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A Review of the Age, Growth Characteristics, and Population Resources of *Ptychobarbus dipogon* in the Middle and Upper Reaches of the Yarlung Zangbo River

Wenjia He [1], He Gao [2], Chaowei Zhou [2], Wanliang Wang [1,*] and Yanchao Liu [3]

[1] Institute of Aquatic Sciences, Tibet Academy of Tibet Academy of Agriculture and Animal Husbandry Sciences, Lhasa 850002, China
[2] College of Fisheries, Southwest University, Chongqing 402460, China
[3] Tibet Plateau Biology Research Institute, Lhasa 850000, China; yanchaoliu1216@163.com
* Correspondence: qlxlsylzfyzx@163.com

Abstract: This paper applies the von Bertalanffy growth equation to study the age structure and growth characteristics of 210 *Ptychobarbus dipogon* collected in September 2019 in the middle and upper reaches of the Yarlung Zangbo River and employs FISAT II software to estimate the population characteristics' parameters. Its aim is to provide a basis for the conservation of the population resources of the *Ptychobarbus dipogon*. In this study, the length of the catch ranged from 137 mm to 475 mm, the weight ranged from 44.04 g to 1142.80 g, the minimum age was 5 years, and the maximum age was 47 years. The body length–weight relationship was $W_{(♀)} = 4.1738 \times 10^{-5}L^{2.7687}$ (n = 86, R^2 = 0.901); $W_{(♂)} = 2.7784 \times 10^{-5}L^{2.8434}$ (n = 100, R^2 = 0.918). The growth equation was $Lt_{(♀)} = 505.000[1 - e^{-0.048(t-1.992)}]$; $Lt_{(♂)} = 452.254[1 - e^{-0.069(t-4.233)}]$; $Wt_{(♀)} = 1296.576[1 - e^{-0.048(t-1.992)}]^{2.7687}$; $Wt_{(♂)} = 1001.872[1 - e^{-0.069(t-4.233)}]^{2.8434}$. The inflection point ages of the female and male *Ptychobarbus dipogon* were 7.95 and 6.05, respectively. The exploitation rate of *Ptychobarbus dipogon* was 0.61, which exceeds the optimum exploitation rate of resources (0.57). The population resources are overfished. It is suggested to strengthen the conservation of *Ptychobarbus dipogon* population resources and the protection of native fish on the Qinghai–Tibet Plateau.

Keywords: Yarlung Zangbo River; *Ptychobarbus dipogon*; age and growth; population resources

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1. Introduction

Ptychobarbus dipogon belongs to Cypriniformes, Cyprinidae, Schizothoracinae, and the genus Ptychobarbus. It is often found in clear and calm waters. It feeds on aquatic insects and benthic invertebrates [1]. In high-altitude habitats, it is distributed in limited areas, grows slowly, has low fecundity and late sexual maturity, and is strongly sensitive to habitat changes due to its own vital characteristic factors [2,3]. Fish are key species in aquatic ecosystems, and changes in their population structure are critical to species diversity and ecological balance. Existing studies have shown that fish resources in the main stream and tributaries of the Yarlung Zangbo River show a declining trend, and *Ptychobarbus dipogon* has been threatened by habitat changes and biological invasions caused by overfishing and dam construction [4].

Ptychobarbus dipogon is a unique economic fish in Tibet, commonly known as "flower fish". It is mainly found in the main stream and tributaries in the middle reaches of the Yarlung Zangbo River in Tibet and has important economic and ecological value in this basin [5]. At present, the relevant research and reports mostly focus on the origin and evolution [6,7], chromosome number [8], mitochondrial genes [9,10], molecular phylogenesis [11,12], early morphological development [13,14], and growth and reproduction strategies [15,16].

Exploring the age structure of this fish is a prerequisite for understanding the dynamics of this population and maintaining the sustainable development of fishery. It is not only of great significance for mastering the individual growth of this species but also can provide a reference basis for the assessment of fish population resources and the formulation of fishery management policies [17]. At present, the research data on the age structure and growth characteristics of the *Ptychobarbus dipogon* are limited to the middle and lower reaches of the Yarlung Zangbo River, and the study on the population resources in the upper reaches has not been reported. Yang et al. [18] estimated the female population at 3~24 years and the male population at 3~13 years, and the corresponding growth inflection point ages of the male and female populations were 9.1 and 6.5 years, respectively. Liu et al. [19] collected samples of 4~49 year-old *Ptychobarbus dipogon* and evaluated the growth inflection point age of the female population to be 3.3 years. Wang et al. [20] collected samples of 2~18 year-old *Ptychobarbus dipogon* in the Niyang River and evaluated the overall growth inflection point age to be 6.7 years. It can be seen that the age structure and growth characteristics of the *Ptychobarbus dipogon* population obtained from the resource survey in different reaches were different.

The *Ptychobarbus dipogon* is a K-select type, which is very sensitive to external interference [21]. The main stream and tributaries in the middle reaches of the Yarlung Zangbo River are areas with frequent human activities, convenient transportation, many towns, and developed agriculture. The increasingly intensified human activities have led to the decline of the *Ptychobarbus dipogon* resources, and the survival of this species is greatly threatened. Moreover, due to the unique geographical location of Tibet and the fragility of the plateau ecological environment, Tibet is facing severe ecological environmental problems and challenges, such as the invasion of alien species and global climate change, making its aquatic ecology more vulnerable to external influences. The disturbance of the ecological environment causes different degrees of changes in fish resources. In this environment, *Ptychobarbus dipogon* is characterized by an unstable population structure, low growth rate, low fertility, and late sexual maturity. Once destroyed, the population resources will be difficult to recover. Therefore, this study selected the middle and upper reaches of the Yarlung Zangbo River, where *Ptychobarbus dipogon* are distributed, to study their age structure characteristics, and thus improves the relevant biological data. It aims to provide a reference basis for the evaluation of fish resource changes and the conservation of the population resources of *Ptychobarbus dipogon* in the middle and upper reaches of the Yarlung Zangbo River.

2. Materials and Methods

2.1. Collection of Samples

In September 2019, 210 *Ptychobarbus dipogon* were collected with a three-layer drift gill net in the Tibet's Sangmuzhang–Xietongmen section of the Yarlung Zangbo River (Figure 1). The body length (L) was measured with a ruler (accuracy: 0.1 cm) on site; the body weight (W) was measured with an electronic balance (accuracy: 0.1 g). The sex of the *Ptychobarbus dipogon* was determined by visual inspection in the laboratory. The lapillus was removed and stored in an EP tube.

2.2. Otolith Preparation

We embedded and fixed the proximal end of the otolith with transparent nail polish, polished from the distal end with $1500^{\#}$, $2000^{\#}$, and $4000^{\#}$ waterproof abrasive paper in turn, and then polished it with $8000^{\#}$ and $10,000^{\#}$ waterproof abrasive paper. We observed the progress of the polishing on the otolith via a microscope continuously until the central nucleus and increment of the otolith were clear under the microscope. We wiped off the nail polish with acetone, removed the otolith from the glass slide and turned it over, then polished it until the core was exposed again. Age identification was performed twice under a microscope (model: Model Eclipse Ni-U) by the same experienced observer, and the two age determinations were separated by at least 1 week in order to ensure the relative accuracy of the age determinations [22].

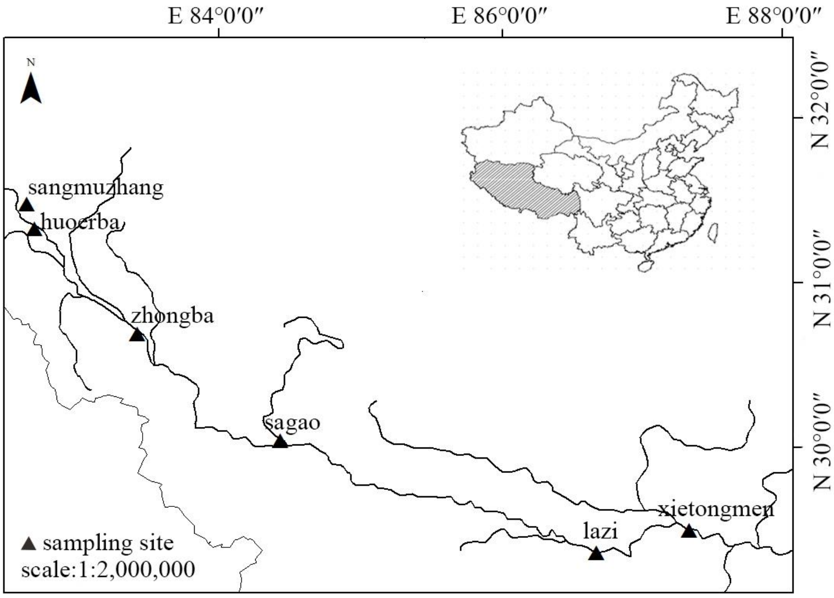

Figure 1. The sampling sites of *P. dipogon.* Note: The Chinese map is drawn by ArcGIS 10.8.2 software.

2.3. Data Analysis

The experimental data were statistically analyzed with Microsoft Office Excel 2007, IBM SPSS Statistics 26.0, and FISAT II software and plotted with Origin 2021. The body length–weight relationship was analyzed using a power function: $W = aL^b$ [23]. The growth equation was described by the von Bertalanffy growth equation, and the apparent growth value and inflection point age were calculated [24,25]. The total mortality coefficient (Z), natural mortality coefficient (M), fishing mortality coefficient (F), and exploitation rate (E) were estimated with the length-converted catch curve of the FISAT II fishery assessment software. The relative yield per recruit (biomass) curve of the Beverton–Holt dynamic pool model was used to estimate the exploitation rate (E_{10}), when the marginal yield of resource population is reduced to 1/10 of the theoretical original marginal yield of resource; the exploitation rate (E_{50}), when the resource is reduced to 50% of the original level; and the exploitation rate (E_{max}), when the maximum yield is obtained. The length-structured VPA module was used to estimate the resource of *Ptychobarbus dipogon*, and the fishing mortality coefficient (F_t) of the group with maximum body length was calculated by the iterative method to calculate the steady-state biomass of the sample.

3. Results

3.1. Sample Composition of Ptychobarbus dipogon

The body length of the samples ranged from 137 to 475 mm, and the body weight ranged from 44.04 to 1142.80 g. Among the 210 samples collected, 100 were females, 84 were males, and 26 were individuals of undetermined sexes (Table 1). The sex ratio was male:female = 1:0.84.

Table 1. Samples collected for the statistical analysis of *P. dipogon*.

Age/a	Female			Male			Undetermined		
	Body Length Range/mm	Body Weight Range/g	Quantity/Nr.	Body Length Range/mm	Body Weight Range/g	Quantity/Nr.	Body Length Range/mm	Body Weight Range/g	Quantity/Nr.
5							137	44.04	1
7							165	59.2	1
8							175	46.1~76.2	2
10				165	62.86	1	195	77.6~100.1	3
11	195	92.7	1	195	84.1	1			
12				185	81.3	1	190	89.7	1
13							200~225	116.5~120.4	2
14				200~210	94.6~108.9	2	220	137.62	1
15	227~240	131.04~140.8	2	255	198.1	1	230	135.1	1
16	230~256	128.2~193.1	3	240~260	145.89~193.7	2	250~260	175.37~235.5	3
17				235~240	177.5~177.7	2	260	234.1	1
18	275~275	233.2~253.6	2	259~290	189.43~282.6	3	260~273	215.78~225.77	2
19	290~297	256.5~315.1	2	265~298	221.49~286.7	4			
20	270~290	223.91~265.3	4	273~307	224.3~339	8			
21	300~317	298.3~368.7	4	285~318	258.36~381.1	8	285	255.77	1
22	300~320	335.2~355.5	4	299~325	293.4~391.8	10	310~320	344.75~346.9	2
23	314~337	336.2~441.4	3	295~355	285.49~479.4	12			
24	310~385	353.2~565.5	5	333~350	422~461.4	4	345	445	1
25	322~361	432.3~490.9	3	310~361	351.6~469	9			
26	350~378	464.3~596.9	4	325~366	340.3~522.5	6	337	392.6	1
27	322~375	416.2~562.9	4	325~376	359.4~557.5	3			
28	338~396	424~630.9	7	320~385	365.9~625.7	2			
29	355~395	489.4~696.7	6				405	694.2	1
30	365~407	506~660.9	7	359	468.19	1	382	547.9	1
31	396~418	665.4~847.5	3	395	755.4	1			
32	315~405	402.1~702.7	7	335	471.5	1			
33	386~425	591.3~778.9	4	420	724.2	1			
34	365~435	519.1~838	5						
35	375~435	655.4~965.4	2	411	778.9	1	443	853.01	1
36	358~387	518.3~743.8	3						
37	340~445	549.5~878.89	4						
38	375~416	687.8~762.3	3						
39	405~414	729.2~874.6	2						

Table 1. *Cont.*

Age/a	Female			Male			Undetermined		
	Body Length Range/mm	Body Weight Range/g	Quantity/Nr.	Body Length Range/mm	Body Weight Range/g	Quantity/Nr.	Body Length Range/mm	Body Weight Range/g	Quantity/Nr.
41	410~420	755.4~820.1	3						
44	405	729.1	1						
45	420	819.3	1						
47	475	1142.8	1						
TOTAL	195~475	92.7~1142.8	100	165~411	62.86~778.9	84	137~443	44.04~853.01	26

3.2. Length–Weight Distribution of *Ptychobarbus dipogon*

The length range of the female fish was 195~475 mm, and the weight range was 92.7~1142.80 g; the length range of the male fish was 165~411 mm, and the weight range was 62.86~778.6 g (Figure 2).

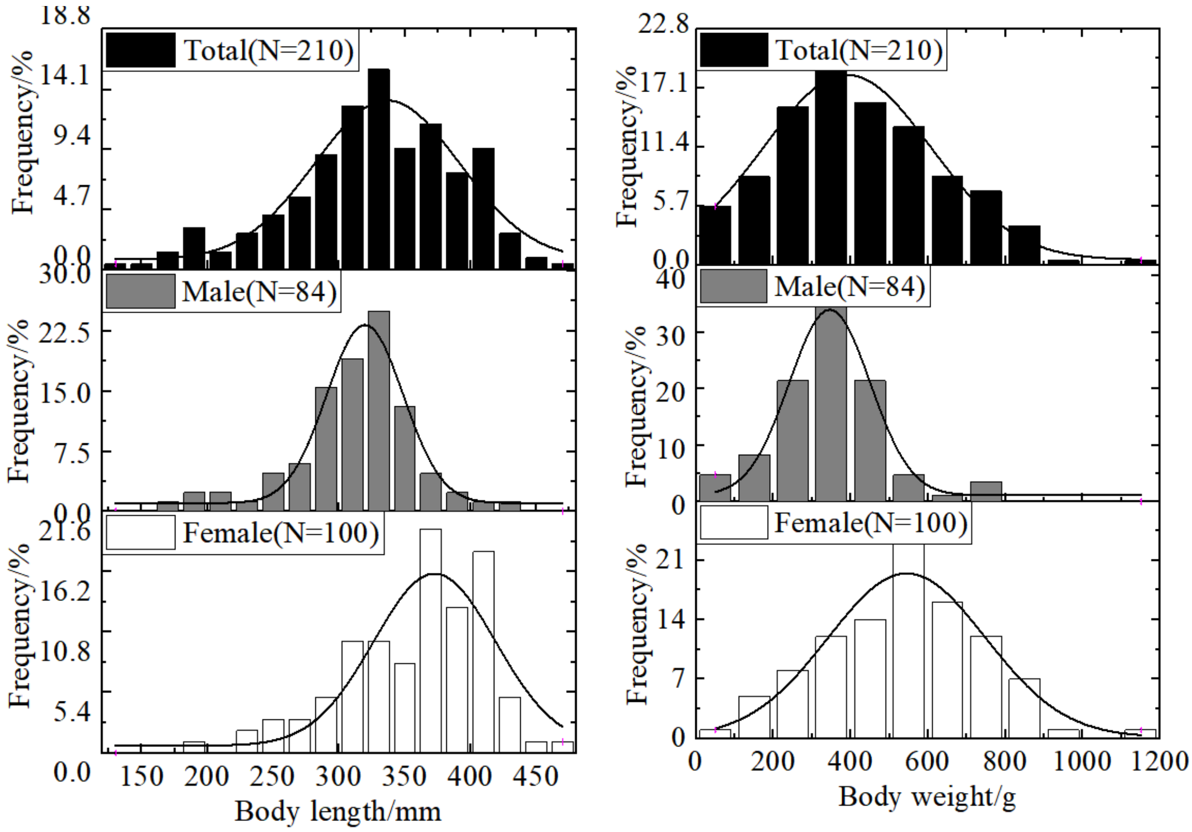

Figure 2. Distribution of the standard length and weight frequency for *P. dipogon*.

3.3. Length–Weight Relationship of *Ptychobarbus dipogon*

The body length–weight relationship of female fish, male fish, and the overall group was fitted, respectively, and the body length–weight power function relationship was obtained as follows (Figure 3):

$$\text{Female: } W = 4.1738 \times 10^{-5} L^{2.7687},\ R^2 = 0.901, \quad (1)$$

$$\text{Male: } W = 2.7784 \times 10^{-5} L^{2.8434},\ R^2 = 0.918, \quad (2)$$

$$\text{Overall: } W = 4.1562 \times 10^{-5} L^{2.7726},\ R^2 = 0.912. \quad (3)$$

3.4. Growth Equation of *Ptychobarbus dipogon*

3.4.1. Growth Curve

The body length and weight were fitted with the von Bertalanffy growth equation (Figure 4), and the body length–weight growth equation was obtained as follows:

The body length growth equation is:

$$\text{Female: } L_t = 505.000[1 - e^{-0.048(t-1.992)}],\ R^2 = 0.869, \quad (4)$$

$$\text{Male: } L_t = 452.254[1 - e^{-0.069(t-4.233)}],\ R^2 = 0.823, \tag{5}$$

$$\text{Overall: } L_t = 518.897[1 - e^{-0.042(t+0.199)}],\ R^2 = 0.899. \tag{6}$$

The weight growth equation is:

$$\text{Female: } W_t = 1296.576[1 - e^{-0.048(t-1.992)}]^{2.7687},\ R^2 = 0.825, \tag{7}$$

$$\text{Male: } W_t = 1001.872[1 - e^{-0.069(t-4.233)}]^{2.8434},\ R^2 = 0.802, \tag{8}$$

$$\text{Overall: } W_t = 1423.208[1 - e^{-0.042(t+0.199)}]^{2.7726},\ R^2 = 0.869. \tag{9}$$

3.4.2. Growth Rate and Acceleration

The first-order derivative and second-order derivative of the body length and weight growth equations were performed, and the growth rate and acceleration equations of the body length and weight were obtained as follows (Figure 5).

Female:

$$dL/dt = 24.24e^{-0.048(t-1.992)}, \tag{10}$$

$$dW/dt = 172.3e^{-0.048(t-1.992)}[1 - e^{-0.048(t-1.992)}]^{1.7687}, \tag{11}$$

$$d^2L/dt^2 = -1.16e^{-0.048(t-1.992)}, \tag{12}$$

$$d^2W/dt^2 = 8.27e^{-0.048(t-1.992)}[1 - e^{-0.048(t-1.992)}]^{0.7687}[2.7687e^{-0.048(t-1.992)} - 1]. \tag{13}$$

Male:

$$dL/dt = 31.21e^{-0.069(t-4.233)}, \tag{14}$$

$$dW/dt = 196.6e^{-0.069(t-4.233)}[1 - e^{-0.069(t-4.233)}]^{1.8434}, \tag{15}$$

$$d^2L/dt^2 = -2.15e^{-0.069(t-4.233)}, \tag{16}$$

$$d^2W/dt^2 = 13.6e^{-0.069(t-4.233)}[1 - e^{-0.069(t-4.233)}]^{0.8434}[2.8434e^{-0.069(t-4.233)} - 1]. \tag{17}$$

The growth rate and acceleration of the female and male fish showed a consistent trend, and the growth rate and the fitted acceleration curves were smooth without growth inflection points. The growth acceleration gradually decreased with age and were lower than 0. The body weight growth rate and acceleration tended to increase first and then decrease gradually. Both the growth rate and acceleration showed inflection points. When the growth acceleration approached 0, the body weight growth rate of *Ptychobarbus dipogon* reached the highest value.

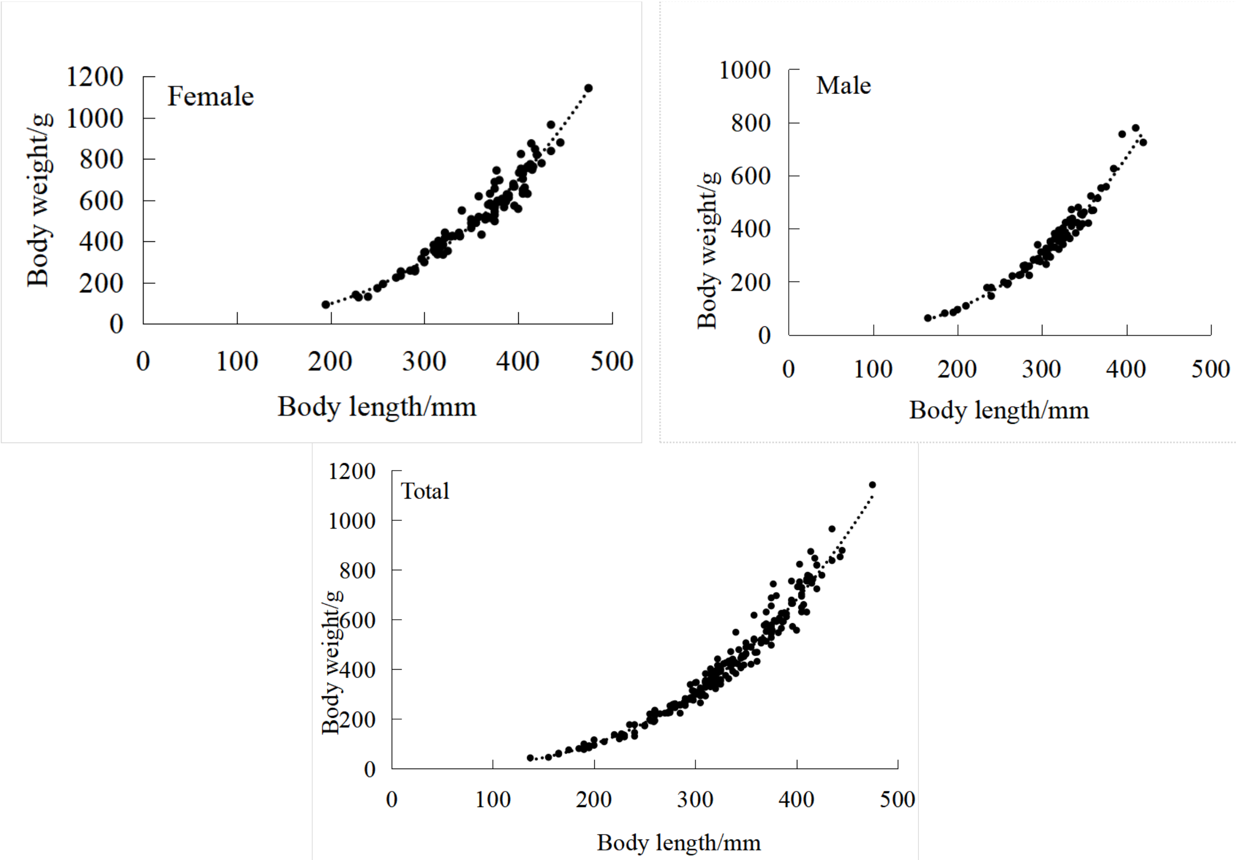

Figure 3. The length–weight relationship of *P. dipogon*.

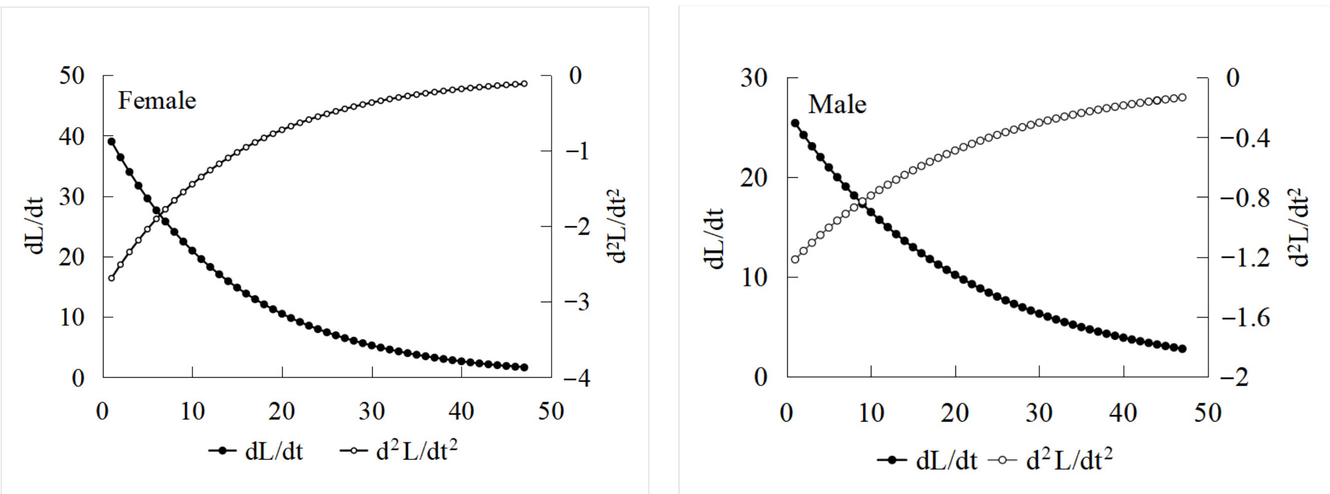

Figure 4. Growth rate and growth acceleration of the length of male and female *P. dipogon*.

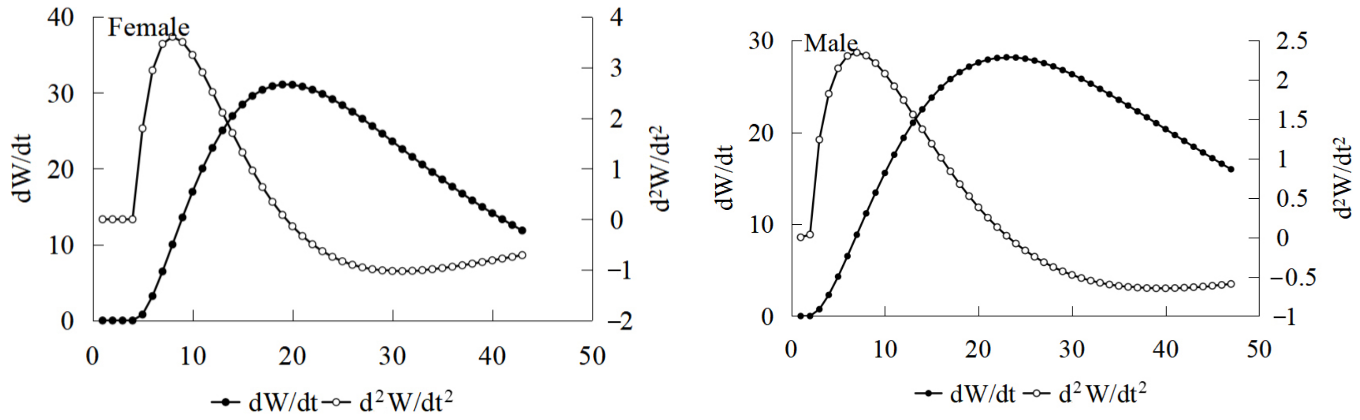

Figure 5. Growth rate and growth acceleration of the weight of male and female *P. dipogon*.

3.4.3. Apparent Growth Value and Inflection Point Age

According to the calculation formula of the apparent growth value and inflection point age (Table 2), the apparent growth value of the female fish was 4.15, and that of the male fish was 4.09. The inflection point ages of females and males were 7.95 and 6.05, respectively, and the overall inflection point age was 3.99.

Table 2. Comparison of the growth parameters of *P. dipogon*.

Sr.No.	Sex	L_∞/mm	K Value	t_0 Value	Φ	Inflection Point Age	b Value	References
1	♀	606.9	0.114	−0.163	4.6231	9.1	2.877	[18]
	♂	496.3	0.162	0.018	4.601	6.5	2.856	
2	♀	431.8	0.19	−1.19	-	3.3	2.3474	[19]
	♂	367.6	0.42	−3.37	-	-	2.8414	
3	Overall	489.938	0.119	−1.245	-	6.697	2.537	[20]
4	♀	598.66	0.09	−0.726	4.426	11.6	-	[26]
	♂	494.23	0.12	−0.73	4.2076	8.5	-	
	Overall	-	-	-	-	-	3.006	
5	♀	505	0.048	1.992	4.09	7.95	2.7687	This study
	♂	452.254	0.069	4.233	4.15	6.05	2.8434	
	Overall	518.897	0.042	−0.199	4.05	3.99	2.7726	

Note: L_∞ is the asymptotic length at age, which represents the average length at age that an individual will reach in the case of infinite growth; the K value is a curvature parameter that determines the asymptotic length of the rate at which the fish reaches the asymptotic length; the t_0 value is a position parameter defining the initial condition on the time axis when the fish length is zero; the Φ value is growth performance index; the b value is the power function index of the body length–body mass relationship.

3.5. Population Resources

3.5.1. Mortality Coefficient and Exploitation Rate

According to the length-converted catch curve, the total mortality coefficient Z of *Ptychobarbus dipogon* was estimated as 0.16. When the average water temperature in this study was taken as 9.6 °C [27] with reference to the relevant literature, the natural mortality coefficient M = 0.06, the fishing mortality coefficient F = 0.10, and the exploitation rate E = 0.61 (Figure 6). E_{10} = 0.570, E_{50} = 0.351, and E_{max} = 0.661 were estimated from the relative yield per recruit (biomass) curve of the Beverton–Holt dynamic pool model (Figure 7). The exploitation rate of *Ptychobarbus dipogon* (0.61) exceeded its optimum exploitation rate (0.57).

3.5.2. Resources

The length-structured VPA module was used to estimate the resources of *Ptychobarbus dipogon*. The fishing mortality coefficient F_t of the group with maximum body length was calculated by the iterative method, and the result was 0.0178. The results (Figure 8) showed that when the individual length was below 270.5 mm, the population resources were mainly reduced because of natural death, while when the individual length was above 270.5 mm, the proportion of the population resources that died from fishing gradually increased. The steady-state biomass of *Ptychobarbus dipogon* obtained by body length analysis was 20.06 t.

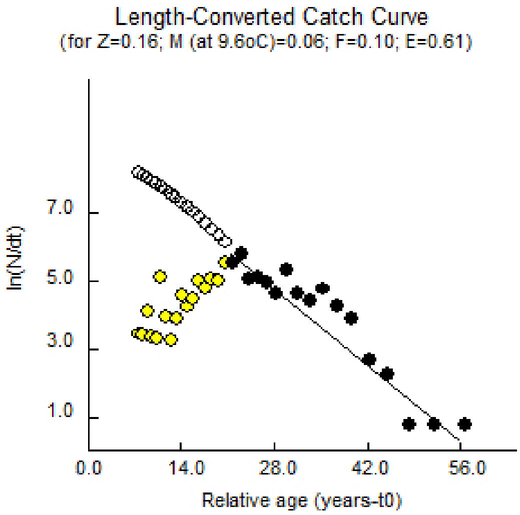

Figure 6. The mortality coefficient of *P. dipogon* calculated with the length-converted catch.

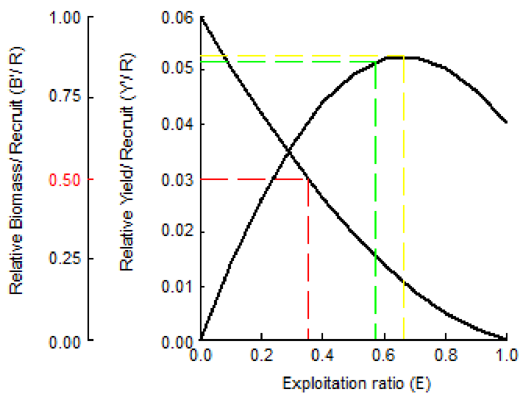

Figure 7. Relative yield per recruit (Y′/R) and relative biomass per recruit (B′/R) curve of *P. dipogon*. Note: The red line indicates E_{50}; the green line indicates E_{10}; and the yellow line indicates E_{max}.

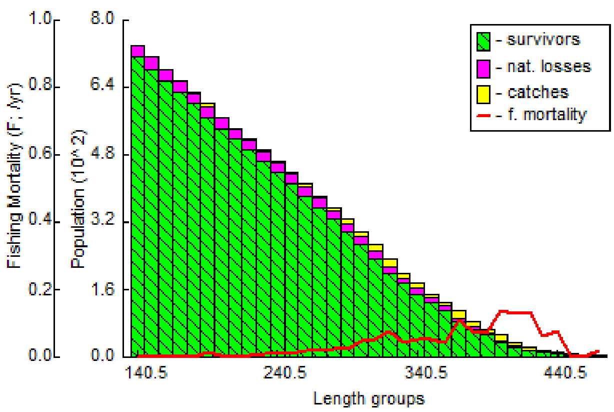

Figure 8. Length-structured VPA for *P. dipogon*.

4. Discussion

4.1. Body Length–Weight Characteristics of Ptychobarbus dipogon

As the most direct external manifestation of fish, the increase in the body length and weight is the result of the combined action of physiological, environmental, nutritional, management, and other factors. The most direct manifestation is that the body length and weight change periodically with time [28]. By measuring fish phenotypic indicators such as body weight and length, the characteristics of species, individual growth, and population changes can be studied [29]. Fei et al. [30] found that $W = aL^b$ when conducting nonlinear fitting of the body length and weight of fish, where the power exponent b is often used to judge the growth state of fish. Brown et al. [31] pointed out that the variation amplitude of the b-value is usually 2.5~4.0, and the b value (2.77) obtained in this study was within its variation amplitude range. Fei et al. [30] pointed out that b = 3 indicates an isokinetic growth, and there is a significant difference between the b value and 3 in this study ($t = 25.385$, $p < 0.05$). This demonstrates that *Ptychobarbus dipogon* is type of fish with allometric growth. Fish have strong adaptability, and the same species of fishes will show individual and physiological differences due to different environments. Similarly, there will also be differences in individuals of different generations at the same site [32]. Genetic and environmental factors, such as low temperature, poor food availability, and fishing pressure have likely driven plasticity adaptation in the longevity of *Ptychobarbus dipogon*. For this study, *Ptychobarbus dipogon* is an omnivorous fish and prefers to live in a clear and calm water bay [33]. The main food sources are chironomid larvae, larvae of macrostemum lautuam, and organic debris in the water. Affected by the physicochemical indicators of habitat environment, biological bait and other factors, its food diversity index and uniformity index show obvious seasonal changes [34,35]. These factors may be the main reason for the allometric growth of *Ptychobarbus dipogon*.

4.2. Growth Parameters of Ptychobarbus dipogon

Growth parameters are parameters that can specifically describe the biological significance of the animal obtained by fitting the phenotypic index information of the animal measured at different growth periods with mathematical models [36]. With the help of parameters, changes in the population structure of biological resources can be visually described, based on which the germplasm resources of the species can be evaluated, managed and utilized. The results of fitting using the von Bertalanffy model showed that the asymptotic length (L_∞) of females was greater than that of males, and this result was consistent with the findings of Yang et al. [18], Liu et al. [19], and Wang et al. [20]. Given that younger samples of fish are not readily identifiable, samples of undetermined sexes can be used to model both sexes [37]. The K value is often used as one of the important parameters of population resource change and can be used to understand the response of fish population to fishing phenomenon [38]. According to Branstetter et al. [39], *Ptychobarbus dipogon* is a kind of slow-growing fish ($K < 0.1$), and it is sensitive to fishing behavior. The apparent growth index Φ combines the asymptotic length and the growth coefficient K value [40]. The K value, Φ value, and inflection point age in this study were lower than those in studies of Yang et al. [18] and Li et al. [26]. The inflection point ages of female and male *Ptychobarbus dipogon* collected by Li et al. [26] in the Lhasa River from 2004 to 2006 were 11.6 years and 8.5 years, respectively, and the inflection point ages of female and male *Ptychobarbus dipogon* collected by Yang et al. [18] in the section from Xietongmen County to Renbu County of the Yarlung Zangbo River and its tributaries, the Xiangqu and Nianchu Rivers, from 2008 to 2009 and 2012 to 2013 were 9.1 years and 6.5 years, respectively. This study concluded that the inflection point ages of female and male *Ptychobarbus dipogon* collected in the section from Sangmuzhang to Xietongmen of the Yarlung Zangbo River in 2019 were 7.95 and 6.05. This was consistent with the conclusion of Liu et al. [19] that the inflection point age of *Ptychobarbus dipogon* is becoming gradually younger. Wang et al. [41] also demonstrated that the resources of *Ptychobarbus dipogon* were sharply reduced, and the captured individuals were smaller and smaller. The t_0 value in this study was larger than that in the studies of Yang et al. [18] and Liu et al. [19]. The main reason is that the age data used to fit the von Bertalanffy model were different, in addition to the difference in the environmental conditions at the sampling site. The age of the fish samples in this study was mainly distributed in the range of 15 to 30 years. In the study of Yang et al. [18], the age of the fish samples was mainly distributed in the range of 1 to 10 years, and in the study of Liu et al. [19], the age of the fish samples was mainly distributed in the range of 10 to 25 years (Figure 9). Paul et al. [42] pointed out that the process of fitting growth parameters using growth models is susceptible to the lack of juvenile individuals or older individuals, and the addition of juvenile fish data tends to bring the t_0 value closer to 0.

4.3. Changes in Population Resources of Ptychobarbus dipogon

Fish resources have the duality of being biodiversity species resources and the fishery utilization of biological resources [43]. The dynamic changes in the fish population resources are assessed by mathematical model methods on the basis of fish biological research. Through assessment, the aim is to master the dynamic changes in the fish population in terms of growth, fishing, and death [44]. Fish population parameters are an important basis for fishery resource evaluation. They can provide a scientific basis for the formulation of fishery management policy [45]. The exploitation rate reflects the utilization degree of population resources. Peng et al. [46] pointed out that when the exploitation rate of fish population $E < 0.5$, there is mild utilization, and when $E > 0.5$, there is overfishing. The E(0.61) value in this study was greater than 0.5. The analysis of the catch samples of Yang et al. [18] and Liu et al. [19] concluded that the exploitation rates were 0.82 and 0.71, respectively, all greater than 0.5 and all greater than the optimum exploitation rates (Table 3). These reveal that the *Ptychobarbus dipogon* is overfished. The exploitation rate of *Ptychobarbus dipogon* was 0.82 from 2008 to 2009 and 2012 to 2013 according to the study of Yang et al. [18], 0.71 from 2013 to 2014 according to the study of Liu et al. [19], and 0.61 in 2019 according to the findings of this study, indicating a slow-down trend in the fishing intensity. This phenomenon may be related to the introduction and implementation of fishery-related policies, the strengthening of fishery law enforcement, the implementation of fishery compensation measures, and the improvement in people's understanding of fishery protection. However, the steady-state biomass of *Ptychobarbus dipogon* has not increased with the decrease in the exploitation rate. This may be related to the vulnerability of the plateau environment and the ecology. In addition, in the face of climate change, construction of hydropower facilities, and invasion of alien fish, fishery resources need a long time to recover after being damaged or overfished for a long time. The conservation of the natural population and exploitation of sustainable resources of *Ptychobarbus dipogon* have been increasingly become matters of concerns. Therefore, in addition to strengthening the basic research on fishery environment investigation and fish population resource monitoring of the Yarlung Zangbo River, it is necessary to strengthen the relevant research on foreign fish in the Yarlung Zangbo River, establish a foreign fish prevention and control mechanism, strengthen the management of artificially cultured fish, prevent the escape of cultured varieties, and establish risk avoidance measures. It is also necessary to strengthen the protection of native fish in Tibet and raise the publicity of native fish protection, to take various measures to publicize the relevant laws and regulations on aquatic life protection and the harmfulness of blind "fish-freeing", guide the masses to free captured fish in a scientific and reasonable manner, make them understand the importance of fishery resources protection, and effectively enhance their awareness of protecting the ecology of the waters and fishery resources. We should continue to promote the artificial breeding of *Ptychobarbus dipogon* and strengthen the research on key technologies of *Ptychobarbus dipogon* aquaculture. As a vulnerable fisheries resource, it is essential to take adaptive management to maintain the sustainability of this species and stability of the fish community; we should improve policies and regulations, strengthen fishery management, and increase the punishment for poaching and overfishing.

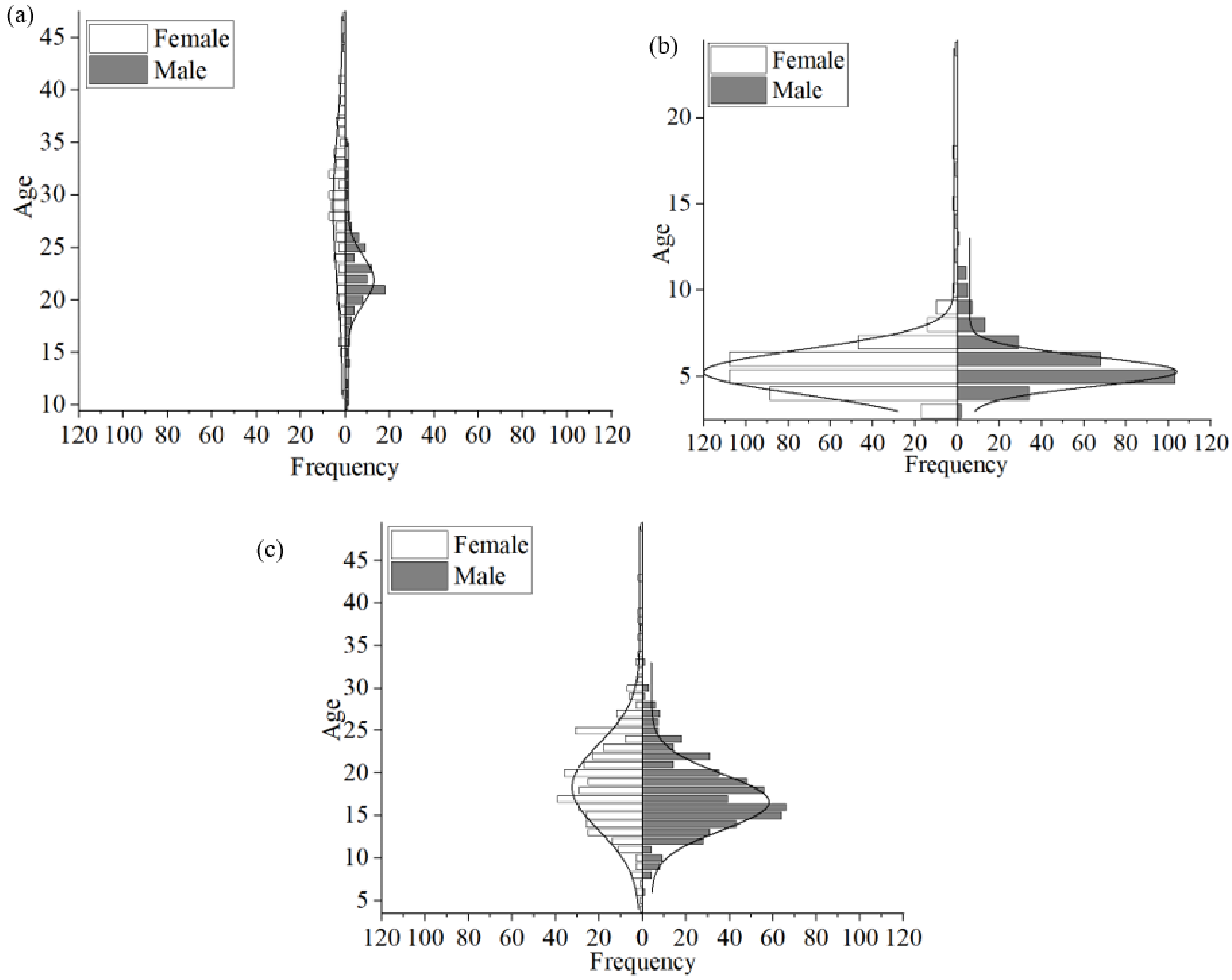

Figure 9. Distribution of the age structure of *P. dipogon*. Note: (**a**) is the age structure of the *Ptychobarbus dipogon* sample in this study; (**b**) is the age structure of the *Ptychobarbus dipogon* sample studied by Yang et al. [18]; (**c**) is the age structure of the *Ptychobarbus dipogon* sample studied by Liu et al. [19].

Table 3. Exploitation rate and steady-state biomass of *P. dipogon*.

Sr.No.	Sampling Time	E10	E50	Emax	E	Steady-State Biomass/Ton	References
1	2008~2009, 2012~2013	0.556	0.36	0.634	0.82	27.99	[18]
2	2013~2014	0.714	0.407	0.809	0.71	26.39	[19]
3	2019	0.570	0.351	0.661	0.61	20.06	This study

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Data Availability Statement: The numerical results reported in this paper may be shared by the interested parties if requested. Please contact the author.

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