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POPULATION DYNAMICS AND FISHERY OF SWIMMING CRAB, *PORTUNUS TRITUBERCULATUS* IN THE ZHEJIANG FISHING AREA, EAST CHINA SEA

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ABSTRACT

This study demonstrates dynamics of growth, mortality, exploitation, maximum sustainable yield of swimming crab, *Portunus trituberculatus* in Zhejiang, East China Sea. Using two types of fishery data, one type is the carapace length, width (in mm) and weight (in g) of 3,176 individuals of swimming crab collected by the scientific voyages conducted in 2005-2016. The other is the time series of catch and effort data from 2005 to 2016. The estimated population parameter from twelve-years' pooled data sets were used to estimate year-on-year variation in asymptotic length (L_∞), growth (K), total mortality (Z), fishing mortality (F), natural mortality (M), and biological reference points of F_{limit} and F_{opt}. Time series catch and catch per unit effort data sets (2006-2015) obtained from two fishing methods gill net and crab pot net fishery were used to estimate maximum sustainable yield (MSY) with two surplus production models of Fox and Schaefer. The MSY estimates from Fox model 42.79 tonnes, R^2 =0.85 and Schafer model, 34.12 tonnes, R^2 =0.79. Based on the outputs from two types of fishery data it is delineated that biological reference points of fishing limitation (F_{limit}), optimum fishing level (F_{opt}) and maximum sustainable yield (MSY) from two production models for swimming crab have been overharvest. To overcome current situation recently swimming crab seed was released in Zhoushan coastal area that can augment recruitment and rebuild stocks. The cohesive data sets presented in this communication would increase understanding about crab population traits and can help in implementation of reasonable measures.

Key words: *Portunus trituberculatus*, population dynamics, fishery, biological reference points, Zhejiang waters.

INTRODUCTION

Swimming crabs (Crustacea, Decapoda) are widely distributed circum globally inhabiting in fresh, estuarine and marine water systems (Bowman and Abele, 1982). One species of swimming crab — *Portunus trituberculatus*, is most important fishery resource in Chinese waters and has attained serious attention of the stakeholders to maintain its sustainable exploitation in Zhejiang province. Such attempts have also been made for swimming crab, *Portunus trituberculatus* for restoration and enhancement of the stock in Zhoushan fishing area. The mark-recapture method was applied on the released crabs to follow-up their moment and watch their growth trends in Zhoushan fishing area. By adding recently Wang *et al*. (2017) worked on spawner-recruit (S-R) relationship of swimming crab, and compared survival and reproductive rate of released stock and wild populations. The study found satisfactory soar of both parameters (survival and reproductive rate) for released stock than wild in Zhoushan fishing area.

Length frequency data of single or multiple species is commonly used when age-structure data is difficult to study or unavailable, in these cases length data are useful for stock structuring and produced reasonable outputs that can easily be interpreted (Quinn and Deriso, 1999).

On the times series data (catch and effort), surplus-production models have popularly been known used fish stock assessment (Prager, 1994; Quinn and Deriso, 1999; Prager, 2002) added that surplus-production models have been proven to be very useful in management of fish stocks, because these models are simple and can work on limited data sets such as catch, effort or CPUE (catch per unit effort) data. In addition production models results (MSY (maximum sustainable yield) and E_{msy}(optimum fishing effort)) are easily interpretable. (Hilborn and Walters, 1992) stated that classical production models have often assumed equilibrium conditions, but this is not true in nature phenomenon of fish stocks. Moreover, equilibrium models require only a linear regression which is easily interpretable whereas, non-equilibrium production models require non-linear regression techniques which challenging to implement. The study was intended to evaluate two types of data to evaluate year-on-year variation in asymptotic length, growth, mortality, exploitation and maximum sustainable yield (MSY) of swimming crab. Plus understand status and produce a cohesive guidance for betterment of stocks in Zhejiang, Zhoushan fishing area.

MATERIALS AND METHODS

The length frequency distribution (LFD) data of swimming crab, *Portunustrituberculatus* from 2005 to 2016 were obtained during the scientific voyage conducted in the territorial waters of Zhejiang province, East China Sea (Fig. 1) of the Zhejiang Marine Fisheries Research Institute to determined asymptotic length (L_∞ mm), growth (Kyr^{-1}), and theoretic age when crab length would be '0' denoted as ($t_0$yr) as described by Quinn and Deriso (1999) VGBF

$$L_t = L_\infty (1 - e \quad (-k(t - t_0)))$$

These parameters were estimated with ELFEFAN-1(Electronic Length Frequency Analysis) of the FiSAT. The natural mortality (M) was estimated as Log10 M = 0.0066 – 0.279 log10 L∞ + 0.654 log10 K + 0.4634 log10 T (the average SST = 21 ^{0}C) Pauly (1980). The fishing mortality (F) was estimated with F= Z−M Sparre and Venema (1992). Following length converted catch method described by Pauly's (1980), annual instantaneous total mortality was calculated as $\ln(N_i / \Delta t_i) = a + b^* t_i$. (Ni = length class *i*, Δt_i= time required for growth of length class *i*. t_i = relative age, describes as t_0 = 0 corresponds to the intermediate length of swimming crab class *i*. and a, b = intercept and slope estimates total mortality Pauly (1980). The exploitation ratio (E) Gulland (1971) was obtained as

$$E = \frac{F}{Z}$$

Following method of Gulland (1969) biological reference points BRP of F_{limit} and F_{opt} were estimated for swimming crab.

The Virtual Population Analysis described by Sparre and Venema (1992) was conducted with input values of carapace length and body weight, growth and mortality estimates to outline fishing mortalities per length class at t_0 value equals (0).

The maximum sustainable yield (MSY) of swimming crab was also described with production models of Fox and Schaefer applied on the time series data sets from 2006-2015 acquired from the Zhejiang provincial government records.

Fox Surplus production model is described with
$Y(i)/f(i) = c \times \exp(d \times f(i))$ Fox (1970)

Description of the model: This model gives a curved line when Y/f is plotted directly on effort (f) and a straight line when the logarithms of Y/f are plotted on effort (f).

Schaefer Surplus production model estimated with
$Y(i)/f(i) = a + b \times f(i)$ Schaefer (1957)

Description of the model: The slope (b) must be (-) if the catch per unit of effort (CPUE), Y/f decreases for increasing effort (f). The intercept (a) is the Y/f value attained just after the first boat catch of swimming crabs on the stock for the first time. The intercept therefore must be (+). Thus, -a/b is (+) and Y/f is zero for (f) = -a/b. Since a (-) value of CPUE Y/f is ridiculous, the model only applies to f-values lower than -a/b.Both models Fox and Schafer are based on the assumption that if Y/f declines as effort increases, but they differ in the sense that the Schaefer model implies one effort level for which Y/f equals zero, namely when f = -a/b whereas in the Fox model, Y/f is greater than (0) for all values of (f).

RESULTS

Length frequency data (LFD) of 3176 individuals of swimming crab, *Portunus trituberculatus*were measured to carapace length, width (in mm) and weight (in g) were taken for each individual. The distribution of each size class was set at 10 mm intervals (Fig. 2). The LDF data sets from 2005-2016 were used to estimate parameters of growth, mortality, exploitation and biological reference point (Table 1). The estimated population parameter from twelve year pooled data sets were 265 mm, 0.29 yr^{-1}, 1.66 yr^{-1}, 1.25 yr^{-1}, 0.39 yr^{-1}, 0.88 yr^{-1}, 0.65 yr^{-1} for asymptotic length (L_∞), growth (K), total mortality (Z), fishing mortality (F), natural mortality (M), and biological reference points of F_{limit} and F_{opt} respectively (Table 1, Fig. 3). The swimming crab growth found to be slow and value of mortality and exploitation demonstrates that stock of swimming crab have been over harvested in the ECS area. Mortality was also tested with virtual population analysis (Table 1, Fig. 4). The length of the high fishing mortality was observed in 260 to 310 mm range for both sexes, while in male from 200 to 250 mm and 270 and 310 mm in females. The growth patterns from 2005-2016 describes insignificant variation in growth rate, however, significant changes in fishing mortality are represented (Fig. 3).

A part from this study maximum sustainable yield (MSY) was also calculated with two production models of Fox and Schaefer using time series catch and effort data from 2006 to 2015 obtained from the Zhejiang provincial Government book logs. Estimation of maximum sustainable yield from crab pot fishing gears for surplus production model of Fox (MSY = 42.79 tones, R^2 =0.85) and Schafer production model (MSY =34.12 tones, R^2 =0.79) respectively, whereas gill net estimation of maximum sustainable are presented in (Table 2, Fig. 5, 6).

Table 1. Summary of population paramters estiamted for swimming crab based on length frequency data (2005−2016) (confidence intervals of total mortalities are indicated in parenthesis)

Year	Asymptotic length mm	Growth (K)	Goodness of fit (score)	Natural Mortality (M)	Fishing Mortality (F)	Total Mortality (Z)	F_{limit}	F_{opt}
Pooled twelve year data	265	0.29	1.00	0.39	1.25	1.25	0.83	0.62
2005	162	0.62	1.00	0.73	0.67	1.4 (-2.59−5.39)		
2006	173	0.57	1.00	0.68	0.46	1.14 (0.83−1.45)		
2007	157	0.39	0.87	0.54	0.13	0.67 (0.36−0.99)		
2008	173	0.39	0.46	0.53	0.6	1.13 (0.81−1.45)		
2009	173	0.63	1.00	0.72	0.84	1.56 (1.01−2.11)		
2010	236	0.81	0.87	0.81	1.66	2.47 (1.59−3.39)		
2011	257	0.34	0.58	0.43	0.71	1.14 0.86−1.41		
2012	163	0.48	1.00	0.4	0.6	1 (0.86−2.85)		
2013	264	0.32	1.00	0.332	1.27	1.07−2.12		
2014	138	0.49	0.88	0.65	1.70	1.28−3.14		
2015	239	0.46	0.65	0.54	1.35	1.29−2.48 0.99		
2016	201	0.44	0.763	0.536	0.454	(0.85-1.14)		

Table 2. MSY outputs from two surplus production models of Fox and Schafer using gillnet and crab pot fishing methods in the Zhejiang provincial fishery territorial waters

Gill nets fishery 2006-2016			
Model	**Fox**	**Schaefer**	**Average**
MSY ($X10^4$ tons)	11.64	15.89	12.03
Catch effort ($X10^6$ nets)	17.27	23.91	20.59
Number of corresponding standardized vessels	1727	2391	2059
Crab pots fishery 2000-2015			
MSY ($X10^4$ tons)	11	9.83	10.5
Catch effort ($X10^4$ crab pots)	624	642	633
Number of corresponding standardized vessels	734	755	745

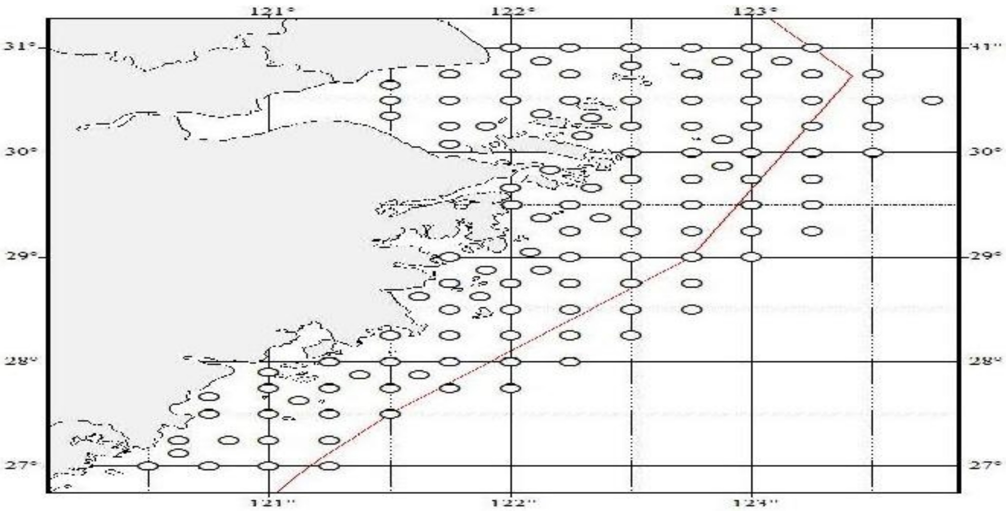

Figure 1. Sampling locations scattered over entire boundaries of the Zhejiang provincial waters, East China Sea, 2013-2017.

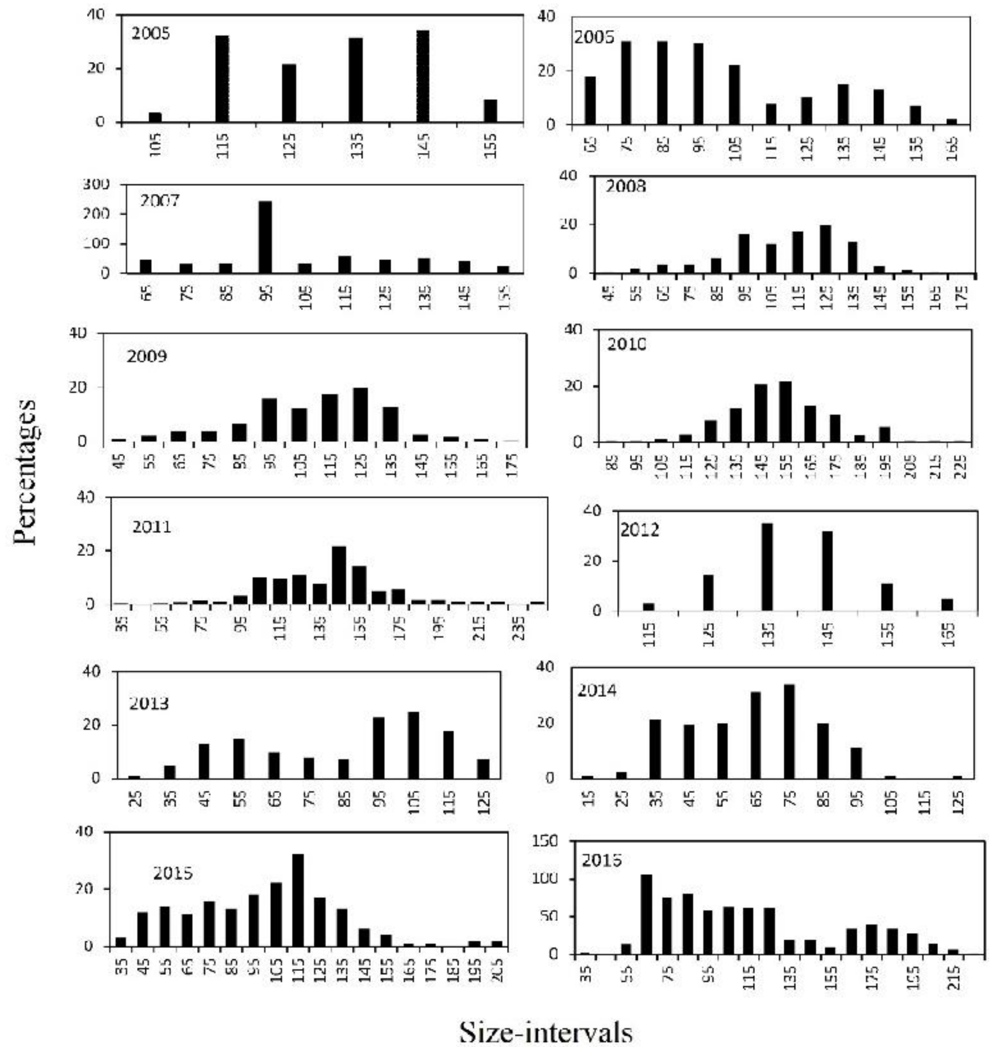

Figure 2. Length frequency distribution of the sampled population of swimming crab from 2006-2016 in fishery surveys made in the Zhejiang territorial waters.

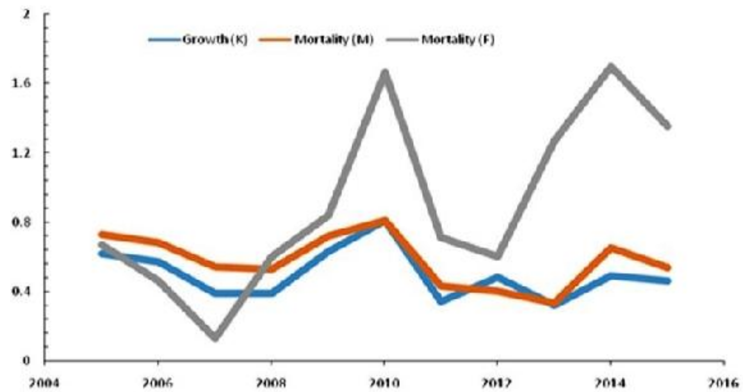

Figure 3. Patterns of growth, natural mortality (M) and fishing mortality (F) estimated from 2005-2016 estimated for swimming crab in the East China Sea area.

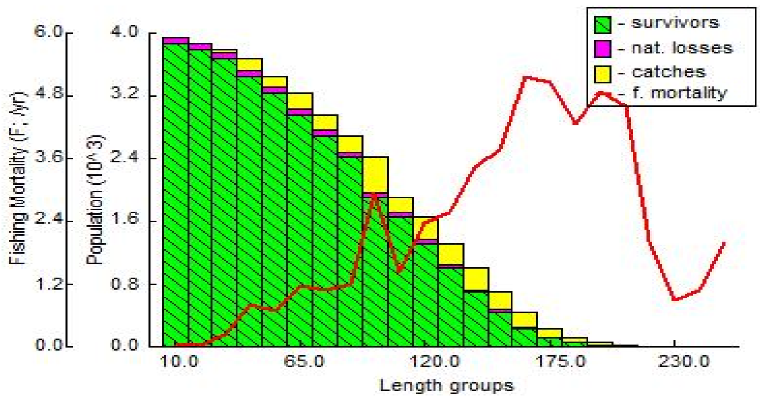

Figure 4. Virtual population analysis (VPA) counter map estimated for swimming crab applying LFD sets from 2005-2016.

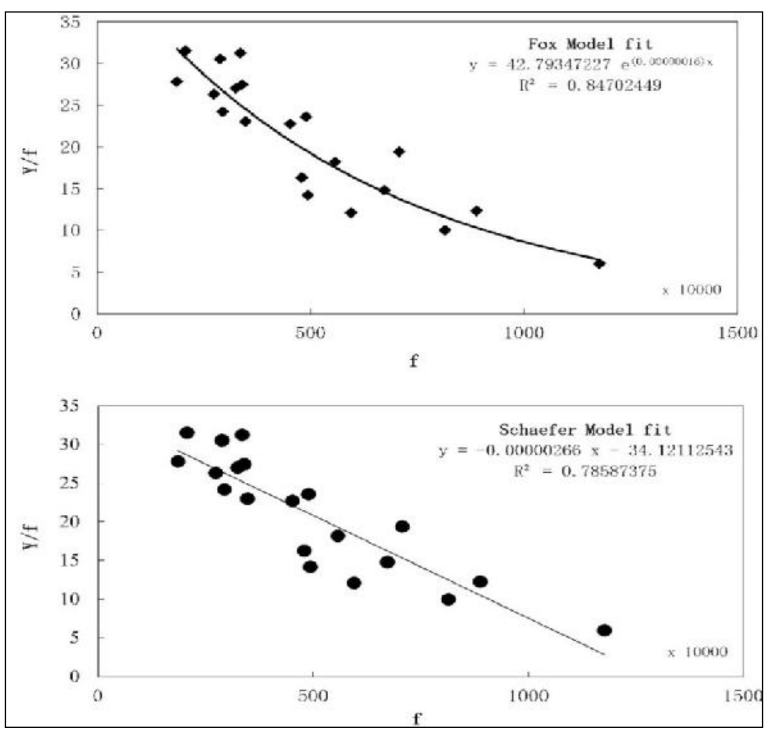

Figure 5. Curve fitting on crab pot data sets, two production model Fox and Schafer from 2006-2015.

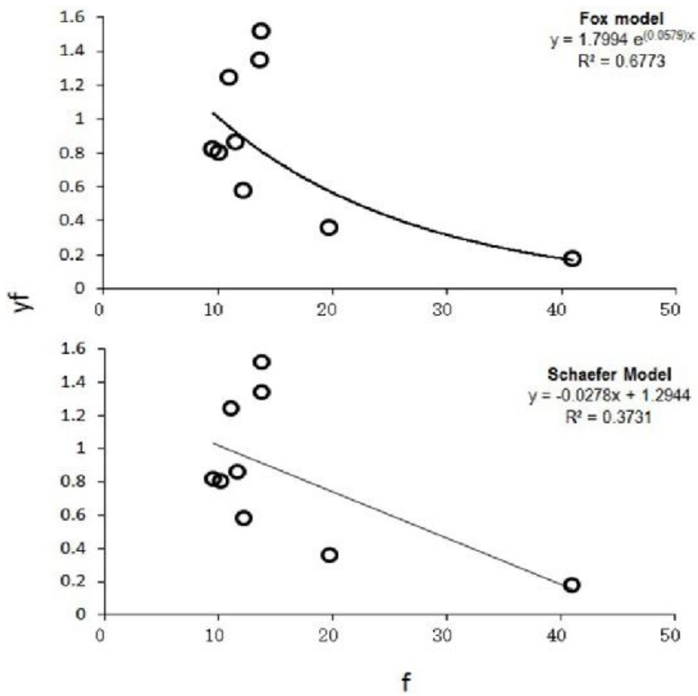

Figure 6. Curve fitting for two surplus production model Fox and Schafer on the time series data collected with gill nets from 2006-2015.

DISCUSSION

Considering dynamics and sustainability of swimming crab, *Portunus trituberculatus*, integrated data sets of length frequency, gill net and crab pots fishery demonstrates that population of swimming crab have been targeted beyond the safe limitations in Zhejiang provincial waters. Study growth rate is a common method to understand health of individual organism or entire populations, the growth pattern of *P. trituberculatus* indicates slow growth traits whereas growth in 2005, 2006, 2009 and 2010 was relatively higher, this growth increase was may be implementation of conservation strategies by the government. The mortalities, natural and fishing are important parameters to know rate of decomposition of wild aquatic animal population by mean of human made activates or natural disastrous Sparre and Venema (1992). Moreover, about natural mortality Quinn and Deriso (1999) added that direct assessment of natural mortality of stock is challenging for exploited stocks. In this study, in contrasts of the natural mortalities, fishing mortality was higher that describes overharvest of stocks. Further, overharvest was validated with the estimation of biological reference points e.g. F_{limit} and F_{opt}that exceeded optimum level of (0.5), this target level was proposed by Gulland (1971). For conservation and management purpose biological reference point is considered as terminal point that is composed by various biological parameters such as growth rate, mortalities and exploitation, that give clue for standing stocks and future perspectives for reasonable decision to framework for conservation of wild stocks Patterson (1992). The virtual population analysis (VPA) was conducted with input values of length, growth and mortality estimates to outline fishing mortalities per length class considering t_0 value equals (0) Sparre and Venema (1992) indicated target size was 175-230 mm shell size**.** Yielded estimates of maximum sustainable yield (MSY) from two surplus production model validate overharvest of the crab stocks in the East China Sea (Zhejiang) fishing area. The simple surplus production models e.g. Fox and Schafer required limited data sets such as catch, effort or catch per unit effort data, their use and interpretation is easy and can be useful for fisheries management strategy. Maximum sustainable yield (MSY) is considered as the target biological reference point based on the assumption that, if surplus production is > than catch, mean population size increases; if catch equals surplus production, catch is sustainable and population size remains constant; if catch is >than surplus production, population size declines. In addition, factors such as environmental can affect those species which they interact. In the modern world mechanization of fishing vessels resulted severe threats to aquatic resources and caused overharvesting of the wild fish stocks. Generally, to frame work for a comprehensive management strategy for any fish/shellfish stock requires retort about what data are collected, how they are analyzed and finally interpretation and suggestions for management strategy? Maximum sustainable yield (biological reference point) considered as indicator of fish population exploitation in surplus production models (Hilborn and Walters, 1992; Prager, 2002; Panhwar *et al*., 2012a). Moreover, (Panhwar *et al*., 2012b) described that production models depend on the assumption that CPUE data can reliably quantify the temporal variability in population abundance, the modeling outputs would be wrong if such an assumption is inappropriate.

Conclusion: Based on the outputs of this study it is concluded that stocks of swimming crab, *Portunus trituberculatus*have been exploited beyond the sustainable level in the ECS area. It is hoped that our finding would contributed scientific profile of the crab fishery to framework conservation of an important resource in the area.

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