The Validity of Length-frequency Derived Growth Parameters from Commercial Catch Data and Their Application to Stock Assessment of the Yellowtail Snapper (*Ocyurus chrysurus*)

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ABSTRACT

Data on length frequency of the yellowtail snapper (*Ocyurus chrysurus*) from the 1984-85 Puerto Rico commercial catch are used to derive von Bertalanffy growth parameters with the ELEFAN method. The length-frequency derived growth parameters are compared to otolith-based age-derived growth parameters to determine the accuracy of the length-base method. Similarity in resultant growth equations suggest that, although commercial catch data have several biases, reasonable estimations of growth parameters can be made from length frequency data obtained from the commercial catch.

Von Bertalanffy growth parameters from both analyses are used in an abbreviated yield-per-recruit model to examine the effects of length at first capture and exploitation rate on yield per recruit. Similar management strategies are recommended for both length-based and age-based growth models. This methodology would be most effectively applied to species where length-at-age data are not available and allow preliminary management strategies to be developed.

INTRODUCTION

In many instances in the tropics, stock assessment is not available due to the lack of long term data bases and poor data collection. The multi-gear/multi-species nature of tropical fisheries exacerbates all data collection problems. Munro (1983) suggests a data acquisition system for tropical fisheries based on length-frequency data collection rather than the classical catch and effort data for stock assessment. A "scientific" sampling scheme (*i.e.*, not based on commercial catch) would give the most accurate information on the fisheries in this type of system. Unfortunately the cost of routine scientific sampling by fisheries personnel is beyond the meager budgets of most tropical fisheries departments. Thus many fisheries organizations rely on sampling the commercial catch to gather data at the lowest possible cost. Such is the case in Puerto Rico where there is a substantial port agent biostatistical sampling program in operation, but little systematic scientific sampling is presently carried out.

Length-frequency data collected from the commercial catch can be highly biased due to non-random sampling of the catch. Careful sampling of all types of gear throughout the year is necessary to produce reliable data. Also the commercial catch rarely reflects the true population structure due to fishing gear selectivity. Sampling requirements for length-frequency analysis have been recently reviewed by Caddy (1986). Monetary and time limitations determine the reliability of the data in the real world situations. Substantial length-frequency data can be rapidly collected, but confidence in the data can be compromised by poor sampling. This type of data may be rejected for analysis or preliminary analysis can be undertaken with caution. I have taken the length-frequency data obtained for yellowtail snapper (*Ocyurus chrysurus*) from the Puerto Rico commercial catch and analyzed the data for parameters needed in a yield-per-recruit type stock assessment. Yellowtail snapper is a particularly good species to analysis as it is a commercially important food fish throughout the Caribbean and comprises a substantial portion of the demersal fish catch of many islands. In 1986 it ranked sixth in weight landed and fifth in value in the Puerto Rico commercial catch (G. Garcia-Moliner, pers. comm., Commercial Fisheries Laboratory, CODREMAR, Mayagiiez, Puerto Rico). In addition, an aging study has been completed for this species in the area under consideration which allows comparison between the length-derived and age-derived results (Manooch and Drennon, 1987).

METHODS

Beverton and Holt (1964) developed a length-based version of their yield-per-recruit model which needs relatively few input parameters. Gulland (1983) gives the least complex formulation of this equation as:

$$Y' = E(1 - C)^{M/K} \sum_{n=0}^{3} \frac{U\,(1-C)^{n}}{1 + \frac{(n)(K)}{M}\,(1 - E)}$$

where

Y' is the relative yield per recruit (independent of units);

E (= F/M) is the exploitation rate, a measure fishing intensity;

$C(= l_c/L_\infty)$ is the relative size at first capture;

l_c is the length at first capture;

L_∞ is asymptotic length of the von Bertalanffy growth function;

K is the growth coefficient of the von Bertalanffy growth function;

M is instantaneous natural mortality;

Z (= M + F) is instantaneous total mortality;

F is the instantaneous fishing mortality;

U = 1 when n = O;

U = -3 when n = 1;

U = 3 when n = 2;
U = -1 when n = 3.
The von Bertalanffy growth function (VBGF) is expressed as:

$$l_t = L_\infty [1 - e^{-K(t - t_0)}]$$

This type of yield-per-recruit analysis assumes:
1. Constant recruitment.
2. Constant fishing mortality over the fishable lifespan.
3. Knife-edge recruitment and selection.
4. Isometric von Bertalanffy growth.
5. Mortality expressed by a negative exponential curve.

A more extensive version of this model has been used to develop management strategies for other reef fishes in the western Atlantic (Huntsman *et al.*, 1983).

VON BERTALANFFY GROWTH PARAMETERS

Many models have been applied to fish growth (Gulland, 1983), but the VBGF has the advantages of physiological plausibility (Pauly, 1981) and utility in many presently available stock assessment models (Ricker, 1975). The VBGF parameters can be estimated in several ways. The common method is the aging individual fish by growth checks on body hard parts. The relationship between growth with time of the hard part and growth in length (or weight) of the fish can be used to back calculate length at a given age. The back calculated length at age is then fitted to the VBGF equation to estimate the parameters, L_∞ the asymptotic size, K, the growth coefficient, and t_0 time at size zero. For the present analysis t_0 is not needed.

Manooch and Drennon (1987) report the growth of otolith aged yellowtail snapper from the Virgin Islands and Puerto Rico. They provide VBGF parameters based on data from ages 1-17 years. Upon examining the data there was an unusual growth increase in the 17 year old fish which does not properly represent Von Bertalanffy growth. As such, I used the mean back calculated lengths (Manooch and Drennon, 1987) for ages 1-16 to recalculate the VBGF parameters using a nonlinear regression analysis with the Marquardt algorithm run on a IBM PC microcomputer (Saila *et al.*, 1988). This is the same procedure as used by Manooch and Drennon, but only using the mean lengths at age rather than the complete data set. These recalculated parameters were considered the best fit age-derived parameters for this analysis.

Another method of estimating VBGF parameters is the length-frequency based method of ELEFAN (Pauly and David, 1981). This method is less subjective than most length-based methods and fits the VBGF to smoothed modes in the data. I used the October 1986 update, compiled Kiel version of

ELEFAN for the IBM microcomputer (Brey and Pauly, 1986). I summarized the length data by month for 1984 and 1985 combining all gear types (primarily hook and line and trap) into 1 cm size classes (e.g., 20 = 20.0-20.9). Data were collected from fishing ports around Puerto Rico by the biostatistical sampling program of the Commercial Fisheries Laboratory, CODREMAR. As the ELEFAN analysis is sensitive to the number of samples used in analysis I selected only months with more than 100 individuals. According to Munro's (1982) sampling scheme this would only represent a fair sample size. From this subset of months initial parameter estimates were made and then corrected for gear selection and reanalyzed (Pauly, 1984). The selection corrected results were used as the best fit length-derived VBGF parameters.

MORTALITY ESTIMATES

Four methods were used to estimate total mortality (Z): length-converted catch curve, age-length-key catch curve, Beverton and Holt's equation, and Hoening *et al.*'s equation. A length-converted catch curve was obtained from the ELEFAN 2A routine using both age-derived and length-derived VBGF parameters to estimate total mortality (Pauly, 1983). A classical catch curve was derived the age length key supplied by Manooch and Drennon (1987). All length measurements were used in mortality estimation. The number per size class was summarized over the year for 1984 and 1985 then allocated to age categories using the age length key.

Beverton and Holt's (1956) equation

$$Z = K \frac{(L_{\infty} - \bar{l})}{(\bar{l} - l'_c)}$$

where $\bar{l}$ = mean length of fish greater than l'_c

l_c' = the initial length of the first fully recruited size class, in this case the modal size class.

was used to estimate Z, as well as the modified version of Hoening *et al.* (1983) based on modal length

$$Z = \frac{K(\log_e 2)}{Y_m - Y_c}$$

where $Y_m = -\log_e (1 - l_m / L_{\infty})$

$Y_c = -\log_e (1 - l_c' / L_{\infty})$

l_m = modal length of fish greater than l_c'

Natural mortality (M) was estimated from Pauly's (1980) equation as a function of L_{∞}, K, and mean annual water temperature. Fishing mortality (F) was simply determined from the equation, F = Z - M.

The mean length at first capture (l_c) is estimated from the selection curve for length-converted catch curve in ELEFAN 2A using Gulland's formula (Gulland, 1983; Pauly, 1984).

Yield per recruit was contour plotted with E versus C to show the simultaneous changes in yield due to both fishing effort and size at first capture.

RESULTS

The number of yellowtail snapper measured per month ranged from 10 to 542 over 1984-85. In 1984, there were 1770 individuals measured and 1389 in 1985. Fish were primarily taken by hook and line and trap (Figure 1). Only nine months had more than 100 individuals: February 84, March 84, October 84, November 84, December 84, March 85, June 85, September 85, and October 85. These nine months were used in the ELEFAN analysis. Table 1 shows the best fit VBGF parameters for the length-derived and age-derived equations.

Estimates of Z ranged from 0.865 to 1.148 for the length-derived parameters and from 0.566 to 0.727 for age-derived parameters (Table 2). All total mortality estimates decreased from 1984 to 1985.

From a mean annual water temperature of 27.5°C the natural mortality (M) was estimated to be 0.321 for the age-derived equation and 0.437 for the length-derived equation.

Mean length at first capture (l_c) was similar for both methods within each year (Table 2). The length at first capture increased from 1984 to 1985 as Z decreased. Based on the estimates of l_c and L_∞ the relative size at first capture (C) ranged from 0.44 - 0.47 for the length-derived equation and 0.43 - 0.46 for the age-derived equation. The exploitation rate ranges from 0.49 - 0.67 to 0.41 - 0.56 based on the length- and age-derived equations, respectively.

Yield per recruit contour plots are shown for the best fit parameters of length-derived (Figure 2) and age-derived (Figure 3) equations. Since there is only a single estimate of M available for each equation I varied M plus or minus 20% to determine the effect of different values of M on yield. Changes in yield due to different M values are expressed in terms of l_c in Table 3.

DISCUSSION

In this analysis determining the VBGF parameters accurately is paramount to obtaining good results in the stock assessment as the parameters are used throughout the yield-per-recruit analysis. I am using the otolith aging results to validate the length frequency based method assuming the aging method is most accurate. Although the aging of tropical reef fish is not without its problems, many tropical species do not form annular marks on hard parts, and those that do may form more than one mark per year. For example, Claro (1983) found two marks per year on hard parts of yellowtail snapper. He was apparently able to interpret a major mark on the otoliths as annular. Also the results of otolith

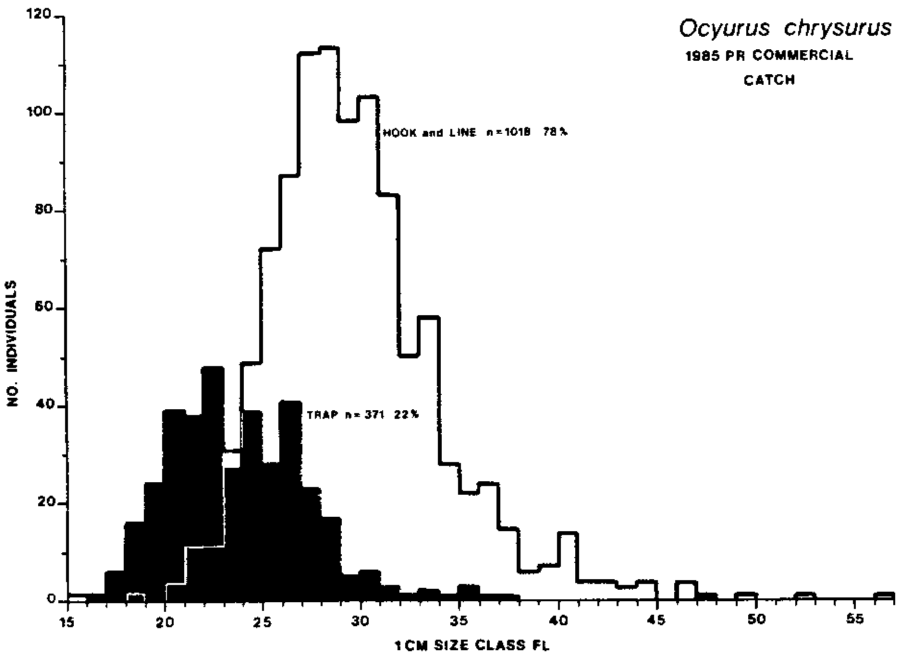

Figure 1. Length-frequency distribution for 1985 Puerto Rico commercial catch separated by gear types.

Table 1. Age-derived (from otoliths) and length-derived (from ELEFAN) von Bertalanffy growth function parameters for yellowtail snapper from Puerto Rico and the Virgin Islands.

	Age Derived*	**Length Derived**
L_∞	54.48	53.42
K	0.1041	0.166
t_0	-1.83	----
M	0.321	0.437

* recalculated from mean back-calculated length for ages 1-16 (data from Manooch and Drennon, 1987).

Table 2. Total mortality estimates and length at first capture for the 1984 and 1985 Puerto Rico commercial catch data.

	1984		**1985**	
	Length Derived	**Age Derived**	**Length Derived**	**Age Derived**
Length-converted catch curve	1.148	0.727	1.051	0.608
l_c	23.53	23.58	25.37	25.20
Beverton & Holt's equation	0.978	0.641	0.824	0.542
Hoening *et al.*'s equation	0.962	0.628	0.865	0.566
Age-length-key catch curve	1.26		1.14	

studies from Puerto Rico-Virgin Islands area are subject to interpretation as the age 17 growth increment is more than double the previous year's growth increment (Manooch and Drennon, 1987). This data hardly fits the expected deceleration in growth predicted by the VBGF at this age. I am not trying to be critical of the otolith growth study, but rather point out that age-based methods have additional problems in the tropical environmental setting (see Manooch, 1987).

Of the two VBGF parameters, L_∞ in the two methods are quite close, but the K parameters diverge somewhat (Figure 4). First, let me compare the two data sets. The age-derived data were collected primarily in the Virgin Islands (only 9.7% from Puerto Rico), whereas the length-derived data were exclusively from Puerto Rico. I have not yet been able to directly compare the two data sets, though the Virgin Islands are believed to have lower fishing pressure and larger fish than the Puerto Rico fisheries. This may be illustrated by the maximum size in the two data sets, 59 cm FL for the V.I. and 56 cm FL for Puerto Rico. If the differences in the two VBGF equation were due to population structure it might be expected that the age-derived data would have a substantially higher L_∞ and

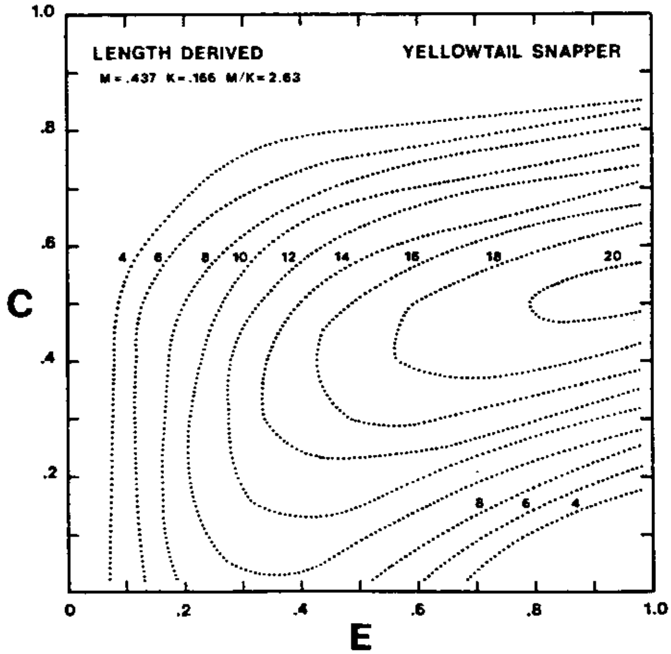

Figure 2. Yield-per-recruit contour plot of exploitation rate (E) versus relative length at first capture (C) for the best length-derived parameters.

lower K. The similarity in L_∞ parameters suggest that there is little effect of the differences in maximum size. The differences in K are more substantial. Although I was unable to directly statistical compare the two estimates, the length-derived K did fall outside the 95% asymptotic confidence limits of the age-derived K based on the mean back-calculated lengths[1]. The differences in K could be due to the different methods used to estimate the VBGF parameters. Length based methods typically have trouble resolving older age classes where there is considerable overlap in size at age and only small differences in size (Manooch, 1987). If the ELEFAN procedure had difficulty resolving older age classes then the maximum age would be underestimated. This would increase the rate at which the fish reaches maximum size, viz. increase K. If the differences in K parameters is strictly due to methodological differences then it can be expected that ELEFAN would overestimate K in most cases. The higher length-derived K results in higher estimates of Z by all methods (Table 2).

[1]If the complete data set would have been used the variance would have been greater increasing the size of the confidence interval and possibly invalidating the difference.

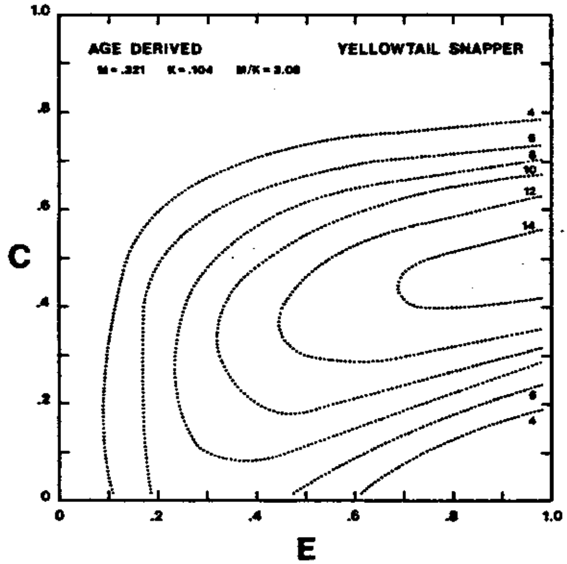

Figure 3. Yield-per-recruit contour plot of exploitation rate (E) versus relative length at first capture (C) for the best age-derived parameters.

Table 3. Optimal size at first capture (1_C) in cm to maximize yield per recruit as a function of exploitation rate (E) and natural mortality (M).

Length-Derived Equation (L_∞ = 53.42)

M	%	E 0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.524	+20	13.36	16.03	18.70	21.37	21.37	24.04	24.04
0.481	+10	14.42	17.63	18.70	21.37	21.37	24.04	24.04
0.437	0	16.03	18.70	21.37	21.37	24.04	24.04	26.71
0.393	-10	16.03	18.70	21.37	24.04	24.04	26.71	26.71
0.350	-20	16.03	18.70	21.37	24.04	26.71	26.71	29.38

Age-Derived Equation (L_∞ = 54.48)

M	%	E 0.2	0.3	0.4	0.5	0.6	0.7	0. 8
0.385	+20	10.90	16.34	16.34	19.07	19.07	21.79	21.79
0.353	+10	13.62	16.34	19.07	19.07	21.79	21.79	24.52
0.321	0	13.62	16.34	19.07	21.79	21.79	24.52	24.52
0.289	-10	16.34	19.04	19.07	21.79	24.52	24.52	27.24
0.257	-20	16.34	19.04	21.79	23.15	24.52	27.24	27.24

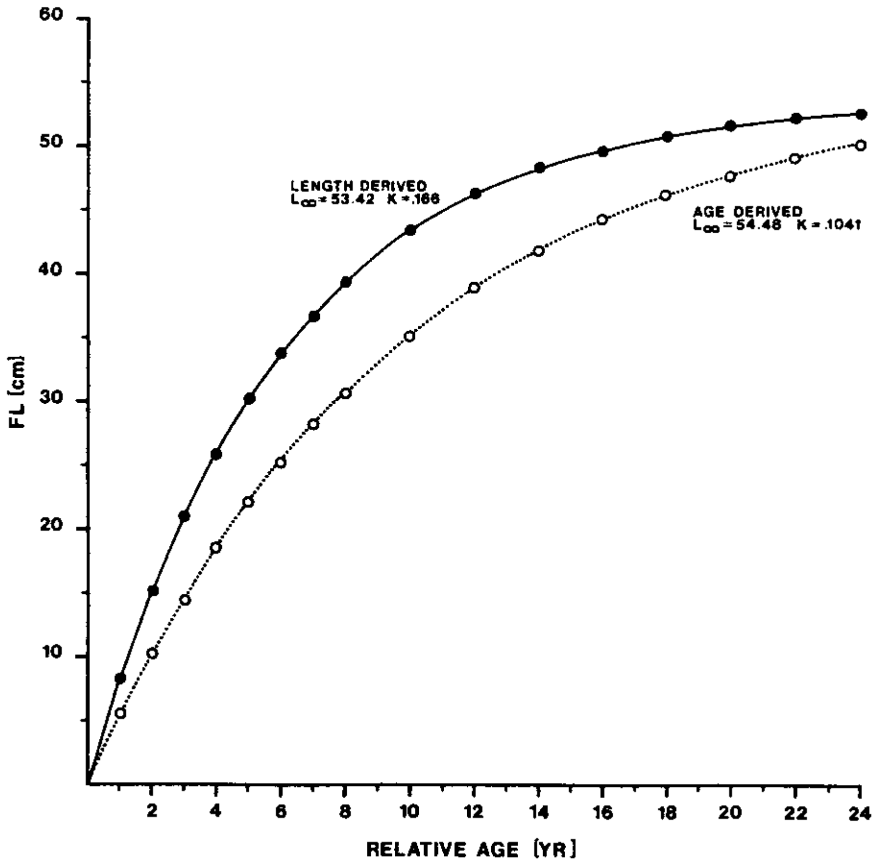

Figure 4. Comparison of length-derived and age-derived von Bertalanffy growth function equations.

The yield-per-recruit results show a higher yield per recruit for the length-derived methods. This is a direct result of the higher M/K ratio from the length-derived parameters. Also, a higher l_c is necessary to maximize the yield in the range of exploitation rate delineated by the length-derived mortality estimates. In general the length-derived parameters indicated a slightly higher exploitation rate (E) with both 1984 and 1985 found to be above 0.5 suggesting overfishing (Pauly and Soriano, 1986). Similar estimates of L_{∞} and l_c for both methods constrain C to similar ranges.

Varying M shows that if M is lower than predicted then l_c will need to be higher to maximize yield. If M is higher than predicted then l_c should be lower to maximize yield. Based on the 1985 estimate of l_c, 25.3, the yield per recruit is lower than optimal. If l_c was maintain at the 1985 level an increase of more double the fishing effort would be needed to result in maximum yield. Maximum yield has been referred to throughout the analysis but a $E_{0.1}$ level analogous to $F_{0.1}$ might be a safer strategy to manage the fishery (Gulland and Boerema, 1973). Pauly and Soriano (1986) give an equation to calculate $E_{0.1}$.

In September 1985 an 8 in TL (17.6 cm FL) size limit was imposed on yellowtail snapper in Puerto Rico and the Virgin Islands federal waters by the Caribbean Fisheries Management Council (CFMC, 1985). This size limit will increase by one inch TL per year to 12 in TL (25.5 cm FL) by September 1989. The imposition (and enforcement) of a size limit directly sets the level of l_c. As can be seen in Figure 1 the trap fishery is most affected by this regulation. The size limit imposed thus far have been below the calculated l_c for the fishery as such would have little effect in improving the state of the fishery until the size limit reaches 11 or 12 in TL (23.6 or 25.5 cm FL). In some ways the fishery may be self-regulating as trap fishermen have tended to move offshore to fish deeper waters over the past several years and yellowtail snapper are larger in size offshore (Kimmel, J., pers. comm., Commercial Fisheries Laboratory, CODREMAR, Mayagüez, PR). This would tend to increase l_c in the fishery. Also, a minimum trap mesh size of 1.25 in (3.175 cm) is now in effect in federal waters surrounding Puerto Rico and the Virgin Islands (CFMC, 1985). This should reduce the chance of decreases in mesh size affecting l_c in the trap fishery.

Other gear types, such as beach seines, may pose future problems for the yellowtail snapper fishery. This gear has increased in effort in recent years and catches many small yellowtail snapper (<20 cm FL) (Garcia-Moliner pers. comm.). Its impact is within the jurisdiction of the commonwealth government of Puerto Rico where no size limit is presently imposed.

In conclusion the length-frequency based method of ELEFAN estimated VBGF parameters similar to those obtained by aging studies. Differences in K were the primary cause of difference throughout the analysis. The final results of yield-per-recruit analysis varied little between the two methods and management recommendations are about the same for both methods. For other species where adequate data exists for ELEFAN analysis but no aging data is available preliminary yield-per-recruit stock assessment could be undertaken with the biases of length-based method taken into account.

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