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Biological parameters estimate for the sickle pomfret (*Taractichthys steindachneri*) in the west-central and eastern Pacific Ocean

Richard Kindong[$], Feng Wu, Siquan Tian, Jiangfeng Zhu, Xiaojie Dai*[†], Jiaqi Wang & Libin Dai
College of Marine Sciences, Shanghai Ocean University, Shanghai- 201 306, China
*[E-mail: [†]xjdai@shou.edu.cn; [$]kindong_richard@yahoo.com]

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This study was undertaken to provide some preliminary biological information for Sickle pomfrets *Taractichthys steindachneri* from length frequency data (LFD) obtained through the Chinese Longline Fisheries Observer Programme in the Pacific Ocean obtained from August 2016 to March 2017. We fitted the seasonally oscillating von Bertalanffy Growth Function (so VBGF) by applying two optimized ELEFAN approaches ('simulated annealing' ELEFAN S.A. and 'genetic algorithm' ELEFAN G.A.). ELEFAN S.A. presented the best score and was later used to obtain the following results: FL_∞ = 101 cm, k = 0.52 yr^{-1}, $t_{\_anchor}$ = 0.73, C = 0.75, ts = 0.2, and growth performance index of $\emptyset'$= 3.72; natural mortality M = 0.55 yr^{-1}, total mortality Z = 1.37 yr^{-1}, fishing mortality F = 0.82 yr^{-1}, exploitation rate E = 0.59, length at first sexual maturity Lm = 67.5 cm corresponding to 2.47 years (age at first sexual maturity); major recruitment and highest catch rate occurred in January. F and E at maximum sustainable yield were Fmsy = 1.7 yr^{-1} and Emsy = 0.754, respectively. In this study, E and results of yield-per-recruit models indicate that these fisheries are sustainably harvested, and maximum sustainable yield could be acquired, if F is increased to Fmsy.

[Keywords: Biological information, ELEFAN, MSY, Sickle pomfret, TropFishR]

Introduction

Sickle pomfret *Taractichthys steindachneri* (Döderlein, 1883) is a member of the Bramidae family and is found in tropical waters throughout the Western Pacific and Indian Oceans. In the Pacific, these species are caught in the pelagic longline and hook and line fisheries. Sickle pomfrets are generally classified under the miscellaneous pelagic and marketed commercially as “monchong”. The species is a common incidental bycatch in western Pacific fisheries, they are not a target species in any fishery and as a result, very limited biological and ecological information pertaining to the species is currently available.

Available information related to this species concerns: 1) Its distribution, as they are widely distributed in the tropical waters of the Pacific and Indian Oceans[1]; 2) Their habitats, Nakano, Okazaki & Okamoto[2], documented that, through the water column, Sickle pomfret live in waters to at least 300 m. They also reported that, longlines that were set during morning periods and retrieved during afternoon or evening periods, these species were among the most caught species as the fish hooks depth increased; i.e., higher catch rates at deeper depths; 3) On their life history, Dotsu[3] reported that Sickle pomfrets could attain about 80 cm TL, Smith[4] also reported a Sickle pomfret of 60 cm TL weighing 11 kg and estimated to be 8 years old.

Life-history parameters including age, growth, natural mortality, recruitment patterns are important biological stock characteristics and input parameters for population dynamics and yield per recruit models. These parameters are; 1) important to providing insights on fisheries population dynamics; 2) crucial in establishing robust assessments and management plans; and 3) important to ensuring fisheries sustainable development[5]. Special set of models are required for fisheries having only catch and/or length-frequency (LFQ) data, generally categorized as data-limited fisheries[6]. Data-limited fish stocks can be found in all regions in the world and could even have a management effect on data-rich fisheries[7]. Sickle pomfret can be categorized as data-limited fisheries; moreover, it is a non-targeted species and only has as available data LFQ. Direct aging methods used to determine fish age such as otoliths are generally expensive, labor-intensive, and are mostly time consuming[8] so; most scientists working with data-poor capacity limited fisheries tend to use LFQ data to perform various analyses. LFQ analysis is cheap, easy to implement, and can produce reasonable results. LFQ data comes with many advantages over time-series of catch and effort or catch-at-age data[7] because they are easy to collect and are less time consuming as compared to the latter.

An attempt is made in the present study to provide some biological data estimate of this non-targeted commercial species. Therefore, the principal objective here is to present first biological parameter estimates of this species and present a preliminary assessment of its stock status via yield per recruit analysis using observers LFQ data.

Materials and Methods

Study area and data collection

Sickle pomfret samples from the west-central and eastern Pacific Ocean (30°00′ N - 33°8′ S, 161°02′ E - 103°56′ W; Fig. 1) were collected through the Chinese Longline Fisheries Observer Programme from August 2016 to March 2017. The trained observers boarded longline vessels targeting commercial tuna species such as bigeye tuna, *Thunnus obesus*. The long line consisted of nylon filament made mainline, with float lines varying between 25–40 m long, branch lines of 20–25 m long and branch lines intervals of 32–40 m. Longline setting and hauling times varied considerably. Three types of hooks (Japanese 3.5 tuna hooks, teracima 3.2 hooks and circular 3.5 hooks) were used by different vessels during this fishing period.

Sickle pomfrets landed on deck during this fishing operation period were measured for their fork lengths (snout to the deepest point of tail fork; FL), and body weight (W). FL was estimated to the nearest centimeter (cm) and W to the nearest 1 g. These species gender information was not recorded. Length frequency data were later pooled into groups of 1 cm length intervals.

Length composition and weight-length relationship

The weight-length relationship was calculated by applying a power regression function:

$$W = aFL^b$$

Where W is the body weight (kg), FL is the fork length (cm), and *a* is the intercept, with *b* the slope of the linear regression[9]. The coefficient of determination (r^2) obtained from this analysis was used as an indicator of the quality of the linear regression. As elaborated by Haddon[10], we used the least square residuals method to minimize residual errors in order to obtain the best regression parameters (*a* and *b*). Student's *t*-test was applied to verify whether the

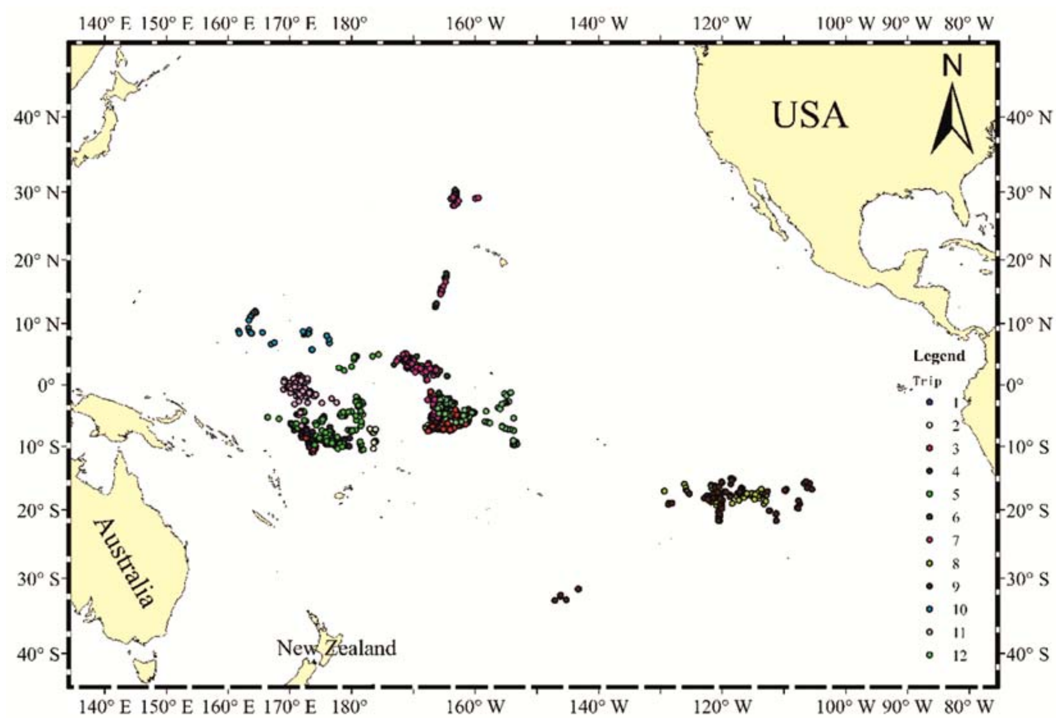

Fig. 1 — Sampling area at which Sickle pomfrets were harvested in the west-central and eastern Pacific Ocean

constant "b" presented a significant difference of 3, indicating the type of growth[9]: isometric (b = 3.0), positive allometric (b > 3.0) or negative allometric (b < 3.0). The hypothesis of isometric growth[11] was tested using the t-test ($p < 0.05$).

Growth, mortality parameters, and exploitation ratio

There are many methods developed that could be used for length frequency data-poor fisheries analysis (i.e. population parameters, stock status etc.). Some of these methods imbedded in the R statistical computing software and developed in the TropFishR package. This package includes traditional and updated versions of the Electronical Length Frequency Analysis (ELEFAN) method, used in growth parameters estimation, with new optimization techniques[12].

Length frequency data was used to calculate the von Bertalanffy growth rate (k) and the asymptotic length (L_∞ or $Linf$) by model progression analysis using the two new optimisation approaches of ELEFAN within the TropFishR package. These new approaches (ELEFAN with simulated annealing (ELEFAN S.A) and ELEFAN with a genetic algorithm (ELEFAN G.A)) were used and the one with the best scoring fit (high Rn) was selected for further analysis in this study[12].

The ELEFAN (Electronic LEngth Frequency ANalysis) methods allow estimating Linf and k from LFQ data by restructuring the data and fitting growth curves through the restructured LFQ data[13]. The Powell-Wether all method[14] was used to provide an initial estimate of the asymptotic length (L_∞); the method requires a catch vector per length class representative for the length distribution in yearly catches instead of the catch matrix[12]. With this initial estimate of (L_∞) as the seeded value, the ELEFAN procedure was used to fit the seasonally oscillating von Bertalanffy growth function (soVBGF) from the length–frequency data. Growth was modelled in this study according to the soVBGF as described by Somers[15] and a separate non-linear fitting of the soVBGF to length-at-age data produced by the same procedure as described in Taylor & Mildenberger[12]. It is important to note here that, the newly implemented ELEFAN methods (ELEFAN S.A. and ELEFAN G.A.) allow for the optimisation of the soVBGF[7,12]. The growth performance index $\emptyset'$ (phi-prime) was calculated based on the growth parameter estimates following the equation of Pauly & Munro[16].

The total instantaneous mortality rate (Z) was estimated through the length-converted catch curve analysis as presented by Pauly[17] by using the pooled length frequency data. The instantaneous natural mortality rate (M) whose estimation is challenging but remains an important parameter of stock assessment models[18] was estimated through the empirical formula developed by Then[19] and requires estimates of the VBGF growth parameters (Linf and k) for its implementation. The instantaneous fishing mortality rate, F, was deduced from the expression F = Z-M[20], and the exploitation ratio (E) from E = F/Z[13,21]. The parameter E expressed the proportion of a given population that ultimately dies due to fishing under an existing exploitation pressure.

Length at first maturity (Lm), optimum length at (Lopt) and recruitment pattern

To estimate the length at first sexual maturity (Lm) for the assessed species which would correspond to letting all (100 %) fish species spawn at least once before they are caught so as to rebuild and maintain healthy spawning stocks; this parameter was determined following the procedures proposed in Hoggarth[22]. Optimum length (Lopt) which is the percentage of fish caught at optimum length is typically a bit larger than Lm and can be easily obtained from growth and mortality parameters or empirical equations[23,24]. In addition, the maximum length Lmax, which is the maximum length reached during this period of the fishing operation. 5 Recruitment as inscribed in TropFishR is observed when individuals are assigned a length of zero in the final LFQ data plot. In this case, the parameter t_0 represents the time (i.e. date) at length zero rather than a theoretical age at length zero[12].

Estimated stock size and yield-per-recruit (YPR)

The stock size was estimated here, thanks to the Jones' length converted cohort analysis[25], which is a modification of Pope's virtual population analysis (VPA) for LFQ data, implemented in TropFishR. This CA needs parameters a and b of the length-weight relationship, the estimated value of F and the other estimates from previous analysis. The cohort analysis estimates the stock size based on the total estimated catch (in numbers). Once these parameters are obtained, the total weight sampled was obtained by simply multiplying the number sampled within each length class with the corresponding weight of the length class. A raising factor was then established and was achieved by dividing the reported total catches in numbers by the sum of the total weight per length class for the study duration. This factor was then used to determine the estimated number of species that would have been landed based on the distribution pattern obtained from the samples by multiplying the frequencies within each length class with the raising factor. It is therefore necessary that the catch vector is representative for the full stock and CA does not allow length classes larger than Linf. The procedure followed in this study is as described in Taylor & Mildenberger[12].

Here the Thompson and Bell model was used to provide biological reference levels and to deduce input control measures, such as restricting fishing effort. In this study, the fishing mortality for which to estimate the yield and biomass trajectories was obtained by varying the parameter F in the Thompson and Bell model. All analyses were conducted using the TropFishR package in the statistical computing software 'R' (version 3.4.2).

Results

Length composition and weight-length relationship

The length distribution of Sickle pomfret ranged between 37 and 92 cm FL (weight ranged between 2 and 17 kg). About 68 % of individuals had fork lengths ranging from 37 cm to 66 cm (Figs. 2, 3). Size groups dominating the catch ranged from 58 to 76 cm indicating that the catches of this species were dominated by medium sized species. Results indicates highest catch in January and shows that the heaviest fish was caught in January (91 cm, FL; 17 kg, BW). New records of weight and length are observed in this study for Sickle pomfret in FishBase[26].

The parameters for the length-weight regression of Sickle pomfret were 0.047 and 2.73 for *a* and *b*, respectively. The correlation coefficient (r^2) was 0.92 strong enough for this species. The slope "*b*" obtained in this study was significantly different from the isometric value of "3" (t-test, P > 0.05), indicating a negative-allometric growth.

Growth, mortality parameters, and exploitation ratio

Two optimisation methods for growth parameters estimation were used for our analysis: (i) ELEFAN with simulated annealing ("ELEFAN S.A.") and (ii) ELEFAN with a genetic algorithm ("ELEFAN G.A."), the methods all allow to estimate k and Linf simultaneously. These optimisation methods require the same LFQ data list; we compared the performances of both methods using the generated data set.

In this study, to determine the first estimate of Linf for Sickle pomfret, we used the Powell-Wetherall method, which provided a Linf (± standard error) of 93.1 ± 13 cm, as determined by the x-intercept of the regression line. We used this estimate for further analysis with the ELEFAN methods. In reference to the results of the Powell-Wetherall plot, a second search within the range of 93.1 ± 13 cm for Linf is conducted for both methods. The search space of k was limited by 0.1 and 4.

For the first method, ELEFAN S.A., its optimisation procedure gradually reduces the stochasticity of the search process as a function of the decreasing "temperature" value, which shows the probability of tolerating worse situations. ELEFAN S.A. requires that a maximum time (argument 'SA_time') be set; this parameter could affect the results when varying the time (Fig. 4). The stable optimum of the objective function in this study was

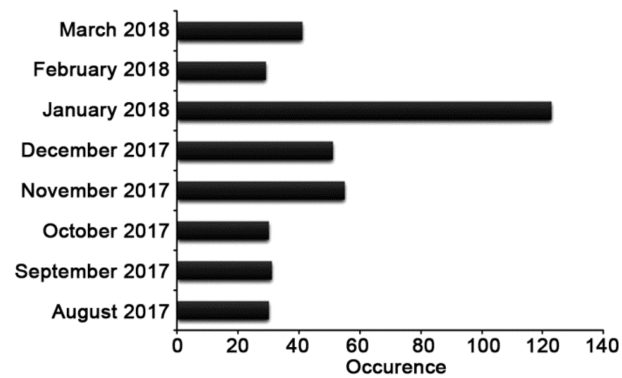

Fig. 2 — Monthly occurrences of sickle pomfret in the west-central and eastern Pacific Ocean

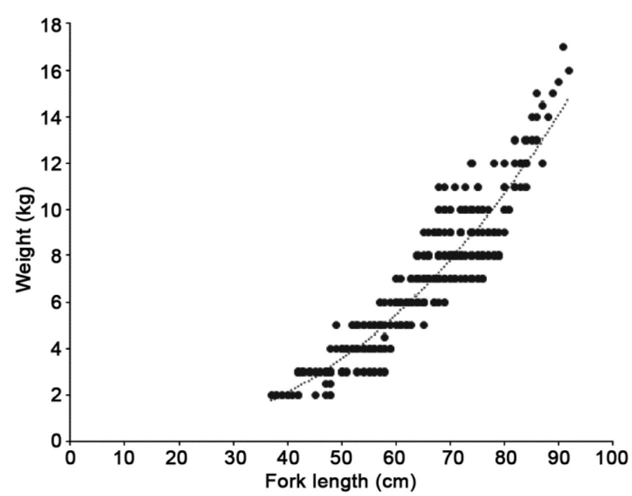

Fig. 3 — Weight-length relationship of sickle pomfret in the west-central and eastern Pacific Ocean

reached when argument 'SA_time' was set to 3 minutes. Results obtained after running both methods are presented in Table 1.

The other optimisation routine ELEFAN G.A. was also used. As with ELEFAN S.A., the initial generations have parameters chosen at random within the defined intervals. Over time, the variability in the parameters gradually decreases becomes more focused on local maxima (Fig. 5). The most important setting is the maximum number of generations, which in this study was set to 100. Results are also presented in Table 1. Our study showed that ELEFAN S.A. had the best goodness of fit, so we used its growth parameters in our subsequent analysis. The fit of the estimated growth parameters could as well be explored visually and the best fit seen through the peaks of the length-frequency data (Fig. 6).

The total mortality rate, '*Z'* estimated from the catch curve incorporated in the model was 1.37 yr^{-1}. The natural mortality '*M'* obtained empirically using ELEFAN S.A. was 0.55 yr^{-1} and the observed fishing mortality rate '*F*' was 0.82 yr^{-1}.

Table 1— Growth parameters and scores obtained from ELEFAN S.A. and ELEFAN G.A.

Parameters	ELEFAN S.A.	ELEFAN G.A.
Asymptotic fork length (cm)	101	97.6
Growth coefficient K (yr-1)	0.52	1.1
ts	0.2	0.35
C	0.75	0.87
Growth performance index (Ø′)	3.72	4
t_anchor	0.73	0.6
Goodness of fit (Rn_max) score	0.46	0.35

Where ts is summer point of oscillation (ts = WP - 0.5) (if seasonalised = TRUE), C the amplitude of growth oscillation (if seasonalised = TRUE), t_anchor the time point anchoring growth curves in year-length coordinate system, corresponds to peak spawning month (ELEFAN S.A. it corresponds to October), Rn_max: highest score value.

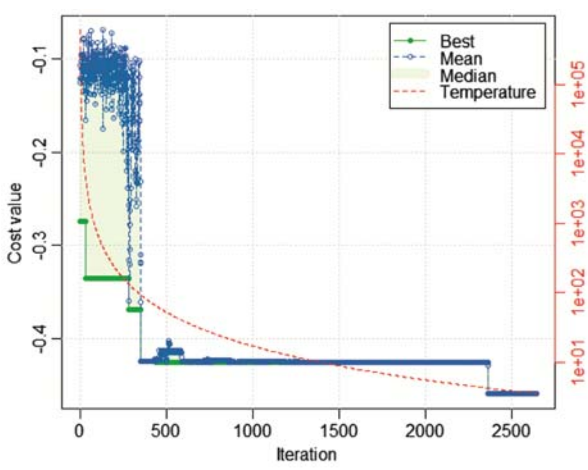

Fig. 4 — ELEFAN method with simulated annealing. Green dots indicate the running minimum value of the cost function, while blue dots indicate the mean score of each iteration. The red line shows the decline of the 'temperature' value, which describes the probability of accepting worse solutions as the parameter space is explored.

Length-at-first maturity (Lm), optimum length (Lopt) and recruitment pattern

In ELEFAN, time is used rather than age, and the point where the growth curve crosses length zero is referred to as the "anchor time" (t_anchor) model[12]. This is interpreted as the time when length equals zero. In this work t_anchor = 0.73, which corresponds October 2017 (Fig. 6). Therefore, in TropFishR, the recruitment pattern of this Sickle pompret's stock was obtained by implementing a backward projection onto

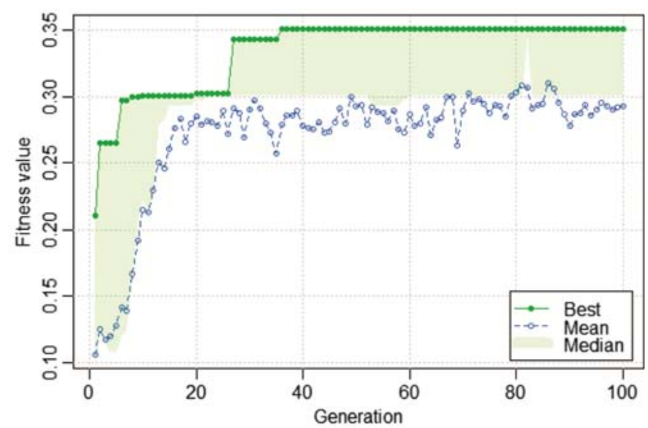

Fig. 5 — ELEFAN method with genetic algorithms. Green dots indicate the running maximum value of the fitness function, while blue dots indicate the mean score of each iteration.

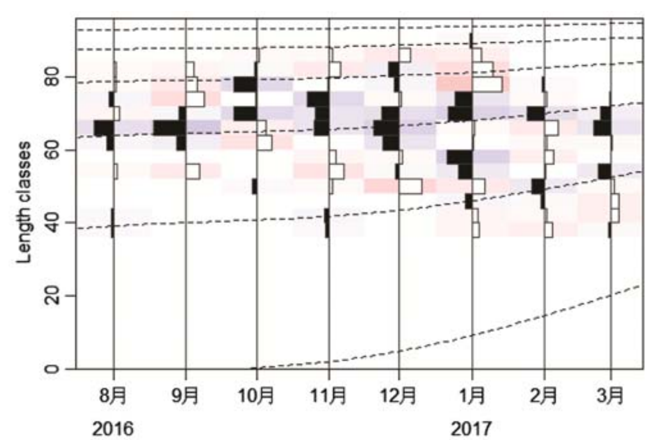

Fig. 6 — Graphical fit of the estimated growth curve plotted using the length frequency data (ELEFAN S.A.)

the length axis of our LFQ data using the seasonalised VBGF[13].

Figure 7, shows that 67 % of sickle pomfret species caught during this fishing operation were immature, just 33 % of species had Lm = 67.5 cm or greater. The optimum length Lopt = 74.3 cm, 13.6 % of species attained this length implying they spawned at least once in their life time; almost 0 % mega-spawner was captured during this fishing operation. TropFishR automatically calculates the maximum age (agemax), in this study agemax was equal to 6 years.

Yield-Per-Recruit (YPR)

Figure 8 depicts the logistic shaped fishing pattern across length classes (red line in CA plot). Fishing mortality was also witnessed throughout all mean size-classes. Length groups from 70-76 cm were more exposed to the fishing gear; fishing mortality rate was higher for this length group.

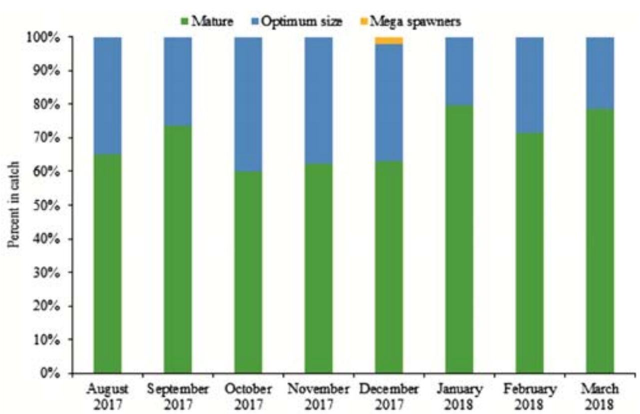

Fig. 7 — Percentages of mature, optimum size and mega spawner of Sickle pomfret caught in the west-central and eastern Pacific Ocean

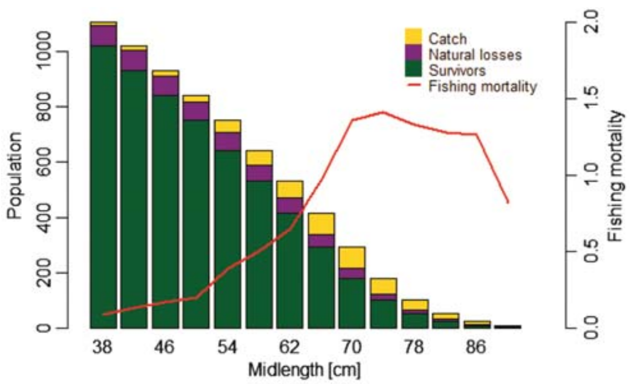

Fig. 8 — Jones' cohort analysis (CA) of sickle pomfret fishery with fishing mortality rate by length classes and resulting reconstructed population structure (survivors, natural losses and catch) in numbers per length class.

Results from Figure 9 show: Biological reference points obtained in this study; Fmsy = 1.7, $F_{0.5}$ = 0.5, Emsy = 0.754, $E_{0.5}$ = 0.475. This result indicates that the fishing mortality (F = 0.82) is lower than the fishing mortality for MSY (F_{MSY} = 1.7), which is confirmed here by an exploitation rate (Ecur = 0.598) lower than Emsy showing the stock is under employed which could be understood since this species are accidental catches. The prediction plot shows that the yield can be increased if 'F' is increased to Fmsy increased. The units are grams per recruit.

Discussion

Length composition and weight-length relationship

Information on the length-structure of a particular fishery is important in developing managing actions aiming at sustainably exploiting fisheries resources. The length-composition of Sickle pomfret specimens perceived in this study represents the catches of length classes observed in the past years; as the length groups of almost all sizes were represented including few small sized species but dominated by medium sized catches. This dominant catch size could confirm the fact that this species was not the main targeted in the longline fisheries in the central eastern Pacific Ocean. The Lmax observed in our study (92 cm, FL) was longer than that reported in FishBase[26].

The smallest Sickle pomfret (37 cm FL, 2 kg BW, n = 2) were caught in January and February and the biggest (92 cm FL, 16 kg BW, n = 1) in December; while the heaviest (91 cm FL, 17 kg BW, n = 1) fish

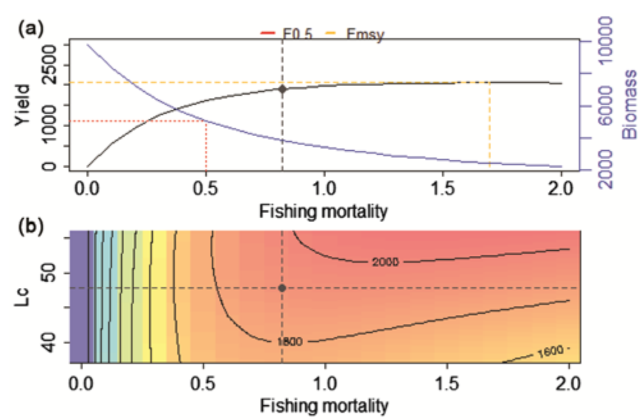

Fig. 9 — Thompson and Bell model: Curves of yield and biomass per recruit. The black dot represents yield and biomass under the current fishing pressure. The yellow and red dashed lines represent fishing mortality for maximum sustainable yield (Fmsy) and fishing mortality to fish the stock at 50 % of the virgin biomass ($F_{0.5}$).

was caught in January. Management of fisheries necessitates information about the species' body weight for the regulation of catches and biomass assessment. The *b* value is species-specific and as a result changes with sex, age, seasons, physiological conditions, growth increment and nutritional status of fish[27]. From the weight-length relationship, parameter "*b*" shows isometric growth in body proportions if $b \sim 3$, and "*a*" is a parameter describing body shape and condition for the same value of '*b*'[9]. Weight-length relationship in Sickle pomfret suggest that the estimated "*b*" value for the population was significantly smaller than the isometric value of 3, $b = 2.73$, showing a negative-allometric growth, meaning that captured Sickle pomprets grew significantly in length than in weight.

Estimation of growth (L_{∞}, K and t_o) and mortality parameters (M, F and Z)

Length-frequency analysis has been used extensively, principally in tropical and subtropical areas. The big advantage of LFQ data is that only a representative subsample of the total catch is required, meaning that not every fish in the catch has to be measured oncethe subsample is random but representative. This approach is very useful in situations where time series data are unavailable and where sophisticated but complicated and expensive methods requiring more data such as aging methods can't be applied due to lack of technical personnel's to carry out these methods or lack of funds for these methods to be implemented[28,29]. According to Zhu[30], the study of growth using length-frequency data analysis has long been the most commonly used approach. TropFishR package has length-frequency data analysis methods, which allows further expansion and flexibility in estimating growth parameters for capacity limited data poor fisheries. Although wider in scope, the main methods follow those outlined in the FAO manual "Introduction to tropical fish stock assessment"[31]. Though length-frequency based analysis are useful for this type of data, interpretation of results obtained from these studies must be considered with caution; if possible, otolith studies should be carried out in order to validate results from indirect methods such as LFQ analysis.

ELEFAN is applied to determine life-history parameters; these parameters are later used as inputs into other models regarding optimal harvest strategies (e.g. yield-per-recruit, YPR; Virtual Population Analysis, VPA)[13]. An advantage of the ELEFAN S.A. and ELEFAN G.A. approaches is their possibilities to estimate all parameters of the seasonalized VBGF (soVBGF) simultaneously (with the additional argument: seasonalized = TRUE). Score value can only be compared relatively (score of simulated annealing is larger indicating better fit than genetic algorithm), and ELEFAN S.A. recorded the highest score value and its growth parameters (Table 1) were therefore used for the rest of the analysis. The growth parameters estimated by ELEFAN S.A. routine and the performance index (Ø′) were as follows: asymptotic length (101 cm), the growth coefficient k (0.52), and the growth performance index Ø′ (3.72). Sparre & Venema[31] stated that the value of k = 1.0 relates to fast growth species, k = 0.5 is medium growth and k = 0.2 is slow growth. The growth coefficient k for this species implies medium growth confirmed by its life span of 6 years obtained in this study. Our study showed strong support for seasonal growth rates (C = 0.75) showing relatively strong seasonality in growth with slowest growth (ts = 0.2) happening in February. Johnson & Swenarton[32] report correlates with our study that strong seasonality in growth are most often correlated with seasonal fluctuations in bottom water temperatures.

The total mortality rate (Z) obtained from the catch curve in this study was 1.37 yr^{-1}. The natural mortality 'M' obtained empirically in this ELEFAN S.A. through the method developed by Then[19] was 0.55 yr^{-1} and F obtained was 0.82 yr^{-1}. When the selection ogive is estimated by means of the catch curve analysis, the hypothesis considered here is that, Z is constant for all length groups, but F and M changes. According, to Sparre & Venema[33] this hypothesis might be true, since in our study F was lower for younger specimens (selectivity) while M was higher (high natural mortality). The reliability of the estimated M was ascertained using the *M/K* ratio because this ratio has been reported to be within the range 1-2.50 for most species[34]. The value of *M/K* ratio was 1.1. The current exploitation ratio (Ecur) from E = F/Z, was 0.59. Few researchers[26] have been conducted for sickle pomprets worldwide, constraining comparisons of these results to other findings of Sickle pomprets.

Length-at-first maturity (Lm), Optimum length (Lopt) and Recruitment pattern

The time when length equals zero in this work (t_anchor = 0.73) corresponds to October (Fig. 6). In

October, recruitment to the fishery started, as revealed from a decreasing number of catches (Fig. 2) and an increasing proportion of specimens resulting to the reduction in mean sizes. Maximum recruitment occurring in January, manifested with rapid increase in catches, in addition to an increase in the proportion of medium-sized specimens. The month of January recorded the highest percentage of matured specimens; captured specimens attained sizes of 67 cm and above, forming part of the reproductive stock in the Pacific and contributing to the next cohort.

Figure 7, shows that 33 % of Sickle pomfret species had attained their first length at maturity, implying they spawned at least once before they were captured by the longline fishing vessels. This shows that most species (more than 65 %) captured during this fishing operation did not spawn even once in their lifetime. Although Sickle pomfret is not a targeted species in the Pacific, measures should at least be taken in order to avoid the catch of species with lengths below the length at first maturity so as to avoid a near collapse of its fishery which also plays a vital role in the ecosystem. The age at first sexual maturity was estimated in this study as 2.47 years while the age at maximum length was agemax = 6 years. This result of agemax differs from the 8 years reported in FishBase[26] by Smith[4]. This variation might be due to different techniques used to estimate ages; so more detailed studies on this species biological information would have to be done in order to confirm its agemax.

Yield-Per-Recruit (YPR)

The results obtained from the Cohort Analysis show that fishing mortality rates changed widely throughout the lifespan if these specimens, as F varied with respect to changes in mean lengths. It could be seen from Figure 9 that the minimum yield for this fishery was obtained at Fmsy (Fishing mortality at maximum sustainable yield) and decreased at F values higher than Fmsy. The stock for this species at the current fishing mortality could be considered sustainable because Fcur was smaller than Fmsy but slightly higher than $F_{0.5}$ (target reference point). This is explained by the occurrence of medium sized species captured at the period they entered the fisheries; and may as well be one of the reasons why some fish species were caught before they could reach their first maturity stage. The YPR analysis revealed that the MSY would be attained using the currently used fishing gear, at an exploitation rate of Emsy = 0.754. The value of Emsy was higher than the present estimated exploitation rate (0.59), indicating sustainable fishery. This can be explained by the fact that this species gets into the longline fisheries as by catches.

Conclusion

Knowledge of a species biological features is essential for producing up-to-date decisions as well as applying effective managing actions. For the first time, we have attempted to evaluate that of the Sickle pomfret *Taractichthys steindachneri* (Döderlein, 1883) from the west-central & eastern Pacific Ocean. This study shows the usefulness of applying LFQ data in TropFishR to estimate growth parameters through optimized ELEFAN methods. Our results indicate that growth of this species can be sensibly modelled through indirect methods (i.e., by using length-frequency data), but reports from this method ought to be viewed with attention as their results may be biased due to uncertainties of used methods. This study show that the stock of Sickle pomfret was not overfished. However, we suggest further biological and stock status analyses be evaluated using long term data in order to better understand the role this species play in the ecosystem.

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