

Article

Fishery Status and Rebuilding of Major Economic Fishes in the Largest Freshwater Lake in China Based on Limited Data

Yang Liu ^{1,2}, Huiyun Fu ³, Linlong Wang ^{1,2} , Li Lin ^{1,2} , Gang He ³, Peifeng Fu ³, Changlai Wang ³, Yanping Zhang ^{3,*} and Bin Kang ^{1,2,*} 

¹ Key Laboratory of Mariculture (Ocean University of China), Ministry of Education, Qingdao 266003, China; yangliuouc1102@163.com (Y.L.); linlong_wang@163.com (L.W.); danielin.fdu@icloud.com (L.L.)

² Fisheries College, Ocean University of China, Qingdao 266003, China

³ Department of Fishery Resources, Jiangxi Fisheries Research Institute, Nanchang 330000, China; huiyunfujxnc@163.com (H.F.); xyz001619@163.com (G.H.); fuyu939673@163.com (P.F.); wangchenglaijx@163.com (C.W.)

* Correspondence: zhangyanpingxie@163.com (Y.Z.); kangbin@ouc.edu.cn (B.K.)

Abstract: Poyang Lake, the largest freshwater lake in China, possesses abundant fishery resources, but its fish stock status is still unclear. In this work, the stock status of and fishing efforts of nine major economic fishes in the Poyang Lake were estimated from 2000 to 2019 with a catch-based maximum sustainable yield (CMSY) model based on catch and resilience data. It was further predicted whether the biomass of those fishes could be restored to support maximum sustainable yield (B_{msy}) under the policy of “Ten years fishing moratorium in the Yangtze River”. The results showed that goldfish *Carassius auratus*, grass carp *Ctenopharyngodon idella*, and black carp *Mylopharyngodon piceus* suffered from higher fishing efforts and low biomass in the past 20 years; bighead carp *Hypophthalmichthys nobilis*, yellow catfish *Tachysurus fulvidraco*, and common carp *Cyprinus carpio* responded differently to their fishing efforts; silver carp *Hypophthalmichthys molitrix*, Amur catfish *Silurus asotus*, and mandarin fish *Siniperca chuatsi* were underexploited. Six species were overfished in 2019, and their biomass would be expected to recover for sustainable exploitation during the fishing moratorium, except for *M. piceus*. This study provided a case study of feasible freshwater fishery evaluation in limnetic ecosystems.

Keywords: lake fisheries; stock assessment; CMSY model; fishing moratorium; fisheries recovery; fisheries management



Citation: Liu, Y.; Fu, H.; Wang, L.; Lin, L.; He, G.; Fu, P.; Wang, C.; Zhang, Y.; Kang, B. Fishery Status and Rebuilding of Major Economic Fishes in the Largest Freshwater Lake in China Based on Limited Data. *Fishes* **2022**, *7*, 47. <https://doi.org/10.3390/fishes7010047>

Academic Editor: Kostas Ganiats

Received: 12 January 2022

Accepted: 11 February 2022

Published: 15 February 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Inland fisheries are characterized by multi-drivers and multi-species [1], providing food and livelihoods for millions of people [2], especially in developing countries. The area of lakes, reservoirs, and wetlands worldwide exceeds more than 12 million km² altogether [3], of which lakes contribute a significant proportion to inland fisheries [4,5]. For example, in China, there are more than 2000 natural lakes with an average surface area of more than 1 km² and a total area of approximately 80,000 km² [6]. The domestic lake fishery experienced three developmental phases: the traditional wild fishery before the 1960s, the rapid growth of fishery production from the 1960s to the mid-1980s, and the fast growth of aquaculture since the mid-1980s [7]. The fishery production increased by 11 times from 75,100 tons in 1979 to 862,300 tons in 2019, with a peak in 2015 at 1,647,800 tons in terms of aquaculture [8,9].

Previous studies on fishery status were mainly based on biological parameters of the targeted fishes, fishing effort, or ecosystem features [10–13]. Different modeling frameworks require diverse fishery parameters, such as catch and abundance data, CPUE or other fishing effort parameters, and length-based or age-based data [14–17]. Limited by incomplete data records, selective data collection, and governmental policy prohibition [18],

available fishery information might not enable more traditional approaches for estimating stock status in inland waters. Fortunately, the catch-based maximum sustainable yield (CMSY) model, based on fewer fisheries parameters such as catch and resilience of species, was firstly proposed by Martell and Froese [19]. Subsequently, this model was supplemented by Froese et al. [15]. The CMSY model performs well in quantifying maximum sustainable yield (MSY), biomass (B), and other related fishery reference points and have been widely applied to assess stock status [20–23].

As the biggest inland freshwater lake in China, Poyang Lake, embedded in the middle and lower reaches of the Yangtze River, covers a surface area of more than 3000 km² in the wet season [24]. It possessed an affluent fishery with an average catch production of 42,600 tons in the 1990s [25] which then decreased significantly (by as much as half) under multiple stresses [26,27] in the last decade [28]. In addition, some species showed fisheries-induced evolution, characterized primarily by miniaturization and lower age in this lake [29], causing undesirable consequences in fishery resources [30]. The Poyang Lake has significant ecological and socio-economic value [31], thus evaluating the fishery status of the lake becomes imperative for sustainable utilization and management. However, fishery assessment in the Poyang Lake was scarce during the past decades because of limited data availability and the lack of applicable methods. To prevent further depletion of fishery resources, a systematic conservation plan in the Yangtze River was enacted in 2019, which mandated a fishing moratorium in the basin and its major tributaries over the next 10 years [32]. Jiangxi Province, which governs the Poyang Lake, responded to this fishing moratorium law on 21 August 2019, and legitimated that local fishing boats should be banned in the lake area since 2020. Therefore, the questions of interest both for the government and local fishery industry are whether and when local fisheries in the lake can be rebuilt to a sustainable status.

In this study, based on the catch data collected from 2000 to 2019 in the Poyang Lake, we assessed the fishery status of main economic fishes with the CMSY model, aiming to evaluate the historical and current exploitation status of the dominant fishes. We expected different levels of stock status for these fishes and predicted whether over-exploited fishes would respond to the fishing moratorium law and when the biomass of these species could be restored. This work is beneficial in comprehending dynamic variations of fishery resources in Poyang Lake and predicting the efficiency of inland fishing moratorium law on stock recovery.

2. Materials and Methods

2.1. Study Area

Poyang Lake is located from 28°24' to 29°46' N and 115°49' to 116°46' E (Figure 1) with an average water depth of 7.38 m and mean annual water level of 12.86 m [33]. Both the surface area and the water storage vary seasonally. During the wet season, when the water level of the hydrological station at Hukou is 22.59 m, the floodplains are inundated with a surface area of 4500 km² and a storage capacity of 340×10^8 m³. These metrics dropped to 146 km² and 4.5×10^8 m³ in the dry season when the water level at Hukou is 5.9 m [34]. Runoffs attributed to the Yangtze River and upstream tributaries are from the Ganjiang River, Fuhe River, Xiuhe River, Xinjiang River, and Raohe River. The lake's outlet flows into the downstream Yangtze River with an annual runoff of 152.5 km³ [33]. The climate is a typical subtropical monsoon with an annual precipitation of more than 1000 mm [35].

Poyang Lake provides abundant ecosystem services, such as supplying water and food, offering recreation, and playing important roles in the socio-economic and ecological fields [31,36]. With the economic development, the domestic sewage and industrial wastewater from the upstream rivers flowed into the lake. The numerous heavy metals and nutrition with nitrogen and phosphorus degraded water quality and led to fishery collapse in Poyang Lake [31,37]. In addition, some anthropogenic activities such as dam construction and navigation have also disturbed the growth of aquatic organisms [35].

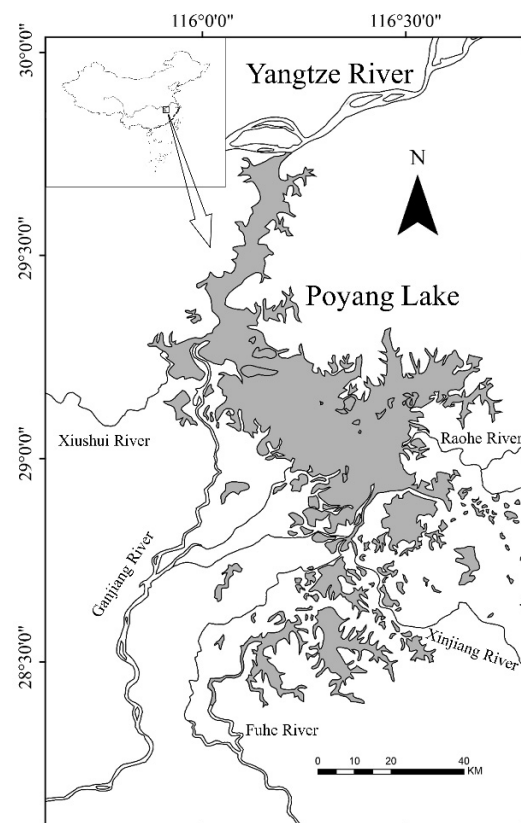


Figure 1. The map of the Poyang Lake basin and its upstream tributaries. The shaded area shows the area of the Poyang Lake.

There was a maximum of 136 fishes according to an investigation of Poyang Lake in the last century [38], whereas only 89 fishes were discovered in 2013, and these species were characterized primarily by miniaturization and lower age [29]. Most of them were cyprinid fishes, contributing to 52.2% and 53.9% of total species, respectively. High fishing pressure was the main factor that caused the decline of fish diversity and resources. The average number of fishermen engaged in the fishing industry was 55,000, and the number of vessels was about 20,000 from 2000 to 2019 [39]. Development of various fishing tools such as cages and gill nets [40] also accounted for the decrease of fish resources. To alleviate these pressures, a series of fishing regulations were implemented before the ten years fishing moratorium. For example, a few legal fishing tools were allowed, such as angling for recreation and entertainment; fishing nets with meshes smaller than the specified minimum size, e.g., the mesh size of the dragging gillnet should be greater than 100 mm [41].

2.2. Fish Data

Catch data were provided by the Jiangxi Fisheries Research Institute and extracted from other published literature, including Qian et al. [25] and Huang and Gong [26]. Twenty years of catch records from 2000 to 2019 were compiled. Nine fishes were selected for assessment based on their economic importance, including goldfish *Carassius auratus*, grass carp *Ctenopharyngodon idella*, common carp *Cyprinus carpio*, silver carp *Hypophthalmichthys molitrix*, bighead carp *Hypophthalmichthys nobilis*, black carp *Mylopharyngodon piceus*, Amur catfish *Silurus asotus*, Mandarin fish *Siniperca chuatsi*, and yellow catfish *Tachysurus fulvidraco*. These nine fishes contributed 64.7% to 89.9% to the total catch production annually in the Poyang Lake during the recent two decades. Among them, the species *C. carpio* contributes the highest to the total annual catch, reaching 36.78% on average, followed by *S. asotus* and *C. auratus* which contributes 13.61% and 10.68%, respectively. The average contributions of other species are all lower than 10%. They are *T. fulvidraco*

(8.53%), *S. chuatsi* (5.48%), *H. molitrix* (2.08%), *C. idella* (1.83%), *H. nobilis* (1.16%), and *M. piceus* (0.83%). Their essential biological information was summarized in Supplementary Material Table S1, including the age of first sexual maturity, the life-history strategies, and the environmental adaptability.

2.3. CMSY Model

Theoretically, temporal fishery catch is highly correlated to yield, biomass, and productivity. The CMSY method uses the catch production and resilience of stocks to assess biomass based on the following equation: $B_{t+1} = B_t + r\left(1 - \frac{B_t}{k}\right)B_t - C_t$, where B_t and B_{t+1} are the biomass in t year and $t+1$ year, respectively, C_t is the catch in t year, parameter r is the maximum intrinsic rate of population growth, and k indicates carrying capacity or unexploited stock size. Relationships between different biomass in two successive years, population growth rate, carrying capacity, and catch are reconstructed by the equation: $B_{t+1} = B_t + 4\frac{B_t}{k}r\left(1 - \frac{B_t}{k}\right)B_t - C_t$ when relative biomass B/k is lower than 0.25. The term $4\frac{B_t}{k}$ assumes a linear recruitment decline below half of the B_{msy} [15]. Furthermore, we assume that the largest catch of each stock in a time series should be lower than the unexploited stock size k to make the prior range of k more reasonable.

Biological parameters of fishery resources play critical roles in assessing population status and different degrees of fishing mortality [42]. We used 20 years of catch data per species and combined prior ranges for the r , k , and the relative biomass (B/k) at the beginning and the end year to output reference points and further evaluate stock status. The equation $r \approx 3K$ was used to determine the ultimate parameter r , where K is the parameter of the Von Bertalanffy somatic growth equation, combined with prior r ranges based on different resilience of species, i.e., High (0.6–1.5), Medium (0.2–0.8), Low (0.05–0.5) and Very low (0.015–0.1) [15,43]. The prior range of k for assessed stocks with low prior biomass in the end year can be determined with the equations: $k_{low} = \frac{\max(C)}{r_{high}}$ and $k_{high} = \frac{4\max(C)}{r_{low}}$, where k_{low} and k_{high} are the lower and upper bounds of the prior range of k respectively, $\max(C)$ is the maximum catch in the time series, r_{low} and r_{high} are the lower and upper bounds of the prior range of r respectively. In addition, the equations: $k_{low} = \frac{2\max(C)}{r_{high}}$ and $k_{high} = \frac{12\max(C)}{r_{low}}$, were used to acquire the prior range of k for assessed stocks with high prior biomass. For realistic outputs from the CMSY model, probability distributions of parameters r and k were estimated by JAGS software [44]. Due to the lack of research data on the historical exploitation status of fishes in Poyang Lake, the prior range of relative biomass B/k at the beginning and the end year depended on the ratio of catch per species relative to its maximum catch in a time series [19,45]. Although this process can result in slight bias, it is still a reasonable method when these parameters are limited. A detailed description of R code, equations, and theoretical backgrounds for the CMSY model was given by Froese et al. [15].

Based on the above-mentioned biological parameters, available indices B/B_{msy} (the ratio of observed biomass to biomass compatible with MSY) and F/F_{msy} (the ratio of fishing mortality to fishing mortality compatible with MSY) were estimated. A value of F/F_{msy} greater or lower than 1 indicates a high and low fishing pressure, respectively. According to the values of B/B_{msy} , a detailed standard was applied to categorize the stock status: $B/B_{msy} > 1.0$, healthy; $0.8 < B/B_{msy} \leq 1.0$, slightly overfished; $0.5 < B/B_{msy} \leq 0.8$, overfished; $0.2 < B/B_{msy} \leq 0.5$, severely overfished; $0 < B/B_{msy} \leq 0.2$, collapsed [46].

2.4. Fisheries Rebuilding

Based on fishery reference points B/B_{msy} and F/F_{msy} , the biomass of nine fish under two exploitation scenarios was predicted to determine future stock status. Under the scenario of a fishing moratorium for ten years, fishing mortality was assumed to approximate to 0 (i.e., minimal F allowed for scientific research or something similar), and values of F/F_{msy} are also 0, which was considered as non-fishing pressure (NFP) scenario. Rebuilding

of a stock will be complete when its biomass recovers to its B_{msy} in the NFP scenario by the equation: $\Delta t = \frac{1}{2F_{msy}-F} \ln \left[\frac{2 \frac{B_{msy}}{B} \left(1 - \frac{F}{2F_{msy}} \right) - 1}{2 \left(1 - \frac{F}{2F_{msy}} \right) - 1} \right]$, where Δt is the time in years to reach B_{msy} , B is the biomass in the last year, and other parameters are defined above. Assuming the same fishing pressure in 2019 during the next ten years, which was considered as the current fishing pressure (CFP) scenario, the effects of current fishing efforts on stock status were predicted. Population biomass and stock status in the next year are thus evaluated by the following equations [47]: $\frac{B_{t+1}}{B_{msy}} = \frac{B_t}{B_{msy}} + 2F_{msy} \frac{B_t}{B_{msy}} \left(1 - \frac{B_t}{2B_{msy}} \right) - \frac{B_t}{B_{msy}} F_t$, when $\frac{B_t}{B_{msy}} \geq 0.5$ or $\frac{B_{t+1}}{B_{msy}} = \frac{B_t}{B_{msy}} + 4 \frac{B_t}{B_{msy}} F_{msy} \frac{B_t}{B_{msy}} \left(1 - \frac{B_t}{2B_{msy}} \right) - \frac{B_t}{B_{msy}} F_t$, when $\frac{B_t}{B_{msy}} < 0.5$ where B_t and B_{t+1} are the biomass in t year and $t+1$ year, respectively; F_t is fishing mortality in t year. B_{msy} was assumed to be constant during the process of rebuilding.

3. Results

3.1. Exploitation Status of Main Economic Fishes

The dynamic catch production of nine fishes and their MSY estimates during the past 20 years are shown in Figure 2. Catches of species *C. auratus*, *C. idella*, and *M. piceus* gradually declined from 2000 to 2019, except for two fluctuations for species *C. idella* in 2008 and 2010. Catches of species *C. carpio*, *S. asotus*, and *S. chuatsi* in most years were within the 95% confidence interval of their MSY, except for a peak value for species *S. chuatsi* in 2008. Irregular variations of catches occurred for species *H. molitrix*, *H. nobilis*, and *T. fulvidraco*.

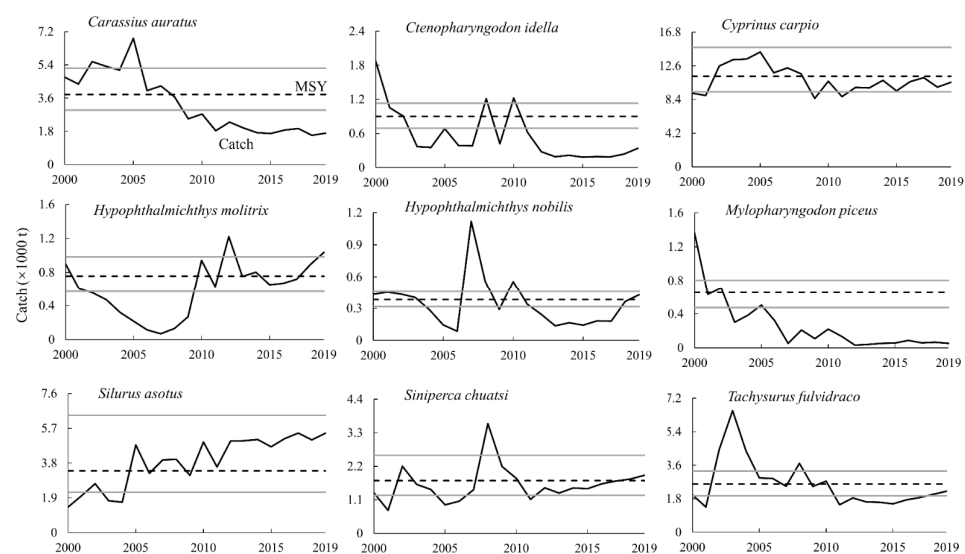


Figure 2. Catches (solid black lines) of nine main economic fishes from 2000 to 2019 and their values of MSY. Black dotted lines indicate mean values of MSY, and solid gray lines represent a 95% confidence interval.

Estimated biological parameters and reference points for these nine fishes are listed in Table 1. Exploitation levels for species *C. auratus* ($F/F_{msy} = 0.94$), *C. carpio* ($F/F_{msy} = 0.80$), *M. piceus* ($F/F_{msy} = 0.47$), and *S. chuatsi* ($F/F_{msy} = 0.93$) were relatively lower than the others ($F/F_{msy} > 1$). The status of species *C. auratus*, *C. idella*, *H. nobilis*, *M. piceus*, *S. asotus*, and *T. fulvidraco* was overfished at different levels with an average B/B_{msy} of 0.55 (0.31 to 0.97) in 2019. The other species were healthy in terms of their B/B_{msy} .

Nine dominant species are classified into four groups based on assessed B/B_{msy} and F/F_{msy} (Figure 3): group 1, species *C. auratus*, *C. idella*, and *M. piceus* with low biomass ($B/B_{msy} < 1$) and high fishing pressure ($F/F_{msy} > 1$); group 2, species *H. nobilis* and *T. fulvidraco* with a biomass greater than their B_{msy} ($B/B_{msy} > 1$) from 2000 to 2007 and 2000 to 2004, respectively, but lower in the last few years; group 3, species *C. carpio* with different

fishing pressure in different years; group 4, including species *H. molitrix*, *S. asotus*, and *S. chuatsi*, showing higher biomass ($B/B_{msy} > 1$) but low fishing pressure ($F/F_{msy} < 1$) in most years.

Table 1. Estimated parameters for nine main economic fishes in the Poyang Lake based on the CMSY model. Parameters r and k are population growth rate and carrying capacity, respectively. MSY indicates maximum sustainable yield. The B_{msy} and F_{msy} indicate biomass and fishing mortality capable of producing MSY, respectively.

Species	r (year ⁻¹)	k (10 ³ t)	MSY (10 ³ t/year)	B_{msy} (10 ³ t)	B/B_{msy} in 2019	F/F_{msy} in 2019	Status in 2019
<i>Carassius auratus</i>	0.38 (0.25–0.58)	41.5 (29–59.3)	3.79 (2.95–5.22)	20.8 (14.5–29.7)	0.48	0.94	severely overfished
<i>Ctenopharyngodon idella</i>	0.47 (0.43–0.51)	7.51 (5.66–9.98)	0.90 (0.69–1.13)	3.76 (2.83–4.99)	0.36	1.55	severely overfished
<i>Cyprinus carpio</i>	0.59 (0.40–0.86)	78.70 (54.6–113)	11.30 (9.35–14.9)	39.30 (27.3–56.6)	1.14	0.80	healthy
<i>Hypophthalmichthys molitrix</i>	0.67 (0.55–0.82)	4.39 (3.19–6.04)	0.76 (0.57–0.99)	2.19 (1.60–3.01)	1.16	1.21	healthy
<i>Hypophthalmichthys nobilis</i>	0.64 (0.52–0.79)	2.37 (1.90–2.95)	0.38 (0.32–0.46)	1.19 (0.95–1.48)	0.58	1.93	overfished
<i>Mylopharyngodon piceus</i>	0.26 (0.25–0.28)	9.18 (6.62–12.7)	0.65 (0.48–0.81)	4.59 (3.31–6.37)	0.31	0.47	severely overfished
<i>Silurus asotus</i>	0.26 (0.11–0.59)	59.00 (38–1.7)	3.37 (2.21–6.4)	29.50 (19–45.8)	0.97	1.46	slightly overfished
<i>Siniperca chuatsi</i>	0.51 (0.30–0.86)	14.20 (9.44–21.4)	1.73 (1.25–2.56)	7.10 (4.72–10.7)	1.14	0.93	healthy
<i>Tachysurus fulvidraco</i>	0.37 (0.25–0.56)	27.80 (20–38.7)	2.59 (1.96–3.29)	13.90 (9.99–19.3)	0.60	1.41	overfished

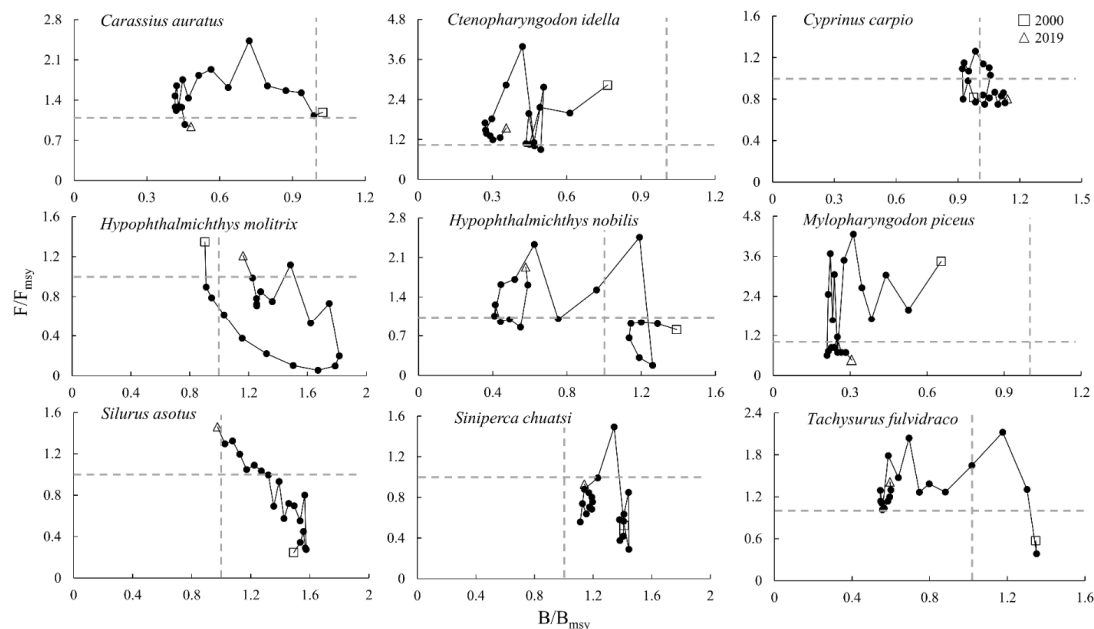


Figure 3. Scatter diagrams between B/B_{msy} and F/F_{msy} extracted from the CMSY models for nine main economic fishes in the Poyang Lake. Square points and triangle points respectively indicate values in 2000 and 2019. Solid black points indicate values in each year, which are connected with black lines sequentially from 2000 to 2019. Gray dotted lines are horizontal lines ($F/F_{msy} = 1$) and vertical lines ($B/B_{msy} = 1$). The $F/F_{msy} > 1$ and $B/B_{msy} > 1$ indicate higher fishing pressure and well biomass, respectively.

3.2. Fisheries Rebuilding

Predictions of exploitation status in 2030 are shown in Table 2. Under the NFP scenario during the fishing moratorium, the biomass of all fishes would increase rapidly by 2030. The five over-exploited fishes would recover in different years ($B/B_{msy} > 1$), such as *S. asotus* in 2021, *H. nobilis* in 2022, *T. fulvidraco* in 2023, *C. auratus* in 2023, and *C. idella* in 2026. However, the biomass of *M. piceus* could not recover its B_{msy} by the end of 2030. Under the CFP scenario in 2030, *C. auratus* and *M. piceus* would be healthier than in 2019, *C. carpio*, *S. chuatsi*, and *T. fulvidraco* would remain stable, and the levels of the remaining species would become worse or even collapse (Table 2).

Table 2. Stocks rebuilding of nine main fishes in 2030 based on two different scenarios. NFP and CFP represent non-fishing pressure and current fishing pressure scenarios, respectively. Reference points B and B_{msy} indicate biomass and biomass capable of producing MSY, respectively. Categories of stock status are: $B/B_{msy} > 1.0$, healthy; $0.8 < B/B_{msy} \leq 1.0$, slightly overfished; $0.5 < B/B_{msy} \leq 0.8$, overfished; $0.2 < B/B_{msy} \leq 0.5$, severely overfished; $0 < B/B_{msy} \leq 0.2$, collapsed.

Species	2030 (NFP Scenario)			2030 (CFP Scenario)			Rebuilding Time for NFP Scenario (year)
	B (10^3 t)	B/B_{msy}	Status	B (10^3 t)	B/B_{msy}	Status	
<i>Carassius auratus</i>	39.72	1.91	healthy	19.61	0.94	slightly overfished	2023
<i>Ctenopharyngodon idella</i>	6.95	1.85	healthy	0.37	0.10	collapsed	2026
<i>Cyprinus carpio</i>	78.58	2.00	healthy	47.14	1.20	healthy	NA
<i>Hypophthalmichthys molitrix</i>	4.38	2.00	healthy	1.75	0.80	overfished	NA
<i>Hypophthalmichthys nobilis</i>	2.37	2.00	healthy	0.001	0.001	collapsed	2022
<i>Mylopharyngodon piceus</i>	4.54	0.99	slightly overfished	2.66	0.58	overfished	unrecovered
<i>Silurus asotus</i>	54.97	1.86	healthy	19.77	0.67	overfished	2021
<i>Siniperca chuatsi</i>	14.18	2.00	healthy	7.61	1.07	healthy	NA
<i>Tachysurus fulvidraco</i>	26.78	1.93	healthy	8.21	0.59	overfished	2023

Note: “NA” shows the status of species is healthy in 2019 without recovery.

4. Discussion

4.1. Historical Status of Main Economic Fishes

Fishing effort is one of the determining factors that affect the fishery resources of the lake [1,48–50]. Under high fishing pressure, stock assessment and managements are in difficulty due to abuse of fishing gears and fishing methods in developing countries or other impoverished regions [51]. Based on habitat conditions and biological characteristics of different fishes, people invented various fishing tools and techniques. Previous studies indicated the use of more than 40 fishing tools in Poyang Lake, such as fish spears, gill nets and trawl nets [38]. Fishing pressure on different fish resources was divergent because of varying fishing gears and efforts, thus the status of these nine fishes in Poyang Lake was classified into four groups.

Group 1, including species *C. auratus*, *C. idella*, and *M. piceus*, suffered from high fishing pressure ($F/F_{msy} > 1$) and dropped in biomass ($B/B_{msy} < 1$) in the past years. These three fishes were also subject to the high fishing pressure in the inland waters of Asia based on the catch data from the FAO [52]. The biomass of the last two species has been declining for at least two decades. They show low r [43] and late age of maturation [53], which limited their ability to recover to a sustainable level. *C. auratus* has a low growth rate and fecundity [53,54], causing difficulty with recovery. Particularly, the species *C. auratus*, one of the primary fishing target species in Poyang Lake, has high catch production and nutritional value [40,55], which have accelerated the overexploitation of this species and led to an unhealthy status.

Group 2, including species *H. nobilis* and *T. fulvidraco*, suffered from low to high fishing pressure, accompanied by healthy to poor stock status. The biomass of these two species

was high in the initial years. The species *H. nobilis* has a high intrinsic rate of population increase ($r = 0.64$), which is beneficial to the resistance of species to overexploitation [43] and recovery of biomass after destroying the population resources. The species *T. fulvidraco* is an equilibrium strategist with parental care, enhancing the survival rate of the offspring [54]. This species exhibits multiple-batch spawning and has strong adaptability [56] to accelerate population recruitment. However, their biomass also declined in Poyang Lake under intensive fishing pressure in the subsequent years. The species *H. nobilis* and *T. fulvidraco* with high edibility are easily subjected to higher fishing pressure because of increased demand for aquatic products, causing the catch production to be higher than the population recruitment.

The species *C. carpio* was classified in group 3 and went through healthy-bad-healthy status in the past. The catch production was the highest in Poyang Lake, ranging from 25.6% to 42% during the recent two decades. Though it was exposed to high fishing pressure, its potential high biomass may make this species resistant to the risk from overexploitation. In addition, its relatively high r ($r = 0.59$), low late age of maturation, and strong adaptability to environmental stress may account for the healthy status in several years [53]. Moreover, the wide feeding habits of *C. carpio* could help it maintain a higher survival rate than species with simple food sources when the food resources are reduced due to water pollution.

Group 4, including species *H. molitrix*, *S. asotus*, and *S. chuatsi*, was subject to low fishing pressure ($F/F_{msy} < 1$) but had high biomass ($B/B_{msy} > 1$). Despite the fact the last two species have the high trophic level, their stock status was only slightly influenced by fishing activities. Both these two species are demersal fish, but they prefer rocky habitats, which suggest they are difficult to capture by fishing practices such as bottom trawling [57,58]. In addition, multiple spawning in a year [59,60] helps their population growth. Since 2007, a protection plan for *S. chuatsi* in Poyang Lake was issued [61], further stifling the resource decline. The species *H. molitrix* has lower economic value and less palatability compared to the other four major domestic carps, and therefore is a less desirable catch. Meanwhile, the highest population growth rate ($r = 0.67$) among these nine fishes supported its strongest resilience and resistance to similar fishing pressures. Since 2002, a series of measures were executed in Poyang Lake to slow down the reduction of the fisheries, including the policy of a closed fishing season in the spring and artificial reproduction and releasing [27]. These measures allowed this species enough time to recover the biomass in the early stage, thus the rate of population recruitment exceeded the fishing mortality resulting from human fishing activities.

Even if some measures were applied to recover poor fishery resources, it is also challenging to bring them back to a healthy status, indicating the impact of potential threats other than overfishing on fishery production [62]. For example, dam construction on the rivers upstream of Poyang Lake has significantly disturbed fish growth, including destroying the spawning grounds of migratory fishes and impeding their migration channels. In another instance, reclaiming land from the lake has resulted in a decline of large areas of aquatic vegetation [63,64], reducing the food resources for herbivorous fish such as the species *C. idella*, and disturbing the spawning substrates of species like *C. auratus* and *C. carpio* that lay sticky eggs, leading to little population recruitment for these fishes. Other factors, such as water pollution [36] and sand excavation [65], were possibly associated with natural fish mortality by altering the habitat environment and irregular catch activities in the lake. Therefore, policymakers need to manage these human activities and protect the habitat environment as crucial as reducing human fishing efforts with relevant measures.

4.2. Rebuilding of Fish Stocks

Rebuilding activities of global fisheries have mainly concentrated on marine fisheries [66,67], whereas little efforts are devoted to inland freshwater systems. Predictions under the NFP scenario suggested that stocks of those over-exploited species in 2019 would recover their levels of B_{msy} except the species *M. piceus* if the fishing moratorium law is followed, indicating that main fisheries in Poyang Lake could be recoverable with proper

fisheries management. Therefore, it is reasonable to deploy fishing banning rules, leaving those overfished fishes enough time to rebuild their stocks. For example, some endangered species such as Chinese sucker *Myxocyprinus asiaticus* [68] and *Ochetobius elongatus* [69], which were found in Poyang Lake, now have benefitted from this fishing moratorium law.

Under the NFP scenario, five fishes that have poor stock status would recover to a biomass level that produces the maximum sustainable yield, including the species *S. asotus*, *H. nobilis*, *C. auratus*, *T. fulvidraco*, and *C. idella*. The results suggest that the recovery rates of different species were mainly dependent on their biological characteristics and stock status in 2019. The species *H. nobilis*, characterized by periodic strategy, large-bodied size, and high r [54], showed the highest recovery rate and healthy status in 2022. The status of both species *C. auratus* and *T. fulvidraco* will be healthy in 2023, but the former has a higher recovery rate (former: 13.65%; latter: 12.91%). Human activities, such as hydraulic engineering and sand excavation, influenced the hydrologic conditions and water qualities of Poyang Lake in the past [27]. In turbulent habitats, *C. auratus* inhabiting frequently disturbed environments [54] showed rapid recovery from severely overfished to a healthy status, while *T. fulvidraco*, sensitive to changeable currents [43], was slower in its resource recovery. The stock status of *C. idella* was outside of safe biological limits ($B/B_{msy} < 0.5$) in 2019, forcing it to require more time to recover its population resources. Compared with the other fishes, the status of *S. asotus* with strong environmental adaptability [70] was slightly overfished in 2019 and can recover to healthy status quickly under fishing closure. The biomass of these fishes can recover to a healthy status, which should help facilitate fishery activity in Poyang Lake and generate more economic value.

The results show that the status of four species would be worse under the CFP scenario, even going from healthy to overfished status in the case of species like *H. molitrix*. This is because the F/F_{msy} value of these fish is greater than 1 in 2019, and their biomass will decline if fishing efforts are kept at the same exploitation levels during the next ten years. In contrast, the fishing pressure of both species *C. auratus* and *M. piceus* were low in 2019, and their stock status in 2030 will be healthier than that in 2019. Therefore, under sustainable exploitation levels ($F < F_{msy}$) rather than high fishing pressure, the stocks are expected to be rebuilt if the fishing moratorium could be extended. This suggests that it may provide an opportunity for scientific research with suitable fishing efforts in the next few years, without prominently affecting fishery resources in Poyang Lake.

5. Conclusions

This study quantifies the stock status of the nine dominant economic fishes in the Poyang Lake using the CMSY model based on limited data. Almost half of them experienced high fishing pressure ($F > F_{msy}$) in the past two decades, and two-thirds of stocks were in different levels of overfished in 2019, indicating the primary fish resources in the Poyang Lake might be declining. However, the biomass of five overfished fishes would likely recover to a healthy status ($B > B_{msy}$) under the policy of ten years fishing moratorium in the Yangtze River, suggesting reasonable management measures would benefit the sustainable development of fisheries. In the future, more fishery organisms, relevant biological parameters, and assessed models should be combined to assess the lake fisheries comprehensively.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/fishes7010047/s1>, Table S1: The biological information of nine fishes in the Poyang Lake [71–73].

Author Contributions: Conceptualization, methodology and software, Y.L. and L.W.; validation and formal analysis, Y.L., L.W. and B.K.; investigation and resources, H.F., G.H., P.F., C.W. and Y.Z.; writing—original draft preparation, Y.L.; writing—review and editing, visualization and supervision, Y.L., L.W., L.L., Y.Z. and B.K. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by the National Natural Science Foundation of China (No. U20A2087 and No. 41976091), China Agriculture Research System (CARS-46), and the Key Research and Development Program of Jiangxi (No. 20203BBFL63072 and No. 20171BBF60056).

Institutional Review Board Statement: The data of this research was extracted from the literature and the official statistics.

Data Availability Statement: The data that support the findings of this study are available with permission from the authors.

Acknowledgments: We are grateful for the assistance of local fishermen and administrative officers in field sampling.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Allan, J.D.; Abell, R.; Hogan, Z.E.B.; Revenga, C.; Taylor, B.W.; Welcomme, R.L.; Winemiller, K. Overfishing of Inland Waters. *Bioscience* **2005**, *55*, 1041–1051. [\[CrossRef\]](#)
2. Funge-Smith, S.; Bennett, A. A fresh look at inland fisheries and their role in food security and livelihoods. *Fish Fish.* **2019**, *20*, 1176–1195. [\[CrossRef\]](#)
3. Lehner, B.; Döll, P. Development and validation of a global database of lakes, reservoirs and wetlands. *J. Hydrol.* **2004**, *296*, 1–22. [\[CrossRef\]](#)
4. Zhang, J.M.; He, Z.H.; Lu, K.X. *Fisheries Resources of Inland Waters in China*; Agriculture Press: Beijing, China, 1990.
5. Deines, A.M.; Bunnell, D.B.; Rogers, M.W.; Bennion, D.; Woelmer, W.; Sayers, M.J.; Grimm, A.G.; Shuchman, R.A.; Raymer, Z.B.; Brooks, C.N.; et al. The contribution of lakes to global inland fisheries harvest. *Front. Ecol. Environ.* **2017**, *15*, 293–298. [\[CrossRef\]](#)
6. Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences. *Investigation Report of Lakes in China*; Science Press: Beijing, China, 2019.
7. Jia, P.; Zhang, W.; Liu, Q. Lake fisheries in China: Challenges and opportunities. *Fish. Res.* **2013**, *140*, 66–72. [\[CrossRef\]](#)
8. Kang, B.; Huang, X.; Li, J.; Liu, M.; Guo, L.; Han, C.C. Inland Fisheries in China: Past, Present, and Future. *Rev. Fish. Sci. Aquac.* **2017**, *25*, 270–285. [\[CrossRef\]](#)
9. Bureau of Fisheries, Ministry of Agriculture. *Chinese Fishery Statistical Yearbooks (2015–2020)*; China Agriculture Press: Beijing, China, 2021.
10. Zhou, S.J.; Punt, A.E.; Smith, A.D.M.; Ye, Y.; Haddon, M.; Dichmont, C.M.; Smith, D.C.; Jardim, E. An optimized catch-only assessment method for data poor fisheries. *ICES J. Mar. Sci.* **2018**, *75*, 964–976. [\[CrossRef\]](#)
11. Privitera-Johnson, K.M.; Punt, A.E. A review of approaches to quantifying uncertainty in fisheries stock assessments. *Fish Res.* **2020**, *226*, 105503. [\[CrossRef\]](#)
12. Froese, R.; Winker, H.; Coro, G.; Demirel, N.; Tsikliras, A.C.; Dimarchopoulou, D.; Scarcella, G.; Palomares, M.L.D.; Dureuil, M.; Pauly, D. Estimating stock status from relative abundance and resilience. *ICES J. Mar. Sci.* **2020**, *77*, 527–538. [\[CrossRef\]](#)
13. Link, J.S.; Huse, G.; Gaichas, S.; Marshak, A.R. Changing how we approach fisheries: A first attempt at an operational framework for ecosystem approaches to fisheries management. *Fish Fish.* **2020**, *21*, 393–434. [\[CrossRef\]](#)
14. Methot, R.D.; Wetzel, C.R. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fish Res.* **2013**, *142*, 86–99. [\[CrossRef\]](#)
15. Froese, R.; Demirel, N.; Coro, G.; Kleisner, K.M.; Winker, H. Estimating fisheries reference points from catch and resilience. *Fish Fish.* **2017**, *18*, 506–526. [\[CrossRef\]](#)
16. Froese, R.; Winker, H.; Coro, G.; Demirel, N.; Tsikliras, A.C.; Dimarchopoulou, D.; Scarcella, G.; Probst, W.N.; Dureuil, M.; Pauly, D.; et al. A new approach for estimating stock status from length frequency data. *ICES J. Mar. Sci.* **2018**, *75*, 2004–2015. [\[CrossRef\]](#)
17. Tsikliras, A.C.; Touloumis, K.; Pardalou, A.; Adamidou, A.; Keramidas, I.; Orfanidis, G.A.; Dimarchopoulou, D.; Koutrakis, M. Status and Exploitation of 74 Un-Assessed Demersal Fish and Invertebrate Stocks in the Aegean Sea (Greece) Using Abundance and Resilience. *Front. Mar. Sci.* **2021**, *7*, 1210. [\[CrossRef\]](#)
18. Welcomme, R.L. An overview of global catch statistics for inland fish. *ICES J. Mar. Sci.* **2011**, *68*, 1751–1756. [\[CrossRef\]](#)
19. Martell, S.; Froese, R. A simple method for estimating MSY from catch and resilience. *Fish Fish.* **2013**, *14*, 504–514. [\[CrossRef\]](#)
20. Demirel, N.; Zengin, M.; Ulman, A. First Large-Scale Eastern Mediterranean and Black Sea Stock Assessment Reveals a Dramatic Decline. *Front. Mar. Sci.* **2020**, *7*, 103. [\[CrossRef\]](#)
21. Liang, C.; Xian, W.W.; Pauly, D. Assessments of 15 exploited fish stocks in Chinese, South Korean and Japanese waters using the CMSY and BSM methods. *Front. Mar. Sci.* **2020**, *7*, 623. [\[CrossRef\]](#)
22. Zhai, L.; Liang, C.; Pauly, D. Assessments of 16 exploited fish stocks in Chinese waters using the CMSY and BSM methods. *Front. Mar. Sci.* **2020**, *7*, 1002. [\[CrossRef\]](#)
23. Falsone, F.; Scannella, D.; Geraci, M.L.; Gancitano, V.; Vitale, S.; Fiorentino, F. How Fishery Collapses: The Case of *Lepidopus caudatus* (Pisces: Trichiuridae) in the Strait of Sicily (Central Mediterranean). *Front. Mar. Sci.* **2021**, *7*, 1188. [\[CrossRef\]](#)

24. Feng, L.; Hu, C.; Chen, X.; Cai, X.; Tian, L.; Gan, W. Assessment of inundation changes of Poyang Lake using MODIS observations between 2000 and 2010. *Remote Sens. Environ.* **2012**, *121*, 80–92. [CrossRef]
25. Qian, X.E.; Huang, C.G.; Wang, Y.M.; Xiong, F. The status quo of fishery resources of the Poyang Lake and its environmental monitoring. *Acta Hydrobiol. Sin.* **2002**, *26*, 612–617. (In Chinese)
26. Huang, X.P.; Gong, Y. Study on the current situation and conservation countermeasures of fishery resources in the Poyang Lake. *Jiangxi Fish. Sci. Technol.* **2007**, *4*, 2–6. (In Chinese)
27. Dai, N.H.; Yao, Z.; You, X.; Huang, C.G.; Chen, F. Study on the utilization and protection of fishery resources in the Poyang Lake. In Proceedings of the Healthy Lakes and Beautiful China—The 3rd China Lakes Forum and the 7th Hubei Science and Technology Forum, Wuhan, China, 24–25 October 2013; pp. 961–969. (In Chinese).
28. Ministry of Ecology and Environment of the People’s Republic of China. The Bulletin on Ecological and Environmental Monitoring of the Three Gorges Project. Available online: <http://www.cnemc.cn> (accessed on 1 January 2011).
29. Fang, C.L.; Chen, W.J.; Zhou, H.M.; Zhang, Y.P.; Fu, P.F.; He, G.; Wu, B.; Wang, S. Fish resources in the Poyang Lake and its utilization suggestions. *Jiangsu Agric. Sci.* **2016**, *44*, 233–243. (In Chinese)
30. Dunlop, E.S.; Feiner, Z.S.; Höök, T.O. Potential for fisheries-induced evolution in the Laurentian Great Lakes. *J. Great Lakes Res.* **2018**, *44*, 735–747. [CrossRef]
31. Wei, Y.H.; Zhang, J.Y.; Zhang, D.W.; Tu, T.H.; Luo, L.G. Metal concentrations in various fish organs of different fish species from Poyang Lake, China. *Ecotox. Environ. Safe.* **2014**, *104*, 182–188. [CrossRef]
32. Ministry of Agriculture and Rural Affairs of the People’s Republic of China. Notice of the Ministry of Agriculture and Rural Affairs of the People’s Republic of China on the Scope and Duration of Prohibited Fishing in Key Waters of the Yangtze River Basin. Available online: http://www.moa.gov.cn/govpublic/CJB/201912/t20191227_6334010.htm (accessed on 27 December 2019).
33. Ding, H.J.; Wu, Y.X.; Zhang, W.H.; Zhong, J.Y.; Lou, Q.; Yang, P.; Fang, Y.Y. Occurrence, distribution, and risk assessment of antibiotics in the surface water of Poyang Lake, the largest freshwater lake in China. *Chemosphere* **2017**, *184*, 137–147. [CrossRef]
34. Wang, S.R.; Chen, H.W.; Peng, K.G.; Feng, M.L.; Du, Y.L. *The Water Environment in the Poyang Lake*; Science Press: Beijing, China, 2014.
35. Liu, X.J.; Qin, J.J.; Xu, Y.; Zhou, M.; Wu, X.P.; Ouyang, S. Biodiversity pattern of fish assemblages in Poyang Lake Basin: Threat and conservation. *Ecol. Evol.* **2019**, *9*, 11672–11683. [CrossRef]
36. Zhang, H.; Jiang, Y.; Ding, M.; Xie, Z. Level, source identification, and risk analysis of heavy metal in surface sediments from river-lake ecosystems in the Poyang Lake, China. *Environ. Sci. Pollut. Res. Int.* **2017**, *24*, 21902–21916. [CrossRef]
37. Zhang, D.; Wang, H.; Zhuang, W.; Yuan, W.H.; Zeng, Y.C.; Tian, Y.Y. Study on Spatial and Temporal Variation Trend of Nutrient Load in Poyang Lake in Recent 30 Years. *Sichuan Environ.* **2021**, *40*, 89–95. (In Chinese)
38. Zhang, T.L.; Li, Z.J. Fish resources and fishery utilization of the Poyang Lake. *J. Lake Sci.* **2007**, *19*, 434–444. (In Chinese)
39. Zhang, Y.P. Jiangxi Fisheries Research Institute, Nanchang, Jiangxi, China. *Unpublished work*, 2000–2019.
40. Jiangxi Fisheries Research Institute. Investigation Report on Aquatic Resources in the Poyang Lake. *Unpublished work*, 1974. (In Chinese)
41. Ministry of Agriculture and Rural Affairs of the People’s Republic of China. Circular of the Ministry of Agriculture on the Implementation of the Minimum Mesh Size System for Fishing Gears and Transitional Gears in the Mainstream of the Yangtze River. Available online: http://www.cjyzbgs.moa.gov.cn/zcjd/201904/t20190428_6220255.htm (accessed on 22 January 2017).
42. Cope, J.M.; Punt, A.E. Length-Based Reference Points for Data-Limited Situations: Applications and Restrictions. *Mar. Coast. Fish.* **2009**, *1*, 169–186. [CrossRef]
43. Froese, R.; Pauly, D. FishBase. World Wide Web Electronic Publication. 2021. Available online: <http://www.fishbase.se/search.php> (accessed on 28 June 2021).
44. Plummer, M. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling. In Proceedings of the 3rd International Workshop on Distributed Statistical Computing, Vienna, Austria, 20–22 March 2003; pp. 1–10.
45. Froese, R.; Zeller, D.; Kleisner, K.; Pauly, D. What catch data can tell us about the status of global fisheries. *Mar. Biol.* **2012**, *159*, 1283–1292. [CrossRef]
46. Palomares, M.L.D.; Froese, R.; Derrick, B.; Nöel, S.L.; Tsui, G.; Woroniak, J.; Pauly, D. *A Preliminary Global Assessment of the Status of Exploited Marine Fish and Invertebrate Populations*; The University of British Columbia: Vancouver, BC, Canada, 2018.
47. Froese, R.; Winker, H.; Coro, G.; Demirel, N.; Tsikliras, A.C.; Dimarchopoulou, D.; Scarcella, G.; Quaas, M.; Matz-Lück, N. Status and rebuilding of European fisheries. *Mar. Policy* **2018**, *93*, 159–170. [CrossRef]
48. Xie, P. Ecological impacts of Three Gorges Dam on lakes Dongting and Poyang. *Resour. Environ. Yangtze Basin* **2017**, *26*, 1607–1618. (In Chinese)
49. Mkuna, E.; Baiyegunhi, L.J.S. Determinants of Nile perch (*Lates niloticus*) overfishing and its intensity in Lake Victoria, Tanzania: A double-hurdle model approach. *Hydrobiologia* **2019**, *835*, 101–115. [CrossRef]
50. Wu, B.; Fang, C.L.; Chen, W.J.; Zhang, Y.P.; Zhou, H.M.; Fu, P.F.; He, G.; Wang, S.; Wang, Q.P. Evaluate the influence of the fishery resources of Poyang Lake and research the countermeasures. *Tianjin Agric. Sci.* **2015**, *21*, 17–20. (In Chinese)
51. Ricard, D.; Minto, C.; Jensen, O.P.; Baum, J.K. Examining the knowledge base and status of commercially exploited marine species with the RAM Legacy Stock Assessment Database. *Fish Fish.* **2012**, *13*, 380–398. [CrossRef]
52. Hélias, A. Data for Fish Stock Assessment Obtained from the CMSY Algorithm for all Global FAO Datasets. *Data* **2019**, *4*, 78. [CrossRef]

53. Fish Laboratory, Institute of Hydrobiology in Hubei Province. *Fishes in the Yangtze River*; Science Press: Beijing, China, 1976.
54. Li, M.Z. Study on the Life History Strategies of Fishes in the Yangtze River and its Adaption to Environment during Early Life History Stage. Ph.D. Thesis, University of Chinese Academy of Sciences, Beijing, China, 2012. (In Chinese).
55. Zhang, A.F.; Chen, W.J.; Fu, Y.L.; Zhou, H.M. Preliminary Investigation on the Changes of *Cyprinus carpio* and *Carassius auratus* Resources in Poyang Lake and Its Causes. *J. Anhui Agri. Sci.* **2011**, *39*, 9286–9288. (In Chinese)
56. Li, M.F. Progress on Study on Biology of *Pelteobagrus fulvidraco* Richardson. *Mod. Fish. Inf.* **2010**, *25*, 16–22. (In Chinese)
57. Zhao, Y.J.; Xu, W.Y.; Zhang, H. Ecology of *Siniperperca chuatsi*, *Ophicephalus argu*, *Elopichthys bambusa*, and *Silurus asotus*. *Fish. Sci.* **2004**, *23*, 26–27. (In Chinese)
58. Shi, B.N. The biology of *Silurus asotus* in the Jialing River. *J. Southwest China Norm. Univ.* **1980**, *2*, 53–59. (In Chinese)
59. Xiao, Z. Studies on the Reproductive Biology of *Silurus asotus*. *J. Sun Yatsen Univ.* **2000**, *20*, 41–44. (In Chinese)
60. Li, M.F. Research Progress on Biology of Mandarin Fish. *Mod. Fish. Inf.* **2010**, *25*, 16–21. (In Chinese)
61. Ministry of Agriculture and Rural Affairs of the People's Republic of China. List of National Aquatic Germplasm Resources Protection Areas. Available online: http://www.moa.gov.cn/govpublic/YYJ/201006/t20100606_1538152.htm (accessed on 12 December 2007).
62. Brown, C.J.; Broadley, A.; Adame, M.F.; Branch, T.A.; Turschwell, M.P.; Connolly, R.M. The assessment of fishery status depends on fish habitats. *Fish Fish.* **2018**, *20*, 1–14. [CrossRef]
63. Xiong, X.Y.; Hu, X.Y. Development and sustainable utilization of fishery resources in the Poyang Lake. *Jiangxi Fish. Sci. Technol.* **2002**, *4*, 7–11. (In Chinese)
64. Yao, Z.; Dai, N.H.; Zhang, J.; You, X. Ecological Status in Poyang Lake and its Protection and Management. *Jiangxi Sci.* **2011**, *29*, 667–671. (In Chinese)
65. Xia, S.X.; Yu, X.B.; Liu, Y.; Jia, Y.F.; Zhang, G.S. Current issues and future trends of Poyang Lake wetland. *Resour. Environ. Yangtze Basin* **2016**, *25*, 1103–1111. (In Chinese)
66. Garcia, S.M.; Ye, Y.; Rice, J.; Charles, A. *Rebuilding of Marine Fisheries Part 1: Global Review*; FAO: Rome, Italy, 2018.
67. Garcia, S.M.; Ye, Y. *Rebuilding of Marine Fisheries Part 2: Case Studies*; FAO: Rome, Italy, 2018; p. 232.
68. Department of Agriculture and Rural Affairs of Jiangxi Province. Available online: http://nync.jiangxi.gov.cn/art/2021/5/28/art_34764_3378936.html (accessed on 28 May 2021).
69. Department of Agriculture and Rural Affairs of Jiangxi Province. Available online: http://nync.jiangxi.gov.cn/art/2021/4/21/art_27777_3326628.html (accessed on 21 April 2021).
70. Hu, X.J.; Pan, T.S.; Hou, G.J.; Li, H.Y. Status of resources and value of protection and utilization for wild Amur catfish *Silurus asotus* in Anhui Province. *J. Anhui Agri. Sci.* **2002**, *20*, 233–247. (In Chinese)
71. Yang, C.G.; Song, X.H.; Wang, Z.L.; Chen, Z.P.; Xu, A.G.; Chen, C. Biological characteristics of *Pelteobagrus fulvidraco* and its conservation techniques in the Chenghu Lake. *Reserv. Fish.* **2003**, *23*, 27–28. (In Chinese)
72. Yang, X.J.; Wang, X.Y.; Feng, X.T.; Liu, Y.; Yang, X.W.; Fang, D.A.; Xu, D.P. Spawning preference of yellow catfish (*Pelteobagrus fulvidraco*) for different artificial fish nests. *J. Fish. Sci. China* **2020**, *27*, 213–223. (In Chinese)
73. Shen, W.X. Biological characteristics of *Siniperca chuatsi* and artificial propagation technology of its offspring. *Shanghai Agric. Sci. Technol.* **2018**, *4*, 70–71. (In Chinese)