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Preliminary analysis for the relationship between otolith weight and fork length of bigeye and yellowfin tunas

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Preliminary analysis for the relationship between otolith weight and fork length of bigeye and yellowfin tunas

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Summary

Previous studies show high correlations between the otolith weight and the fork length or the age estimated from otolith annulus of bigeye (*Thunnus obesus*) and yellowfin (*Thunnus albacares*) tunas. However, the relationship between otolith weight and age of fish is temporarily shelved because of the potential for uncertainty in the results of otolith annulus reading. In this study, the relationships among otolith weight, fork length and elapsed days in captivity were analyzed for 0 to 2 years old bigeye and yellowfin tunas which were reared in a fish pen in the southern part of Japan. In addition, the relationship between otolith weight and fork length of wild captured fish was supplementarily examined. This study could contribute to develop a growth model based on the otolith weight in bigeye and yellowfin tunas.

Introduction

Stock assessments are being conducted to discuss management measures on bigeye (*Thunnus obesus*) and yellowfin tunas (*Thunnus albacares*) in the western and central Pacific Ocean (WCPO). Growth parameters have strongly affected on the stock assessment results of both species in the area recently. The growth models being applied to the stock assessments have been considered from various perspectives. For the WCPO bigeye tuna, the growth models using propagation of modes of size composition in catch (Harley et al. 2014), based on otolith increments reading (Farley et al. 2020), combination of otolith increments reading dataset and tag-recapture data (Vincent et al. 2020), and conditional age-length dataset constructed from the combined daily and annual otolith dataset were tested (Eveson et al. 2020). However, the growth model based solely on otolith increments reading analysis was considered unsuitable for the stock assessment because it produced excessive abundance estimates. In the latest stock assessment for yellowfin tuna in WCPO in 2020, three kinds of growth models were examined, which are based on conditional catch at age, length compositions, and otolith increments readings. The stock status of yellowfin tuna had substantially changed to more optimistic than previous results as is the case of bigeye tuna (Vincent et al. 2020). Therefore, the growth factors

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are notably unstable in the stock assessments. In recent years, the relationships between otolith weight and fork length and otolith annuli reading for both species were investigated (Farley et al. 2018, 2020), and also new approaches such as bomb radiocarbon analysis (Andrews et al. 2020, 2021) and rearing experiment in captivity (Okamoto et al. 2021) are being progressed. The aim of the present study is to evaluate the preliminarily relationship between increase of otolith weight and the number of reared days using the data sets from the rearing experiment in captivity for the bigeye and yellowfin tunas which were caught and reared in the southern part of Japan.

Materials and methods

The young fish of bigeye and yellowfin tunas used for this study were captured by pole and line fishery between July 2020 to May 2021 around the Amami Archipelago, Japan (27^{o} 24′ N–28^{o} 45′ N, 128^{o} 24′ E–129^{o} 56′ E; Fig. 1). The fork length (FL) was measured in 0.1cm by caliper and the sagittal otolith was kept in microtube after extracting from 72 bigeye and 88 yellowfin tunas (wild specimen). A total of 7 bigeye and 241 yellowfin tunas and 29 bigeye and 136 yellowfin tunas captured in October 2020 and May 2021, respectively were transported to the sea cages (18m and 20m diameters each) of Japan Fisheries Research and Education Agency, Fisheries Technology Institute, Amami Field Station (28^{o} 09′ N, 129^{o} 15′ E) with keeping in the fish tank on the fishing vessel. After measuring FL, the fish was injected with plastic tipped dart tag (PDA Tag, Hallprint, Australia; 15cm length) and/or passive integrated transponder (PIT) tag (HPT9, Biomark, USA) before releasing into the fish cage. Under the rearing condition, the fish were fed mainly sand eels (Ammodytidae), sardines (Clupeiformes) and occasionally krills (Euphausiidae) until satiation for 1 to 4 times per day except for the staff′s holidays. Reared fish were pulled out once to four times in December 2020, March to April and October 2021, and February and April 2022 from the cage, and FL was measured, then released into the other cage. Retrieval of dead individuals was conducted every day except for the staff′s holidays, then the sagittal otoliths were extracted from dead fish after being kept frozen (reared specimen). Otoliths extracted from wild and reared specimens were kept in normal and light-shielded microtubes, respectively. The otoliths were weighed in 0.1mg by a high precision weighinscale if the otolith was not lost a piece after removing debris of tissues on the otoliths and completely being dried. Right otolith weight was primarily used to determine the otolith weight (OW) for the statistical analysis, but left otolith weight was also used when the right otolith was not available. The growth increment analyses of FL and/or OW were conducted with using the fish reared for 30 days or more. Regarding estimation of the OW growth increment of reared fish, the OW of the fish at the starting point of rearing was assumed to be average OW of wild fish and early died (within 10 days) reared fish of which FL was close to the specimen’s one.

In terms of the seasonality of OW growth, only for yellowfin tuna, the growth of summer season was estimated using fish which were reared in duration between 30 and 180 days captured in May 2021 and reared duration in more than 270 days captured in October 2020. The winter growth analyses included the fish were reared in duration between 30 and 180 days captured in October 2021. Considering the seasonal growth increment in FL and OW for yellowfin tuna, monthly growth increments were calculated by the formula as follows;

$$Monthly\ growth\ increment\ (FL\ or\ OW) = \frac{(final\ value - start\ value)}{reared\ days} * 30$$

Student′s t-test was performed for the comparison of the growth increments in OW between summer and winter for yellowfin tuna after confirming normality.

In considering the seasonality of FL growth in yellowfin tuna, the individuals that survived for one and a half year from October 2020 to May 2022 were used. We defined summer as March to October and winter as October to next March. In order to compare the monthly growth rate in FL for yellowfin tuna between seasons (2020-winter, 2021-summer, 2021-winter), analysis of variance was performed followed by Tukey’s HSD test as post-hoc analysis for pairwise comparisons.

In all cases significance was defined when $p<0.05$.

Results

The FL and OW of bigeye and yellowfin tunas captured in wild and reared in captivity used for this study were shown in Table 1. The FL and OW in bigeye and yellowfin tunas of all the individuals including wild and captive reared fish showed a positive linear regression (Fig. 2 and 3). While yellowfin tuna showed a strong correlation up to 80cm in FL, bigeye tuna showed the weaker correlation than that of yellowfin tuna due to the small sample size but there was still a strong correlation. The OW of wild and reared individuals were fallen in a similar weight range.

The relationship between OW growth rate and reared days in summer and winter for bigeye and yellowfin tunas was shown in Fig. 4 and Fig. 5, respectively. In addition, seasonal comparison of growth increments in OW for bigeye and yellowfin tunas was shown in Fig. 6 and Fig. 7, respectively. For bigeye tuna, the sample size was too small, therefore the statistical analysis related to the seasonal difference was not conducted. Yellowfin tuna showed a significantly higher growth rate in summer than in winter ($p<0.05$). Seasonal variation in FL for reared bigeye and yellowfin tunas was shown in Fig. 8 and Fig. 9, respectively. Although the number of samples for bigeye tuna was small, the growth in summer was higher than that in winter, especially for yellowfin tuna. The seasonal growth in FL for yellowfin tuna was shown in Fig. 10. The results of analysis of variance showed significant difference in both comparisons between 2020 winter and 2021 summer and between 2021 summer and 2021 winter.

Discussion

There was a strong correlation between the increase in FL or OW and the rearing period for both bigeye and yellowfin tunas. There was also clear seasonal variation in the growth rate of FL and OW for yellowfin tuna. The growth rates of both FL and OW were higher in summer and lower in winter season, which should be reflected to the seasonal variation of metabolic rate caused by environmental temperature changes. This result suggests that seasonality should be considered when developing growth models for these tuna species at least in the study area, temperate region. It will be investigated whether or not the seasonality in growth rate can be found if the seasonal temperature changes are small which is not in the case of the study area. Furthermore, the relationship between seasonality of growth FL or OW and otolith ring formation pattern will also be examined in the near future.

While previous studies found that wild fish have shown the strong correlation between FL and OW (Farley et al. 2020, Pacicco et al. 2021), this study has revealed that the growth rate of OW is strongly correlated with the growth rate of FL. This means that OW growth rate can be converted to FL growth rate, which should be verified in the near future by comparing OW growth between captive and wild fish.

In this study, there is no substantial analysis for bigeye tuna due to the small sample size at this stage. The small sample size of bigeye tuna was mainly due to low catch in the sampling season. Although there were large individual variation and small sample size, a linear relationship between FL and OW for bigeye tuna and seasonality in FL growth were shown. Therefore, the seasonality in OW growth could be also suggested like yellowfin tuna.

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Table 1. FL and OW of bigeye and yellowfin tunas used for this study.

Bigeye tuna	Otolith weight (mg)	FL (cm)	N
Wild	9.0–24.9	42.4–75.0	72
Reared（start）	—	38.0–57.3	17
Reared（end）	6.9–19.9	40.8–61.1	17

Yellowfin tuna	Otolith weight (mg)	FL (cm)	N
Wild	6.4–21.2	36.5–65.7	88
Reared（start）	—	34.6–62.2	136
Reared（end）	5.8–29.5	34.1–81.6	136

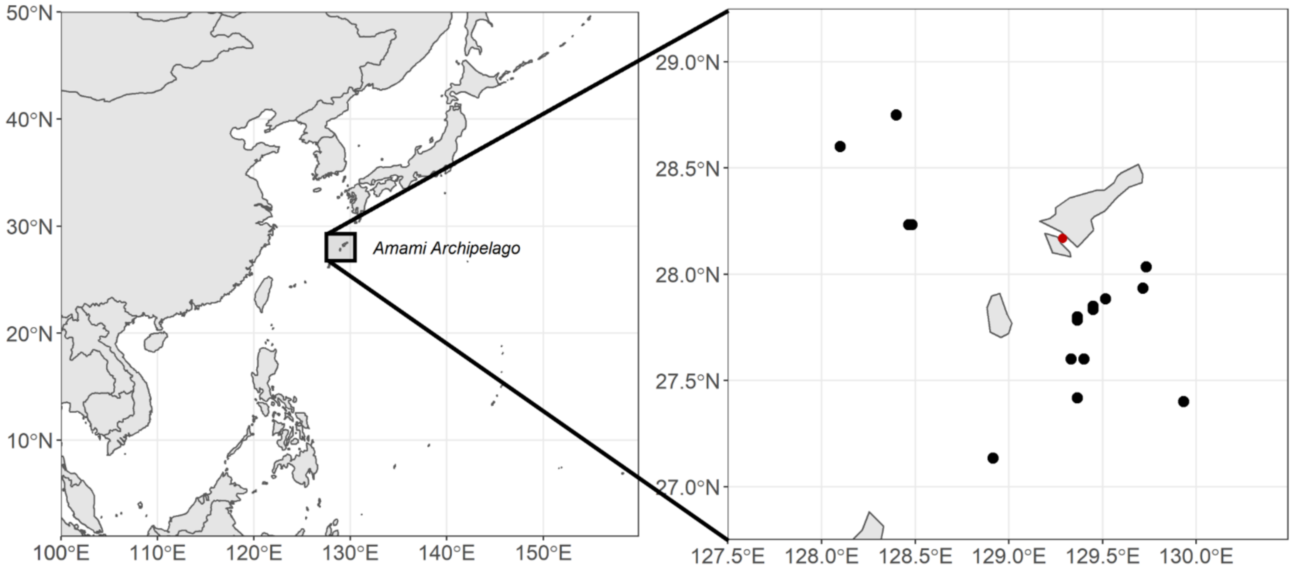

Fig. 1. Sampling sites

The blue dots indicate the sampled positions of bigeye and yellowfin tunas. The red point indicates the position located the fish cage.

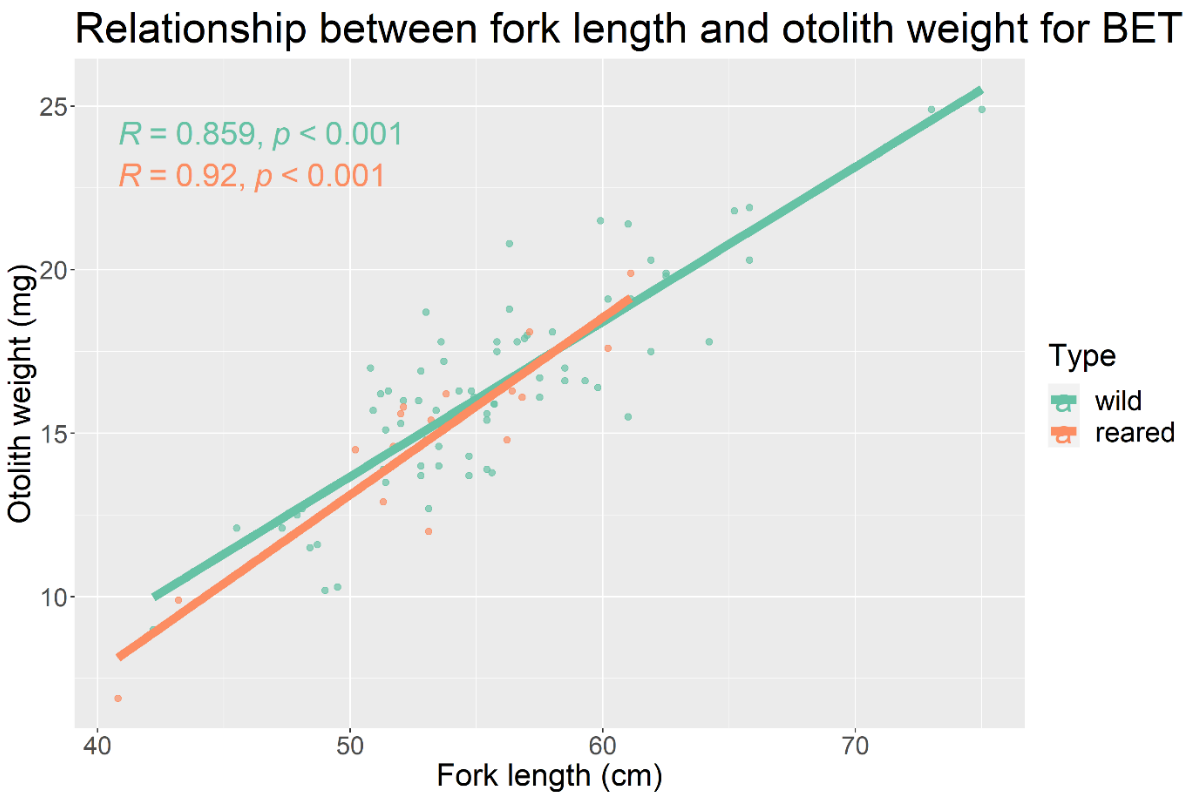

Fig. 2. The relationship between FL and OW for bigeye tuna.

Both wild and reared fish show the positive linear regression relationship.

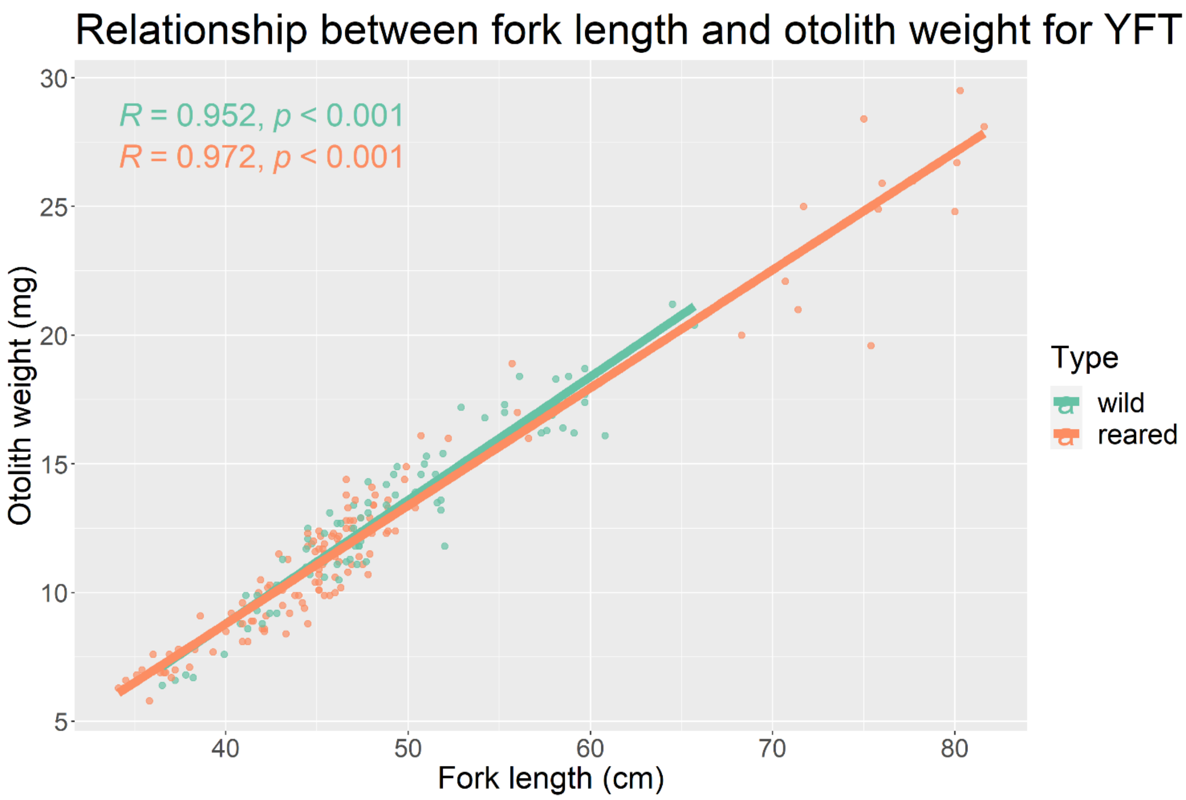

Fig. 3. The relationship between FL and OW for yellowfin tuna.

Wild and reared fish show the similar and positive linear regression relationship.

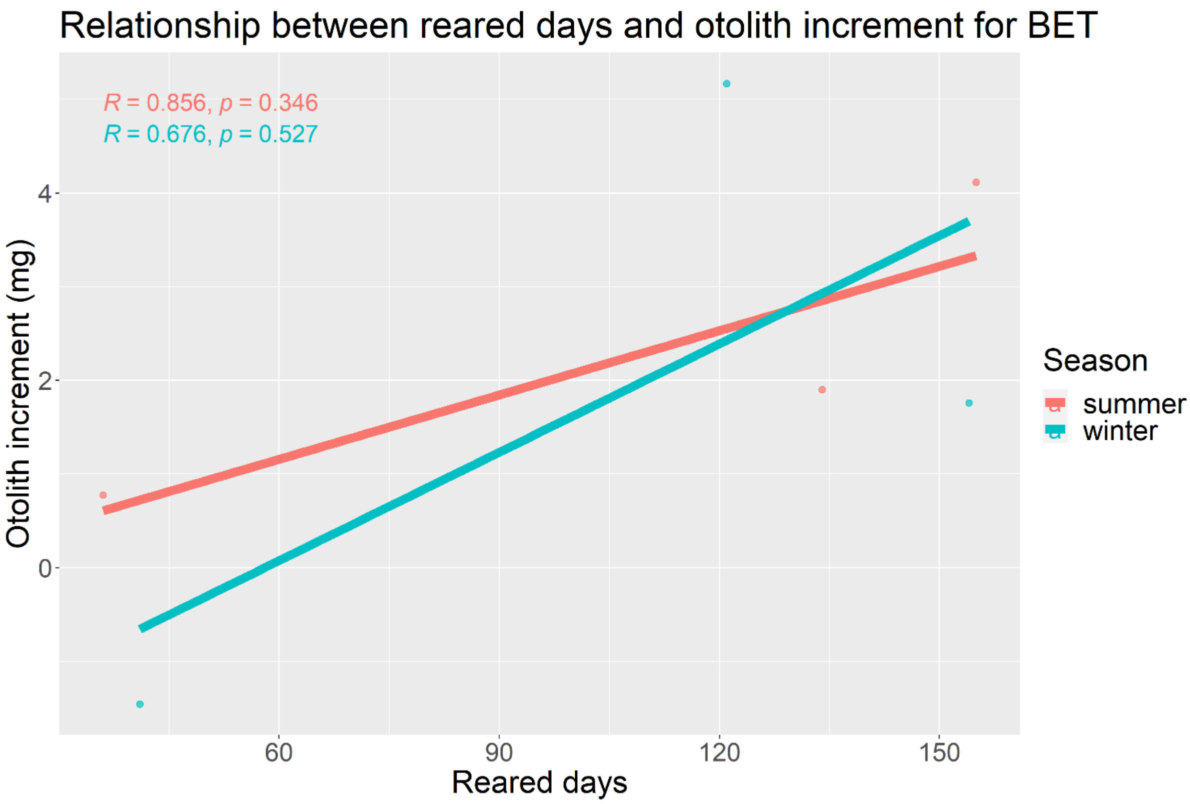

Fig. 4. Relationship between reared days and growth increment in OW for bigeye tuna.

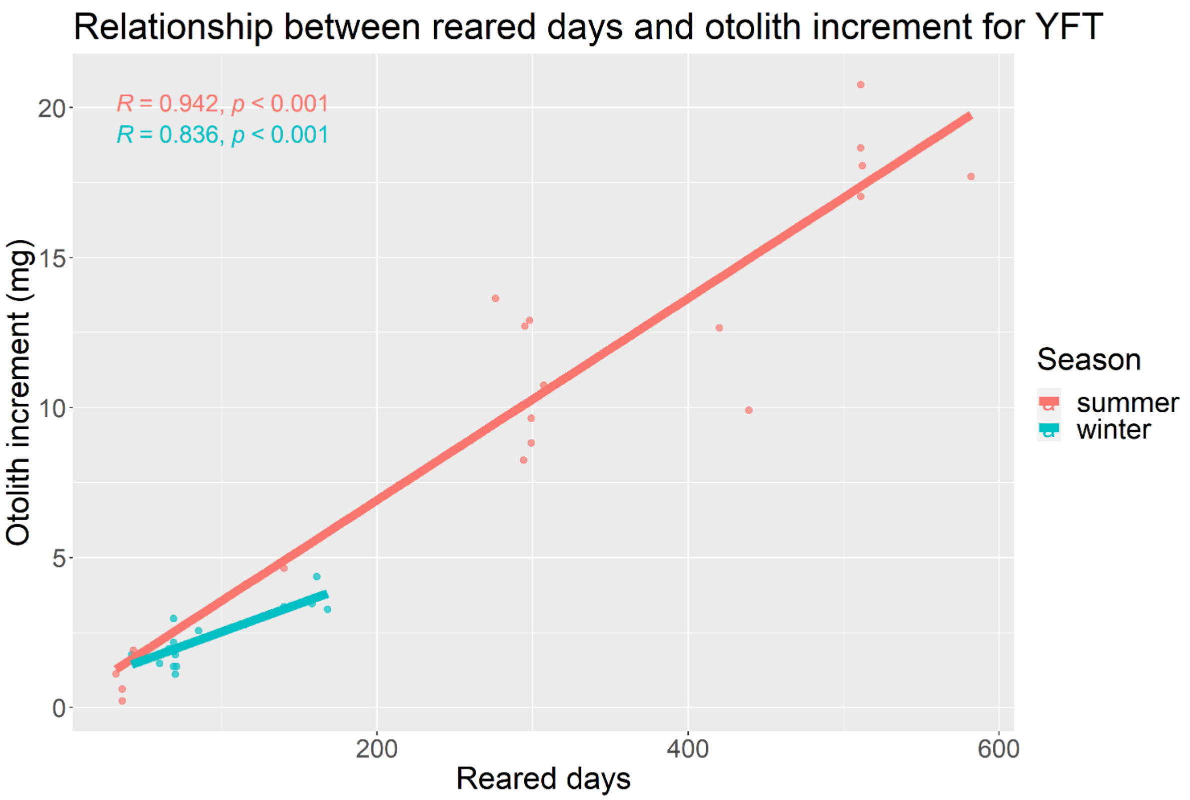

Fig. 5. Relationship between reared days and growth increment in OW for yellowfin tuna.

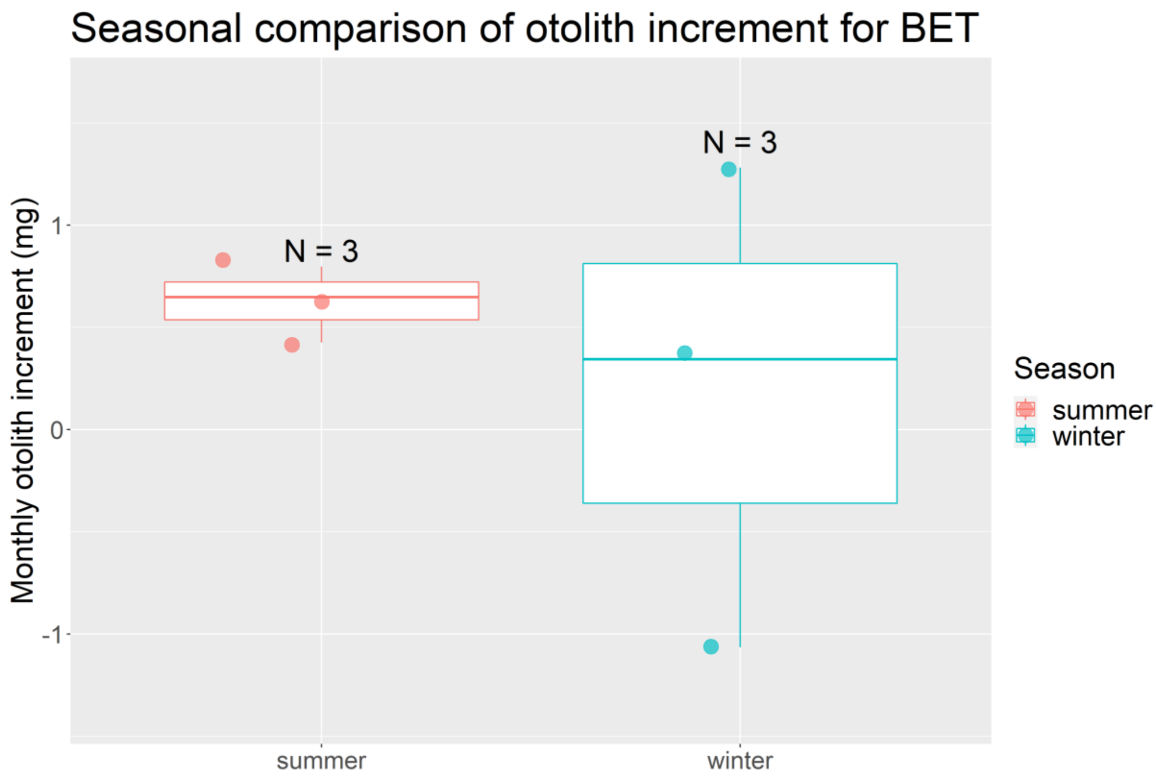

Fig. 6. Seasonal comparison of monthly OW growth increment for bigeye tuna.

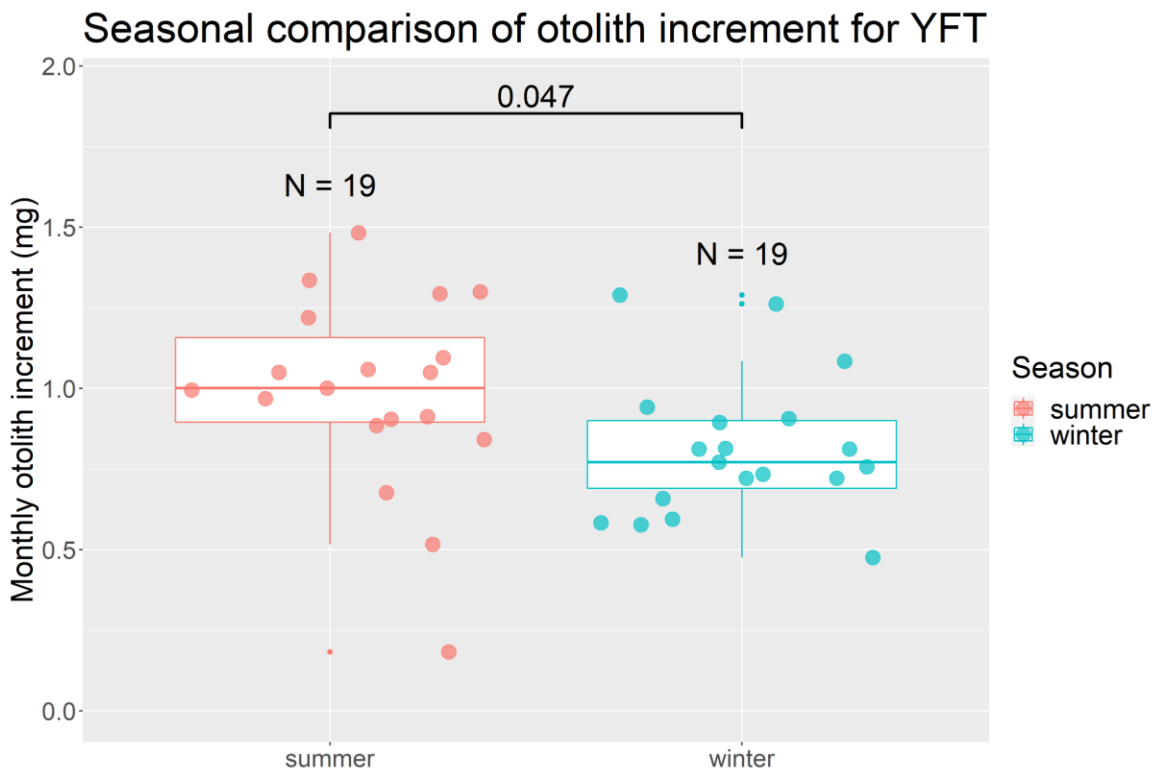

Fig. 7. Seasonal comparison of monthly OW growth increment for yellowfin tuna. The monthly growth of otolith inclement in summer is higher than that in winter.

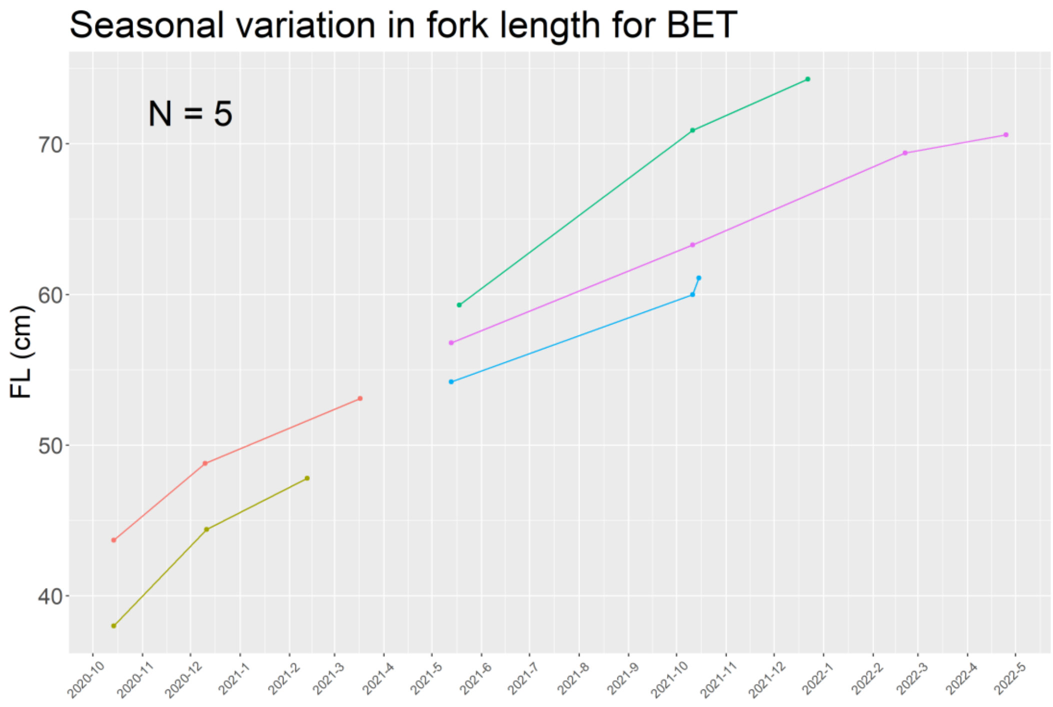

Fig. 8. Seasonal variation in FL for bigeye tuna.

Summer tends to show the higher growth rate than winter.

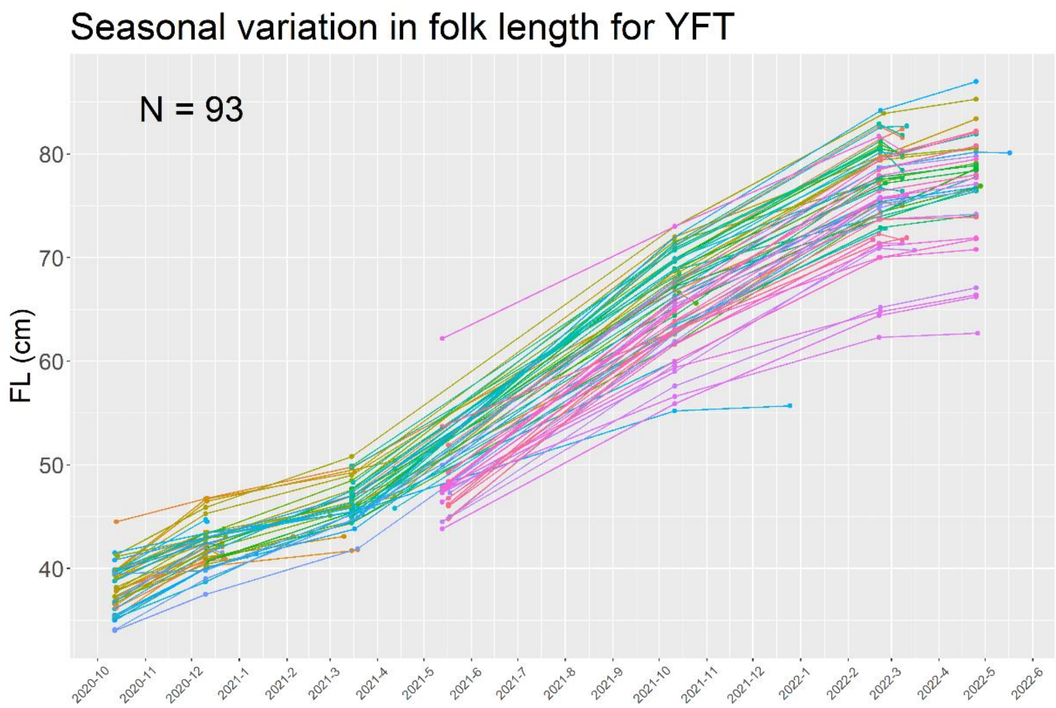

Fig. 9. Seasonal variation in FL for yellowfin tuna.

Summer tends to show the higher growth rate than winter.

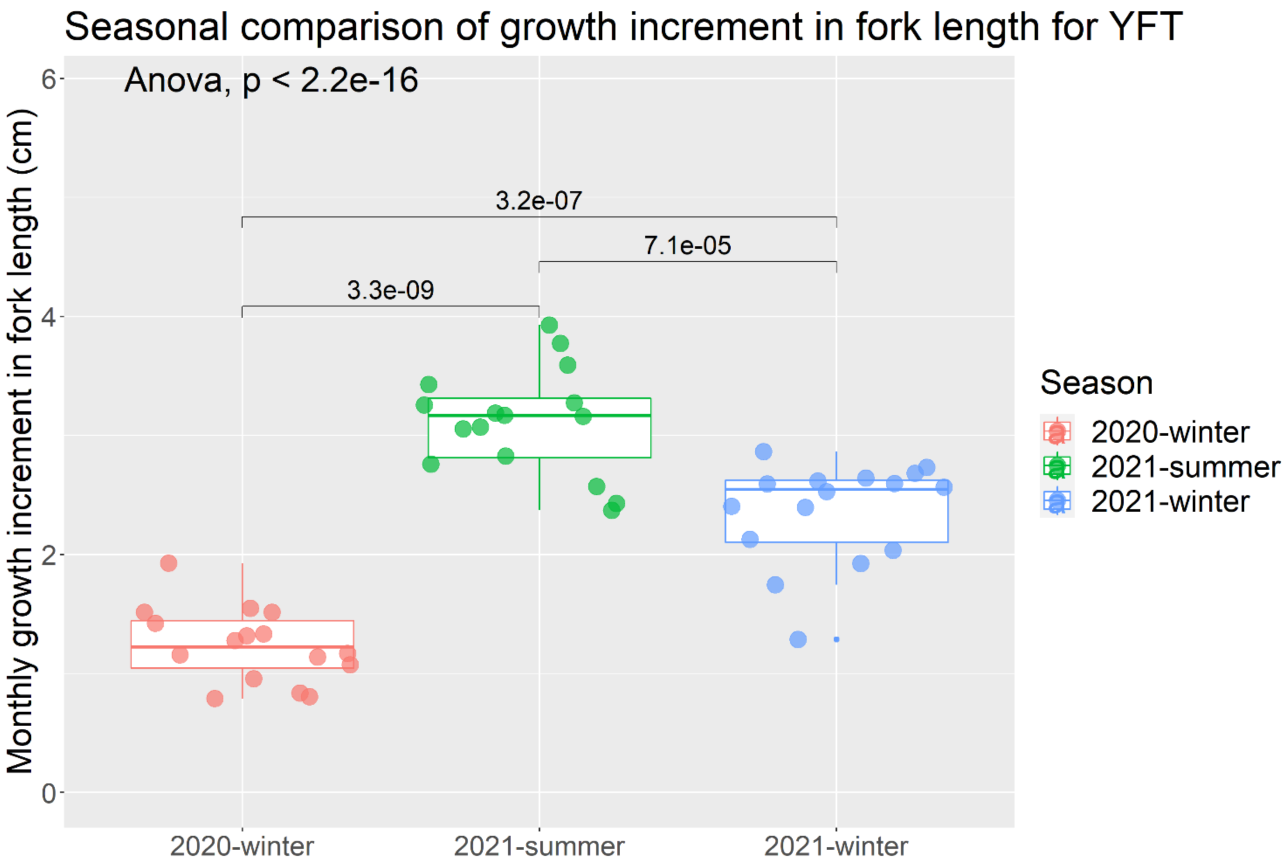

Fig. 10. Seasonal comparisons of growth increment in FL for yellowfin tuna. Summer shows significant higher growth rate than winter.