NPFC-2025-TWG CMSA11-WP13

**Analysis of identification method for gonadal maturity and MAA calculation methods on Chub mackerel in China**

Heng ZHANG1, Sisi HUANG1, 2, Yongchuang SHI1, Famou ZHANG1, 2

1. East China Sea Fisheries Research Institute, Chinese Academy of Fishery Science, Shanghai, China

2. College of Marine Living Resource Sciences and Management, Shanghai Ocean University, Shanghai, China

**Summary**

In order to maintain consistency in the standards of gonadal maturity, both China and Japan use gonadal development stage IV as the mature individual for chub mackerel by visual inspection method. At the same time, age identification is conducted for each sample. Both 0-year-old and 1-year-old individuals are immature, and 2-year-old individuals are also almost immature, with only very few mature individual during studying samples. Individuals aged 4 years or older are considered mature individuals. Three years old fish is the age that marks the boundary between mature and immature gonadal development. The maturity fluctuation range of a 3-year-old individual with the gonad stage is 0.15-0.3. Considering that visual methods may have some errors in determining the developmental level of ovarian fish eggs, the GSI index is used for correction and reference. As defined GSI greater than 1.6 as matured individuals based on the result of NPFC-2025-TWG CMSA11-WP10. The range of sexual maturity ratio for 3-year-old individuals with GSI≥1.6 is 0.03-0.375 (mean=0.12), and 2-year-old individuals also have an average ratio of 0.057. If we consider including 2-year-old sexually mature individuals as 3 years old, the proportion of sexual maturity at 3 years old reaches 0.19, but this is still lower than the research results of Japanese colleagues (0.3). KG=3 as a criterion (represents stricter standards than GSI) for determining sexual maturity is not suitable for the Chub Mackerel population in the open sea.

Overall, it indicates that the gonadal development of chub mackerel in the open sea area is relatively slow, which may be due to the fact that this area is not a spawning ground. We adjusted the MMA table based on the threshold of gonadal index, as shown in Table 5. Considering the criteria for mature eggs and the comprehensive factors of GSI, we suggest using the simplify the average value MMA values in Table 5 to be closer to the true values. Therefore, the preliminary conclusion is that the maturity of chub mackerel in the CA sea area should generally be lower than that of individuals near Japanese EEZ area.

1. **Introduction**

The maturity of gonads is an important indicator of the developmental maturity stage of fish populations, generally characterized by full and uniform color of female individual fish eggs. Different types of fish eggs have different colors, commonly including yellow, orange, etc. In the Chinese domestic fishery biology survey standard documents, observation and recording of gonadal maturity are carried out using visual methods. The gonads are divided into 6 stages, represented by stages I to VI, and the basic staging criteria are as follows (GB/T12763.6-2007 Marine Survey Specification Part 6: Marine Biological Survey [S]):

I: Immature larvae, with transparent and thin gonads that cannot be distinguished by the naked eye as male or female;

II: During the resting period, the gonads remain transparent, slightly enlarged, flattened, and difficult to distinguish between males and females with the naked eye;

III: During gonadal maturation, the weight of the gonads increases, and the ovaries become pale yellow or yellowish. The egg granules begin to deposit yolk. The testis changes from transparent to light rose red. Easy to distinguish between males and females;

IV: Mature stage, without laying eggs or ejaculating. The ovarian weight reaches its maximum value, occupying most of the abdominal cavity, and the egg granules deposit yolk, which is compressed into polygonal circles in the ovary. The testis turns milky white;

V: Genitalia, also known as spawning period. The egg is transparent, round, and free in the ovarian cavity. Gently press the abdomen, and eggs or sperm can flow out automatically;

VI: Weak period, also known as the late stage of egg laying. The egg or sperm is released, and the weight of the reproductive gland is reduced. The reproductive glands are relatively loose. There is a small amount of non oviposition in the ovaries and a small amount of sperm in the testes.

In the Maturity at age (MAA) file data submitted before 2024, we started with gonadal maturation at stage III. But at the 8th Chub Mackerel working group meeting held in Niigata, Japan in 2024, the Japanese colleagues communicated with us and adopted the same fish egg maturation standard as the starting point for its maturity, which is mainly gonadal development stage IV. In the suggestions on the report NPFC-2025-TWG CMSA11-WP10, this paper suggests that, in order to improve maturity-at-age (MAA) data for future stock assessment, it is more appropriate to use 50% maturity, notably GSI of 1.6 as the maturity criterion for stock assessment purpose, while noting KG=3 accurately designates maturation in the Japanese EEZ zone area. But is this also applicable to the criteria for determining the sexual maturity of chub mackerel populations in the high sea?

Therefore, in this report, we have reorganized and calculated our MAA based on the fish egg maturity starting point of the Chub Mackerel population in Phase IV (Mature stage), and also referred to the Gonad index (such as GSI, KG) index as a backup reference.

1. **Materials and Methods**

 Chub mackerel samples were collected in the purse seine fleet in the high seas during April-December, 2018-2024. Fork length (FL) was measured to the nearest 0.1 cm and total body weight (BW) and gonad weight (GW) were measured to the nearest 0.1 g. Sex was determined by visual observation of the gonads. For observation and analysis, 500 females samples were used.

**2.1** Gonad stages

The gonads are divided into 6 stages, represented by stages I to VI, while the gonad stage IV (Mature stage) as a mature individual by visual inspection method. At the same time, age identification is conducted for each sample. Both 0-year-old and 1-year-old individuals are immature, and 2-year-old individuals are also almost immature, with only very few mature individual during studying samples. Individuals aged 4 years or older are considered mature individuals. Three years old fish is the age that marks the boundary between mature and immature gonadal development.

****

**Stage Ⅴ**

Fig. 1 Gonad stage identification on the Chub mackerel population (Stage IV means mature stage)

Calculate the proportion of mature fish individuals in each age group (0~7 years) and the tail number of that age group at least based on gonadal maturity stage IV, and calculate the MAA data table. The formula is as follows:

$Maturity ratio\_{0\~7}=\sum\_{j=1}^{n}Nj/\sum\_{i=1}^{m}Mi$ (1)

Where $Maturity ratio\_{0\~7}$ means the proportion of mature fish individuals in each age group (0~7 years) in the equation (1), $Nj$ means the number of the *j* th mature fish individuals in each age group samples, Mi means the *i* th individuals in each age group samples.

Considering that visual methods may have some errors in determining the developmental level of ovarian fish eggs, the GSI and KG index is used for correction and reference.

**2.2** KG and GSI

KG and GSI index were calculated by using the following equations (Sayoko Isu et al., NPFC-2025-TWG CMSA11-WP10).

KG = (GW (g) / FL3 (cm)) × 10000

GSI = (GW (g) / (BW(g) - GW (g))) × 100

Here, total body weight (BW) and gonad weight (GW) were measured to the nearest 0.1 g.

1. **Results**

We found the 0 and 1-year-old chub mackerel individuals are all immature, while the 4 and above 4-year-old chub mackerel individuals are all mature (Table 1). Three years old fish is the age that marks the boundary between mature and immature gonadal development. The maturity fluctuation range of a 3-year-old individual is 0.15-0.3.

Table 1 Maturity ratio on each age groups of chub mackerel samples by started with the gonad stage IV in 2018-2024, China (this data have submitted in the 10th TWG CMSA as a sensitivity analysis data)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Member | Year | SeasonType | Area | Species | Age group |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| China | 2018 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.15 | 1 | 1 | 1 | 1 |
| China | 2019 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.2 | 1 | 1 | 1 | 1 |
| China | 2020 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.15 | 1 | 1 | 1 | 1 |
| China | 2021 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.2 | 1 | 1 | 1 | 1 |
| China | 2022 | Calendar Year | CA | MAS | 0 | 0 | 0.01 | 0.3 | 1 | 1 | 1 | 1 |
| China | 2023 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.2 | 1 | 1 | 1 | 1 |
| China | 2024 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.2 | 1 | 1 | 1 | 1 |

The range of GSI index variation for mature individuals is 0.2-9.6, with a proportion of 12% exceeding 1.6. The annual average GSI index varies between 0.03-0.375, with a relatively large range of changes due to the small sample size in some years. Two-year-old individuals also have a very low proportion of sexual maturity, below 0.06 (Table 2). If we consider including 2-year-old sexually mature individuals as 3 years old, the proportion of sexual maturity at 3 years old reaches 0.19, but this is still lower than the research results of Japanese colleagues (0.3).

If KG is greater than or equal to 3 (a stricter standard) to calculate sexual maturity, the proportion of sexual maturity will further decrease, with an annual range of 0-0.21(Table 3). Among them, in 2019, no 3-year-old fish met the criteria. According to Table 4, the gonadal weight of chub mackerel in the open sea area is relatively low (0.1-66.7g), with an average annual variation range of 1.86-5.44g. Hence, we believe that KG=3 as a criterion for determining sexual maturity is not suitable for the Chub Mackerel population in the open sea.For populations in the open sea, it may be better to judge based on GSI or gonadal stage.

Overall, it indicates that the gonadal development of chub mackerel in the open sea area is relatively slow, which may be due to the fact that this area is not a mainly spawning ground.

Table 2 Maturity ratio on each age groups of chub mackerel samples combined withe GSI index started with the GSI≧1.6 in 2018-2024, China

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Member | Year | SeasonType | Area | Species | Age group, (n= means the number of GSI ≧1.6/total number) |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| China | 2018 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.28（n=5/18） | 1 | 1 | 1 | 1 |
| China | 2019 | Calendar Year | CA | MAS | 0 | 0 | 0.05(n=1/20) | 0.14（n=6/45） | 1 | 1 | 1 | 1 |
| China | 2020 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.03（n=3/83） | 1 | 1 | 1 | 1 |
| China | 2021 | Calendar Year | CA | MAS | 0 | 0 | 0.017(n=1/59) | 0.11（n=8/75) | 1 | 1 | 1 | 1 |
| China | 2022 | Calendar Year | CA | MAS | 0 | 0 | 0.076(n=1/13) | 0.375(n=9/24) | 1 | 1 | 1 | 1 |
| China | 2023 | Calendar Year | CA | MAS | 0 | 0 | 0.09(n=15/164) | 0.15(n=2/42) | 1 | 1 | 1 | 1 |
| China | 2024 | Calendar Year | CA | MAS | 0 | 0 | 0.04(n=7/183) | 0.17(n=3/18) | 1 | 1 | 1 | 1 |
|  |  |  |  |  |  |  | Mean=0.057 | Mean =0.12 |  |  |  |  |

Table3 Maturity ratio on each age groups of chub mackerel samples combined withe KG index started with the gonad KG≧3.0 in 2018-2024, China

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Member | Year | SeasonType | Area | Species | Age group, (n= means the number of GSI ≧1.6/total number) |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| China | 2018 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.17(n=3/18) | 1 | 1 | 1 | 1 |
| China | 2019 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0(n=0/25) | 1 | 1 | 1 | 1 |
| China | 2020 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.03（n=3/83） | 1 | 1 | 1 | 1 |
| China | 2021 | Calendar Year | CA | MAS | 0 | 0 | 0.017(n=1/59) | 0.06(n=4/75) | 1 | 1 | 1 | 1 |
| China | 2022 | Calendar Year | CA | MAS | 0 | 0 | 0.07（n=1/13） | 0.21(n=5/24) | 1 | 1 | 1 | 1 |
| China | 2023 | Calendar Year | CA | MAS | 0 | 0 | 0.02（n=2/142） | 0.05(n=2/42) | 1 | 1 | 1 | 1 |
| China | 2024 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.13(n=3/19) | 1 | 1 | 1 | 1 |
|  |  |  |  |  |  |  | Mean=0.02 | Mean=0.07 |  |  |  |  |

Table4 Maturity ratio on each age groups of chub mackerel samples combined withe KG index in 2018-2024, China

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Member | Year | SeasonType | Area | Species | Gonad weight(g) by each Age group |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| China | 2018 | Calendar Year | CA | MAS | / | / | / | 5.2（0.1-59.6） | / | / | / | / |
| China | 2019 | Calendar Year | CA | MAS | / | / | 0.67（0.1-2.95） | 1.86（0.1-6.4） | / | / | / | / |
| China | 2020 | Calendar Year | CA | MAS | / | / | 0.65（0.1-1.6） | 1.97（0.1-66.7） | / | / | / | / |
| China | 2021 | Calendar Year | CA | MAS | / | / | 0.88（0.1-3.0） | 2.31（0.3-20.7） | / | / | / | / |
| China | 2022 | Calendar Year | CA | MAS | / | / | 1.83（0.5-8.8） | 5.35（1.0-29.0） | / | / | / | / |
| China | 2023 | Calendar Year | CA | MAS | / | / | 1.40（0.2-4.2） | 1.94（0.2-6.5） | / | / | / | / |
| China | 2024 | Calendar Year | CA | MAS | / | / | 1.06（0.1-4.8） | 5.44（0.6-46.3） | / | / | / | / |

**4.Conclusion and Recommendation**

Based on the above analysis, it can be concluded that the 3-year-old individual is the critical age period for maturity, but there is also a few proportion of individuals who reach sexual maturity at the age of 2 (according to the criteria of GSI≧1.6 or KG≧3). This may be due to the smaller fork length of 2-year-old fish, which leads to the calculation results, and of course, it cannot be ruled out that phenomena such as premature sexual maturity may occur.

The average values calculated based on GSI, KG, and maturity stage levels from different years may fluctuate to some extent, and some years may also be relatively large. This may be due to sample issues or changes in the marine environment that drive the occurrence of inter annual differences in the Chub Mackerel population. For simplify of calculation process, the average sexual maturity ratio only apply into 3 years old individuals of the high seas population from 2018 to 2024 can be taken to maintain consistency with the report from Japanese colleagues (Table 5).

Considering the criteria for mature eggs and the comprehensive factors of GSI, we suggest using the MMA values in Table 5 to be closer to the true values. Therefore, the preliminary conclusion is that the maturity of chub mackerel in the CA sea area should generally be lower than that of individuals near Japanese EEZ area. We adjusted the MMA table based on the threshold of gonadal index, as shown in Table 5. Due to the high difficulty of collecting samples in the open sea and the possibility of underestimating the number of large individual samples, the overall range of gonadal indices is relatively low, resulting in a certain degree of uncertainty in MAA data.

Table 5 The recommendation on the maturity ratio on each age groups of chub mackerel samples by started with the gonad index GSI=1.6 in 2018-2024, China

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Member | Year | SeasonType | Area | Species | Age group |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| China | 2018 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.19 | 1 | 1 | 1 | 1 |
| China | 2019 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.19 | 1 | 1 | 1 | 1 |
| China | 2020 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.19 | 1 | 1 | 1 | 1 |
| China | 2021 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.19 | 1 | 1 | 1 | 1 |
| China | 2022 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.19 | 1 | 1 | 1 | 1 |
| China | 2023 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.19 | 1 | 1 | 1 | 1 |
| China | 2024 | Calendar Year | CA | MAS | 0 | 0 | 0 | 0.19 | 1 | 1 | 1 | 1 |

**Reference:**

General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, China National Standardization Administration. GB/T12763.6-2007 Marine Survey Specification Part 6: Marine Biological Survey [S]. Beijing: China Standard Press, 2008:6-17.

Yukami, R., Oshimo, S., Yoda, M., and Hiyama, Y. (2009). Estimation of the spawning grounds of chub mackerel Scomber japonicus and Scomber australasicus in the East China Sea based on catch statistics and biometrics data. Fish. Sci. 75, 167-174. (doi: 10.1007/s12562-008-0015-7)

Kamimura Y, Taga M, Yukami R, Watanabe C, Furuichi S (2021) Intra- And inter-specific density dependence of body condition, growth, and habitat temperature in chub mackerel (Scomber japonicus). ICES J Mar Sci 78:3254–3264. https://doi.org/10.1093/icesjms/fsab191

Sayoko Isu, Shota Nishijima, Akihiro Manabe, Yasuhiro Kamimura, Sho Furuichi, Kazunari Higashiguchi, Ryosuke Watanabe, Yuto Izawa and Ryuji Yukami (2025) Review of the maturity criterion using gonad index in Pacific stock chub mackerel. NPFC-2025-TWG CMSA11-WP10.