North Pacific Fisheries Commission

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Content of the document for data on biological information on the chub mackerel

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1. Methodology

1.1 Sampling methodology, frequency, and size

We collected the chub mackerel samples since 2016 in the NPFC areas. In 2017-2020, more than 2000 individuals were measured in the lab. The size range of fork length was 110-400mm (Table 1).

Since in the December, 2017, we began to collect the samples for their otolith identification of the chub mackerel population in the CA areas (Table 2). The random samples were collected by the fishermen in two different fishing boats every month, then taken to the lab for further analysis. First, we measured the fork length (FK, mm), total length (mm) and wet weight (g) of each fish. Second, we took out a pair of sagittal otoliths and ground the right otolith. Finally, the age of every otolith was identified by otolith ring method under the microscope.

Table1 Data, frequency, and size on the samples of the chub mackerel in the CA areas

Data	Frequency	Size range (FK, mm) of fishes
August to November, 2016	3 months	129~378
May to November, 2017	9 months, every month	130~345
April to October, 2018	7 months, every month	178~388
April to November, 2019	8 months, every month	154~358
April to December,2020	9 months, every month	110~400

Table2 Data, frequency, and size on the samples for otolith identification of the chub mackerel in the CA areas

Data	Frequency	Size range (FK, mm) of fishes
December, 2017	1 month	178~244
April to October, 2018	7 months, every month	195~367
April to November, 2019	8 months, every month	154~339
April to December,2020	9month, every month	115~370

1.2 Methodology of ALK-development

The forward age-length key (ALK) was first developed by Fridriksson (1934). The method works on the premise that given a random sample of *N* fish for which only lengths have been measured and a subsample of *n* fish whose lengths and ages have been measured, the probability $P(i|j)$ that a fish is age *i* given that it belongs to length bin *j* is the same for both samples. This probability can be estimated from the age-length sample as:

$$\hat{P}(i|j) = \hat{q}_{ij} = {}^{n_{ij}}/_{n_{.j}} \qquad (1)$$

where $\hat{q}_{ij}$ is the estimated probabilities of age given length that populate the cells of the forward ALK. n_{ij} is number of fish of age *i* and length bin *j* in the age-length sample, $n_{.j}$ is total number of fish belonging to the *j*th length bin of the age-length sample.

The probabilities of age given length from the forward ALK are then simply multiplied by the marginal probabilities $\hat{P}(j) = {}^{y_j}/_{N}$ to obtain an estimate of age composition from the forward key, $\hat{A}$. This can be expressed using matrix algebra as follows:

$$\hat{A} = QY/N \qquad (2)$$

where Q is the I by J matrix with elements $\hat{q}_{ij}$. Equation (2) can be shown to give maximum likelihood estimates; it is presented in the form above to emphasize the logic of the approach.

1.3 Criteria if multiple ALKs are used in different regions

The forward age-length key:

(1) The age-length and the length frequency samples must originate from the same statistical population, i.e. within a length class, the underlying age composition must be the same for the two samples. In other words, the two samples must be drawn from the same available population. This implies that:

(a) A forward key developed from one year cannot be applied to another year.

(b) A forward key developed from one area cannot be applied to another area if the two areas are characterized by differences in age composition.

(2) A forward key developed from one gear can be used to age catch from a different gear even if the two gears have different size selectivities, so long as the two selectivity curves within a length bin are parallel. With narrow length bins, selectivity is almost constant, hence, the requirement of parallel selectivity curves is met.

The inverse age-length key:

(1) The number of length bins (*J*) must be greater than or equal to the number of age classes (*I*) in order to obtain a unique solution (in some cases, a plus group will need to be implemented).

(2) The age-length and the length frequency sample do not need to have been collected in the same year. They can be collected from two populations with different age compositions as long as size at age does not differ between the two populations.

(3) The Hoenig and Heisey (1987) method is the superior method for applying inverse keys when there is a single length frequency and a single age-length sample as it allows for uncertainty in both the length frequency sample and the age-length sample.

The combined forward-inverse age-length (FIAL) key:

(1) The number of length bins (*J*) must be greater than or equal to the number of age classes (*I*) in order to obtain a unique solution.

(2) Size-at-age is assumed constant among samples.

(3) The estimator is valid even if length stratification is used.

1.4 Methodology of estimating catch-at-age from ALK

$$N_{i,j} = \frac{TC_j \times P_{i,j}}{\widehat{BW_i}} \qquad (3)$$

where i is the ith class interval of KnL; j is the jth cell of year; P is the proportion of samples' weight; TC is the catch; $\widehat{BW}$ is the fitted body weight by Length-weight relationships(Froese, 1998), the formula is:

$$BW_1 = a \times KnL^b \qquad (4)$$

We have obtained the relationship between age and length through ALK, therefore, the relationship between age and weight can be obtained.

$$BW_2 = f(age) \qquad (5)$$

So, the yearly catch-at-age can be estimated by

$$N_{i,j} = \frac{TC_j \times P_{i,j}}{\widehat{BW_2}} \qquad (6)$$

2 Results

2.1 Sample sizes of length measurements and age determination

We have collected 3573 individuals of chub mackerel to measure the biological parameter from 2016 to 2020 Every month, 2~3 samples including 50~100 individuals were collected during the fishing boats and then be transferred to lab to further measured (Table 3).

Table3 Sample sizes of length measurements

Year	month	samples	individuals
2016	August to November	8	254
2017	May to November	15	842
2018	April to October	14	345
2019	April to November	16	869
2020	April to December	18	1263

Table4 Sample sizes of age determination

Year	month	samples	individuals
2017	December	2	40
2018	April to October	14	260
2019	April to November	16	469
2020	April to December	18	322

2.2 Length and age distribution

Using of catch samples from fishing boats, the biological parameters of chub mackerel were measured. In 2017, the average fork length was 227.3mm, in 2018 was 366.1mm, in 2019 was 239.4mm and in 2020 was 237.1mm. It can be seen that the average fork length presents a trend of gradual increase to stability in 2016-2020.

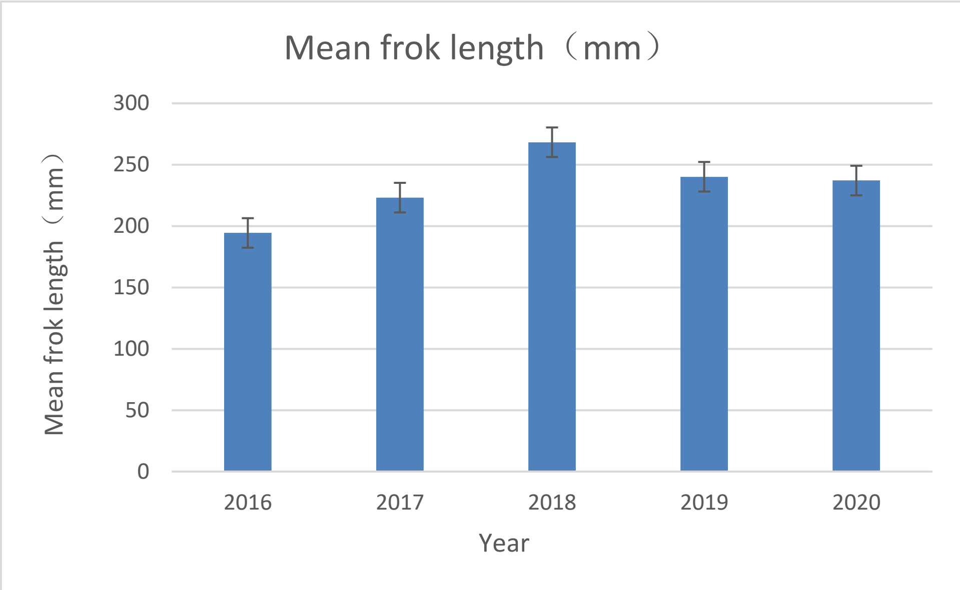

Fig.1 the mean fork length on the chub mackerel in CA areas in 2016-2020

We analyzed that the distribution of different fork length groups and ages distribution in 2018 ,2019 and 2020. In the 0+ age group, mainly fork length range was less than 200mm, which mean that more than 98% of the individuals less than 200 mm were 0+-year-old fish. The individuals which fork length ranged from 200-260mm were mainly 1^+ year old. The individuals which fork length ranged from 240-320mm were mainly 2^+ year old. The individuals which fork length ranged from 280-360mm were mainly 3^+ year old. In 2019, it was found that the individuals which fork length ranged from 300-360mm were also distributed 4^+ year old.

Table5 Fork length and age distribution of chub mackerel in the North Pacific Ocean in 2018

Fork length （mm）	Age group (percentage, %)				
	0+	1+	2+	3+	4+
160-180	66.7				
180-200	33.3	15.9			
200-220		38.1			
220-240		28.6			
240-260		15.9	7.1		
260-280		1.6	23.8		
280-300			16.7		
300-320			42.9	22.2	
320-340			9.5	50	
340-360				22.2	
360-380				5.6	

Table6 Fork length and age distribution of chub mackerel in the North Pacific Ocean in 2019

Fork length （mm）	Age group (percentage, %)				
	0+	1+	2+	3+	4+
160-180	66. 7				
180-200	28.8				
200-220	3.0	11.2			
220-240	1.5	61.2	20.0		
240-260		27. 8	60.0		
260-280			0		
280-300			20.0	11.1	
300-320				55.6	24.5
320-340				33.3	50.0
340-360					25.5
360-380					

Table7 Fork length and age distribution of chub mackerel in the North Pacific Ocean in 2020

Fork length （mm）	Age group (percentage, %)					
	0+	1+	2+	3+	4+	5+
100-120	3.5					
120-140	19.3					
140-160	57.9					
160-180	19.3					
180-200		29.5				
200-220		70				
220-240		0.5	30.6			
240-260			30			
260-280			39.4	42.9		
280-300				57.1		
300-320					42.9	
320-340					57.1	59.8
340-360						25
360-380						11.8
380-400						4.4

2.3 ALK

Unless regional growth patterns differ, the relationship between age and length should be the same for all groups, based on a large length sample and backed up by a smaller age sample. In the first step, we expressed the actual age determination according to the number of otoliths in each length group of each age，The next stage is to calculate, within each length group, the proportions of each age-group. In table8, we analyzed that the distribution of different length groups and ages distribution in 2020.

Table8 Age-Length key of chub mackerel in the North Pacific Ocean in 2020

	Age						
Length（mm）	0+	1+	2+	3+	4+	5+	Total
105-135	13						13
135-165	75						75
165-195		243					243
195-225		242	143				385
225-255			234	63			297
255-285				155	11		166
285-315					12	32	44
315-345						34	34
345-375						6	6

2.4 Length-weight relationship

Body size is a basic biological characteristic in fish populations and can reflect individual physiology as well as changing environment conditions. Length-Weight relationship is an important characteristic to describe this change. For figures 2-7，The R^2 of length-weight of *Scomber japonicus* were larger than 0.94. It is represent that chub mackerel has a significant relationship between length and weight. In accordance with the samples in 2020, the relationship between with fork length and biomass of chub mackerel was $y= 0.000002x^{3.3482}$ (R^2 = 0.9526), where y is the weight (g) of chub mackerel individual, x is the fork length (mm).

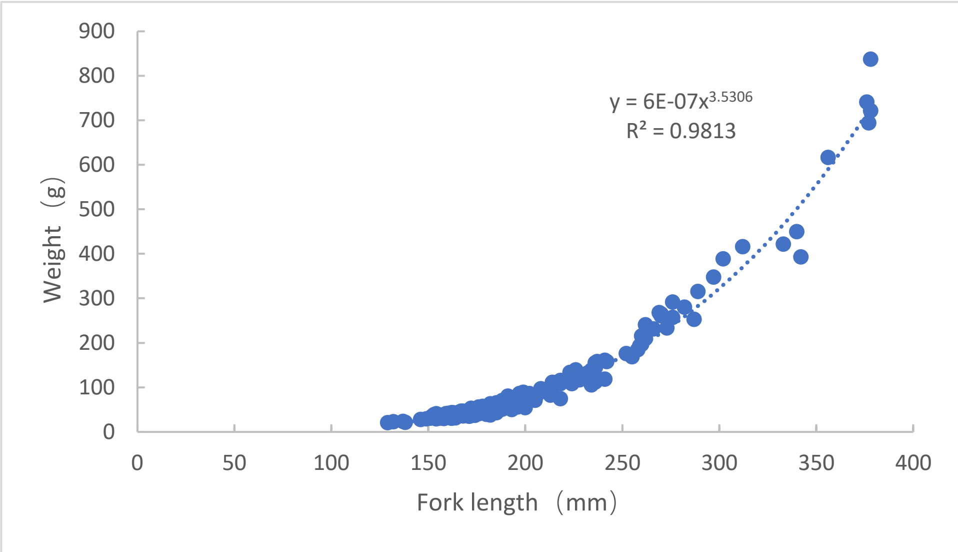

Figure 2 Length-Weight relationship of China_chub mackerel in 2016 (n=230)

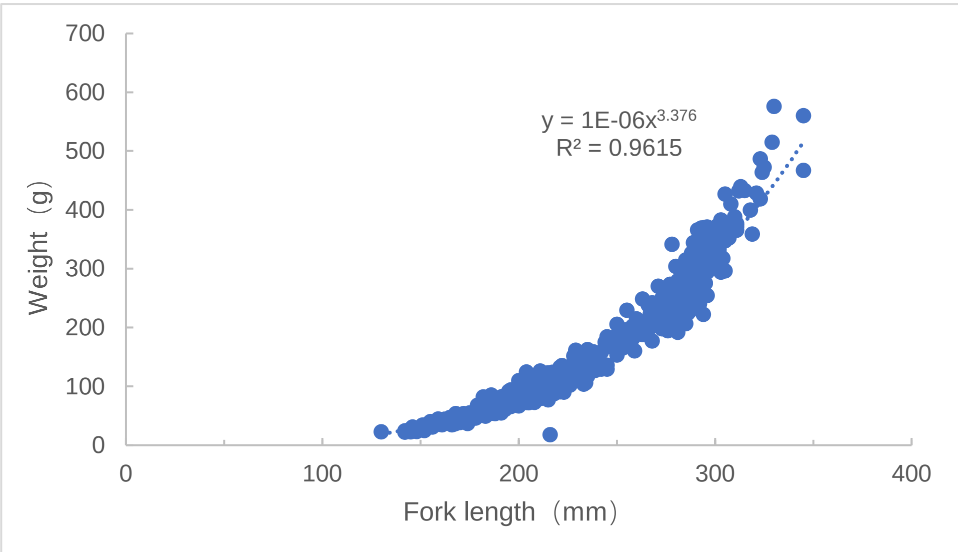

Figure 3 Length-Weight relationship of China_chub mackerel in 2016 (n=842)

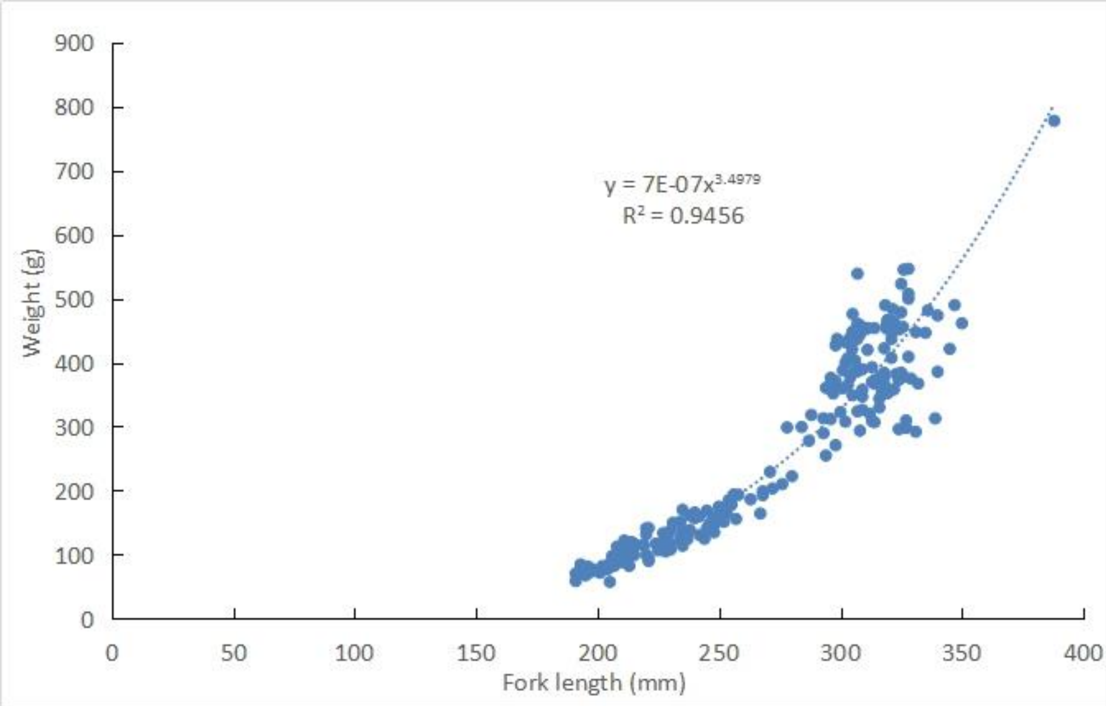

Figure 4 Length-Weight relationship of China_chub mackerel in 2018 (n=345)

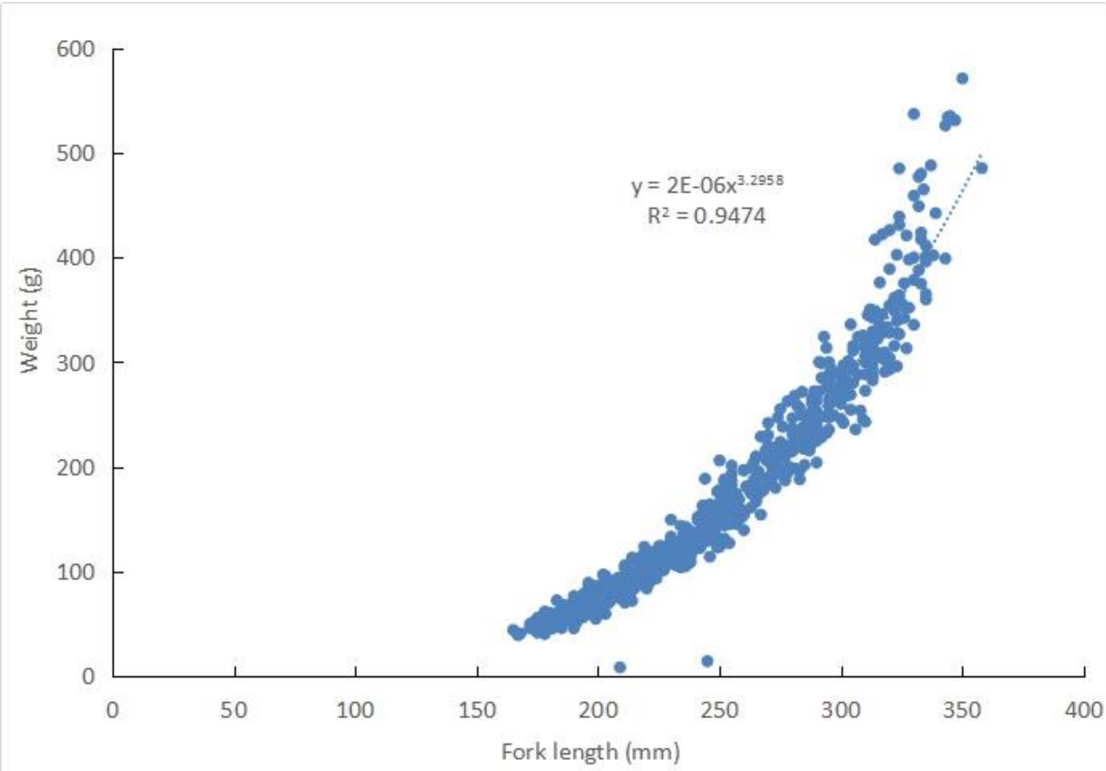

Figure 5 Length-Weight relationship of China_chub mackerel in 2019 (n=869)

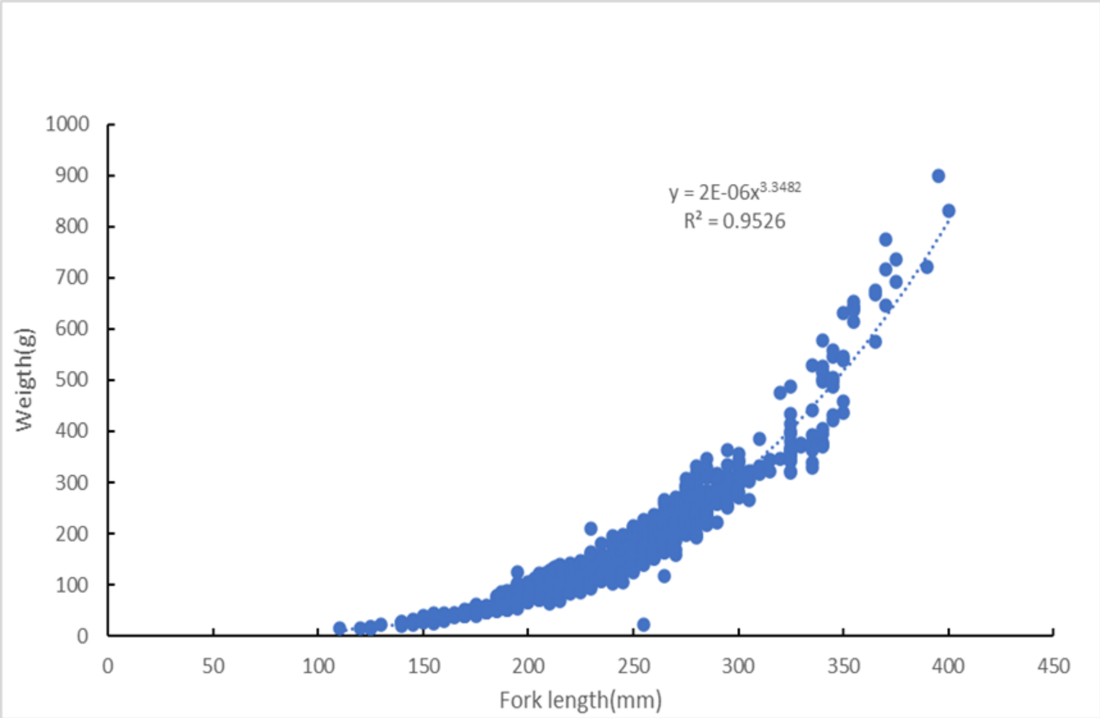

Figure 6 Length-Weight relationship of China_chub mackerel in 2020 (n=1264)

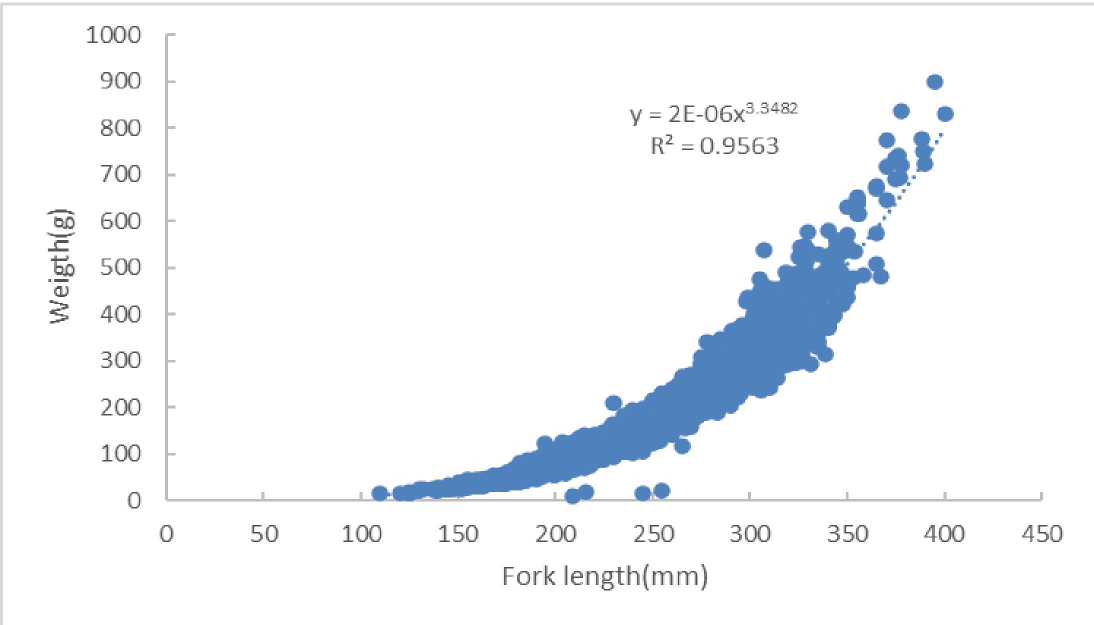

Figure 7 Length-Weight relationship of China_chub mackerel in 2016-2020 (n=3477)

2.5 **Catch-at-age**

Using otolith age identification technology, we analyzed the Catch-at-age composition in chub mackerel catches (Fig.3). The catch-at-age 1^+, $2^+$and 3^+ in 2020 both exceed those in 2019. For the first time, in 2020 we have the samples of the catch-at-age 5^+.

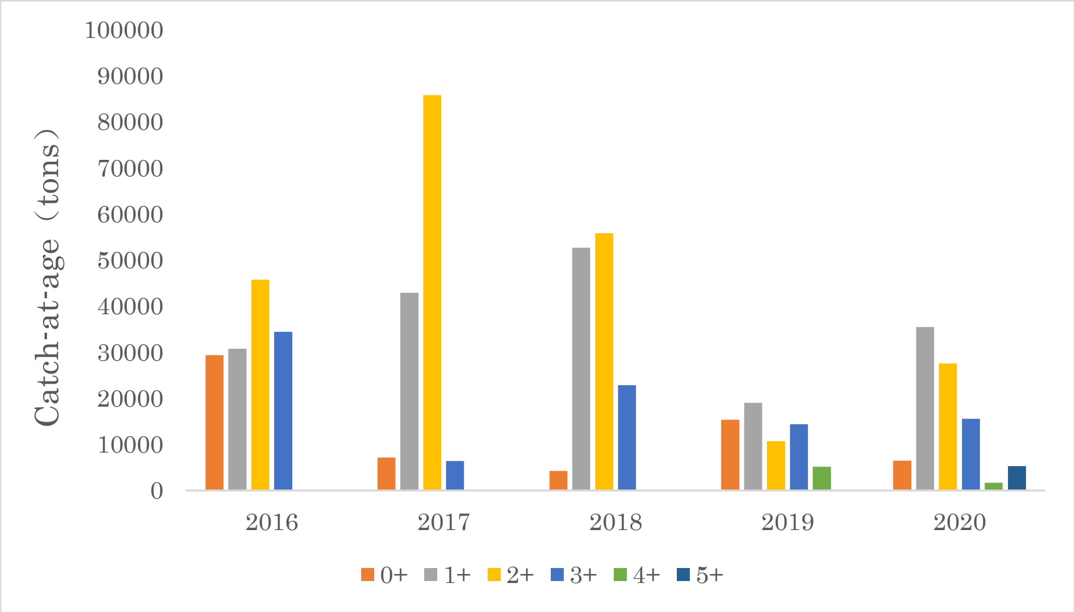

Figure 8 Catch-at-age on the chub mackerel in the CA areas in 2016-2020

2.7 **Number-at-age**

Using otolith age identification technology, we analyzed the Number-at-age composition in chub mackerel catches (Fig.7). The catch-at-age 1^+, $2^+$and 3^+ in 2020 both exceed those in 2019, the number of 0^+ is the same as the year before.

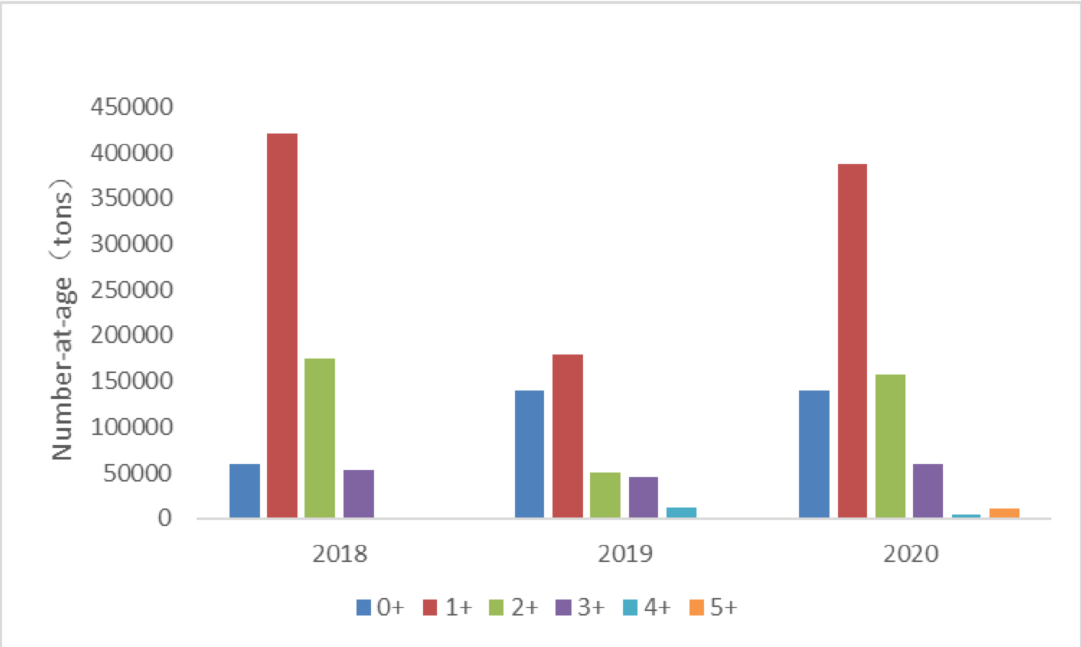

Figure 9 Number-at-age on the chub mackerel in the CA areas in 2018-2020