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STOCK STATUS, BIOLOGICAL REFERENCE POINT AND MANAGEMENT IMPLICATIONS OF PAINTED SPINY LOBSTER (*Panulirus versicolor* Latreille, 1804) IN WEST PAPUA WATERS

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ABSTRACT

As the main target species with high economic value, painted spiny lobster (P. versicolor) is highly vulnerable to fishing impacts. The study on stock status and biological reference points are needed to develop management strategies for sustainable lobster fisheries in West Papua. This research aimed to understand the stock status, obtain the biological reference points, and set the management tools for *P. versicolor* fisheries in West Papua. The length-based assessment of *P. versicolor* stock has been conducted to obtain the life history parameters and analyze the yield per recruit and spawning potential ratio. The growth overfishing has occurred based on the current length at selectivity of P. versicolor, which is lower than the optimal selectivity. The indication of recruitment overfishing has been found based on the current fishing mortality, which exceeds 24% of reference point $F_{40\%}$. A reduction of 24% from current fishing mortality and the minimum legal size of 83 mm are needed to obtain the optimal yield in sustainable conditions.

Keywords: Growth overfishing; length-based assessment; recruitment overfishing

INTRODUCTION

West Papua Waters has a large area of coral reef, which is very important as permanent habitat for some commercial fish resources, including coral fishes and lobsters. The most common lobster in West Papua Waters was from *Palinuridae* family with dominant species of painted spiny lobster (*Panulirus versicolor*) and ornate spiny lobster (*Panulirus ornatus*). The local fishers conduct lobster fishing activities in this area, producing 1,789 tons in 2016 (DGCF, 2017). Its production was distributed to some other regions in Indonesia and exported to other countries as luxurious seafood. Hence, the lobster fisheries are coastal fisheries as the main livelihood for local fishers in West Papua Waters. It significantly contributed to the economy of some fishing businesses in Indonesia.

Lobster fisheries in West Papua Waters need proper management to maintain the stock sustainability and obtain the optimum yield for the local fishers. Lack of management will lead to stock depletion, and lobster is vulnerable to the fishing impacts due to its limited distribution and high economic values. Some studies have reported the overfishing condition for lobster fisheries due to a lack of management systems (Ernawati *et al*., 2019; Saputra, 2011; Thangaraja *et al*., 2015). The study on stock status and some biological reference points are critical parameters for developing management tools.

Length-based assessment is one of the standard methods in stock assessment that can be used in data-limited situations. Tirtadanu & Yusuf (2018) reported that the stock status of ornate spiny lobster (*Panulirus ornatus*) in West Papua waters was still in optimal condition. The stock status for painted spiny lobster (*Panulirus versicolor*) as a dominant catch in West Papua Waters has not been reported yet. The yield per recruit and spawning stock biomass per recruit analysis can be used to study the stock status and biological reference points (Beverton & Holt, 1957; Sparre & Venema, 1992). This study applied the length-based assessment to detect the level of growth overfishing and recruitment overfishing based on the current fishing mortality and size at first capture. The objectives of this study were to understand the stock status, to determine the biological reference points, and to develop management tools for painted spiny lobster (*P. versicolor*) in West Papua Waters.

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MATERIALS AND METHODS

Materials

The scope area was in West Papua Waters, and the fishing grounds were common in the coastal of Misool, Salawati, Sorong, and Raja Ampat waters (Figure 1). Lobsters were captured by gillnet vessels. The fishers used 3 GT of wood vessels with 2 to 3 crews and used a mesh size of 4 inches for gillnet. The length and weight data of painted spiny lobster (*Panulirus versicolor*) were collected from May to October 2,015 and from January to June 2,016. The carapace length was used as length data for painted spiny lobster.

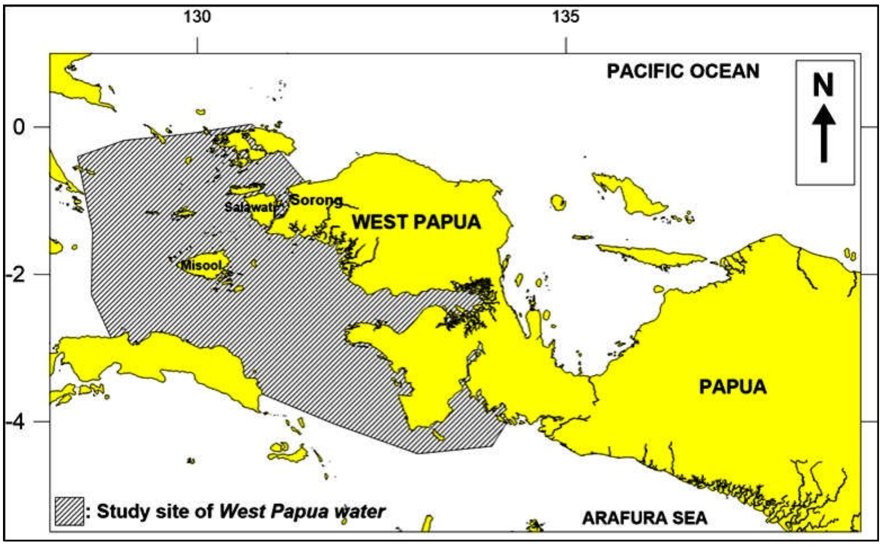

Figure 1. Scope area of lobster fisheries in surrounding West Papua Waters.

Methods

Population Parameters

The length-based assessment was used to estimate the population parameters, yield per recruit, and spawning potential ratio of painted spiny lobster (*P. versicolor*). The modal progression analysis was used to estimate the growth parameters following Von Bertalanffy growth model (Sparre & Venema, 1992):

$$L_t = L\infty\left[1 - e^{-K\left(t-t_0\right)}\right] \quad \text{..............................(1)}$$

Where L_t is the carapace length at age t, L_∞ is the asymptotic carapace length of lobster, K is growth rate (year^{-1}), and t_0 is the point in time when the lobster has zero length.

The length-weight relationship was analyzed by the equation (Ricker, 1975) :

$W=aL^b$ ....(2)

Where a is a constant, b is coefficient of growth, L is carapace length (mm), and W is the weight of lobsters (gr). The 95% confidence interval of b was estimated based on Sparre & Venema (1992).

The mortality parameters included total mortality (Z), natural mortality (M), and fishing mortality (F). The natural mortality (M) was estimated based on Zhang & Megrey (2006) :

$$M = \frac{\beta K}{e^{K(Ci.t\max - to)} - 1} \quad \text{..................................(3)}$$

Where M is the natural mortality. C_i is 0.440, which considered lobster as a demersal fishery (Zhang & Megrey, 2006). K is the growth rate, t_0 is theoretical age when the lobster has zero length, t_{max} is maximum age, and â is the coefficient growth from the length-weight relationship. Total mortality (Z) was estimated from the linearized length-converted catch curve, and the fishing mortality was obtained from the difference between the total mortality and natural mortality (Sparre & Venema 1992).

The logistic model was used to estimate the length at selectivity (Sparre & Venema 1992; King, 1995). The length at first maturity of *P. versicolor* was estimated based on its relationship with the asymptotic length using equation Froese & Binohlan (2000) :

$Log10Lm = 0.8979 * log10L_\infty - 0.0782$ .... (4)

Where Lm is the length at first maturity and L_∞ is the asymptotic length.

Biological Reference Points

The yield per recruit analysis was used to estimate the biological reference point of Fmax as the fishing mortality, which gives maximum yield per recruit, and F0.1 as the fishing mortality of 10% slope of yield per recruit. The yield per recruit analysis was used based on the Beverton & Holt (1957) equation:

$$\frac{Y}{R} = F\left(\alpha L\infty^{\beta}\right)\left[\frac{L\infty - Ls}{L\infty}\right]^{\frac{M}{K}}\left[\frac{L\infty - Lr}{L\infty}\right]^{\frac{M}{K}}\Sigma_{n=0}^{3}\frac{U_n\left[\frac{L\infty - Ls}{L\infty}\right]}{F + M + nK} \quad .....(5)$$

Where Y/R is the yield per recruit, a and b are the constants from the length-weight relationship, F is the fishing mortality, L8 is the asymptotic length, Ls is the length at selectivity (gillnet selectivity), M is natural mortality, and K is the growth rate. Un includes U0=1, U_1=-3, and U_3=-1.

The spawning potential ratio was used to measure the impact of fishing to the potential productivity of stock (Goodyear, 1993). It can determine the target reference point of fishing mortality, which gives a 40% spawning potential ratio (F40%) (Hordyk *et al*., 2015; Hordyk *et al*., 2016; Goodyear, 1993). The spawning potential ratio was considered as the ratio of the spawning stock biomass per recruit ($SSBR_{fished}$) in the exploited stock with the spawning stock biomass per recruit in the absence of fishing ($SSBR_{unfished}$):

$$SPR = \frac{SSBR_{fished}}{SSBR_{unfished}} \quad .... (6)$$

RESULTS AND DISCUSSION
Results

Growth Parameters

The mid-length of painted spiny lobster (P. versicolor) in West Papua Waters ranges from 42.5 mm to 122.5 mm (Figure 2). The mean size was 83.13 ± 0.68 mm. The asymptotic length (L8) and growth rate (K) were estimated as 128.63 mm and 0.57 year-1, respectively. The theoretical age when lobster has zero length (t0) was -0.059 years, so the Von Bertalanffy growth was following the formula Lt=128.63(1-$e^{0.57(t+0.05942)}$).

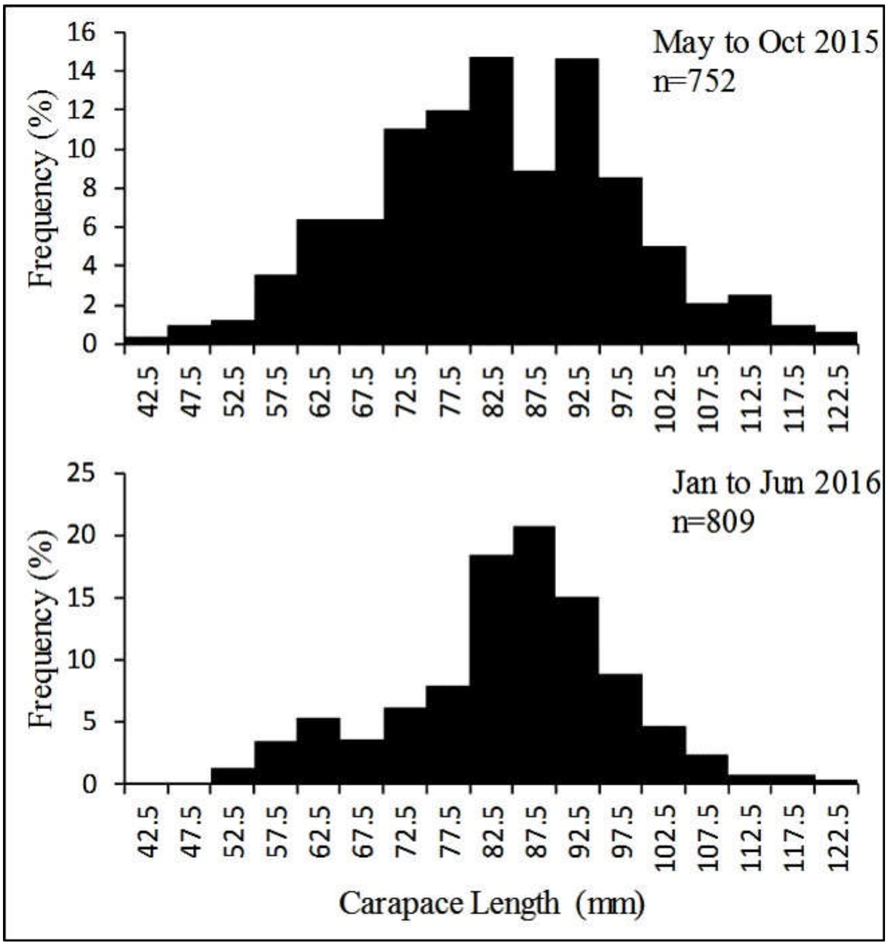

Figure 2. Length-frequency of painted spiny lobster (*P. versicolor*) in West Papua Waters, 2015-2016.

The weight of P. versicolor captured was from 100 gr to 1,820 gr, while the mean weight was 671.99 ± 10.24 gr. The combined length-weight relationship showed the negative allometry pattern (b<3) with the coefficient of growth (b) 2.69 (Table 1). The monthly length-weight relationship showed a varied growth coefficient from 2.39 to 3.04. The coefficient of growth for P. versicolor from June to October 2015 and June 2016 was lower than May 2015 and January to May 2016. The lowest coefficient of growth was found in July 2015 (b=2.39).

Table 1. Length-weight relationship of painted spiny lobster (*P. versicolor*) in West Papua Waters.

Months	n	a	b	R^2	95% CoI of b	
					Lower	Upper
May 2015	94	0.0012	2.94	0.91	2.74	3.14
Jun 2015	190	0.0039	2.64	0.77	2.44	2.85
Jul 2015	140	0.0138	2.39	0.76	2.17	2.61
Aug 2015	80	0.0084	2.49	0.91	2.31	2.68
Sep 2015	82	0.0067	2.56	0.90	2.38	2.75
Oct 2015	163	0.0112	2.45	0.88	2.31	2.58
Jan 2016	163	0.0009	3.04	0.83	2.82	3.26
Feb 2016	138	0.0019	2.87	0.83	2.65	3.09
Mar 2016	184	0.0023	2.81	0.93	2.69	2.92
Apr 2016	130	0.0017	2.88	0.97	2.79	2.97
May 2016	162	0.0026	2.78	0.93	2.66	2.90
Jun 2016	19	0.0041	2.68	0.96	2.41	2.95
Combined	1545	0.0038	2.6908	0.8703	2.64	2.74

Mortality Parameters

The total mortality (Z) was 1.90 year-1 (Figure 3). The fishing mortality (F) was higher than the natural mortality (M). The natural mortality and the fishing mortality were 0.58 year-1 and 1.32 year-1. The exploitation rate was 0.69. The age at first capture based on the catch curve analysis was before the age of 2 years.

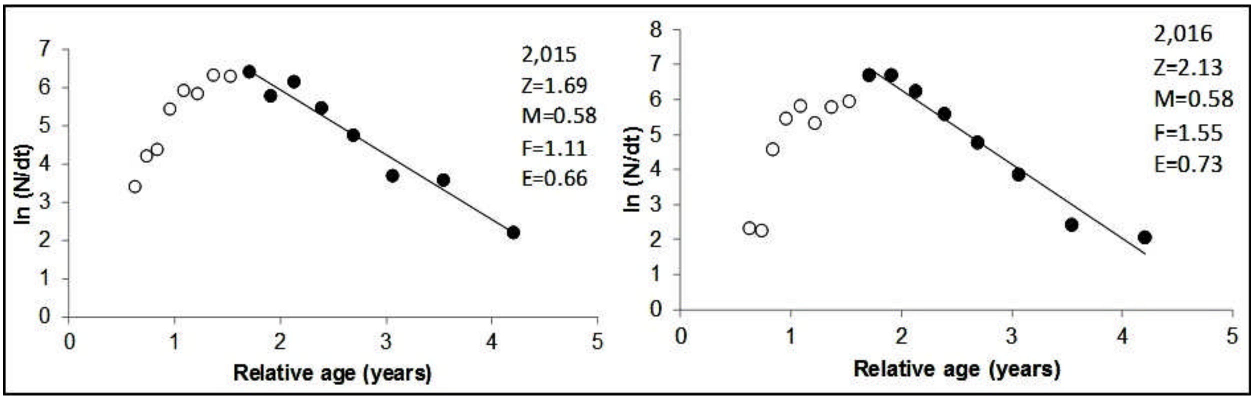

Figure 3. Length-converted catch curve of painted spiny lobster (*P. versicolor*) in West Papua Waters, 2,015 and 2,016.

Biological Reference Points

The yield per recruit analysis and spawning potential ratio was used to estimate the biological reference points of P. versicolor in West Papua Waters. The life history parameters are needed as input to estimate the yield per recruit and spawning potential ratio (Table 2). The length at selectivity (Ls50) for P. versicolor were determined as 73 mm in 2015 and 79 mm in 2016, and the length at first maturity (Lm50) was 65 mm.

Table 2. Input parameters of yield per recruit analysis and spawning potential ratio for painted spiny lobster (*P. versicolor*) in West Papua Waters

Parameters	Note	Values	Units
L_∞	Asymptotic length	128.63	mm
K	Growth rate	0.57	year^{-1}
M	Natural mortality	0.58	year^{-1}
Ls_{50} (2015)	Length at 50% selectivity in 2015	73	mm
Ls_{50} (2016)	Length at 50% selectivity in 2016	79	mm
Ls_{95} (2015)	Length at 95% selectivity in 2015	90	mm
Ls_{95} (2016)	Length at 95% selectivity in 2016	90	mm
Lr	Length at recruitment	42	mm
Lm_{50}	Length at first maturity	65	mm
Lm_{95}	Length at 95% maturity	85	mm
a	intercept of LW relationship	0.00377	
b	Coeffient of growth	0.58	
F_{2015}	Fishing mortality in 2015	1.11	year^{-1}
F_{2016}	Fishing mortality in 2016	1.55	year^{-1}
t_0	age at zero length	-0.0605	year

The yield per recruit in 2,015 and 2,016 were 250.98 gr recruit-1 and 258.02 gr recruit-1, respectively. The selectivity in 2015 (73 mm) and 2016 (86 mm) were lower than the selectivity which can give the maximum point of yield per recruit. By increasing the selectivity to 83 mm in 2015 (Lsmax(2015)) and 86 mm in 2016 (Lsmax(2016)), the maximum yield per recruit can be reached as 258.02 gr recruit-1 in 2015 and 262.47 gr recruit-1 in 2016 (Figure 4). The fishing mortality in 2015 (F2015=1.11) and 2016 (F2016=1.55) were larger than the refence point of F0.1 (F0.1(2015)=0.58; F0.1(2016)=0.65) (Table 3).

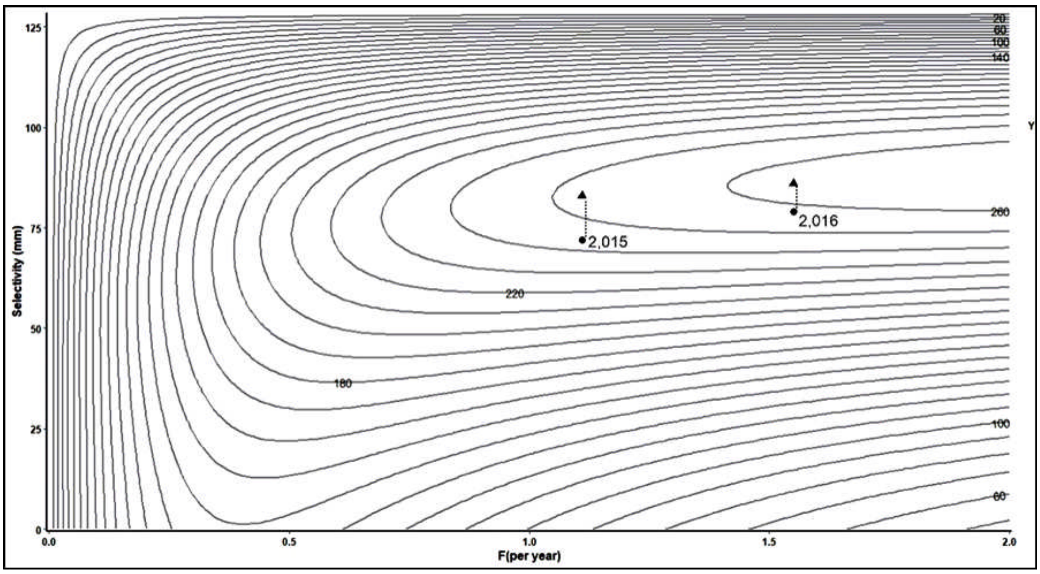

Figure 4. Isopleth of yield per recruit as a function of length at capture and fishing mortality for painted spiny lobster (*P. versicolor*) in West Papua Waters. The circle dot is the current condition. The triangular dots are the length at selectivity, which gives the most significant yield per recruit (Ls_{max}).

The current spawning potential ratio for P. versicolor in West Papua Waters (SPR2015=35.1%; SPR2016=35.4%) were lower than the 40% spawning potential ratio (Figure 5). The fishing mortality, which remains 40% spawning potential ratio (F40%), were 0.87 year-1 in 2015 and 1.17 year-1 in 2016. The current fishing mortality (F2016=1.55) was 24% higher than F40% (F40%(2016)=1.17). At the current fishing mortality, the remaining 40% SPR can be reached at selectivity (Lc40%) of 86 mm. The current selectivity (Ls2016=79 mm) is lower than the selectivity, which gives 40% SPR (Ls40%(2016)=86 mm).

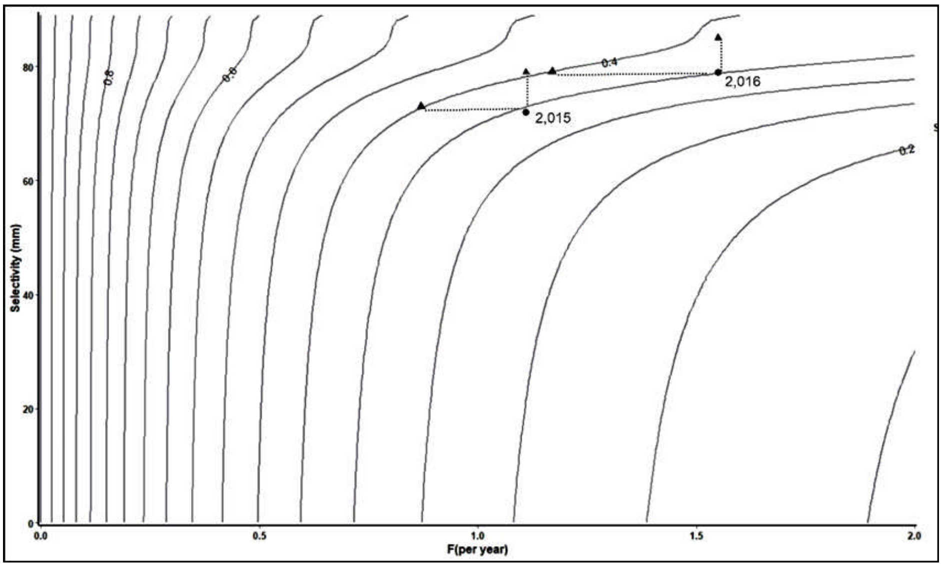

Figure 5. Isopleth of spawning potential ratio (SPR) as a function of length at selectivity and fishing mortality for painted spiny lobster (*P. versicolor*) in West Papua Waters. Remarks: The circled dot is the current condition. The triangular dots are the length at selectivity at 40% SPR ($Ls_{40\%}$) and the fishing mortality at 40% SPR ($F_{40\%}$).

Table 3. Biological reference points for painted spiny lobster (*P. versicolor*) in West Papua waters

	Current conditions			Reference points			
	F_{cur}	Ls_{cur}	SPR_{cur}	Ls_{max}	$Ls_{40\%}$	$F_{0.1}$	$F_{40\%}$
Years	(year^{-1})	(mm)		(mm)	(mm)	(year^{-1})	(year^{-1})
2015	1.11	73	35.1	83	79	0.58	0.87
2016	1.55	79	35.4	86	85	0.65	1.17

Discussion

The painted spiny lobster (Panulirus versicolor) in West Papua Waters is relatively small (Mean size=83 mm, L8=128.63 mm) compared with some other areas. The asymptotic length of P. versicolor was 144 mm in the Great Barrier Reef and 131 mm in Karimunjawa Waters (Ernawati *et al*., 2019; Frisch, 2007). Some factors can affect the size of lobsters. Fishing activities can be the main factor affecting the size structure of commercial species (Tu *et al*., 2018). As a dominant catch in West Papua Waters, P. versicolor is vulnerable to the declining of size structure due to high fishing activities.

The growth rate of P. versicolor (K=0.57 year-1) is faster than the growth rate of P. versicolor reported in Sikka Waters (K=0.44 year-1) (Ernawati *et al*., 2014) and Great Barrier Reef (0.27 year-1) (Frisch, 2007). Food supply and high temperature can increase the frequency of molting, which causes a high growth rate of lobster (Chittleborough, 1975). West Papua Waters has a large area of coral reef, which is the habitat for some prey for lobsters, such as sea urchins (D. setosum) and sea snails (D. cornus) (Supriyadi *et al*., 2017). The food availability and warm temperature could probably affect the faster growth of P. versicolor in West Papua Waters.

The growth coefficient of b in the length-weight relationship can be used to detect the indication of spawning season (Saha *et al*., 2009; Olamide *et al*., 2014). The monthly growth coefficient of b varied from 2.39 to 3.04. The coefficient of growth for P. versicolor from June to October 2015 and June 2016 (2.39 – 2.68) was lower than May 2015 and January to May

2016 (2.78 – 3.04). The rainy season during January to May in West Papua Waters increase the nutrient, so it may increase the food and develop the maturity of lobster. Kim *et al*., (2014) reported that the increasing biomass of phytoplankton can be affected by precipitation which increase the nutrient in coastal area. The lowest b was found in July, which can be the indication that lobsters have already released their eggs. The berried female lobster can bring their fertilized eggs in pleopods for one month until they release (Pitcher, 1993).

The natural mortality (M) of P. versicolor in West Papua Waters was 0.58 year-1, the same value as found in Karimunjawa waters (Ernawati *et al*., 2019). Yusuf *et al*, (2017) found higher natural mortality for P. versicolor in Simeulue as 0.99 year-1. Environmental condition, predation, cannibalism and spawning stress can be the factors affecting the natural mortality (Sparre & Venema, 1992; King, 1995). A low natural mortality might due to a good environmental condition, a large area of coral reef in West Papua Waters where is still suitable as preferred habitat for P. versicolor.

The objective of using yield per recruit analysis was to obtain the level of fishing mortality and selectivity, which can give the optimum yield per recruit (Beverton & Holt, 1957). The increasing fishing mortality will reduce the yield per recruit after reaching the maximum yield per recruit. Gabriel & Mace (1999) noted that Fmax could give the overestimated values for optimum fishing mortality. Gulland & Boerema (1973) suggested F0.1 as a reference point that provides the optimum yield per recruit. The current fishing mortality is (1.55 year-1) more extensive than the optimum fishing mortality F0.1 (0.65 year-1), indicating the high exploitation of P. versicolor in this area and the increasing effort will lead to the overfishing status (Table 4). Hence, the managing fishing mortality through catch limit can be applied to avoid exceeding the current fishing mortality.

The length at selectivity in 2015 and 2016 (Ls2015=73; Ls2016=79) were smaller than its optimum selectivity (Lsmax(2015)=83, Lsmax(2016)=86), indicating the growth overfishing condition which means that P. versicolor is captured before it can reach the size which give the optimal yield (Table 4). The minimum legal size can be applied to improve the healthiness of lobster stock and sustain fisher's catch (Cruz *et al*., 2013). Mesh size regulation for lobster gillnet also can be considered to avoid the small-size lobster. Khikmawati *et al*. (2017) suggested of using 5-inch mesh size for lobster gillnet in Pelabuhan Ratu (southern part of west Java). By increasing the length at selectivity from 79 mm to 83 mm in West Papua Waters, it could be predicted that the optimal yield can be obtained, and the fishers will get more benefit from their catch.

The spawning potential ratio (SPR) is an important assessment to study the condition of the spawning stock biomass in the exploited area (Goodyear, 1993; Hordyk *et al*., 2015). The spawning stock biomass should be maintained in the optimum condition to replenish the stock by sustaining reproduction cycles. Clark (2002) suggested 40% SPR as the optimum spawning stock biomass per recruit, which should be remained. The current spawning potential ratio is lower than the reference point SPR. The current fishing mortality is 24% higher than the fishing mortality, giving 40% spawning stock biomass per recruit (F40%). Therefore, light recruitment overfishing has already occurred for P. versicolor.

Some management strategies can be developed by reducing 24% of the current fishing mortality to reach the optimum fishing mortality. It can be implemented by some management options: area closure during the spawning season (June to July) and protected area at some coral reef habitats. The minimum legal size can be regulated as 83 mm to increase spawning stock biomass of lobster and fisher's benefit. We conclude that reducing 24% of the current fishing mortality and increasing the minimum legal size to 85 mm will improve the stock sustainability and catch for painted spiny lobster fisheries in West Papua Waters.

CONCLUSION

The indication of growth overfishing and recruitment overfishing have been found for painted spiny lobster (Panulirus versicolor). The reduction of 24% from current fishing mortality need to be applied and length at selectivity need to be initiated as 83 mm CL to produce the optimal yield and maintain stock sustainability.

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