Culture-based fisheries in lakes of the Yangtze River basin, China, with special reference to stocking of mandarin fish and Chinese mitten crab

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Abstract: Lakes amount to 15% of the total freshwater surface area in China and are important for land-based fisheries. More than 10 species are stocked into lakes to increase production and/or improve water quality. The most common species stocked are the Chinese major carps, i.e. silver carp, bighead carp, grass carp and black carp. In recent years, increasing amount of high valued species such as mandarin fish, mitten crab, yellow catfish and culters were stocked. However, the stocking of mandarin fish and mitten crab perhaps are the most successful because stock enhancement of these two species has been systematically conducted.

In this paper, the culture-based fisheries in lakes are presented, with special reference to mandarin fish and mitten crab stocking in lakes in China. The stocking rate of mandarin fish is determined by food consumption rates, which are mainly related to water temperature and fish size, and prey fish productivity. A bioenergetics model of mandarin fish was established to predict the growth and consumption of prey fish in stocked lakes. Impacts of stocked mandarin fish on wild mandarin fish populations are also dealt with. The stocking model of mitten crab in of culture-based fisheries was also determined based on biomass of macrophyte coverage, benthos biomass and ratio of Secchi depth to mean water depth in lakes.

Since increasing attention is being paid to eutrophication of lakes in China, land-based fisheries development now prioritise maintaining integrity of water quality and biodiversity conservation. Integrated stocking of different species and lakes fisheries management are also addressed.

Keywords: *Culture-based fisheries, stock enhancement, Chinese mitten crab, mandarin fish, lakes, Yangtze River basin.*

Introduction

Aquaculture, a millennia old tradition, is thought to have originated in China over 2,500 years back and have achieved great success in global food security and social economy (Wu et al., 1992). China is the largest inland fishery producer in the world, with a total production of 28.74 million tonnes corresponding to 54.5% global inland fishery production (52.78 million tons) including capture and aquaculture production totally in 2012 (FAO, 2014).

Culture-based fisheries (CBF), a mode of fisheries enhancement, are mostly or entirely maintained by the regular stocking of certain fish species (De Silva, 1991; 2003) which rely on the natural productivity of the water body for growth, and on artificial stocking for recruitment (Lorenzen, 1995; Welcomme and Bartley, 1998). Although CBF are very diverse in nature in the type of water bodies utilised, species stocked, harvesting techniques, and management strategies (De Silva, 2003), they are conducted almost exclusively for food fish production in the developing world. In this regard, for the management of CBF in the developing world, attempts have been made to relate yield to parameters such as morphometric parameters of lakes or reservoirs, species combinations and overall stocking rates and physico-chemical parameters (Hasan and Middendorp, 1998; Nguyen et al., 2001; Gomes et al., 2002; Nguyen et al., 2005; Wijenayake et al., 2005; Jayasinghe et al., 2006; Pushpalatha and Chandrasoma, 2010). Developments of CBF, however, need to have a scientific basis that includes information on optimal stocking rates, species combinations and ratios thereof, optimal time of harvesting and the like, if they are to realise the full potential and become a significant contributor to inland fish production (Wijenayake et al., 2005).

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In China, CBF, an indispensable fishery form for its contribution to the volume of the inland fishery, are enjoying an enhanced reputation for its ability of producing aquatic food with high nutritional quality and high level of food safety. CBF practices in Chinese reservoirs have been well documented (Li and Xu, 1995). Jia et al. (2013) dealt with lake fisheries including cage culture, pen culture and integrated aquaculture in China. However, there are few accounts exclusively on CBF in Chinese lakes, especially on aspect of the development of techniques and environmental protection. This paper attempts to trace the development trends, techniques used and environment protection in CBF in lakes of the Yangtze River basin. It should also be noted that in view of the great diversity of CBF practices in China, it will be futile to attempt to review all these. We have endeavored here to address with suitable and special reference to mandarin fish *Siniperca chuatsi* and Chinese mitten crab, *Eriocheir japonica sinensis*, widely stocked in Chinese lakes.

Contribution of CBF to inland fisheries of China

CBF in China are well developed and practised in most lakes and reservoirs, making a significant contribution to inland fisheries (Li and Xu, 1995). Overall, CBF production has continued to increase over the last three decades (Wang et al., 2014). Based on 5-year average production and area for each type of water bodies from 2006 to 2010 in China, the CBF production from lakes and reservoirs accounted for 6.9% (1,482,187 t) and 11.9% (2,556,932 t) of inland aquaculture production, respectively. The area of lakes and reservoirs used for CBF accounted for 14.8% (997,007 ha) and 24.6% (1,656,105 ha) of inland aquaculture area, respectively (Fig. 1). CBF production from lakes showed a regular increase through the years from 67,568 t (1981) to 1,614,977 t (2012) corresponding to a unit production of 91 kg/ha to 1,576 kg/ha, a significant increase through the years, averaging 46.4 kg/ha/year (Fig.2).

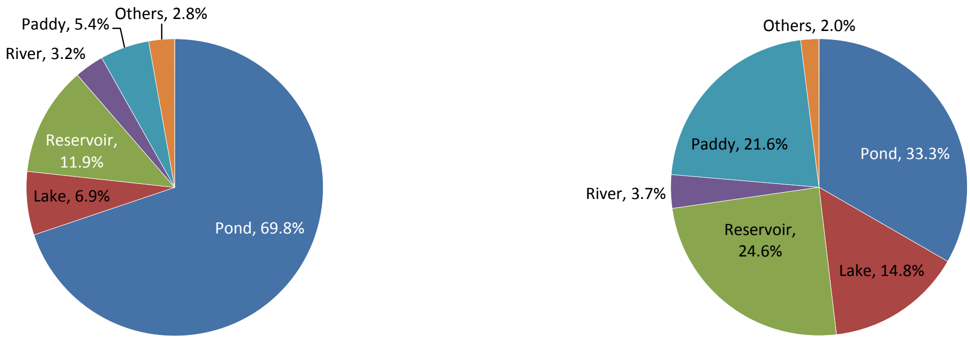
Overall, the increase of CBF production over the years has resulted from better management of the fishery resources, adoption of proper stocking and harvesting strategies (e.g. time window of harvest, size at harvesting and techniques used) in Chinese lakes.

Brief history of CBF in China and main techniques used

China has a long history of CBF in lakes. Prior to the 1960s, and before the development and extension of artificial propagation techniques for the four Chinese major carps species (*Mylopharyngodon piceus* (Richardson 1846), *Ctenopharyngodon idellus* (Valenciennes 1844), *Hypophthalmichthys molitrix* (Valenciennes 1844) and *Aristichthys nobilis* (Richardson 1845)), wild capture fisheries predominated the freshwater fisheries in the country. Since the 1970s, stock enhancement of the four Chinese major carps in lakes has been practised. In the 1980s, cage culture and pen culture dominated the fisheries in lakes. Since the 1990s, high valued species such as Chinese mitten crab, mandarin fish, Mongolian culter (*Culter mongolicus* (Basilewsky, 1855)) have been stocked in lakes.

In the new millennium, China began to address issues related to primary production and environmental impacts from intensive aquaculture practices in lakes and reservoirs. Increasingly strict regulations of the scale of cage culture, pen culture and culture-based fisheries operations in selected lakes have been gradually implemented. For example, the extent of pen culture area in East Taihu Lake has been reduced from 11,267 ha to 3,000 ha in 2009 (Wang et al., 2014). Undoubtedly, semi-intensive and intensive aquaculture practices in lakes such as for example cage culture and pen culture especially with use of feed and/or fertilisers will be further curtailed in the near future. All in all, CBF which is balanced and efficient through stock enhancement and fisheries management will be favoured, and eco-

Figure 1. Percent contribution of production for each of the freshwater environment types (left) and percent contribution of farming area for each of the freshwater environment types (right). Both are based on five year averages from 2006 to 2010 in China base on the average of five years from 2006 to 2010.

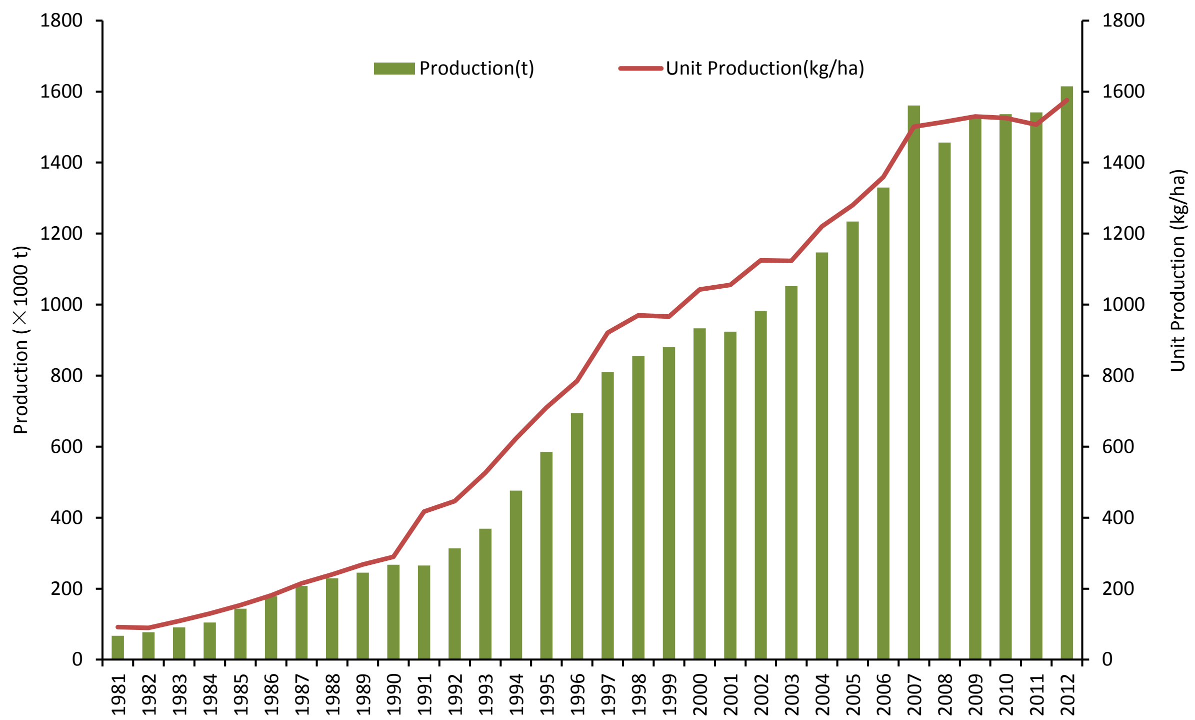


fisheries, the responsible use of natural food resources and protection of biodiversity and ecosystem health will be encouraged.

A range of CBF techniques are being implemented in China as follows:

- Introduction of new species (e.g. introduction of ice fish, *Neosalanx taihuensisi* to Dianchi Lake) to exploit under-utilised fishery resources.
- Stock enhancement of four Chinese major carps, mitten crab, and mandarin fish.
- Large-scaled rotational extensive-culture of mitten crab or grass carp in lakes.
- Transplanting aquatic plants.
- Encouraging the establishment of natural food organisms (e.g. snails) for economically important species such as Chinese mitten crab.
- Removal of aquatic macrophytes with high coverage such as *Potamogetoncrispus*.
- Fertilisation to maximise the productivity of water bodies enabling better growth of targeted species (e.g. silver carp and bighead carp).
- Elimination of unwanted species, especially carnivorous fishes (e.g. snakehead fish, *Channa argus* (Cantor)).
- In general, size and stocking rates of species are the two main factors influencing success of CBF. Success is mainly influenced by survival rate, size at harvesting and cost. As for stocking rates a number of models investigated some aspects of the dynamics of natural resources (e.g. zooplankton, macrophytes and zoobenthos) and bioenergetics model of stocked fish in CBF. These models derived management guidelines and served as a basis for rigorous evaluation of biological and economical effectiveness of these practices. For example:
    - Hu (1995) documented that the monthly dynamics of zooplankton which is the natural food for bighead carp and silver carp and adopted predictive models that are related to the production/biomass ratio to estimate the production capacity of filter-feeding fish in Baoan Lake in the middle reach of Yangtze River.
    - Cui and Li (2005) established a mathematical model based on the bioenergetics model of grass carp and the growth model of macrophytes to estimate the production capacity of grass carp stocked in macrophyte lakes.

Figure 2. Increase in total production and unit production of CBF in China over time.



Harvesting of mitten crab in a lake practicing CBF, Hubei Province.

- Bioenergetics model related to the productivity of zoobenthos and the production/biomass ratio was also used to estimate the production capacity of fishes, such as black carp and/or common carp that feed on the zoobenthos (Liang et al., 1995).

Stock enhancement of four major Chinese carps in China

With increasing pressure on inland fisheries, increases in production or yield are being sought through the application of a range of enhancement techniques. Stock enhancement of four Chinese major carps, the most common species that were stocked in lakes is considered as one of the most efficient means to restore the fish communities and improve fish production in lakes (Zhang et al., 1997). In the 20th century, their production often accounted for 60% of the freshwater fish catch in China (Wu et al., 1992).

However, some enhancement practices and/or poor fisheries management have resulted in environmental deterioration. In this regard, perhaps stocking of grass carp in lakes in the Yangtze River basin provides an impressive lesson. Since grass carp show a rigid selection for aquatic plant species when feeding (Li, 1998; Pípalová, 2002), stocking have resulted in the exhaustion of the preferred food supply, bringing about a replacement of palatable species with unpalatable species (Liu, 1990; Xiao et al., 2010). On the other hand, stocking rates of grass carp, depended on the biomass of macrophytes which can vary with water depth, species and climate, can rarely be accurately estimated (Killgore and Payne, 1984; Cassni et al., 1995; Pípalová, 2002). In the above context, stock enhancement of grass carp in macrophytic lakes in China has generally resulted in either complete macrophyte removal or desired/favourable macrophyte biodiversity being dominated by unpalatable species (Chen, 1989;Li, 1998).

As for stock enhancement of silver carp and big head carp in lakes, most of the lakes have reached their maximum potential under natural production regimes and the rising demand for fish is pushing many waters to maximise yields through a range of enhancement techniques. Stocking alone will result in a marginal sustainable increase of yields unless accompanied by other measures to increase the productivity of the water body (Welcomme and Bartley, 1998). In general, fertilisation is usually the first of these measures to be adopted and once a fertilisation program is initiated, it appears that it could not be withdrawn if increase productivity of waters is to be maintained. The negative impacts generated by large-scale fertilisation on water quality and structure of ecosystems have been documented previously (Yang et al., 1991;Vaux et al., 1995; Cottinghamand Carpenter, 1998; Vadeboncoeur et al., 2001).

Trade-off between enhanced production from CBF and environmental protection

Undoubtedly, CBF practices in China have contributed significantly to increasing fish production and in turn to national food security and socio-economically. The constraints facing the development of CBF and the importance of overcoming such constraints, especially the increasing challenges associated with the conflicts between CBF production and environmental protection need to be emphasised. In general, although a range of unsustainable techniques such as overstocking of four major carps and/or mitten crab, using fertiliser or animal manure, using various kinds of feed and elimination of carnivorous fishes could raise the CBF production in the short-term in certain waters, these practices resulted in concerns regarding declining quality of the aquatic environments. Meanwhile, there will be increasing competition with agriculture, industry, recreation, drinking water and landscape for the use of water resources. In the future, CBF programs should benefit all stakeholders that have a claim on the respective water resources. Currently, in China the orientation of lake fisheries is being gradually diverted from seeking fish production to protection of water quality. Fisheries capacity will be estimated according to the environmental carrying capacity of the respective waters. Therefore, aquatic environment protection oriented fisheries (or eco-fisheries) are beginning to be advocated and are gaining increasing attentions of biologists and culturists.

CBF of Chinese mitten crab and mandarin fish

Chinese mitten crab

Chinese mitten crab, is a catadromous crustacean with a life-span of about 2 years and with high nutritional and economic value in China (Pan, 2002; Jin, 2003; Chen et al., 2007).In the natural environment, it grows in freshwater until maturity and then migrates into saline water to spawn (Pan, 2002). Chen et al. (1989) reported that mitten crab from Lake Taihu fed on hydrophytes, fish, shrimp, mollusc, aquatic insects, and worms. Jin et

Mitten crab, the bulk of which is produced in CBF, is a highly priced and marketable commodity. Photo courtesy of Peter Edwards.

al. (2003) observed that mitten crab, in a natural lake in the Yangtze basin fed on macrophyte, algae, arthropods, oligochaetes, fish and detritus.

During the early 1970s to the middle 1980s, wild-caught megalopae in the Yangtze River was released into the open lakes and farmers benefitted from this stocking strategy (Chen et al., 2008). This rather primitive enhancement of Chinese mitten crab is the beginning of mitten crab farming in China and currently this farming sector has achieved remarkable success. The production of mitten crab has increased from 4,833 t corresponding to 36 million USD (1990) to 714,380 t corresponding to 4,972 million USD (2012) in China (FAO, 2014). Among all the types of aquatic environments used for mitten crab culture, lakes with high natural productivity (e.g. benthos) and macrophyte presence that favour the growth of mitten crab are favoured. In view of the above, CBF of mitten crab have been widely practised in the lakes in the middle and lower reaches of Yangtze River (Jin et al., 2000).

Seed stock

CBF practices of mitten crab are variable in regard to stocking material used. Before the 1980s, the stocking material used in CBF in lakes relied on megalopae caught in the Yangtze River. However, natural recruitment declined in the late 1980s due to over-fishing and the construction of dams. Artificial propagation of mitten crab was developed and extended at the beginning of the 1980s. Since then, an increasing number of seed of mitten crab are hatchery produced.

In general, the broodstock of major populations of mitten crab used in CBF in lakes were from the Yangtze, Liao and Ou rivers. Of these, the mitten crab from the Yangtze River enjoys good reputation for its excellent growth performances and unique taste. Mitten crab population from the Liao River is usually cultured in three provinces in the northeast China.

Until the 1980s, most of the crab seed used in CBF was megalopae. Megalopae has been gradual and increasing replaced by the coin-sized crab in practices of CBF due to the higher recovery rate of the latter.

Size of seed stock

Before or just after the Chinese Spring Festival (normally in January and February), coin-sized mitten crab ranging from 2.5 to 10 g in weight are stocked in lakes in the Yangtze basin. The two main factors that influence the size chosen were cost and survival. Apart from the above, the availability of crab seed is also a factor that influences the size chosen.

Stocking models

The deterioration of water quality and the decline of natural food resources in many lakes resulting from over-stocking of mitten crab have been dealt with (Song et al., 2010). Xu et al. (2003) found that intensive culture of mitten crab in lakes resulted in the decline of biodiversity, density and biomass of the zoobenthic community. Intensive culture in Chinese lakes also resulted in reduced submerged vegetation biomass and cover, which significantly decreased the subsequent formation of seed banks (Xiao et al., 2010). Therefore, carrying capacity estimate of mitten crab in CBF in lakes could serve as a basis for guiding stocking.

There are three steps to determine the stocking model. The first step is to select key factors affecting crab yield and driving variable of the models. In this regard, Wang et al. (2006) documented that the annual yield (CY) of mitten crab in lakes was positively correlated to biomass of submerged macrophyte (BMac), Secchi depth (ZSD), annual pH, gastropod density (DGas) and insect density (DIns), but negatively to total nitrogen (TN), chlorophyll l a (Chl a), oligochaete density (DOli) and biomass (BOli). Among these, BMac is the most important factor affecting CY and can be statistically considered as the key factor affecting crab yield (Wang et al 2006). The second step is to determine the maximal yield (kg/ha) model in lakes. It can be expressed by the equation:

$CY_{Max} = b_o + b_1 Z_{SD}/Z_M$ (Wang et al., 2005).

The final step is to determine the optimal stocking model for determining the stocking rate (SROpt, ind/ha) of coin-sized mitten crab, and is expressed by the equation:

$SR_{Opt} = (1000\ CY_{Max} \times 50\%)/BW \times RR$ (Wang et al., 2006),

where BW is the adult crab size (g/indivdual) and RR is the recapture rate (%).

Based on the maximal yield estimates and using 150 g/ind. for BW and 30% for RR, it is estimated that the optimal stocking rates are 700+60 ind./ha (Wang et al., 2006).

Harvesting and marketing

In general, mitten crab is harvested from October to November. Net traps of approximate 15 m length , are set in the night and hauled early next morning. All the mitten crab in a lake could be harvested in 15 to 20 days, and harvested crab will be stored in a net pen system near the lake shoreline until sold.

Aquatic product vendors often negotiated with managers of CBF in lakes based on quality tests and weight classification of mitten crab. Such as for example the appearance (e.g. abdomen colour, cheliped loss or damage), degree of gonads maturity, degree of muscle maturity were all included in such assessments. Normally, mitten crab stocked in lakes often is thought to have better nutritional quality and tastes than that cultured in ponds and are priced higher. Wu et al. (2007) documented that the lake-stocked crab is characterised by a blue carapace, white abdomen, golden legs and yellow setae while crab cultured in ponds have a brown carapace, grey abdomen, black legs and similar yellow setae.

Mandarin fish

Mandarin fish, is a typical piscivore, that has a natural range of distribution from southern Zhujiang River through to the north in the Amur River and found to feed on live prey fish only throughout life (Liang et al., 1998; Li et al., 2013). Wild stocks of mandarin fish have been exhausted due to the damming of rivers, pollution, large-scale elimination of unwanted species in CBF since the 1970s and over-fishing driven by the increasing demand for high valued fishes in recent decades (Liang et al., 2001, Cui and Li, 2005).This aspect is best exemplified in Honghu Lake in the Yangtze basin. In 1959-1960, mandarin fish contributed 5% to the total catch, and declined to 0.2% in 1981-1982 (Song et al., 1999). Meanwhile, the rapid decline of piscivorous fish (e.g. mandarin fish) has resulted in the expansion of small fish communities in lakes adopting CBF.

There are thousands of lakes along the middle and lower reaches of the Yangtze River typically with large small sized fish resources (Xie et al., 2000; Xie et al., 2001; Ye et al., 2006; Li et al., 2010) which are natural prey fish for the mandarin fish (Xie et al., 1997; Cui and Li, 2005). Because of its high value, it has become a new species for stocking lakes. This kind of fisheries can be profitable at relatively low yields reduce the pressure of fisheries on the natural habitats (Liu et al., 1998). Studies in North American and European lakes suggested that stocking piscivorous species into lakes may improve water quality through trophic-cascading effects (Carpenter and Kitchell, 1988; Liu et al., 1998). Since the middle of the 1990s, mandarin fish stocking has been widely practised on a large scale in Yangtze lakes and esulting in the production of an increasing amount of high valued food fish and economic opportunities for livelihoods. Li et al. (2014) demonstrated that competition for food between hatchery-reared and wild mandarin fish was insignificant during the critical periods of early stocking stages and that moderate stocking of may not have a negative effect on the variability of wild *Siniperca* populations.

Stocking material

The major populations of mandarin fish are from the Yangtze, Pearl, Min, Qiangtang, Huai, Liao and Amur rivers (Li, 1991). In CBF, the population of mandarin fish from the Yangtze River which is considered to have a preferable growth performance and higher resistance to diseases is stocked in lakes in Yangtze basin. Normally, the overwhelming majority of mandarin fish fry or fingerling used in stocking in lakes are artificially propagated since 1990s.

Size at stocking

The size of stocked mandarin fish ranged from 0.5-1.0 cm (fry) to fingerling of 2.0-10.0 cm or even larger. Overall, the survival rate of fingerlings prevailed over fry, but the latter cost much less. Hence, it's also a trade-off between cost and survival rate in CBF (Table 1).

Stocking model

In order to achieve the maximum yield of mandarin fish in CBF without affecting the natural recruitment of small-sized fish estimation of the productivity of the latter could serve as a basis for guiding the stocking in certain lakes. This includes two aspects: One aspect is to estimate the growth and food demand of mandarin fish in lakes which can be estimated with a bioenergetics model, and the other is to estimate the productivity of food fishes in lakes by studying population dynamics and community ecology of food fishes in lakes (Cui and Li, 2005).

The bioenergetics model of mandarin fish includes a series of sub-models:

- Maximum food consumption sub-model: $\ln C_{max} = -4.880 + 0.597\ln W + 0.284T - 0.0048T^2$, where C_{max} is the maximum food consumption (g/individual/day), W is wet weight (g) and T is water temperature.
- Specific growth rate sub-model: $\ln(SGR + 0.25) = -0.439 - 0.500\ln W + 0.270T - 0.046T^2$, where SGR is the specific growth rate (%/d)
- Standard metabolism sub-model: $\ln R_S = -5.343 + 0.772\ln W + 1.387\ln T$, where R_S is the standard metabolism rate mg/ind/fish.
- Faecal production sub-model: $F = -0.161 + 0.077C$, where F is faecal production (kJ/d) and C is food consumption (kJ/d).
- Excretion sub-model: $U = 0.376 + 0.047C$, where U is excretion (kJ/d)

- Specific dynamic action sub-model: $SDA = 0.0873C$, where C is specific dynamic action (kJ/d).

- Activity metabolism sub-model: it is estimated from the energy budget equation.

- Energy of sub-model: $EW = (2.077 + 0.367R_p)W^{0.153}$, where $R_p = R_a/R_s = -0.0038 + 1.076R_p^{3.0382}$.

Using computer programming, we can calculate any parameter in the above mentioned model and sub-models (Liu, 1998). Using the bioenergetics model, it was estimated that 1 g of mandarin fish stocked in June 1st can reach 661 g by the end of next March, consuming 2,133 g food fish (Liu, 1998).

Zhang et al. (2001) estimated the mean biomass, annual production and P/B ratio of small fish populations in Yangtze Lakes by using methods documented by Ricker (1971). Hence, productivity of small fish which could serve as potential prey for mandarin fish, can be estimated based on the monitored mean biomass of small fish in certain lakes.

In conclusion, the steps for calculating the production of mandarin fish in lakes are:

- Based on the monthly water temperature changes in lakes and the stocking time and stocking size, calculate the harvest weight of mandarin fish and the amount of food fish consumed.

- Based on the macrophyte distribution, calculating food fish biomass.

- Determining the productivity of predominant food fishes in lakes and calculate P/B ratio.

- If 10% of the food fish productivity is consumed by mandarin fish, then the production potential of mandarin fish is: harvest weight × (0.1 × food fish productivity)/food consumption by individual mandarin fish.

Harvesting and marketing

In general, mandarin fish is harvested from October to April in lakes. The gill nets made of polyethylene and hooks are mainly used to capture mandarin fish. Electricity is also used in some areas to harvest mandarin fish.

Conclusion and future trends

Over last three decades, CBF have been practised widely in Chinese lakes, particularly in the Yangtze lakes. CBF have contributed to production of significant amounts of high quality aquatic food types, and also enabled substantial monetary gains and created large number of job opportunities. All of these have contributed to national food security, economic growth and social stability. Although in the course of development of CBF,

Table 1. Annual stocking rate, size of stocked fish and yield of mandarin fish culture-based fisheries in five lakes in the Yangtze basin from 1995 to 1999.

Year	Niushan Lake	Zhangdu Lake	Wu Lake	Taojiada Lake	Caipo Lake
	Stocking rate (×10⁴ individuals)				
1995	0	0	0	0	0
1996	60	11	1.6	0.5	1.2
1997	100	15	2.5	0.8	1.1
1998	110	11.5	3.8	0.7	1.3
1999	280	12.8	3.6	0.7	1.5
	Size of fish (cm total length)				
1995	-	-	-	-	-
1996	0.5-1.5	3.3-3.5	3.3-3.5	3.3-3.5	3.0-3.5
1997	0.5-1.5	3.4-3.5	3.4-3.5	3.4-3.5	3.3-3.5
1998	0.5-1.5	3.3-3.6	3.3-3.6	3.3-3.6	3.0-3.5
1999	0.5-1.5	3.5-4.0	3.5-4.0	3.5-4.0	3.8-4.0
	Yield (kg)				
1995	9,200	-	-	-	-
1996	17,500	27,600	1,500	1,200	1,400
1997	59,800	28,500	5,600	1,100	1,700
1998	59,200	29,400	7,600	1,400	1,600
1999	73,000	28,000	8,200	1,600	1,600

The surface area of the lakes are: Niushan Lake 4,000 ha; Zhangdu Lake 2,670 ha; Wu Lake 1,667 ha; Taojiada Lake 267 ha; Caipo Lake 100 ha. Data of Niushan Lake was cited from Cui and Li (2005), data of Zhangdu Lake, Wu Lake, Taojiada Lake and Caipo Lake were cited from He et al. (2002).

there is an increased concern with regard to intensification of aquaculture practices for varying reasons, some of which may be socio-economic and/or environmental. The situation is further exacerbated because of the increasing competition for primary resources such as land and water. The contribution of CBF in lakes could not be ignored especially in China, such a populous country.

In regard to the trends of CBF in Chinese lakes, three aspects can be expected. Firstly, it is becoming increasingly stricter to use fertilisation, various kind of feed and modification of water bodies (e.g. cut off a small and control water body from the main body by bunds, weirs or nets). Hence, it can be foreseen that the production of CBF in Chinese lakes would decrease, overall. Secondly, a growing number of fisheries communities and/or farmers will incur economic losses if they were for example to culture filter feeding fish (e.g.big head carp and silver carp). However, the gradual shift to using high valued species such as mandarin fish and mitten crab will offset economic losses even though the overall production volume is reduced. Thirdly, direct stocking is not the only answer, while habitat restoration or improvement may offer a more widely applicable means of making more resources available or improving recruitment of fish stocks.

In regard to the harvesting and marketing in CBF, most fish were harvested within a narrow time frame, normally in winter before the Chinese spring festival. This could result in decline of market price of the produce due to glut in the markets in this short period. This effect could, however, be minimised if the harvest is staggered. Such a staggered harvesting will not only have a positive influence on the market price, but will also enable the fish supplies to be maintained (De Silva, 2003).

In China, permanent water bodies are government property and have traditionally been considered a land resource under the jurisdiction of various kinds of state organisations which lease out fishing rights to the highest bidder with the sole objective of generating government revenue. Lease holders have long been among the local rich and influential people who have the political and social power to enforce their control over the resource. The leases are short-term arrangements and the leaseholders therefore try to exploit the resources to the maximum without any concern and or regard of the aquatic environments. Hence, more attention should be paid to legislation on ecological compensation mechanisms to realise payment for environmental resources usage or punishment for environmental resources damage.

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