CURRENT STATE OF FRESHWATER FISHERIES IN CHINA

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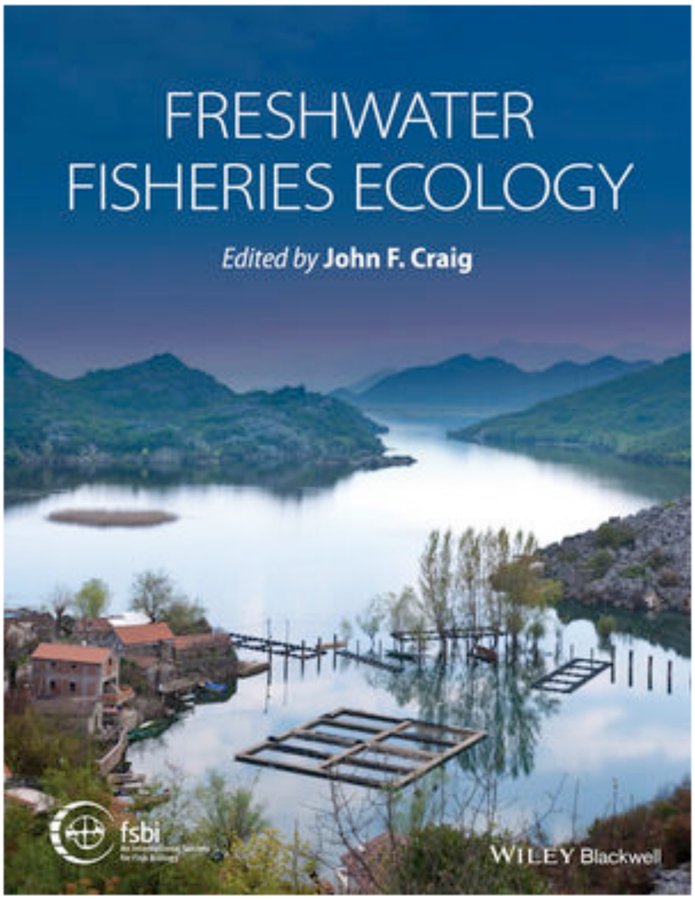

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Current state of freshwater fisheries in china

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Freshwater fishery tradition in China goes as far back as the Zhou dynasty (3059 – 2269 ago), when special officers were in charge of fish capture and putting regulations in place to set fishing seasons and ban harmful fishing. Despite this, the overall inland fish production has only increased rapidly in the second part of the 20th century with a current annual freshwater fish production of *c.* 52 x10^6 t making China the most significant contributor to world fisheries (derived from 15.4 x10^6 t of captured fishes, *i.e*. 17 % of global capture and 36.7 x10^6 t from aquaculture, *i.e.* 61.4 % of global aquaculture production). The rapid economic development in China since the 1980s has also led to a range of environmental changes directly affecting freshwater fisheries and fish biodiversity. Most affected were migratory and endemic species with a restricted distribution but even the most charismatic domestic carps (*i.e*. grass *Ctenopharyngodon idella*, black *Mylopharyngodon piceus*, silver *Hypophthalmichthys molitrix* and bighead *Hypophthalmichthys nobilis*) show some sign of decline. This chapter summarizes over 3000 years of freshwater Chinese fisheries history yet it is hard to believe that policies and adapted management will not soon catch up with the last few decades of unregulated inland production.

Keywords: economic; tradition; cyprinids; ecosystem service; sustainability; biodiversity; ecological impact**.**

A BRIEF HISTORY OF INLAND FISHERY AND AQUACULTURE IN ANCIENT CHINA

The Yin-Yang symbol, also known as the Tai-chi symbol, resemble a pair of fishes, one white with a black eye and the other black with a white eye, nestling head to tail against each other. It symbolizes an ancestral tradition of China with fishes but it also indicates the complicated and interconnected relationship between man and fishes. China has a very ancient history of both capture fisheries and aquaculture. Harpoons made of long bones as early as 7500 years ago were followed by fishing nets, fishhooks (6000 years) and basket-like traps made of bamboo (4500) and fish species captured at the time included grass carp *Ctenopharyngodon idella*, common carp *Cyprinus carpio*, black carp *Mylopharyngodon piceus* and barbel chub *Squaliobarbus curriculus* (Shi, 1999). Already during the Zhou dynasty (3059 –2269 years ago), there were special officers in charge of fish capture and putting regulations in place to set fishing seasons and ban harmful fishing (Li & Qu, 1937).

Pond culture can be traced back to around 3300 years ago (Yue & Liang, 1995; Shi, 1999) with *C. carpio* being the first domestic fish in the world (Cheng, 1999; Shi, 1999; Balon, 2004), although there is still uncertainty if its culture started in China or in Rome (Balon, 2004). The book entitled *Fan li on Pisciculture* (范蠡养鱼经) also known as *The Reserved Mr Zhu of Tao on Pisciculture* (陶朱公养鱼经) is believed to have been written during the Han Dynasty (202 BCE–220 CE) (You, 2004) and compiled knowledge of *C. carpio* pond culture during 5th century BCE. It is the earliest work in China on fish culture, and also the first literature on fish raising in the world (Wu & Ma, 1986). During the Han dynasty, lake fish farming and rice field pisciculture began to appear (Shi, 1999). During the Tang dynasty (618–907), however, *C. carpio* culture was forbidden due to the pronunciation of the fish, which sounded the same as the family name (Li) of the emperor. Nonetheless, it did not impact on the development of fish culture in China and instead stimulated the culture of other species such as *C. idella*, *M. piceus*, bighead carp *Hypophthalmichthys nobilis* and silver carp *Hypophthalmichthys molitrix* (Wang, 2000). Fingerlings were mostly collected from the Yangtze (=Changjiang) and Pearl (=Zhujiang) Rivers underpinned by an advance in live fish transportation techniques as reported in Zhou Mi's book (1232–1298) the *Gui Xin Za Zhi* (=*Kwai Sin Chak Shik*, 癸辛杂识; Yue & Liang, 1995; Balon, 2004). Later on during the Ming Dynasty (1368–1644), the culturing techniques of inland fish species had reach maturity and in 1641 the *Complete Book of Agriculture* (农政全书) provided a detailed account of fish culture techniques and pond building as well as disease prevention (Yue & Liang, 1995) which remains today. For example, it explained that the north part of a fish pond should be dug deeper than the south part to allow fishes to warm up faster during sunny days and to buffer the effect of harsh winters. Also, during this dynasty agro-ecosystem recycling nutriment techniques combining mulberry and fruit tree dike-fish ponds thereby producing little waste appeared in the Pearl River delta (Shi, 1999). Much later during the Song Dynasty (960–1279), the culture of goldfish *Carassius auratus* started around 1157–1206

(Cheng, 1999) and never stopped, making it the most domesticated fish in the world with > 300 different varieties such as fantail, comet, lionhead, bubble eye and black moor.

CURRENT STATUS OF INLAND CAPTURE AND AQUACULTURE

China has been the most significant contributor for world fisheries and aquaculture, with an aquaculture production of *c.* 36.7 x10^6 t in 2010 (*i.e.* 61.4 % of global aquaculture production) and 15.4 x10^6 t from capture fisheries (*i.e.* 17 % of the global capture) (FAO, 2012). Back in 1949, the year of the foundation of the People's Republic of China, however, the combined total output of both aquaculture and capture was only *c.* 0.45 x10^6 t, accounting for only 2 % of world production (Fig. 3.10.1). Then, due to social stability and economic development, it increased rapidly to 3.10 x10^6 t in the mid-1960s (*i.e.* 7 % of the global fish production) to later stagnate between 1966 and 1976 during the "cultural revolution" (Bureau of Fisheries, Ministry of Agriculture of the People's Republic of China, 1991). Now, *c.* 60 years later, with an annual fish production of 53.73 x10^6 t, China's fish production is 120 times that of 1949 (FAO, 2012). Although China has a long history in terms of freshwater fisheries, production only really 'took off' during the 1980s (Fig. 3.10.1) and today represents about half of the total output of Chinese fisheries (Bureau of Fisheries, Ministry of Agriculture of the People's Republic of China, 2011).

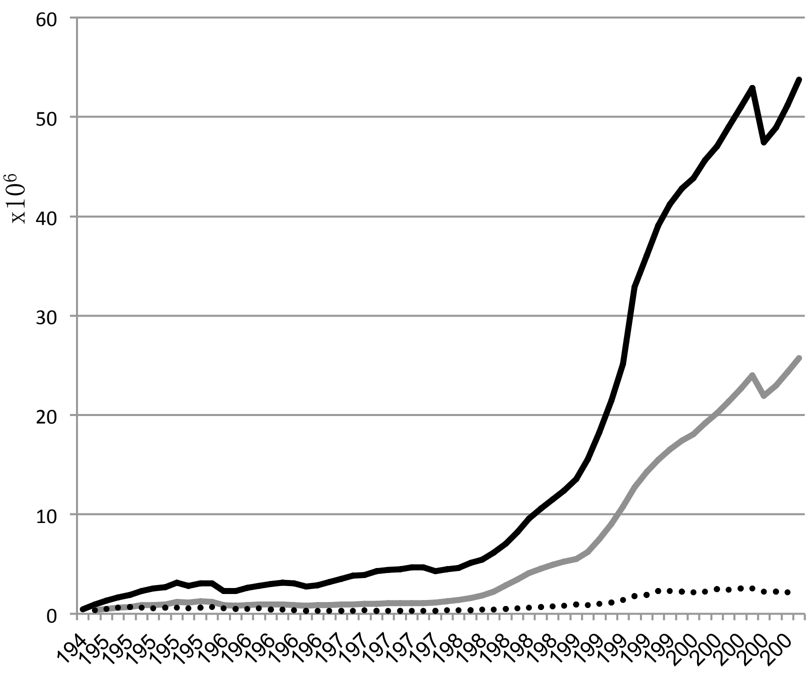

FIG. 3.10.1. The total fish output (numbers) (black line), total inland fish output (grey line) and the output from the inland capture fisheries (dotted line) in China from 1949 to 2010

INLAND CAPTURE

Founded on ancient traditional practices, inland capture represented most inland fishery production between the 1950s and the mid-1960s (*i.e.* *c.* 70 % of the total freshwater production). Under growing fishing pressure in many inland waters, habitat modifications that had seriously degraded some important water bodies and the construction of many small and mid-sized dams during the late 1950s to 1960s, the volume of inland capture decreased (Gong & Tu, 1991). From 1980, production from inland capture rose again due in part to water bodies that were artificially restocked (*e.g.* lakes and reservoirs). Today, the global capture production from inland waters is estimated at *c.* 11.2 $x10^6$ t (FAO, 2012) and China contributes *c.* 2.29 $x10^6$ t (*i.e.* 20 %). In contrast to the 1950s, inland catches now only account for 8.3 % of the total freshwater output of China. Based on incomplete statistics, primary fish species for inland fisheries are just below 200 species (Table 3.10.1) with a great spatial heterogeneity in the different climatic regions of China which ranges from continental to subtropical. For example, in the north-east of China, Arctic lamprey *Lampetra camtschaticum*, Amur sturgeon *Acipenser schrenckii*, kaluga *Huso dauricus*, Amur pike *Esox reicherti*, chum salmon *Oncorhynchus keta*, taimen *Hucho taimen*, lenok *Brachymystax lenok*, Ayu sweetfish *Plecoglossus altivelis*, Amur ide *Leuciscus waleckii* and burbot *Lota lota* are the main capture targets. In south-west China, the four domestic carps, *M. piceus*, *C. idella*, *H. molitrix* and *H. nobilis* are not naturally distributed and therefore some tropical fishes such as the Goonch catfish *Bagarius yarrelli* and two barb species *Spinibarbus hollandi* and *Spinibarbus denticulatus* became primary target species for local fisheries (Li, 1981). Similarly in Tibet, although Tibetans generally do not eat fishes for religious reasons, in the past a few local Tibetans (in Junba Village, Qushui County) engaged in fishing for rulers and foreigners. Twenty-one endemic species, accounting for 30 % of Tibetan fish diversity are primary targets for the fisheries (Zhang *et al.*, 1995). Most of them are Schizothoracinae, a subfamily of Cyprinidae with fast diversification as the result of the uplift of the Qinghai-Tibet plateau. Many schizothoracinid species, however, grow slowly with a narrow distribution, which make them particularly vulnerable to over-fishing.

Many traditional fisheries on the Yangtze River but also across China have disappeared or are in the process of doing so. Not so long ago, in the 1980s, Chinese sturgeon *Acipenser sinensis*, Chinese paddlefish *Psephurus gladius* and Chinese sucker *Myxocyprinus asiaticus* fisheries were abundant in the upper region of the Yangtze River and represented an old heritage from before 1874. *Acipenser sinensis* fishing was seasonal, mostly in the autumn using a triple drift gill-net, which allowed a rapid increase of captures between 1965 and 1974 (Sichuan investigation group on fishery resources of the Changjiang River, 1975). Some fishery statistics from Yibin, show records of *c.* 200–250 fishes a season (river sturgeon *Acipenser dabryanus* and *P. gladius*) with an average individual mass around 100 kg (Sichuan investigation group on fishery resources of the Changjiang River, 1975). Before the closure of the Gezhouba Dam in 1981, the annual mean catch of migratory adults from 1972 to 1980 for the entire river was around 517 fishes (*i.e*. 77 550 kg) (Wei *et al.*, 1997). Post 1981, *A. sinensis*, which used to migrate in the upper reach of the Yangtze to spawn, has seen its populations shrinking so fast that commercial fishing was banned in 1983 and *A. sinensis* listed as a state protected animal in 1988 (Wei *et al.* 1997). Similarly *M. asiaticus*, belonging to the Catostomidae family, is the only catostomid in China and now endemic to the Yangtze River. In the late 1950s, *M. asiaticus*,was subject to commercial fisheries in the Minjiang River, a branch of the upper Yangtze River accounting for 13 % of the overall catch (Zhang *et al.,* 2000). Due to over-fishing and dam construction (post Gezhouba Dam), however, *M. asiaticus* gradually decreased (Yue & Chen, 1998) and was listed in 1988 as a national protected animal.

TABLE 3.10.1. List of the main native freshwater fish species used in the capture fishery in China

Name	Name	Name
Abbottina obtusirostris	*Glyptothorax sinensis sinensis*	*Rhinogobio ventralis*
Abbottina rivularis	*Gymnocypris przewalskii przewalskii*	*Rhinogobius giurinus*
Abramis brama	*Gymnocypris waddelli*	*Rutilus rutilus lacustris*
Acipenser dabryanus	*Hemibarbus labeo*	*Sarcocheilichthys sinensis sinensis*
Acipenser ruthenus	*Hemibarbus maculatus*	*Saurogobio dabryi*
Acipenser schrenckii	*Hemibarbus medius*	*Schistura fasciolata*
Acrossocheilus beijiangensis	*Hemiculter leucisculus*	*Schizopygopsis malacanthus malacanthus*
Acrossocheilus clivosius	*Hemiculter lucidus lucidus*	*Schizopygopsis younghusbandi younghusbandi*
Acrossocheilus fasciatus	*Hemiculter tchangi*	*Schizothorax davidi*
Acrossocheilus hemispinus hemispinus	*Hemiculterella sauvagei*	*Schizothorax kozlovi*
Acrossocheilus iridescens iridescens	*Hemiculterella wui*	*Schizothorax longibarbus*
Acrossocheilus iridescens longipinnis	*Hucho taimen*	*Schizothorax macropogon*
Acrossocheilus labiatus	*Huso dauricus*	*Schizothorax taliensis*
Acrossocheilus parallens	*Hypomesus olidus*	*Schizothorax waltoni*
Acrossocheilus wenchowensis	*Hypophthalmichthys molitrix*	*Schizothorax yunnanensis yunnanensis*

Acrossocheilus yunnanensis	*Jinshaia sinensis*	*Schizothorax chongi*
Anabarilius alburnops	*Leiocassis crassilabris*	*Schizothorax dolichonema*
Anabarilius grahami	*Leiocassis longirostris*	*Schizothorax prenanti*
Ancherythroculter kurematsui	*Leptobotia elongata*	*Schizothorax wangchiachii*
Ancherythroculter lini	*Leuciscus baicalensis*	*Silurus asotus*
Ancherythroculter nigrocauda	*Leuciscus idus*	*Silurus cochinchinensis*
Ancherythroculter wangi	*Leuciscus waleckii waleckii*	*Silurus gilberti*
Aristichthys nobilis	*Leucosoma chinensis*	*Silurus meridionalis*
Bagarius yarrelli	*Liobagrus marginatus*	*Silurus soldatovi*
Barbatula nuda	*Lota lota*	*Sinibrama macrops*
Barbodes daliensis	*Luciobrama macrocephalus*	*Sinibrama melrosei*
Bostrychus sinensis	*Macrognathus aculeatus*	*Siniperca chuatsi*
Botia pulchra	*Mastacembelus armatus*	*Siniperca knerii*
Botia reevesae	*Megalobrama amblycephala*	*Siniperca obscura*
Botia robusta	*Megalobrama elongata*	*Siniperca roulei*
Brachymystax lenok	*Megalobrama pellegrini*	*Siniperca scherzeri*
Carassius auratus auratus	*Megalobrama skolkovii*	*Siniperca undulata*
Carassius auratus gibelio	*Megalobrama terminalis*	*Sinobdella sinensis*
Channa argus	*Misgurnus anguillicaudatus*	*Sinocyclocheilus angustiporus*
Channa asiatica	*Monopterus albus*	*Sinocyclocheilus grahami*
Channa maculata	*Mylopharyngodon piceus*	*Sinocyclocheilus tingi*
Cirrhinus molitorella	*Mystus guttatus*	*Sinocyclocheilus yangzongensis*
Clarias fuscus	*Mystus macropterus*	*Sinocyclocheilus yishanensis*
Coreius guichenoti	*Mystus pluriradiatus*	*Spinibarbus denticulatus denticulatus*
Coreius heterodon	*Myxocyprinus asiaticus*	*Spinibarbus hollandi*
Coreius septentrionalis	*Neosalanx tangkahkeii*	*Spinibarbus sinensis*
Coreoperca whiteheadi	*Ochetobius elongatus*	*Squalidus argentatus*
Cranoglanis bouderius bouderius	*Odontobutis potamophila*	*Squaliobarbus curriculus*
Ctenopharyngodon idellus	*Odontobutis sinensis*	*Thymallus arcticus arcticus*
Culter alburnus	*Onychostoma angustistomata*	*Thymallus arcticus grubei*
Culter dabryi dabryi	*Onychostoma macrolepis*	*Tinca tinca*
Culter dabryi shinkainensis	*Onychostoma sima*	*Tor (Foliter) brevifilis brevifilis*
Culter mongolicus mongolicus	*Opsariichthys bidens*	*Tor (Parator) zonatus*
Culter oxycephaloides	*Oxygymnocypris stewartii*	*Tribolodon brandti*
Culter oxycephalus	*Parabramis pekinensis*	*Triplophysa pseudoscleroptera*

Culter recurviceps	*Paramisgurnus dabryanus*	*Triplophysa scleroptera*
Cultrichthys erythropterus	*Parazacco spilurus fasciatus*	*Triplophysa siluroides*
Cyprinus (Cyprinus) carpio	*Parazacco spilurus spilurus*	*Triplophysa yarkandensis yarkandensis*
Cyprinus (Cyprinus) pellegrini	*Pelteobagrus fulvidraco*	*Xenocypris argentea*
Cyprinus (Cyprinus) yunnanensis	*Pelteobagrus intermedius*	*Xenocypris davidi*
Cyprinus (Mesocyprinus) multitaeniata	*Pelteobagrus nitidus*	*Xenocypris microlepis*
Distoechodon macrophthalmus	*Perca fluviatilis*	*Zacco platypus*
Distoechodon tumirostris	*Perccottus glenii*	
Elopichthys bambusa	*Procypris merus*	
Esox lucius	*Procypris rabaudi*	
Euchiloglanis davidi	*Protosalanx chinensis*	
Euchiloglanis kishinouyei	*Pseudocrossocheilus bamaensis*	
Gagata cenia	*Pseudogyrinocheilus procheilus*	
Garra orientalis	*Pseudohemiculter dispar*	
Glyptothorax fukiensis fukiensis	*Pseudorasbora parva*	

Many other migratory species have followed the same fate such as the Chinese shad *Tenualosa reevesii*, a clupeid species. In 1974, the *T. reevesii* fishery of the Yangtze and Xiajiang Rivers reached 1575 t to decline to 3 to in 1985 (Zhang, 2001). Since 1990, *T. reevesii* has been declared near extinct in the Yangtze River with only one individual caught in Jiangsu Province in 1998 (Liu *et al.*, 2002). Overfishing of spawning fish is the main reason causing its decline (Yue & Chen, 1998) but degradation of spawning habitat and dam construction made the situation worse. Many species have now been deleted from the list of traditional commercial fish including *A. sinensis*, *A. dabryanus*, *P. gladius*, *T. reevesii*, Sichuan taimen *Hucho bleekeri*, *B. lenok*, sheefish *Stenodus nelma*, *P. altivelis*, *M. asiaticus*, silvery minnow *Anabarilius alburnops*, Kunming nase *Xenocypris yunnanensis*, Dianchi golden-line barb *Sinocyclocheilus grahami*, Fuxian golden-line barb *Sinocyclocheilus tingi*, northern bronze-gudgeon *Coreius septentrionalis* and roughskin sculpin *Trachidermus fasciatus*.

Miniaturization of natural fish resources

The reduction in the size of fish species has been noticed since the 1960s. For example in Lake Taihu, large-sized fishes such as ‘four domestic carps’ were gradually replaced by species with lower economic value (Liu *et al.*, 2005). This phenomenon is increasing since the 1980s as a result of the significant intensification of commercial fisheries. For comparison in Lake Taihu, Japanese grenadier anchovy *Coilia nasus* and Noodle fish (Salangidae) accounted for 69 % of the total catch in 2003 but 29 % in 1952. In Lake Honghu, the seventh largest freshwater lake in China, the catch of large-sized *C. carpio* declined from 36.0 to 0.4 % in 40 years since 1950 (Song *et al.*, 1999). In the meantime, during the same period small sized crucian carp *Carassius auratus* increased from 28.0 to 53.7 %. Over 80 % of the total catch in the 1990s was composed of *C. carassius*, yellow catfish *Pelteobagrus fulvidraco* and redfin culter *Chanodichthys erythropterus*, three small-sized fishes of < 200 g (Xie & Chen 1999). The same situation can be observed in Lake Hongzehu. This goes along with a decrease in the age-structure within fish populations and is another aspect of fish miniaturization. In Lake Honghu, 9 year-old *C. carpio* was common in the 1960s, while in the 1990s young-of-the-year and 1 year old fish dominated the population (Xie & Chen, 1999). The same can be said for wild caught *C. idella* and *M. piceus* where juvenile individuals *c.* 6 months old dominated the catch (i.e. 96.3 and 99.6% of the overall catch) in the 1990s (Xie & Chen 1999).

INLAND AQUACULTURE

Inland capture is no longer the main component of the Chinese freshwater fisheries (Table 3.10.2). The share of inland aquaculture of China has increased significantly since the 1980s to 23.5 $x10^6$ t in 2010 (*i.e.* 64% of world inland aquaculture production). A major limitation during the 1950s was the limited availability of fingerlings (fish seed), despite mastering the artificial reproduction of *H. nobilis*, *H. molitrix*, *M. piceus* and *C. idella* as well as white bream *Parabramis pekinensis* between 1958 and 1961 (Hishamunda & Subasinghe 2003). Political movement was an important factor in influencing inland aquaculture and in the mid-1980s Chinese aquaculture entered a new era with exponential growth and has not stopped since (>1 $x10^6$ t in 1981; >10 $x10^6$ t in 1996; >20 $x10^6$ t in 2005). Most of the production is dominated by cyprinid species, which is the dominant fish family in China. Even the world freshwater fishes production is dominated by cyprinid species (*i.e.* 71.9 %, 24.2 $x10^6$ t) (FAO 2012). Chinese freshwater aquaculture, however, is diversified including fishes, crustaceans (shrimp, crayfish and crab), molluscs (pearl), amphibians, reptiles and algae with fishes in 2010 still accounting for 88% of the total freshwater production (Table 3.10.2). Diversification of aquaculture target species was achieved through (1) picking up and acclimatizing wild species with suitable size and behaviour, (2) developing new varieties through cross breeding and artificial selection and (3) introducing non-native species with good qualities.

Table 3.10.2 Main Chinese freshwater fish aquaculture production during 2010

Fish species	Common name	Output (t)	Global output [1] (t)	Percentage of global production
Ctenopharyngodon idellus	Grass carp	4222198	4337114	97.4
Hypophthalmichthys molitrix	Silver carp	3607526	4116835	87.6
Aristichthys nobilis	Bighead Carp	2550848	2585962	98.6
Cyprinus spp.	Common carp	2538453	3444203	73.7
Carassius auratus	Crucian carp	2216094	2217799	99.9
Oreochromis spp.	Tilapia	1331890	2538052	52.5
Parabramis pekinensis	White bream	652215		
Mylopharyngodon piceus	Black carp	424123		
Channa argus	Snakehead	376529		
Silurus spp.	Amur catfish etc	374093		
Monopterus albus	Asian swamp eel	272939		
Siniperca spp.	Mandarin fish	252622		
Ictalurus punctatus	Channel catfish	217303	444937	48.8
Anguilla japonica	Eel	213811	261617	81.7
Misgurnus anguillicaudatus	Pond loach	204552		
Lateolabrax japonicus	Japanese seabass	185941		
Pelteobagrus fulvidraco	Yellow catfish	184281		
Piaractus brachypomus	Pirapatinga	85415		
Acipenser spp.	Sturgeon	35324		
Salangidae spp.	Noodle fish	18481		
Leiocassis longirostris	Chinese longsnout catfish	17100		
Oncorhynchus spp.	Trout	16397	728448	2.3
Hypomesus spp.	Pond smlet	12962		
Takifugu spp.	Fugu	2842		
Salmo spp.	Salmon	1433	137510	1

[1] Data of global output from FAO website: http://www.fao.org/fishery/culturedspecies/search/en

Before the mid-1960s, *C. carpio*, *H. nobilis* and *C. idella* were primary aquaculture target species but with increasing handling of artificial reproduction techniques in the last 50 years, more and more species were included in the portfolio of cultivated species. For example, the Wuchang bream *Megalobrama amblycephala* has a long tradition of being captured from the wild, transplanted and then fed (Xinhua News Agency, 1974). It is said that the fish got its name during the Three Kingdoms Period (220–280) and even Mao Zedong mentioned this fish in his poem in 1956, 'no sooner had I drank water of Changsha than I savored a Wuchang fish'. Dozens of other wild fish species have since become target species of pond-aquaculture by domestication of wild specimens including among others the small scale yellowfin *Plagiognathops microlepis*, *S. curriculus*, Hong Kong catfish *Clarias fuscus*, tench *Tinca tinca*, pond smelt *Hypomesus olidus*, Asian swamp eel *Monopterus albus*, yellowfin *Xenocypris davidi*, *T. fulvidraco*, snakehead *Channa argus* and Chinese noodlefish *Protosalanx chinensis*. Now, even some endemic fish species are subject to breeding trials such as, for example, *Procypris rabaudi* an endemic species of the upper Yangtze River leading to a high market value. Their overexploitation in combination with the construction of dams has seen the decline of that species but recently a breakthrough has permitted its artificial reproduction and cultivation making a recovery of wild populations possible (Zhou *et al.,* 2008).

China resorted to farming non-native species (Table 3.10. 3) as early as the 1950s with the introduction of the Mozambique tilapia *Oreochromis mossambicus* to Taiwan from Singapore by Zhenhui Wu (Chen-hui Wu) and Qizhang Guo (Chi-chang Kuo). It is now used for export and domestic consumption (Fig. 3.10.2) and has been renamed Wu-Guo (Wu-Kuo) in memory of Wu and Guo, with China becoming the largest *Oreochromis* spp. producer in the world (i.e. 38% of the total of *Oreochromis* spp. production).

FIG. 3.10.2. Three young men in Hainan Island with their harvest of Mozambique tilapia *Oreochromis mossambicus* caught by rod and line in the Nandu River.

Also, in 1959, China introduced 50 $x10^3$ eyed eggs and 6 $x10^3$ fingerlings of rainbow trout O*ncorhynchys mykiss* from North Korea achieving today 16 397 t $year^{-1}$. Large-scale introduction of high-quality fishery species, however, started after 1980, when freshwater fish species from Bangladesh, Japan, Egypt, U.S.A., Thailand, Vietnam, Mexico, Russia, India, Australia, U.K. and some African countries were introduced (Wang, 1999; Wang & Cao, 2006). The Chinese National Certification Committee for Aquatic Varieties is an organization under the Ministry of Agriculture and is in charge of evaluating and approving the breeds that can be spread around China. Between 1996 and 2010, this committee approved the introduction of > 100 species or varieties.

TABLE 3.10.3. Main non-native freshwater species in terms of abundance introduced in China

Species/varieties	Origins	Sources	First year of introduction	Specifications	Number
Mississippi paddlefish *Polyodon spathula*	North America	U.S.A.	1990	Eyed eggs	
Danube sturgeon *Acipenser gueldenstaedtii*	Eurasia	Russia	1995	Parents	40
Sterlet sturgeon *Acipenser ruthenus*	Eurasia	Russia	1995	Fry	
Rainbow trout *Oncorhynchus mykiss*	North America	North Korea	1959	Eyed eggs	50,000
Golden rainbow trout (a variety of *O. mykiss*)[2]		Japan	1988		
European eel *Anguilla anguilla*	Europe	Europe	1994	Fry	40 t
Bigmouth buffalo *Ictiobus cyprinellus*	North America	Thailand	1993	Fry	5000
Germany mirror carp[3]	Germany	Japan	1982	Eyed eggs	30 000
Scattered mirror carp		USSR	1987	Fries	1,000,000

[2] Golden rainbow trout are bred from a single mutated colour variant of *Oncorhynchus mykiss*, lacking the typical green field and black spots, but retaining the diffuse red stripe.

[3] Mirror carps are varieties of the common carp *Cyprinus carpio*, found in Europe (including the U.K.).

Koi[4]	Japan	Japan	1987	Fries	50
Pirapatinga (*Piaractus brachypomus*)	South America	Thailand	1986	Fries	6,000
North African catfish (*Clarias gariepinus*)	Africa	Africa	1981	Fingerling	11
Channel catfish (*Ictalurus punctatus*)	North America	US	1983		
Mozambique tilapia (*Oreochromis mossambicus*)	Africa	Viet Nam	1957		
American bullfrog (*Rana catesbians*)	North America	US	1958		
Pig Frog (*Rana grylio*)	US	US	1987		
Giant river prawn (*Macrobrachium rosenbergii*)	Indo-Pacific	Japan	1976	Parents	2
Red swamp crayfish (*Procambarus clarkii*)	North America	Japan	1938		
Whiteleg shrimp[5] (*Litopenaeus vannamei*)	Eastern Pacific	US	1988		

The development of inland culture is very geographically imbalanced in China. Economically developed provinces are mainly in the central and south-east of China. The first three provinces in terms of production are Hubei, Guangdong and Jiangsu (Fig. 3.10.3). Their productions are over or very close to 3 x10^6 t, much higher than other provinces. In contrast, the production of Xizang (Tibet) is almost negligible with only 72 t. As stated above Tibetans do not have a tradition of eating fishes due to their religious beliefs. In addition, the climate and altitude of Qinghai-Xizang Plateau is not very suitable for the development of aquaculture. If we were looking at aquaculture

[4] Koi is ornamental variety of the common carp.

[5] Whiteleg shrimp is mainly cultured in China in freshwater.

areas rather than production, however, a very different picture would emerge with the top five provinces belonging to the Yangtze River basin due to several large freshwater lakes in these provinces. For example, Lake Boyang, the largest freshwater lake in China, locates in Jiangxi Province, Lake Dongting the second largest lake, is in Hunan Province, Lake Taihu the third and Lake Hongzehu the fourth are in Jiangsu Province and Lake Chaohu fifth is in Anhui Province. Although the Hubei Province is the first province in terms of aquaculture area, it does not have very large lakes *per se* but is called the 'thousand-lakes province' with 217 lakes > 1 km^2.

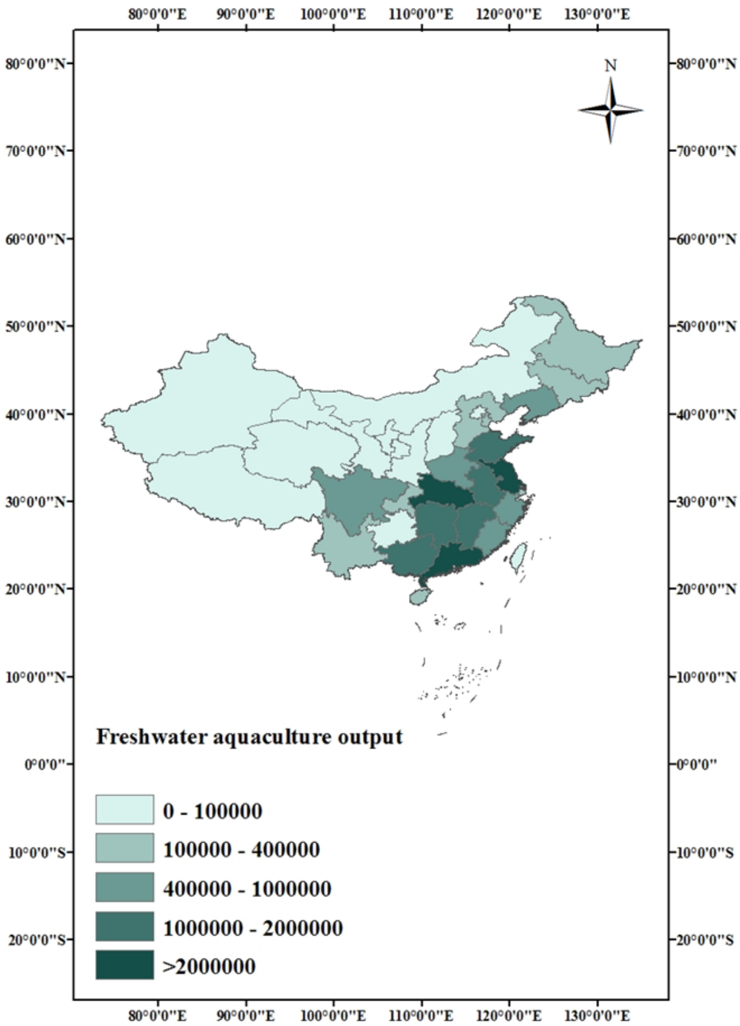

FIG. 3.10.3. Distribution by province of freshwater aquaculture production (number of fishes).

MAJOR IMPACT ON WILD FRESHWATER FISHERY RESOURCES

As already seen in the previous section, Chinese freshwater ecosystems and biological communities have changed rapidly since the mid-1980s. Together with a set of environmental stressors such as overfishing, habitat degradation, dam construction and pollution, non-native introductions have been responsible for some fisheries decline. Fisheries for food are much more important than recreational fisheries in China. Almost all freshwater fishes, whatever their size, have been targeted for commercial fisheries with direct impact on fish abundance and diversity (Xie & Chen, 1999). Capture pressure on wild fish populations have not stopped increasing in almost all main water bodies despite the implementation of a closed fishing season for many years. Such overfishing leads to what is known as 'fishing down the food web', the successive removal of the larger elements of a multispecies fish assemblage and their replacement by smaller elements of the assemblage, which are typically at lower trophic levels (Allan *et al.*, 2005). This happened in several large lakes such as Lake Taihu. Therefore, as overfishing reduces the mean size of fishes and species in the assemblage, it is followed by a reduction of mesh size of nets (Allan *et al.*, 2005). For example, the minimum mesh size should be > 160 mm for keeping young adults of 'four domestic carps' and even for small-sized *C. carassius*, the mesh size still needs to be > 50 mm. Gillnets with mesh size < 20 mm, however, are very common in many places (Wang *et al.,* 2007) with consequently intense selection on size and age at maturity. Other fishing techniques such as electrofishing, explosives or poisons have disastrous consequences on aquatic communities and microhabitats. Today, blast or poison fishing is less frequent due to new legislation on explosive and pollution control. Although electrofishing is totally forbidden by law it remains very popular throughout the country.

China started to build dams and hydraulic structures on a large scale from the 1950s. Between 1951 and 1977, 18595 dams of different sizes were built, totaling 53.4 % of the total numbers of dams in the world (Pan & He, 2000). This has had some direct consequences on migratory species as seen above with several endemic migratory species (Zhang *et al.*, 2011). This should be put in perspective, however, of China's economic development in last few decades and the increasing need for clean energy and accessible water resources for agriculture, leading in 1990 to the record-breaking construction of the Three Gorges Dam, the largest power station in the world. In addition, dams also provide large reservoirs suitable for aquaculture production, which will support an increasing need for fishes. The resulting pattern of fish diversity will definitely be changed.

` During these rapid economic changes, water quality in rivers and lakes is getting worse and worse. Water pollution is also a major cause of a decline in wild fish resources. The freshwater environment suffers from three main types of pollution: industrial waste-water polluted with nitrates, phosphates and heavy metals, pesticides and fertilizer washed off from farmland by the rain and untreated sewage. In particular, eutrophication caused by the agriculture non-point source pollution has long-lasting effects on fisheries, which is rarely treated. For inland waters, biochemical oxygen demand (BOD), nitrogen and phosphorus have also been a serious concern. Currently and despite the large input of cash by the government for water pollution control, the situation has not significantly improved. To illustrate this, emergency pollution events account for *c.* 73 % of the total number of the pollution events (Hou *et al.*, 2010) costing > 3.8 x10^9 RMB between 2001 and 2008. These are illegal discharges of pollutants directly into water systems and are likely to remain as if the perpetrators are caught the resulting penalties are less than the cost of installing a sewage treatment.

The synergetic effects of rapid economic development and urbanization are clearly seen by an overall degradation of aquatic habitat, including shrinkage of lakes, decline of habitat diversity and overstocking of plant-eating fishes. For example, in April of 1981 Lake Yilong was completely dried up for over 20 days after consecutive years of drought. Endemic species such as *Cyprinus yilongensis* have vanished (Yue & Chen, 1998). Continuous sedimentation and land reclamation activities (*e.g.* building and agriculture) in the middle and lower basins of the Yangtze River are reasons for lake shrinkage (Xie & Chen, 1999). Also, loss of habitat heterogeneity such as (1) the channelization of one section of the Nanpanjiang River in the Yiliang County of the Yunnan Province is detrimental to freshwater water fish diversity in China and in this case has caused the disappearance of *Anabarilius liui yiliangensis* (Chen *et al.*, 1998), or 2) the overstocking of plant-eating fishes that caused 32 aquatic macrophytes (*e.g. Potamogeton maackanus* and *Potamogeton cristatus*) to disappear from Lake Donghu, Wuhan City (Xie & Chen, 1999).

Finally, as previously discussed, a large number of non-native species have been introduced into China (*e.g.* 140 aquatic animals including 89 species of fishes, 12 species of shrimps and 12 species of mollusks; Table 3.10.3) (Hu *et al.*, 2006). Inland waters, however, are suffering the consequence of these introduced species. Normally, invasive species will have ecological effects on native species and ecosystems through direct or indirect ways including predation, habitat degradation, increased competition for resources, hybridization and disease transmission (Gozlan *et al.*, 2010). Tilapias (*i.e.* includes several species and some hybrids) is a good example as despite being unable to survive in temperate regions, they have been widely cultured in provinces south of the Yangtze River. Tilapias have become the dominant fish species in the natural waters in Hainan Island and very common in Guangdong, Guangxi and Fujian Provinces directly responsible for species loss and population collapse of native fishes in these areas. Similarly, with the expansion of the culture of *C. idella*, *H. molitrix* and *H. nobilis*, which were originally distributed in the east of China has allowed the spread and invasion of small cyprinids in the west part of China. For example, Lake Qionghai, located in the south of Sichuan Province, had 30 native fish species in the 1960 (Liu, 1964; Liu *et al.*, 1988) but in 2011 only nine remained (Zheng *et al.*, 2012) with endemic species such as *Cyprinus qionghaiensis* and *Anabarilius liui liui* extinct from the lake and other native fishes including *Anarilius qionghaiensis, Distoechodon tumirostris, Percocypris pingi, Garra pingi, Triplophysa beevicauda* and *Euchiloglanis davidi* had also disappeared or were very rare. In the meantime the lake is now dominated by introduced species such as *C. idella*, *H. nobilis*, topmouth gudgeon *Pseudorasbora parva*, Chinese false gudgeon *Abbottina rivularis* and bitterlings (Peng 2007; Zheng *et al.,* 2012). This pattern of extinction and replacement by introduced species is extremely common all over Chinese lakes (Chen *et al.*, 1998) and even on the Plateau of Tibet is it easy to find *C. carassius*, *C. carpio* and *P. parva* in natural water bodies,

CONCLUSION AND PERSPECTIVES

The link between China and freshwater fishes is too ancient and too significant, not to believe that policies and adapted management will soon catch up with the last few decades of unregulated inland production. Unfortunately by then, the wealth in aquatic biodiversity will inevitably be eroded but the extent of the damage will depend on the ability of conservation biologists to use and integrate modern artificial fertilization techniques in support of conservation programmes. Structural changes to the rivers continuum remain and their restoration is one the major challenge for the decades to come if species such as the largemouth bronze gudgeon *Coreius guichenoti*, the elongate loach *Leptobotia elongata* and the long-fin rhino gudgeon *Rhinogobio ventralis* are to be an integral part of the future Chinese fish diversity. Even the 'four domestic carps' are facing a sharp decline in areas such as in the Three Gorges Dam due to these species relying on long undisturbed sections of river to sustain successful reproduction (Stone, 2008). In Lake Dongting, the second largest freshwater lake of China and one of most important fisheries, the catch of 'four domestic carps' declined in 40 years from 21 to 6 % of the total catch and in other places such as in Beijing and adjacent areas have totally disappeared (Zhang *et al.*, 2011). The chapter of rapid economic growth and sustainable Chinese fisheries remains to be written.

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