and Russia including in eastern Siberia and the Amur River system (Froese and Pauly, 2024; Shireman and Smith 1993) but is now widely introduced globally including in Pakistan

Genus *Hypophthalmichthys* Bleeker, 1860
Hypophthalmichthys molitrix (Valenciennes, 1844)
(Fig. 8)

The silver carp is a narrow, laterally compressed and deep-bodied fish. It has a toothless mouth with upturned lower jaws that lack barbels. . It has very tiny scales on the body but the head and the opercles are scaleless. It is silvery in colour , however, old specimens have a greenish colour on the back to silver on the belly.

Silver carp differs from other cyprinids because of their size and unusual position of the eye. They are more similar to *Hypophthalmichthys nobilis* with which it can be distinguished by having a smaller head, an upturned mouth that lacks teeth, a keel that extends forward past the pelvic fin base, lack the dark blotches and highly branched gill rakers.

Fig. 8. *Hypophthalmichthys molitrix*

Silver carp is an Asian carp that known from major Pacific drainages of East Asia from Amur to Xi Jiang, China, and Hanoi, Vietnam (Froese and Pauly, 2024). It is introduced around the world at least in 88 countries for aquaculture and control of algal blooms. Introduced in Pakistan and considered as an invasive species.

Hypophthalmichthys nobilis (Richardson, 1845)
(Fig. 9)

Fig. 9. *Hypophthalmichthys nobilis.* Chhenawan Hatchery, Gujranwala (Courtesy A. M. Chatta)

The body of bighead carp is laterally compressed with a round abdomen before the ventral fin. It has a large head with a terminal mouth which is slanting upwards. There are no barbels. Its body is black dorsally and laterally. The abdomen is silvery white with irregular black spots on the lateral side of the body. This species differs from silver carp in having a scaled keel from pelvic to anal and in having dark overall coloration. Its flank has dark, large, very irregularly shaped blotches whereas fin bases and belly are yellowish.

The bighead carp are known from eastern China in the lowland rivers of the North China Plain and South China, including the Huai, Yangtze, Pearl, West, Han Chiang, and Min Rivers (Jennings, 1988; Li and Fang 1990; Robins *et al.*, 1991). It is introduced globally for aquaculture including Pakistan.

Genus *Carassius* Jarocki, 1822
Carassius auratus (Linnaeus, 1758)
(Fig.10)

The body of the goldfish is stout and robust with an elevated back. It has a short head and lacks barbels. Its caudal peduncle is thick and short. Its dorsal fin is long and has a stout, saw-toothed spine-like ray. Its colour is olive-brown, slate olive, olive green, with a bronze sheen, silvery, greyish yellowish, grey-silver, through gold to creamy white; yellowish white or white below. Its ornamental forms vary through scarlet, red-pink, silver, brown, white, black, and combinations of these colours. When released into a natural environment, the goldfish will revert to the yellow-orange colour after a couple of generations.

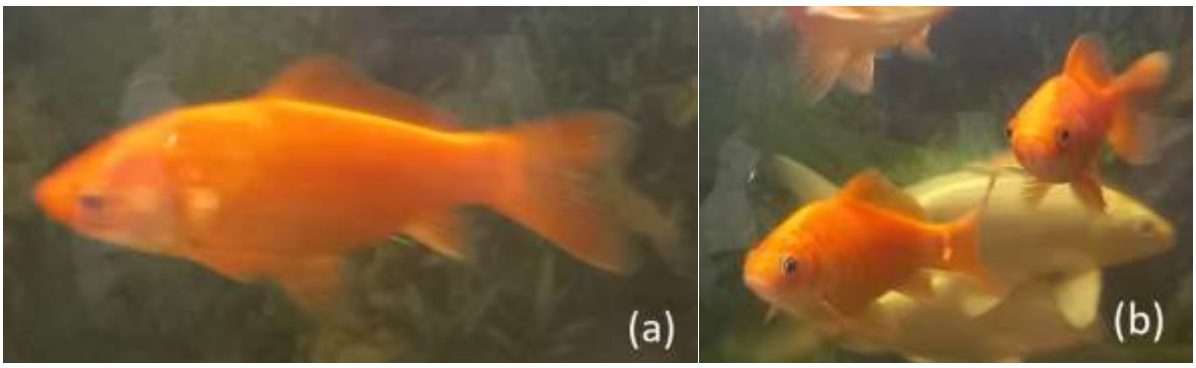

Fig. 10. *Carassius auratus* (a) Lateral view; (b) Front view.

Goldfish are known from East Asia, China, and Japan (Froese and Pauly, 2024). It is generally introduced through aquarium trade as well both deliberately and accidentally, throughout the world including Pakistan.

Tilapias (Order Cichliformes)

Members of Order Cichliformes include commercially important tilapia consisting of about 100 species that are native to the African continent. These are mainly freshwater fish inhabiting shallow streams, ponds, rivers, lakes, and brackish water. Three species of tilapia including Mozambique tilapia (*Oreochromis mossambicus*), blue tilapia

(*Oreochromis aureus*) and Nile tilapia (*Oreochromis niloticus*) were deliberately introduced in Pakistan to enhance fish production of natural water bodies and aquaculture ponds. Ashraf *et al.* (2022) reported Mozambique and blue tilapias from Ravi River whereas Ashraf *et al.* (2023) reported redbelly tilapia from Ravi River. Muhammad *et al.*, (2017) reported all three species from River Indus at Taunsa Barrage. In addition, redbelly tilapia (*Coptodon zillii*) and mango tilapia (*Sarotherodon galilaeus*) have also been introduced possibly accidentally in water bodies of Sindh and Balochistan. Banded tilapia (*Tilapia sparmanii*) was reported from District Mardan and Swabi, Khyber Pakhtunkhwa (Ahmad, 2023) which seems to be a new addition to tilapias in Pakistan. It is recently reported to occur in water bodies in lower Sindh and now frequently landed at commercial centes in Thatta and Karachi.

Mozambique tilapia (*Oreochromis mossambicus*) was introduced in Pakistan from Malaysia in 1951 (Naik, 1973). It is now found in almost all parts of Pakistan including Punjab, Khyber Pakhtunkhwa, Sindh, and Balochistan (Rafique and Khan, 2012). Latif *et al.,* (2016) reported this species from Head Qadirabad, River Chenab.. Ahmad, *et al.,* (2022) reported that this tilapia is a rare fish found in Taunsa Reservoir. Basharat *et al.*, (2024) observed this species at Qadirabad, Malara and Khanki Headworks, River Chenab. It is abundant in Manchar Lake (Achakzai, *et al.,* 2013) and the Malir River, Karachi (Bano, *et al.,* 2009). Atia (2018) studied the biology of *Oreochromis mossambicus* in Keenjhar Lake and observed a wide range of expansion and prolific colonization of this species in the lake as well as in most freshwater and saline inland waters of Pakistan affecting biodiversity and natural fish fauna.

Mahar (2016) has observed the presence of Mozambique tilapia in almost all water bodies of the Province of Sindh. *O. mossambicus* was also recorded in the estuarine lakes in Badin where it is known to be breeding. It is possibly the only invasive species that occur in estuarine waters in Pakistan. In some water bodies, especially small dhands and lakes, Mozambique tilapia became the most dominating species leading to the complete alteration of the aquatic ecosystem which, in some cases, has a serious impact on the socio-economic conditions of the fishermen community such as Manchar and Keenjhar Lakes in Sindh.

Nile tilapia (*Oreochromis niloticus*) was introduced in Pakistan in1985 from Egypt (De Silva *et al.,* 2004; Khan *et al.,* 2011a) for aquaculture in brackish and saline water but it is now well established in natural water bodies in Sindh, Balochistan, Khyber Pakhtunkhwa and Punjab. Naeem *et al.,* (2010) reported *O. niloticus* from the Indus River whereas Batool *et al.,* (2017) reported it to colonize Keenjhar Lake. Mahar (2016) reported *O. niloticus* from all major inland water bodies in Sindh. Imran *et al.,* (2021) reported it to be widely present at Head Qadirabad, Head Baloki and, Islam Headworks in Punjab. Mehak *et al.* (2017) reported Nile tilapia's establishment at Chasma Barrage, Punjab. Latif *et al.,* (2016) reported this species from Head Qadirabad, River Chenab. Altaf *et al.,* (2011b) this species at Head Qadirabad, District Gujranwala. Basharat *et al.,* (2024) observed this species at Qadirabad, Malara and Khanki Headworks, River Chenab. Ahmad (2023) reported it from District Mardan and Swabi, Khyber Pakhtunkhwa. Masood *et al.,* (2015a) reported this species from Damai stream Tehsil Domel, District Bannu. Rehman, *et al.,* (2016b) reported it from Barganat Dam, North Waziristan Agency. Azeem *et al.,* (2016) reported it from Ghol Dam Bahadur Khan, district Karak,

Through selective breeding choosing broodstock from eight strains of Nile tilapia (*Oreochromis niloticus*) from Egypt, Ghana, Senegal, Philippines, Israel, Taiwan, Thailand, and Kenya, GIFT (Genetically Improved Farmed Tilapia) strain was developed which is hardier, more disease-resistant and faster-growing fish. On-farm conditions, the GIFT strain gives up to 40% higher yield in comparison with local strains. GIFT tilapia fry was imported from Thailand for culture but now locally produced fries and fingerlings of GIFT are also available. This strain is now one of the popular farmed fish in Pakistan especially in Punjab.

Blue tilapia (*Oreochromis aureus*) is an invasive species which has established in most freshwater habitats in Punjab (Khan *et al.,* 2011a), Khyber Pakhtunkhwa (Masood *et al.,* 2015a; Pervaiz, 2015), Balochistan (Masood *et al.,* 2015b; Nazeer *et al.,* 2015) and Sindh (Mahar, 2016). *Oreochromis aureus* was introduced in Pakistan in 1985by importing it from Egypt (De Silva *et al.,* 2004; Khan *et al.,* 2011a) for aquaculture in brackish and saline water but it is now well established in natural water bodies in Pakistan. *O.aureus* is now well established in most large reservoirs in Punjab including Balloki and Trimmu reservoirs and the River Ravi (Altaf *et al.,* 2015; Pervaiz, *et al.,* 2018)). Rehman, *et al.,* (2016b) reported it from Barganat Dam, North Waziristan Agency..

Redbelly tilapia (*Coptodon zillii*) is reported from Sindh by Mahar (2016) and now occupying natural water bodies in Sindh and Balochistan. It was collected by Sherzada (2019) from River Chenab near Head Trimmu District Jhang and Asharf *et al.,* (2023) from the River Ravi. This fish is found widely in fresh and brackish waters in the northern half of Africa and the Middle East but it was introduced in some other countries where it turned into an invasive species. *Coptodon zillii* is spreading in Balochistan. Recent floods (2022) have further spread its distribution in the province. It was observed to be among the most common species in Siranda Lake, Lasbela District after the post-flood period.

Mango tilapia (*Sarotherodon galilaeus*) is a native species of fresh and brackish waters in Africa and the Levant. It was introduced in China, Congo, Japan, and South Africa. It seems to have been introduced accidentally in Pakistan and is now common in the inland water bodies of Sindh (Mahar, 2016).

Banded tilapia (*Tilapia cf. sparrmanii*) has recently mentioned about the occurrence of this species from Mardan, Khyber Pakhtunkhwa, Pakistan by Ahmad (2023). This species has also occupied the water bodies in lower Sindh, especially in Thatta District, and regularly landed at Thatta Fish Market and Karachi Fish Harbour. It is now an invasive species and spreading in other areas. It is also invasive in South Africa and Madagascar but it is not known to have been established in any other country. Ullah *et al.,* (2016) reported *Tilapia baloni* Trewavas and Stewart 1975 from Muzaffargarh and Tanusa Link Canals, however, it seems to be a misidentification as this species is not introduced in Pakistan.

Genus *Oreochromis* Günther, 1889

Oreochromis aureus (Steindachner 1864

(Fig. 11)

Fig. 11. *Oreochromis aureus*

Blue tilapia belongs to Family Cichlidae and subfamily Pseudocrenilabrinae. It is known to have narrow preorbital bone and no enlargement of the jaws in mature fish. Its caudal fin lacks regular dark vertical stripes, but it may have a broad pink to bright red distal margin. Breeding males may have an intense bright metallic blue on the head, a vermilion edge to the dorsal fin, and an intense pink on the caudal fin margin. Breeding females have paler and orange edges of dorsal and caudal fins.

This species is known from Africa and Eurasia including Jordan Valley, Lower Nile, Chad Basin, Benue, middle and upper Niger, Senegal River (Froese and Pauly, 2024). It was introduced for aquaculture in the USA, South and Central America, and South East Asia including Pakistan. It is considered invasive because competes with native fish fauna for space and food.

Oreochromis mossambicus (Peters 1852)

(Fig. 12)

Fig. 12. *Oreochromis mossambicus*

Mozambique tilapia also belongs to Family Cichlidae and subfamily Pseudocrenilabrinae. It is known to have a long snout, and forehead with relatively large scales, Adult males develop a pointed, duckbill-like snout. Its caudal fin is not densely scaled. The female and non-breeding male are silvery with 2-5 mid-lateral blotches whereas breeding male are black with white lower parts of head and red margins to dorsal and caudal fins.

Mozambique tilapia is native to Lower Zambezi, Lower Shiré, and coastal plains from Zambezi delta to Algoa Bay and southwards to the Brak River in the Eastern Cape and in the Transvaal in the Limpopo system (Froese and Pauly, 2024). Widely introduced for aquaculture globally including Pakistan.

Oreochromis niloticus (Linnaeus 1758)
(Fig. 13)

Nile tilapia also belongs to the Family Cichlidae and subfamily Pseudocrenilabrinae. It is known to have a large deep body, with a relatively small head. There are regular vertical stripes on the caudal fin. Its males are bluish pink, with a dark throat, belly, anal and pelvic fins whereas females are usually brownish, silvery/white beneath with around 10 thin vertical bars.

Nile tilapia naturally is known from the coastal rivers of Israel, Nile basin (including lake Albert, Edward and Tana), Jebel Marra, Lake Kivu, Lake Tanganyika, Awash River, various Ethiopian lakes, Omo River system, Lake Turkana, Suguta River, and Lake Baringo) and from West Africa including the basins of Senegal, Gambia, Volta, Niger, Benue, and Chad (Froese and Pauly, 2024). Widely introduced for aquaculture globally including Pakistan. GIFT (Genetically Improved Farmed Tilapia) strain which is now a popular farmed species in Pakistan is a popular strain of Nile tilapia

Fig. 13. *Oreochromis niloticus*

Red Tilapia

Fig. 14. Farmed red tilapia from lower Sindh

The red tilapia is a crossbreed of *Oreochromis aureus x Oreochromis mossambicus* that has been developed as a food fish (Lingam *et al.,* 2021). Red tilapia is introduced in Pakistan and cultured on a small scale in some parts of Pakistan (Fig. 14). It is more deeply compressed than other tilapias. It is very tolerant of brackish waters and opportunistic omnivore-consuming diatoms, invertebrates, small fry, and veisgetation ranging from macroalgae to rooted plants to decaying plant material. It only grows in aquaculture ponds ans not inhabited in the natural water bodies except some fingerlings that have escaped from ponds and grown in natural water bodies but could not breed.

Genus *Coptodon* Gervais, 1853
Coptodon zillii (Gervais 1848)
(Fig. 15)

Redbelly tilapia also belongs to Family Cichlidae and subfamily Pseudocrenilabrinae. It is a large, deep-bodied species with a narrow head and small strong jaws. It may have a bright red belly and prominent vertical bars. It lacks bifurcated dark vertical bars on flanks whereas dorsal and caudal fins are not blotched. Its body is brownish-olivaceous with an iridescent blue sheen. Dorsal, caudal, and anal fins are brownish-olivaceous with yellow spots whereas dorsal and anal fins are outlined by a narrow orange band.

Fig. 15. *Coptodon zillii*

It is native to North Africa including Morocco east to Egypt, south to Nigeria and Central African Republic; Middle East: Syria south to Israel and Jordan (Froese and Pauly, 2024). It is accidentally introduced in Sindh, Punjab, and Balochistan and now spreading to other areas.

Genus *Sarotherodon* Rüppell, 1852
Sarotherodon galilaeus (Linnaeus, 1758)
(Fig. 16)

Fig. 16. *Sarotherodon galilaeus*

Mango tilapia is belong to Family Cichlidae and subfamily Pseudocrenilabrinae. Its colour is fair silvery-radish with 7-9 ventricle blackish lines on the side of the body. Reproductive active specimens are greyish dorsally and silvery ventrally. Dorsal and caudal fins are usually with pinkish margins. Males have longer soft dorsal and anal fin rays.

It is native to Africa and Eurasia including Jordan system, Israel; Nile system, Congo basin, West Africa (Senegal, Gambia, Casamance, Géba, Konkouré, Sassandra, Bandama, Comoé, Niger, Volta, Tano, Lake Bosumtwi, Mono, Ouémé, Ogun, Cross, Benue, Logone, Shari and Lake Chad), Draa (Morocco), Adrar (Mauritania), Saharian oases (Borku, Ennedi) and Tibesti in northern Chad; Sanaga and Nyong basins in Cameroon (Froese and Pauly, 2024). Mango tilapia is possibly accidentally introduced in Sindh and spreading to other areas.

Genus *Tilapia* 1840
Tilapia cf. sparrmanii Smith 1840
(Fig. 17)

Fig. 17. *Tilapia cf. sparrmanii*

Banded tilapia as it is commonly known has a small, deep-bodied species with a narrow head and small strong jaws. Its colour may be rich deep yellow with wide dark brown bands, and red/orange fin margins. Mature adults are very dark with prominent black stripes and a patch of scarlet scales behind the head.

This species is native to Africa: including middle Congo River basin in the Kwilu Kwango, Kasai drainage and Lomami; upper Congo River basin including the Lualaba, upper Lualaba, Lufira, Upemba region, Luvua, Lake Mweru, Luapula and Bangweulu; Cunene, Okavango, Lake Ngami, Zambezi, Limpopo, northern tributaries of the Orange River, Cuvelai, upper Cuanza, Sabi, Lundi and Lake Malawi (Froese and Pauly, 2024). It is also exotic in USA (Courtenay, *et al*., 1984), colonized estuarine waters around Okinawa Island, Japan (Chiba, *et al.*, 1989), and Pakistan (Ahmad, 2023; Present study).

Tilapia baloni Trewavas and Stewart 1975

It was reported from Muzaffargarh and Tanusa Link Canals, Pakistan by Ullah *et al.,* (2016). It is known only from African continent including rivers Luongo (middle Luapula tributary, Kalungwishi (Lake Mweru tributary and in the upper Congo River basin (Froese and Pauly, 2024). The report from Pakistan seems to be a misidentification as this species is not known to have been introduced in Pakistan.

Catfishes (Order Siluriformes)

Some catfish species are known to be important invasive fish species that can change the structure of the food web by occupying as top predators which may also decrease the available food for native species. This direct may lead to declines in the population native fish species as well as loss of biodiversity of the freshwater bodies. Representatives of the genera *Pterygoplichthys, Pangasius,* and *Clarias* have been introduced to enhance the fish production of the aquaculture ponds or accidentally through aquarium trade, however, in most cases, these catfish species became invasive in the area of introduction. Seven species of catfishes are introduced in Pakistan which include *Pterygoplichthys pardalis*, *Clarias magur*, *Clarias gariepinus*, *C. batrachus, Clarias ngamensis, Pangasianodon hypophthalmus* and *Ictalurus punctatus.*

Pterygoplichthys pardalis (Castelnau, 1855) which belonged to family Loricariidae (armored catfishes) is a popular aquarium fish. It has been introduced globally through the aquarium trade (Wakida-Kusunoki *et al.,* 2007) and is considered invasive in the tropical and subtropical freshwater ecosystem (Page, 1994; Liang *et al.,* 2005; Chavez *et al.,* 2006, Nico, 2010a, 2010b; Wu *et al.,* 2011). This catfish feeds on algae and detritus (Li-Wei *et al.,* 2011; Ozedilek, 2007) as well as insects, fish eggs and other invertebrates (Mendoza *et al.,* 2009).

Armored catfishes are established in USA (Nico and Martin, 2001), Europe (Keszka *et al.,* 2008), the Philippines (Chavez *et al.,* 2006; Hubilla *et al.,* 2007), Vietnam (Zworykin and Budaev 2013), Israel (Golani and Snovsky 2013), Iraq (Qasim and Jawad, 2022), Japan (Nakabo 2002), Taiwan (Wu *et al.,* 2011), Turkey (Ozdilek, 2007), Singapore (Page and Robins, 2006), Indonesia, Malaysia (Page and Robins, 2006), Thailand (Chaichana and Jongphadungkiet. 2012; Chaichana et al. 2013), Bangladesh (Hoover *et al.,* 2004; Hossain *et al.,* 2008; Hossain, 2020; Krishnakumar *et al.,* 2009; Liang *et al.,* 2005; Nonogaki *et al.,* 2007; Parvez *et al.,* 2023; Wakida-Kusunoki *et al.,* 2007), Mexico (Armando *et al.,* 2007; Piazzini *et al.,* 2010; Simonović *et al.,* 2010), India (Veena *et al.,* 2023) and Sri Lanka (Sumanasinghe and Amarasinghe, 2013).

The Amazon sailfin catfish and its allied species are covered with strong body plates, therefore, another predator cannot feed upon them (Liang *et al.,* 2005; Nico *et al.,* 2012; Özdilek *et al.,* 2007; Wakida-Kusunoki *et al.,* 2007)). These catfishes also have fins that are equipped with sharp hard spines, therefore, predators cannot affect them (Quan *et al.,* 2020; Peplinski *et al.,* 2021; Hill and Sowards 2015; Hossain *et al.,* 2018; Patoka *et al.,* 2020). It is a facultative air-breather and therefore can tolerate a wide range of environments (Capps *et al.* 2011); therefore, this species can survive in degraded habitats. These catfish compete with native fish fauna for food as well as consume their eggs and larvae, thus outcompeting native fish (Al Mamun *et al.,* 2023a, 2023b; Capps and Flecker 2013; Capps and Flecker 2015; Chaichana and Jongphadungkiet 2012; Chaichana *et al.,* 2013; Chavez *et al.,* 2006; Liang *et al.,* 2005; Meena *et al.,* 2016; Page and Robins 2006). This armored catfish is known to damage banks of waterbodies through burrowing and tunneling (Bunkley-Williams *et al.,* 1994; Gibbs *et al.,* 2010; Hoover *et al.,* 2004; Nico *et al.,* 2009a; 2009b). It also competes with native species for food and space (Nico and Martin, 2001), modifies substrates and disrupts benthic communities (Hossain *et al.,* 2024; Hoover *et al.,* 2004). Orfinger and Goodding (2018) reported that *Pterygoplichthys pardalis* may damage fisheries equipment and bio-accumulate heavy metals and coliform bacteria.

In some cases, the population of Amazon sailfin catfish may increase substantially and its overpopulation may lead to the decline of commercially important inland native fish as observed by Singh *et al.,* (2013) and Bijukumar *et al.,* (2015) in Kerala and Tamil Nadu, India respectively. In Bangladesh, species of the genus *Pterygoplichthys* has spread widely and impacted negatively on ecosystem health, biodiversity, and economics (Armbruster 1998; Armbruster and Page, 2006; Hoover *et al.,* 2004; Gibbs and Groff, 2014; Hossain *et al.,* 2018). Like most other species of invasive fish, the new population of this catfish is very difficult to eradicate (Hill and Sowards 2015; Orfinger and Goodding, 2018). Fishermen are suffering economic losses due to damage to their fishing gear and poorer catches (Chavez *et al.,* 2006; Wakida-Kusunoki *et al.,* 2007; Krishnakumar *et al.,* 2009).

In Pakistan, this species has been used in the aquarium trade for a long period, primarily based on specimens imported from Thailand, Hong Kong, and Singapore, however, it started appearing in natural water bodies in lower Sindh in 2018. This is an invasive species that is now established in Keenjhar Lake, and many dhandhs in Thatta and Sujawal District. It is also found in natural ditches and natural water bodies on the outskirts of Karachi City. The

first set of specimens was noticed in 2018 from Keenjhar Lake but since then this species has been observed regularly in the commercial landings originating from the lower Sindh area.

In India and Bangladesh *Pterygoplichthys pardalis* does not hold any market value, therefore, after harvest people discard the species on the banks of the lake, where it is not even scavenged (Soundararajan *et al.,* 2015). In Pakistan also *Pterygoplichthys pardalis* is not consumed or used for any purpose, therefore, mostly discarded or used as raw material for fishmeal production.

Some catfishes of the family Clariidae (air-breathing catfish) are widely farmed in ponds, cages, and pens for commercial purposes, however, several countries often cite negative environmental effects following its release in wild. *Clarias* catfishes are found in inland waters throughout much of the old world, and are among the most widespread catfish in the world. The genus *Clarias* is found in the Southeast Asia and East Asia westwards through India and the Asia Minor to Africa (Froese and Pauly, 2024).. *Clarias* catfish including North African catfish (*C. gariepinus*), the Philippine or walking catfish (*Clarias batrachus*) and magur catcfish (*C. magur*) have been introduced to many different areas of the world including Pakistan. Blunt-toothed African catfish (*Clarias ngamensis*) is a species that has recently appears as an invasive species in Pakistan. It may be pointed out that the identification of genus *Clarias* in Southeast and South Asia including Pakistan is problematic. These species may invade aquaculture farms and preying on the fish cultivated there. Countries where one or several *Clarias* species have been introduced include Indonesia, USA, Cuba, Hong Kong, China , UK, Papua New Guinea , Taiwan, Thailand, India, and now Pakistan. In most of these countries members of genus *Clarias* have turned into serious invasive species.

The Philippine or walking catfish (*Clarias batrachus*) does not occur naturally in Pakistan but seeds of this species were imported from Thailand in 2000 for aquaculture farming in District Thatta but some specimens escaped from the ponds and colonized natural water bodies in the areas. Within a period of about three years it spreads profusely in the lower Sindh including Thatta, Sujjawal, Badin, Benazirabad, Dadu and Karachi Districts and still spreading. It is an aggressive exotic species which competes with other catfish and other local fauna for food and space. It especially competes with stinging catfish (*Heteropneustes fossilis*) as the Philippine catfish share habitat with this species. The production of *Clarias batrachus* from natural waters has increased substantially in the last two decades and now it is exported in substantially large quantities. Because of the increase in their number local fish fauna is seriously affected in lower Sindh. There are reports that it is also appearing in commercial catches at Sukkur in upper Sindh

*Clarias gariepi*nus which is commonly known as African catfish, African sharptooth catfish, or Thai magur, is an invasive African catfish that was first introduced in Pakistan in 2015 by importing its fingerlings from Thailand. It was farmed in parts of Punjab and Sindh (Sujjawal and Badin Districts), however, specimens of this fish have escaped from the aquaculture farms and are now established in water bodies especially in the lower Sindh. It is not uncommon and is now being landed at important markets including Karachi at Thatta and also small quantities are exported.

De Moor and Bruton (1988) reported that African catfish also devour small reptiles, amphibians, and birds, destroying the ecological balance of water bodies by affecting indigenous biodiversity and reduces the food base for water birds. It possesses a supra-branchial organ which allows it to utilize atmospheric air and "walk" overland using its strong pectoral fins (Bruton, 1979; Cambray, 2003), and spreads into adjacent water bodies (Burgess, 1989; Bruton, 1979, 1986; Winemiller and Kelso-Winemiller, 1996). Impacts of *Clarias gariepinus* may lead to decline of native species through ecological (competition, predation) and genetic interactions (e.g., hybridisation, introgression) (Low, 2018; Low *et al.,* 2022). Furthermore, invasive *C. gariepinus* is known to substantially reduce native macro-invertebrate and fish population densities owing to its generalist predatory feeding habits (Cambray, 2003; Weir, 1972), and would therefore be expected to pose a threat to freshwater communities in the most countries (Aqmal- Naser and Amirrudin, 2019; Low *et al.,* 2022). It is already invasive in more than 30 countries and further spreading (Froese and Pauly, 2024; GISD, 2024; Bhandarkar, 2022).

Clarias ngamensis commonly known as the blunt-toothed African catfish is another species belonging to the family Clariidae which is turning into an invasive species in Pakistan. This species is frequently encountered in the commercial catches from natural water bodies in lower Sindh. No information about its introduction or being invasive in any other country is available, however, Fishbase (Froese and Pauly, 2024) has a photo from Assam Silchar, India. It is not known, how it was introduced in Pakistan (or India) but possibly it was imported for aquarium trade and escaped to colonize some water bodies. Its food may consist of mollusks, terrestrial and aquatic insects, insect larvae, shrimps, grain, crabs, and fish (Konings 1990). Blunt-toothed African Catfish breeds during the summer rainy season when it moves via shallow flooded drainage channels onto the floodplain to spawn (Skelton 2001). It is already introduced in Romania (Gavriloaie and Chisamera, 2005).

In Pakistan, the aquaculture of the channel catfish was introduced and promoted by the National Agriculture Research Centre, Islamabad. Although its culture in ponds is not popular there are reports of this species becoming invasive in part of upper Sindh. A few specimens of this species were seen at the landing centre at Sukkur which was brought by fishermen from nearby impoundments. It is feared that it may become invasive, at least in Sindh where a large number of water bodies exist.

The channel catfish can be a potentially invasive species because of prolific reproduction, tolerance to a wide range of conditions (Haubrock *et al.*, 2021). It is already introduced in 40 countries (Froese and Pauly, 2024) and has become invasive in some of these countries including Japan. In Japan it is known to prey on aquatic species such as small fishes and shrimps in Kasumigaura Lake (Yanai *et al.*, 2008), Greece, Bulgaria, Finland, Iberian Peninsula, Hungary, Italy (Haubrock *et al.*, 2021).) and Brazil (Faria *et al*., 2019).

Striped pangasius (*Pangasianodon hypophthalmus*) was introduced in Pakistan in 2010 but failed to be established again attempts were made, in subsequent years to introduce it in Pakistan which did not produce the desired results. It was observed that pangasius cannot tolerate low temperatures during winter in Pakistan. Considering the wider market and high productivity, several more attempts to introduce pangasius were made and ultimately overwintering of the fries and fingerlings some success was achieved, and its farming was started mainly in Punjab and Sindh. Although pangasius (*Pangasianodon hypophthalmus*) is not reported from natural water bodies in Pakistan except record a few specimens caught from Thatta. However, their presence in natural water cannot ascertain it to be an invasive species.

Froese and Pauly (2024) reported that *Pangasianodon hypophthalmus* has become established in Myanmar (where it was introduced in 1982) and Bangladesh (introduced in 1990), and probably established in the Philippines (introduced in 1978). They also reported that *P. hypothalamus* was also introduced in Guam, Malaysia, Singapore, Taiwan, Indonesia, and Chinto the following countries where establishment either failed or is unknown. Lakra and Singh (2010) reported that a few specimens of *P. sutchi* have been caught from the wild in Andhra Pradesh, India, and also from wetlands in West Bengal, India. Benchmark surveys indicated the availability of *P. sutchi* in natural waters.

Escapes from fish farms have introduced *P. hypophthalmus* to several regions, such as Taiwan (Welcomme 1988), Singapore (Ng *et al*. 1993), Philippines (Guerrero, 1997), Bangladesh (Barua *et al.*, 2001), Guam, China, Myanmar (Singh and Lakra 2012), India (Zeena and Jameela Beevi 2013), and Sri Lanka (Jayaneththi 2015). In 2015, the species was detected in South America in the Magdalena River basin (Colombia), also from the accidental escape from illegal fish farms (Valderrama *et al.*, 2016).

The striped catfish (*P. hypophthalmus*) has high fecundity (>1,000,000 eggs). Larval hatching corresponds to the beginning of the monsoon season (Van Zalinge *et al.*, 2002; Jayaneththi 2015). It has a greater dispersion ability, and omnivorous, feeding upon zooplankton, insects, crustaceans, fish, and fruits (Lakra and Singh 2010; Singh and Lakra 2011). Garcia *et al.* (2018) feared that the uncontrolled introduction of striped catfish can lead to the species becoming invasive in Brazil and could have serious consequences on the biodiversity of aquatic habitat in the area.

Although no evidence of striped catfish as an invasive species is available from Pakistan, however, it is feared that the environmental conditions required for this fish is ideally available in some large dhands lower Sindh. There are large water bodies where fish harvesting is carried out after many years. If introduced in such dhands, *P. hypophthalmus* can reproduce naturally and may become an invasive species. A similar fear was shown by Garcia *et al.* (2018) about the introduction of this species in Brazil.

Genus *Clarias* Scopoli (ex Gronow) 1777
Clarias gariepinus (Burchell 1822)
(Fig. 18)

Belonging to Order Siluriformes and Family Clariidae (air-breathing catfish, North African catfish is known to have pectoral fins that extend from the operculum to below 1st dorsal fin rays. The anal, caudal, and dorsal fins are not united. The males can be easily recognized by a distinct sexual papilla located immediately behind the anal opening. Its body is usually greyish-black with the underside of the head and body a creamy-white colour, with a distinct black longitudinal band on each side of the ventral surface of the head.

This species can be distinguished from its congeners in having a high number of gill rakers (varying from 24-110) which are long, slender and closely set.

This species is native to almost Pan-African areas excluding Maghreb, the Upper and Lower Guinea and the Cape province, Jordan, Israel, Lebanon, Syria and southern Turkey (Froese and Pauly, 2024, Teugels, 1986). This species is widely introduced to other parts of Africa, Europe, and Asia including Pakistan.

Fig. 18. *Clarias gariepinus*

Clarias batrachus (Linnaeus 1758)
(Fig. 19)

Fig. 19. *Clarias batrachus*

The walking or Philippine catfish has a posteriorly compressed body. The genital papilla in males is elongated and pointed. Dorsal and lateral surfaces of head and body are grey to dark grey, fading to pale grey on ventral surfaces. Dorsal and caudal fins are grey to dark grey with very thin hyaline distal margins. Anal fin light grey, with thin hyaline distal margin. Pectoral-fin rays are grey to dark grey, with hyaline interradial membranes. Pelvic fin hyaline. Barbels and pectoral spine are grey to dark grey dorsally and light grey ventrally.

This species is known from Java, Indonesia (Froese and Pauly, 2024; Ng and Kottelat, 2008). It is introduced in many countries including Pakistan with adverse ecological impacts.

Clarias magur (Hamilton 1822)
(Fig. 20)

This species was originally described as *Macropteronotus jagur* by Hamilton (1822). Since *M. jagur* is a simultaneous synonym of *M. magur*, therefore, Day (1889) selected *magur* for this species. The head of this species has rough skin and is covered with fine granules. There are two depressions on the head, the anterior oblong and the posterior oval. The nasal barbels are long and reach the base of the occipital process; the maxillary barbels extend to the base or middle of the pectoral fin, and the mandibular barbels are shorter. The species is dingy green or brownish superiorly, becoming lighter beneath; the vertical fins usually with reddish margins.

Fig. 20. *Clarias magur*

This species is known from India, Bangladesh, and Pakistan (Froese and Pauly, 2024). The fish being cultured in Pakistan is imported from Thailand and has now become invasive in natural water bodies, especially in lower Sindh

Clarias ngamensis Castelnau 1861

(Fig. 21)

Blunt-toothed African catfish is characterized by a relatively long vomerine tooth plate and by a relatively short adipose fin, head oval to rectangular in dorsal outline; the suprabranchial organ consists of well-developed arborescent structures. It is distinguished from *Clarias gariepinus* by having a short adipose fin behind the rayed dorsal and an ovoid vomerine tooth-plate with granular or blunt teeth.

It is a wide-ranging species in the southern half of Africa, from the Democratic Republic of Congo to South Africa. It is not reported from Asian countries, however, Fishbase shows a photo from Assam, India. Several specimens of this were collected from Lower Sindh.

Genus *Ictalurus* Rafinesque 1820
Ictalurus punctatus (Rafinesque 1818).

Channel catfish belongs to the Family Ictaluridae which is usually bluish-olive, gray or black colour on the upper part of the body, becoming white below; dark spots usually scattered along the side. There are long barbels surrounding the mouth and its tail is deeply forked.

It is native to North America (St. Lawrence-Great Lakes, Hudson Bay), and Missouri-Mississippi river basins from southern Quebec to southern Manitoba and Montana south to Gulf. It is introduced in many countries including Pakistan for aquaculture.

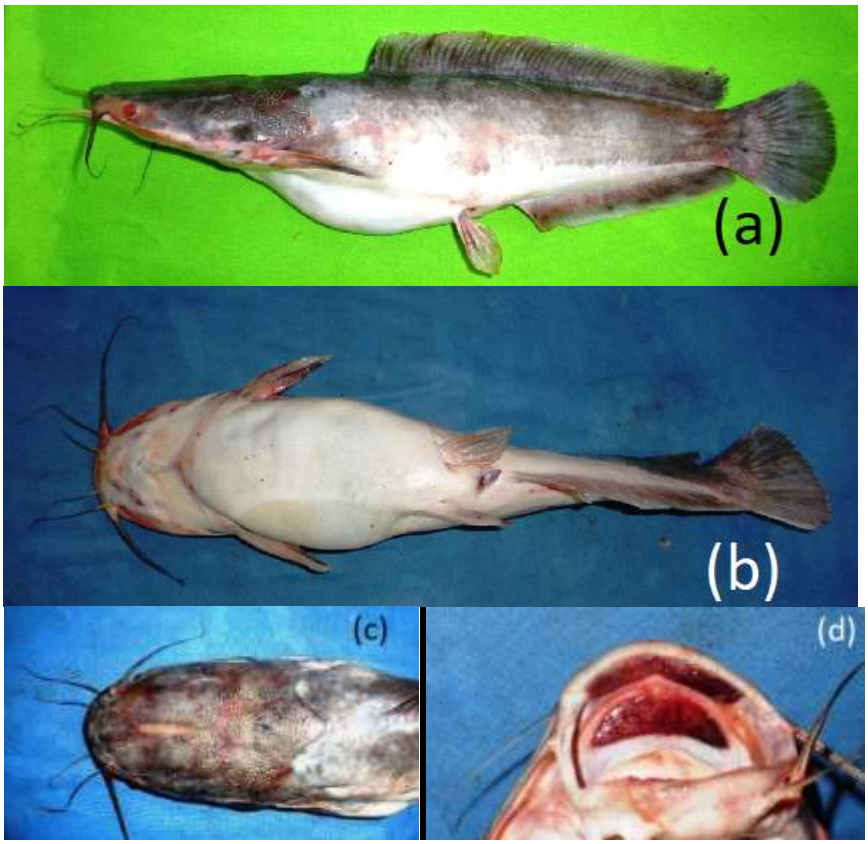

Fig. 21. *Clarias ngamensis* (a) Lateral view; (b) Ventral view; (c) Head-dorsal view (d) tooth patch

Genus *Pangasianodon* Chevey 1931
Pangasianodon hypophthalmus (Sauvage 1878)
(Fig. 22)

Striped catfish belonging to the family Pangasiidae can be distinguished from the congeners in having a higher number of pelvic fin rays. Its fins dark grey or blackyoung with a black stripe along the lateral line and a second long black stripe below the lateral line. Large adults are uniformly grey with a dark stripe on the middle of the anal fin. There are dark stripes in each caudal lobe.

Fig. 22. *Pangasianodon hypophthalmus*

This species is known from Mekong, Chao Phraya, and Maeklong basins (Froese and Pauly, 2024). It is introduced into many countries including Pakistan for aquaculture.

Genus *Pterygoplichthys* Gill 1858
Pterygoplichthys pardalis (Castelnau, 1855)
(Fig. 23)

Fig. 23. *Pterygoplichthys pardalis* (a) First record from Keenjhar Lake (February 22, 2018) (ventral viw); (b) Lateral view.

Amazon sailfin catfish belongs to the Order Siluriformes (Family Loricariidae). The body and edge of the snout in this species are covered with bony plates. The caudal peduncle has round and sucking lips are present. The ventral side of the body is smooth and ornamentation up to the anal fin after that it is covered with bony plates with spines. The fish has distinct black spots on its lateral and caudal peduncle with a pattern of un-coalesced light background covered by dark dots. Its abdomen consists of dark markings on a light background.

Its native range is limited to South America including the lower, middle, and upper Amazon River basin. It is introduced to many countries including Pakistan where it has become an invasive species.

Toothcarps (Order Cyprinodontiformes)

Order Cyprinodontiformes is an order comprising mostly small, freshwater fish including live-bearers (Family Poeciliidae). This family includes live-bearing aquarium fish including guppy, molly, platy, and swordtail. The members of this family are native to the Southeastern United States to Argentina, and Africa, including Madagascar. Genera *Poecilia* and *Gambusia* have been introduce in many countries for mosquito control. In addition, due to accidental or intentional release from aquarias, poeciliids are now found almost in all tropical and subtropical areas of the world. Pakistan is no exception, as mosquitofish and guppies have been introduced for mosquito control whereas some other species are released from aquarium trade in Pakistan

Many members of Family Poeciliidae are popular in aquaria in Pakistan. Among these, mosquitofish (*Gambusia affinis*), common molly or black molly (*Poecilia sphenops*), sailfin molly (*Poecilia latipinna*), guppy (*Poecilia reticulata*), green swordtail (*Xiphophorus hellerii*) and variable platyfish (*Xiphophorus variatus*) are most common. Some of these species are accidentally or intentionally released in the natural waters, however, most of these species do not survive long, but some have established, at least, in some important lakes and natural water bodies in the country. Mosquitofish (*Gambusia affinis*), sailfin molly (*Poecilia latipinna*) and guppy (*Poecilia reticulata*) are considered invasive in Pakistan as they interact with local fish fauna. Ullah *et al.*, (2016) reported black molly to be established in Muzaffargarh and Taunsa Punjab Link Canals.

Mosquitofish were introduced in British India for antimalarial work in 1928 from Itlay (Talwar and Jhingran, 1991), and through this introduction, this species was also introduced in Pakistani waters. It is well established in some natural water bodies. This species is considered effective for mosquito control, therefore, widely introduced in the country. *Gambusia* was, however, found to compete with indigenous fish and to upset the ecological balance (Shrestha, 1990). It is widely reported in Pakistan including in Khyber Pakhtunkhwa, Punjab, Sindh and Balochistan (Mirza, 2003; Mirza and Mirza, 2014; Rafique, 2000). It is known to feed on eggs on larvae of native fish, thus seriously affecting the indigenous fish fauna of the water bodies (Khan *et al.*, 2011a).

Sailfin molly (*Poecilia latipinna*) is another popular aquarium fish that is now widely established in water bodies in Pakistan. Guppy (*Poecilia reticulata*) was introduced in British India in 1908 for mosquito control (Talwar and Jhingran, 1991), and possibly through that introduction, it was established in Pakistani waters. It is well-established in various water bodies in Pakistan, especially in small ditches and roadside ponds that are generally teemed with this species. Black molly (*Poecilia sphenops*) is a melanistic breed that is black all over. It is among the most well-known aquarium fishes, however, it is usually not established in natural water bodies in Pakistan. It was observed to crossbreed with another member of *Poecilia* or lose its black colour and turn into spotted or white forms.

Green swordtail (*Xiphophorus hellerii*) and variable platyfish (*Xiphophorus variatus*) when released in the natural water bodies survive for a while and may breed but were not observed to be established in natural water bodies except in some shallow ditches and roadside ponds near large cities where these species may survive for a few generations. Their impact on local fish fauna was not studied.

Genus *Gambusia* Poey 1854
Gambusia affinis (Baird and Girard 1853)
(Fig. 24)

The body of mosquitofish is small that has a large abdomen, rounded dorsal and caudal fins and an upturned mouth. The origin of the dorsal fin in this fish is opposite the 7th anal ray. Ventrals terminate immediately before anal fin. Pelvic fins reach ventrals. Mature females reach a maximum overall length of 7 cm, while males reach only 4 cm. The anal fins of adult females resemble the dorsal fins, while the anal fins of adult males are pointed (called gonopodium) which is used to deposit milt inside the female. Adult female has a gravid spot on the posterior of their abdomens. Colour usually dark grey or olive on the head and back, becoming lighter on the belly. Faint pigment spots on the fins and under the eyes.

This species known from Mississippi River basin from central Indiana and Illinois in USA south to Gulf of Mexico and Gulf Slope drainages west to Mexico (Froese and Pauly, 2024). Because of introductions, it became a near pan-global distribution including in Pakistan.

Genus *Poecilia* Bloch and Schneider, 1801
Poecilia sphenops Valenciennes 1846
(Fig. 25)

Commonly known as molly or common molly and as compared to other livebearers, it is slightly larger and more energetic. The head and body of the black molly are moderately robust and moderately compressed at the rear. Its mouth is small and slightly oblique. The tip of the pectoral fin of males is swollen and elongated. Through selective breeding, several colour variations and different body shapes have been produced which includes short-finned molly or common molly (which is dull, and silvery in colour), black molly (a melanistic breed), White molly (a white-coloured form), golden molly (golden coloured which is also called "24 karat"), balloon molly (it has a deformed spine due to a genetic defect), lyretail (with an altered caudal fin structure) and Dalmatian molly (a silver-coloured breed with black speckles). Several of these breeds are available.

Fig. 24. *Gambusia affinis* (a) Male with prominent gonopodium; (b) Female.

Common molly inhabits freshwater streams, coastal brackish, and marine waters from Central and South America (from Mexico to Colombia). It is introduced globally including in Pakistan.

Fig. 25. *Poecilia sphenops*

Poecilia latipinna (Lesueur, 1821)
(Fig. 26)

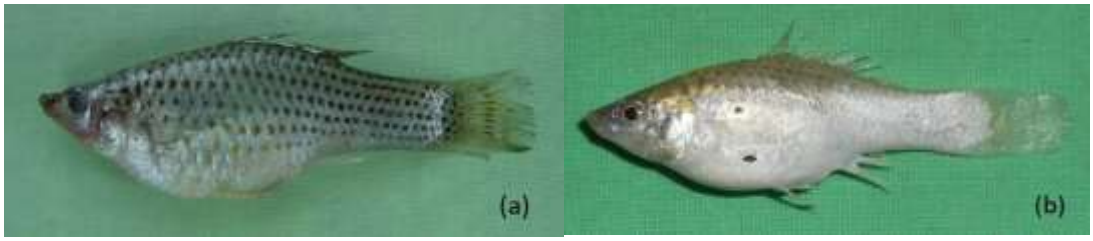

Fig. 26. *Poecilia latipinna* (female) May 2007 (a) specimen with spots in rows; (b) light colour morph.

The body of the sailfin molly is oblong with a small and dorsally flattened head that has a small, upturned mouth. The caudal peduncle is broad and the caudal fin is large, rounded, and sometimes tipped with black. Females tend to be larger and more plainly coloured.

It is known from Cape Fear drainage in North Carolina, USA to Veracruz, Mexico (Froese and Pauly, 2024) and has been introduced in many countries including Pakistan.

Poecilia reticulata Peters, 1860
(Fig. 27)

It is commonly known as guppy, millionfish or rainbow fish. Its males are smaller, reaching an average length of 3.5 cm as compared 5 cm in females. Besides being half the size of females, males have a colourful tail and caudal fin. Females are usually grey and males have coloured splashes, spots, or stripes.

This species is known from Venezuela, Barbados, Trinidad, northern Brazil and the Guyanas (Froese and Pauly, 2024) but introduced in many countries including Pakistan.

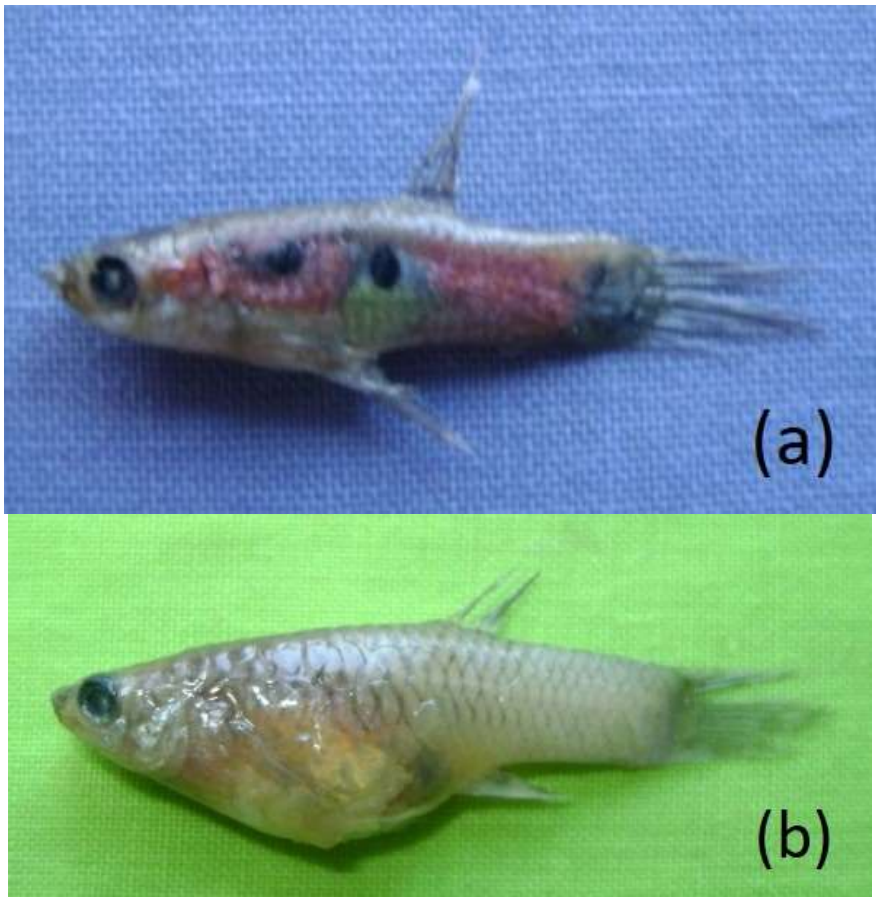

Fig. 27. *Poecilia reticulata*. (a) Male 17-3-2010, 5 cm; (b) Female 17-3-2010, 5 cm

Genus Xiphophorus Heckel, 1848
Xiphophorus hellerii Heckel, 1848

The male green swordtail grows to a maximum overall length of 14 cm and the female to 16 cm. Lower lobe of the caudal fin in males is elongated (tailfin). It is usually olive green in colour, with a red or brown lateral stripe and speckles on the dorsal and caudal fins. The male's 'sword' can be yellow, edged in black below. Many colour varieties, including black, red, and many patterns are produced through selective breeding.

It is native to North and Central America including Rio Nantla, Veracruz in Mexico to north-western Honduras (Froese and Pauly, 2024). Introduced in many countries including Pakistan for the aquarium trade.

Xiphophorus variatus (Meek, 1904)

Variable platyfish have no claw at the tip of the fifth anal fin ray. The fourth pectoral ray shows well-developed serrae (saw-like notches). Males exhibit a more pointed or "needle-like" anal fin whereas the female have a more triangular anal fin. It is olive in colour with black marbling or spots on the side of the caudal peduncle. Large males show blackish blotches on the dorsal fin.

This species known from North America and Mexico from southern Tamaulipas to northern Veracruz (Froese and Pauly, 2024). It has been introduced in many countries including Pakistan. whereas some countries have reported adverse ecological impacts after introduction. This species occurs in warm springs, weedy canals and ditches

CONCLUSION

The introduction of exotic fish in Pakistan started with the aim to promote sport fishing in cold water rivers, lakes, and streams in Kashmir, Gilgit Baltistan, Khyber Pakhtunkhwa, and some parts of Punjab and Balochistan which turned trouts to be commercially important species that is caught from natural water bodies as well as farmed in lakes and aquaculture raceways. Because of their commercial importance, no attention has been paid in Pakistan to the negative impacts of trouts especially their role in modifying the ecosystem in the coldwater habitats of Pakistan. Trouts are known to have a serious impact on local fauna in other countries (Blinn *et al.*, 1993, Kumar, 2000, Rinne, 1995), therefore, there is a need to carry out a detailed study on the resident fauna and flora of the coldwater habitat of in Kashmir, Gilgit Baltistan, Khyber Pakhtunkhwa, and some parts of Punjab and Balochistan. The socioeconomic impacts of trout's introduction in Pakistan are also required to be studied, as the loss of local fish fauna is expected due to changes in the native ecosystem.

The introduction of Mozambique tilapia in 1951 was made to enhance fish production in natural water bodies such as large reservoirs and lakes (Naik, 1973). Tilapia was established in most warm water bodies of the country including rivers, streams, lakes, reservoirs, dhands, and other water bodies. Instead of enhancing fish production, the tilapia became an invasive pest species in Pakistan which replaced local fauna in some water bodies including Manchar, Keenjhar, and several other lakes and water bodies mainly in Sindh and Punjab having serious socioeconomic impacts on the coastal communities that are dependant on the fisheries resources. Because of extensive breeding, the tilapia population has increased whereas commercial important local species which used to grow to large sizes have been eliminated. In some water bodies such as Manchar Lake, almost the entire catch consisted of small-sized tilapias that did not have a local market, therefore, these were dried and used for conversion into poor-quality fishmeal (Fig. 28).

Introduction of other tilapia species including *Oreochromis niloticus* and *O. aureus* have been introduced to enhance fish production from aquaculture and in the brackish and saline water bodies but it is now well-established in natural water bodies in Pakistan (De Silva *et al.*, 2004; Khan *et al.*, 2011a). In addition, redbellu tilapia (*Coptodon zillii*), mango tilapia (*Sarotherodon galilaeus*) and now banded tilapia (*Tilapia sparmanii*) have also been introduced possibly accidentally in some of the water bodies of Khyber Pakhtunkhwa, Sindh and Balochistan. These tilapia species are spreading in water bodies, especially in Balochistan and Sindh where 2000's Super-flood has played a major role in their dispersion. The abundance of *Coptodon zillii* in the ephemeral Siranda Lake in the Lasbella area is evidence of the uncontrolled spread of tilapias in Pakistan. At present, GIFT tilapia and red tilapia are being cultured mainly in Punjab and the use of these species in farming is increasing. There is a need for proper management of tilapia farming to ensure that the ill impacts of these exotic species do not become an ecological burden for the country.

Exotic catfishes are also considered serious threats to the aquatic biodiversity in Pakistan. The walking catfish (*Carias batrachus*) has already been established in Sindh and has serious impacts on the biodiversity of the natural water bodies in lower Sindh. Introduction of other catfishes (*Clarias magur*, *Clarias gariepinus*, and *Clarias ngamensis*) have also been established in some water bodies in Sindh and spreading their range within the country. Although *Pangasianodon hypophthalmus* and *Ictalurus punctatus* seem to have not become invasive, however, considering that the habitat of some of the areas including lower Sindh and Balochistan may suit them, these catfishes can become a potential threat to the biodiversity of the area. It is feared that the promotion of catfish farming in Punjab and Sindh and the uncontrolled import of seeds of *Pangasius* and African catfish may lead to their establishment in water bodies if these are released intentionally or accidentally.

Amazon sailfin catfish (*Pterygoplichthys pardalis*) is considered as invasive and spreads globally. It has already been established in Indonesia, Malaysia, Singapore, the Phillippine, Bangladesh, India, Spain, Puerto Rico, and USA and now in Pakistan. It is now frequently encountered in fish landings in lower Sindh and known to have infested some large lakes including Keenjhar Lake.

Like *Pterygoplichthys pardalis* which is an aquarium fish, several members of Order Cyprinodontiformes are popular fish for aquarium in Pakistan. The release of the small, freshwater fish including live-bearers (molly, platy, and swordtail) in natural water bodies as well as their deliberate introduction of mosquitofish and guppies for mosquito control, have resulted in their establishment in natural water bodies. These mouth (live) bearers are small fishes of less than 5 cm but are prolific breeders, they have occupied several small lakes and water bodies in Punjab

and Sindh and competed with local fish and invertebrate fauna. Their impacts on freshwater biodiversity are not well studied, however, considered to be a threat to fauna in some small water bodies around large cities.

Fig. 28. Heap of dried *Oreochromis mossambicus* on the bank of Manchar Lake

Various carp species have been introduced in Pakistan mainly for enhanced production from natural water bodies as well as for aquaculture. Grass carp, however, was initially introduced to control weeds in large lakes such as Haleji and Keenjhar. Because of their adaptability, these species of carp got established in most of the natural inland waters including rivers, lakes, streams, canals, dhunds, wetlands, and village ponds in the country. Almost all species of these carp are considered highly invasive and may compete with the native fish species (Hume *et al.*, 1983; Khan *et al.*, 2011a; Pallewatta, *et al.*, 2003). There is a need for the evaluation of the impact of common carp on the local fauna as well as on the ecosystem in major water bodies in Pakistan.

It is estimated that more than 1,200 introduction records of fish for aquaculture purposes are available; of these 50 % are reported to have established in the wild, 35 % are reported to be noninvasive whereas 15 % with unknown establishment (Froese and Pauly, 2024). Introduced for aquaculture and enhancing fish production in natural water bodies is considered to be noble economic or aesthetic objectives, however, when such species escape into the wild or turn into invasive thus, invading native ecosystems usually with disastrous results (McNeely, 2001; Pyšek, *et al.*, 2020).

Invasive alien aquatic species spread widely in areas where they are not native and may result in significant adverse effects on ecosystems including a major reduction in biodiversity (Clavero and García-Berthou, 2005; Cuthbert *et al.*, 2021; Simberloff *et al.*, (2013). As compared to terrestrial and marine ecosystems, freshwater biodiversity decline more rapidly due to the establishment of invasive species (Jenkins, 2003). Several management measures can be taken to minimize, if not eliminate, the impact of invasive freshwater species but it can be a challenging task. In most cases, such efforts are limited to reducing the population and abundance of exotic species and controlling their further dispersal into other areas (Britton, 2023; Britton *et al.*, 2011). There are cases where some successes have been obtained in managing non-native species in the wild (Rytwinski *et al.*, 2019). Banning the introduction of some species may not work because, by the time the ban is implemented, the species may have been established in natural water bodies. 'Thai Magur', being an alien and invasive species, is banned in India but its consumption and marketing continue unabated in many parts of India (Gul, *et al.*, 2020). There is a need for the prevention of the introduction of new invasive species as well as the identification of those species that are already present are required for rapid management actions of invasive fish species (Anas and Madrak, 2021).

Import of live fish for aquaculture and aquarium trade are covered under the Pakistan Animal Quarantine (Import and Export of Animals and Animal Products) Ordinance, 1979 and Rules, 1980. However, the required quarantine infrastructure and protocols are not adequately described under these legislations. These laws are implemented through the Animal Quarantine Department which works under the Ministry of National Food Security and Research, Government of Pakistan. The Department provides its quarantine, inspection, and certification services at seven different geographical locations all over Pakistan namely, Karachi, Lahore, Islamabad, Multan,

Sialkot, Peshawar, and Quetta. In addition to these, three other quarantine facilities are available at Gwadar, Khunjrab, and Khokrapar, thus providing these facilities at all legal entry points in the country. The Department, however, does not have any quarantine facilities for live fish at any of its offices. If control on the import of exotic fish species (for both aquaculture and aquarium trade), there is a need to have quarantine facilities including inspection, retention, confiscation, and disposal of live imported fishes for which there is a need to make provisions in the Rules and develop required infrastructure facilities at all import entry points in the country. Establishing quarantine facilities for live fish at all entry points of the country will be extremely difficult and expensive, therefore, import of live ornamental fishes may be permitted to only one or two airports in Pakistan, like in India important of live fish is permitted to only two airports (Mumbai and Chennai).

In India, the consignment of imported ornamental fishes are required to have an import license issued by the Directorate General of Foreign Trade (DGFT). This import license is issued based on a "No Objection Certificate (NOC)" issued by the Department of Animal Husbandry, Dairying and Fisheries (DADF). The ornamental fish from any country to India can be imported through either Mumbai or Chennai because the Marine Products Export Development Authority (MPEDA) has given permits to only these two airports as they have quarantine facilities. The import is permitted if the imported fish should not be under any endangered species list of any environmental agency. In addition, no fish that is already available in native Indian waters is allowed to be imported. An import license has to be obtained from MPEDA.

In Bangladesh all types of activities related to farming of some exotic fishes such as *Pterygoplichthys spp.* (suckermouth catfishes) is banned since 2023 (Ahamad 2023). Permission from the Bangladesh Department of Fisheries, Ministry of Fisheries and Livestock is required for importing these species but these fish being imported are perceived as a 'conditional' species. "Conditional non-native species" includes species that may endanger the environment, native biota, and/or humans. However, aquarium traders import and breed these fish commercially in huge quantities in local hatchery facilities without seeking any such permission (Hossain and Mohsin, 2021).

The total number of invasive species in Pakistan is not enumerated, however, their numbers seem to be around 26. In India, 300 exotic fishes were introduced of which 29 were reported as food fishes (Kumar,2000, Lakra *et al.*, 2008, Singh and Lakra, 2011). The need for the spread of exotic and invasive fish species is required on a regional basis, as there are water bodies that are shared between the countries and control can be only effective if adequate quarantine facilities are available at the airports of these countries. Past practices of indiscriminate introductions and transplantations for ornamental purposes, enhanced fish production, and biological control have had detrimental effects on the local biodiversity and ecosystem functioning. To prevent such consequences there is a need for following appropriate procedures and effective national regulations, however, because of aquaculture promotion in the country it seems very difficult to avoid the introduction of exotic species for commercial production.

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