Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 26(5): 1211 – 1227 (2022)
www.ejabf.journals.ekb.eg

Morphometrics Diversity and Phenotypic Relationship of the Red Snapper (*Lutjanus gibbus*) in Northern Papua Waters

Ridwan Sala[1], Aradea Bujana Kusuma[1], Surianto Bataradewa[2], Bayu Pranata[3,*]

[1]Department of Marine Science, Faculty of Fisheries and Marine Sciences, University of Papua, Jl. Gunung Salju Amban, Manokwari 98312, Indonesia
[2]Department of Mathematics and Statistics, Faculty of Math and Science, University of Papua, Jl. Gunung Salju Amban, Manokwari 98312, Indonesia
[3]Department of Fishery, Faculty of Fisheries and Marine Sciences, University of Papua, Jl. Gunung Salju Amban, Manokwari 98312, Indonesia
[*]Corresponding Author: b.pranata@unipa.ac.id

ARTICLE INFO

Article History:
Received: Oct. 14, 2022
Accepted: Oct. 21, 2022
Online: Oct. 29, 2022

Keywords:
Lutjanidae,
Morphological,
Lutjanus gibbus,
Northern Papua Waters

ABSTRACT

Morphometric and meristic studies can be used to identify stocks and relationships between populations of fish resources. *Lutjanus gibbus* is a fish species commonly found in the waters of northern Papua and is one of the fishery commodities targeted by fishermen other than groupers. In this study, the morphometric and meristic characteristics of *L. gibbus* snapper from several locations in the northern Papua Seas were addressed. The study was conducted in June and July 2022. One hundred and six fish individuals of the *L. gibbus* species were examined using cluster, Pearson correlation, and Principal Component Analysis (PCA). The findings demonstrated a substantial correlation between these species' morphometric traits, particularly regarding the relationship between total length and standard length (0.960) of the fishes' bodies. According to PCA analysis, total length, standard length, and distance between the ventral fin and the end of fin origin are the three most important morphometric features. Meristic traits like anal-fin spine and anal-fin soft ray exhibit stable numbers across all populations, but other morphometric traits show significant individual variation. According to the results of Pearson Correlation analysis and dendrogram reconstruction, the populations of *L. gibbus* in the waters off northern Papua had a strong correlation and a high degree of morphometric similarity. Character relationships and a high degree of similarity indicate that there is no morphometric structure formed between populations.

INTRODUCTION

Red snappers are distributed throughout the subtropical and tropical waters of the Indo-West Pacific, from Australia to southern Japan and Korea **(Randall *et al*., 2003)**. According to **Allen *et al*. (2013)**, the Indo-West Pacific is the habitat of forty-three species of snappers (Lutjanidae), one of which is the *Lutajanus gibbus* species. Fishermen in the waters of northern Papua regard *L. gibbus* as one of their primary targets.

Red snappers in these waters are exposed to the pressure of catching. Based on the Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 19/KEPMEN-KP/2022, the coral fisheries resources, including snapper (*Lutjanus*) in the Fisheries Management Area of the Republic of Indonesia (FMA-RI) 717 which includes the waters of northern Papua, and its surroundings have been declared as fully exploited. Remarkably, the level of physical and genetic diversity of fishes in the area can be affected by overfishing.

In order to sustain fish stock in the FMA-RI 717, it requires a proper management by taking into account the characteristics of the stock or stock structure, where different stocks require different management treatments. An understanding of stock structure is highly significant in managing biological resources in a sustainable manner **(Izzo *et al*., 2017; Zhang *et al.*, 2021)**. Whereas, the lack of understanding of stock structures can lead to inaccurate determination of managed stock units and biased stock assessments **(Reiss *et al.*, 2009)**.

The issue that arises in the management of the *L. gibbus* snapper species in the northern waters of Papua which is part of WPPNRI 717 is the extent of the management area, which includes the Cenderawasih Bay and the Pacific Ocean (based on the regulation issued by the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia No. 18/Permen-KP/2014), stretching from the northern waters of North Maluku to Papua. This raises the following question: does the stock structure of *L. gibbus* species in these waters consist of a single stock or is it a group of stocks? There are almost or no answers to questions related to the stock structure, especially through scientific research activities.

Various methods have been used in the analysis or delineation of the stock structure, as summarized by **Zhang *et al.* (2021)**, including demographic, phenotypic, natural markers and applied marks. Specifically, the phenotypic method has been widely used, among others, considering morphometric and meristic body and otoliths **(Nama *et al.*, 2022**).

Morphological analysis offers useful information regarding population structure and can be utilized as a technique for species identification **(Rawat *et al.*, 2017)**. For taxonomy studies, the analysis of statistical relationships between these features and the morphometric and meristic data are crucial **(Narejo, 2010)**. To determine whether a species in two or more populations has morphological differences, morphological characteristics made up of morphometric and meristic information can be used.

Environmental and genetic factors can contribute to differences in physical characteristics. **Heino (2014)** explains that the morphological character of a living thing can vary when it lives in unique and different environmental conditions. Fish typically exhibit more variety in physical features both within and between groups **(Brraich & Akhter, 2015)**. Fish morphological changes are a type of environmental adaptation **(Hossain *et al.*, 2010)**.

The most straightforward and accurate method of identifying specimens is known as morphological systematics, which involves measuring morphometric and meristic characteristics **(Nayman 1965)**. Stocks of numerous fish species have been described using morphometric and meristic characteristics **(Brraich & Akhter, 2015; Soliman *et al.*, 2018; Gonzalez-Martinez *et al.*, 2020; Soliman *et al.*, 2020; Awad *et al.*, 2022)**.

Identification of the stock of *L. gibbus* snappers in northern Papua waters can provide information about the relationship between populations. This information can be beneficial for the management of *L. gibbus* resources. In this study, *L. gibbus* snappers from various locations in northern Papua waters were compared for their morphometric and meristic characteristics.

MATERIALS AND METHODS

Study area

The current study was carried out in June and July 2022 in the northern Papua waters, including the waters of Manokwari, Numfor, Biak, Nabire and Jayapura. Fig. (1) presents the study areas.

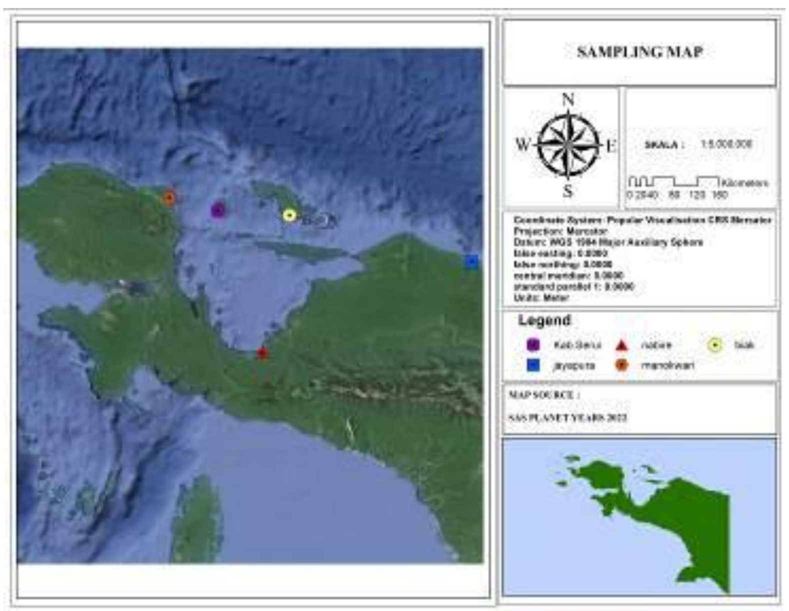

Fig. 1. A map showing the sampling locations of snapper in the northern waters of Papua

Sampling methods

Snapper samples were obtained from fish markets, fishing areas and fish landings. The total number of fish individuals sampled from the areas was 106. Table (1) lists the number of samples collected from each site.

Table 1. Number of samples collected from each study area

No.	Location	Number of samples
1.	Manokwari Waters	30
2.	Numfor Waters	33
3.	Biak Waters	31
4.	Nabire Waters	7
5.	Jayapura Waters	5
	Total	**106**

Morphometric and meristic analysis

The morphometric characteristics were determined following the method of **Soliman *et al.* (2018)**, while the meristic characteristics were assessed using the steps of **Awad *et al.* (2022)**. Digital calipers were used to measure each sample to obtain the morphometric and meristic data. Table (2) displays the morphometric and meristic variables measured in each fish sample.

Table 2. Morphometric and meristic variables **(Soliman *et al.*, 2018; Awad *et al.*, 2022)**

No.	Name	Description
Morphometric measurements		
1	TL	Total length
2	SL	Standard length
3	BD	Body depth
4	CPD	Caudal peduncle depth
5	HL	Head length
6	PRDFL	Predorsal fin length
7	HD	Head depth
8	PRDFL	Preventral fin length
9	VDOL	Distance between ventral and dorsal fins origin
10	ADFEL	Distance between anal and dorsal fin ends
11	DFBL	Dorsal fin base length
12	VOAEFL	Distance between the ventral fin origin and the end of anal fin
13	SPDAEFL	Distance between the first spine of the dorsal fin & the end of anal fin
14	DEVOFL	Distance between dorsal fin end and ventral fin origin
15	VEADFL	Distance between the ventral fin and the end of fin origin
16	DEDCF	Distance between dorsal fin end and dorsal caudal fin origin
17	AEVCFL	Distance between anal fin end and ventral caudal fin origin
18	ED	Eye diameter
Meristic Characters		
1	PF	Number of soft fin rays on pectoral fin (Written Arabic: 1 2 3 4)
2	DF	Number of spines on dorsal fin (Written in Roman: I, II, III, IV)
	DR	Number of soft fin rays on dorsal fin (Written Arabic: 1 2 3 4)
3	AF	Number of hard fin rays on the anal fin (Written in Roman: I, II, III, IV)
	AR	The number of soft fin rays on the anal fin (Written Arabic: 1 2 3 4)

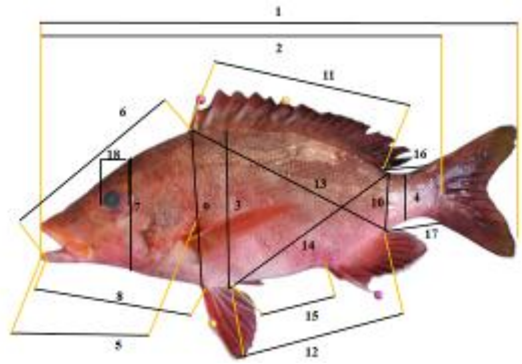

Fig. 2. Morphometric measurements recorded for *L. gibbus*, modified from **Soliman *et al*. (2018)**

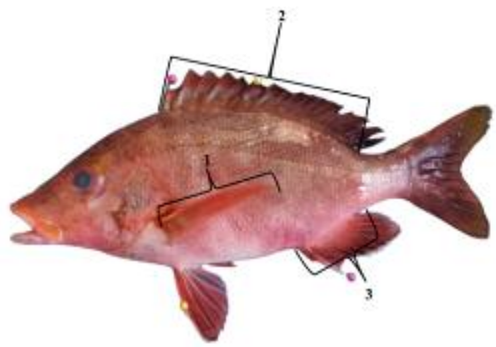

Fig. 3. Meristic measurements determined for *L. gibbus*, modified from **Awad *et al*. (2022)**

Data analysis

A statistical study was conducted to determine the correlation between the morphometric characteristics of the *L. gibbus* population at various research sites. For the sampled fish, 18 morphometric characteristics and 5 meristic characteristics were analyzed. Pearson's test of correlation was utilized to determine the relationship between morphometric variables **(Bailey *et al.*, 2021)**. Using cluster analysis, the similarity of the morphometric features created was determined **(Zamroni *et al.*, 2021)**. Principal component analysis (PCA) was used to identify the morphometric characteristics that are most helpful in separating populations **(Aryani *et al.*, 2013; Bal *et al*., 2021)**.

RESULTS

Description of *Lutjanus gibbus* morphometric

The *L. gibbus* species from Nabire recorded the highest mean score for all morphometric characters, while the *L. gibbus* species from Jayapura had the lowest mean score (Table 3). Total length in the Numfor population showed the biggest standard deviation (3.854), whereas the distance between the anal fin end and ventral caudal fin origin in the Jayapura population had the lowest standard deviation (0%). The average length of *L. gibbus* was between 19.4 and 28.3 centimeters. The Nabire population had the heaviest *L. gibbus*, while the Jayapura population had the lightest snapper (Table 4).

Phenotypic relationships between *L. gibbus* populations

Pearson correlation analysis between populations showed that *L. gibbus* species had a very strong relationship or positive correlation in morphometric characters (Table 8). In general, *L. gibbus* species from five research sites had a strong association, with a coefficient ranging between 0.996 and 0.1.

Table 3. Descriptive analysis on morphometric diversity of red snapper *L. gibbus* in the northern Papua waters

Morphometric characters	Biak (n = 31)		Jayapura (n = 5)		Manokwari (n=30)		Nabire (n=7)		Numfor (n=33)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
TL	24.55	2.548	19.48	1.879	25.37	2.313	28.3	2.125	24.46	3.854
SL	19.69	2.142	16.38	0.976	20.27	1.752	21.8	1.39	19.68	2.936
BD	7.85	1.036	6.98	0.606	8.38	0.827	9.39	0.855	8.06	1.175
CPD	2.27	0.2883	1.92	0.1924	2.52	0.4544	2.58	0.1773	2.47	0.387
HL	7.38	0.802	5.74	0.532	7.62	1.295	8.42	0.692	7.49	1.303
PRDFL	8.25	0.857	6,5	0.442	8.83	1.026	9.41	1.011	8.77	1.519
HD	5.12	0.77	5.18	0.1643	6.26	0.754	6.14	0.6	6.25	1.076
PRvDFL	7.58	0.848	6.32	0.54	7.79	0.769	8.51	0.538	7.67	1.061
VDOL	7.96	1.028	6.92	0.576	8.35	0.906	9.23	0.859	7.97	1.308
ADFEL	3.21	0.4199	2.88	0.1643	3.52	0.4396	3.52	0.227	3.32	0.589
DFBL	9.99	1.127	8.44	0.862	10.53	0.837	11.23	1.038	10.23	1.361
VOAEFL	8.57	1.054	6.92	0.683	8.54	0.806	9	0.648	8.35	1.195
SPDAEFL	11.01	1.302	9.26	0.654	11.49	0.985	12.35	0.835	11.09	1.51
DEVOFL	10.28	1.18	8.78	0.968	10.56	1.014	11.21	0.629	10.18	1.456
VEADFL	4.99	1.37	4.68	1.41	4.56	0.5126	5.04	0.787	4.43	0.702
DEDCF	2.28	0.397	2.4	0.255	2.31	0.4821	2.45	0.284	2.22	0.3328
AEVCFL	3.04	0.4725	3	0	3.09	0.548	3.08	0.085	2.78	0.858
ED	1.73	0.2332	1.58	0.1643	1.89	0.2808	1.9	0.2236	1.88	0.2451

Note: SD (Standard Deviation)

Table 4. Average, minimum, and maximum weight of the *L. gibbus* species in northern Papua

Location	Total count (n)	Mean	StDev	Minimum	Maximum
Biak	31	258	79.2	126	422
Jayapura	5	122	26.3	102	167
Manokwari	30	275.4	123.5	169	849
Nabire	7	337.9	65.7	254	414
Numfor	33	224.8	103.5	128	614

The correlation between morphometric characteristics of *Lutjanus gibbus*

Table (5) displays the Pearson correlation coefficients that describe the phenotypic correlation between *L. gibbus* fish individuals. Positive coefficients are present in 153 relationships. The range of correlation coefficient values was between 0.112 to 0.960. The correlation coefficient between the total length and standard length was 0.96, the highest value. This value indicates that the total length is directly proportional to the standard length of the fish. The increase in total length is followed by an increase in standard length. The correlation between eye diameter and distance between anal fin end and ventral caudal fin origin was the weakest (0.112). In addition, head depth and distance between dorsal fin end and dorsal caudal fin origin also showed the lowest coefficient of correlation (0.113).

PCA analysis on morphometric data is shown by eigenvalue, proportion and cumulative (Table 6). Principal component (PC) 1 reported the highest proportional value of 87.7%, whereas P2, PC3, PC4, and PC5 each contributed with 3.2%, 1.7%, 1.6%, and 1.2%, respectively. Table (7) displays the morphometric character values that can determine morphometric variances among *L. gibbus* species.

Based on the eigenvalues, there are two primary components that can describe the researched phenomenon, as evidenced by eigenvalues with a value greater than 1, and the combined percentage of the two main components' ability of 90.9%. However, one major component is sufficient, as it can explain 87.7% of the morphometric properties.

Table 6. Eigenvalue, proportion and cumulative morphometric characteristics

PC	Eigenvalue	Proportion %	Cumulative
1	27.731	87.7	0.877
2	1.022	3.2	0.909
3	0.549	1.7	0.927
4	0.503	1.6	0.943
5	0.371	1.2	0.954

Table 5. The phenotypic correlation between 18 morphometric characters among 106 *L. gibbus* individuals

	TL	SL	BD	CPD	HL	PRDFL	HD	PRvDFL	VDOL	ADFEL	DFBL	VOAEFL	SPDAEFL	DEVOFL	VEADFL	DEDCF	AEVCFL
SL	0.96																
BD	0.88	0.86															
CPD	0.71	0.63	0.72														
HL	0.88	0.83	0.78	0.63													
PRDFL	0.93	0.91	0.85	0.74	0.89												
HD	0.70	0.69	0.69	0.64	0.66	0.79											
PRvDFL	0.94	0.93	0.86	0.72	0.84	0.89	0.69										
VDOL	0.93	0.91	0.93	0.71	0.84	0.88	0.69	0.91									
ADFEL	0.79	0.78	0.77	0.67	0.74	0.78	0.69	0.75	0.84								
DFBL	0.94	0.94	0.87	0.77	0.84	0.91	0.75	0.92	0.91	0.82							
VOAEFL	0.87	0.89	0.79	0.62	0.76	0.81	0.55	0.85	0.82	0.74	0.84						
SPDAEFL	0.94	0.93	0.88	0.71	0.83	0.89	0.71	0.91	0.93	0.82	0.93	0.83					
DEVOFL	0.92	0.92	0.89	0.68	0.81	0.86	0.66	0.88	0.92	0.81	0.91	0.92	0.89				
VEADFL	0.45	0.47	0.43	0.32	0.43	0.36	0.16	0.52	0.47	0.41	0.46	0.63	0.35	0.54			
DEDCF	0.28	0.37	0.32	0.25	0.14	0.19	0.12	0.35	0.32	0.19	0.38	0.36	0.35	0.32	0.34		
AEVCFL	0.22	0.27	0.24	0.18	0.12	0.15	0.08	0.25	0.25	0.17	0.28	0.24	0.28	0.25	0.22	0.53	
ED	0.50	0.49	0.46	0.48	0.53	0.51	0.45	0.53	0.52	0.49	0.54	0.49	0.49	0.46	0.31	0.43	0.12

Note: Size Correlation coefficient 0.90-1.00 (very high positive correlation); 0.70-0.9 (High positive correlation); 0.50-0.70 (Moderat positive correlation); 0.30-0.50 (Low positive correlation); 0.00-0.30 (Negligible correlation) (**Mukaka, 2012**).

Table 7. Eigen vector of the main components' coefficients

Morphometric characteristics	Principal component				
	PC1	PC2	PC3	PC4	PC5
Total length	**0.611**	-0.09	-0.035	0.479	0.146
Standard length	**0.448**	0.115	0.358	0.115	-0.555
Body depth	0.188	-0.02	0.015	-0.338	0.405
Caudal peduncle depth	0.053	-0.048	-0.056	-0.15	0.124
Head length	0.2	-0.1	-0.491	0.147	0.142
Predorsal fin length	0.225	-0.224	-0.235	-0.096	-0.101
Head depth	0.138	-0.398	-0.154	-0.577	-0.455
Preventral fin length	0.17	0.045	-0.02	-0.037	-0.008
Distance between ventral and dorsal fins origin	0.204	0.006	-0.027	-0.215	0.339
Distance between anal and dorsal fin ends	0.076	-0.023	-0.048	-0.148	0.052
Dorsal fin base length	0.222	-0.028	0.065	-0.182	-0.004
Distance between the ventral fin origin and the end of anal fin	0.179	0.313	-0.029	-0.003	-0.114
Distance between the first spine of the dorsal fin & the end of anal fin	0.245	-0.138	0.219	-0.081	0.243
Distance between dorsal fin end and ventral fin origin	0.225	0.167	-0.008	-0.231	0.131
Distance between the ventral fin and the end of fin origin	0.088	**0.747**	-0.396	-0.197	-0.111
Distance between dorsal fin end and dorsal caudal fin origin	0.024	0.145	0.262	-0.107	-0.009
Distance between anal fin end and ventral caudal fin origin	0.029	0.175	0.513	-0.204	0.185
Eye diameter	0.026	0.002	-0.039	-0.052	-0.016

Phenotypic relationships between *L. gibbus* populations

Pearson correlation analysis between populations showed that *L. gibbus* species had a very strong relationship or positive correlation on morphometric characters (Table 8). In general, *L. gibbus* species from five research sites had a strong association, with a coefficient ranging between 0.996 and 0.1.

Table 8. The Correlation Coefficient of *L. gibbus* Morphometric Characteristics in the Study Areas

	Manokwari	Numfor	Biak	Nabire
Numfor	1.000			
Biak	0.999	0.998		
Nabire	0.999	0.999	0.999	
Jayapura	0.997	0.996	0.998	0.996

The dendogram reconstruction in Figure 4 shows the relationship of morphometric characters between species at the study sites. The dendogram divides species into the Jayapura population cluster and the Biak, Nabire, Numfor, and Manokwari population clusters (Figure 4). Morphometrically, *L. gibbus* species in Manokwari waters are comparable to those in Numfor waters but differ slightly from those in Nabire and Biak waters. In contrast, the population of Jayapura is a distinct lineage. In general, the dendogram reconstruction revealed a high degree of morphometric feature similarity amongst populations of *L. gibuss* at the five research sites.

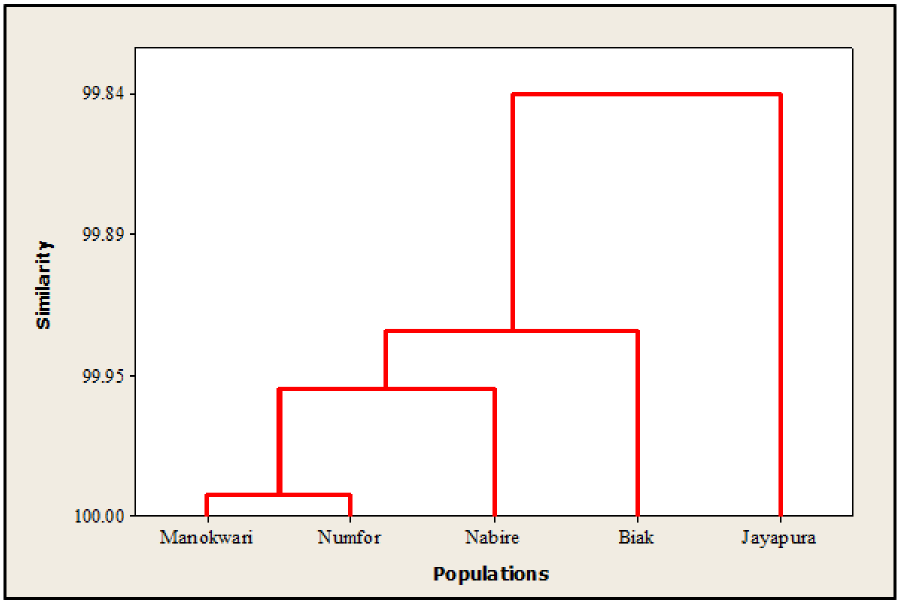

Fig. 4. Dendogram of morphometric similarity level of *L. gibbus* in Northern Papua Waters

Meristic characteristics of *L. gibbus*

Table 9 presents the meristic characteristics of *L. gibbus* species in each population. Fifteen to seventeen soft fin rays are present on the pectoral fins. Generally, the hard fin rays on the dorsal fin are numbered X, whereas the soft fin rays are numbered 13 to 16. In all populations, there are III hard spines on the anal fin, while there are nine soft fin rays.

Table 9. Meristics characteristics of *L. gibbus*

No	Meristic charactteristics		Range Date				
			Manokwari	Numfor	Biak	Nabire	Jayapura
1	PF	Number of soft fin rays on pectoral fin	15-17	15-17	16-17	15-17	16-17
2	DF	Number of spines on dorsal fin	VIIII-XI	X	X	X	X
3	DR	Number of soft fin rays on dorsal fin	14-16	14-15	14-16	15	13-15
4	AF	Number of hard fin rays on the anal fin	III	III	III	III	III
5	AR	The number of soft fin rays on the anal fin	9	9	9	9	9

DISCUSSION

In this study, the average total length of *L. gibbus* ranged between 19.4 and 28.3 centimeters. The average length of *L. gibbus* found was not much different from those found in several regions in Indonesia, such as those found in the South Sunda Strait waters (23.6 – 33.7 cm) (**Prihatiningsih *et al*., 2017; Prihatiningsih *et al*., 2020**) and the waters of Alor, East Nusa Tenggara (23.5 – 58.8 cm, male individuals; 18.3 – 31.5 cm, female individuals) (**Pakro *et al*., 2020**). More than half (53%) of the overall sample of 29,803 individuals in the Timor Sea measured 29 to 31 centimeters in length (**Peter *et al*., 2022**). *L. gibbus* species can reach a maximum length of 54 cm (**Peter *et al*., 2022**). The Nabire population of *L. gibbus* had the most average weight (337.9 g), whereas the Jayapura population had the least (122 g). Possible cause of the disparity in weight between areas is overfishing. In the waters of northern Papua, catching red snapper, including the *L. gibbus* species, is extremely competitive. Currently, red snapper fishing falls under the category of unrestricted exploitation (Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia No. 50/KEPMEN-KP/2017). Individuals in the waters of northern Papua may have a very minimal chance of reaching full adult size before being captured, because of overexploitation. Similar circumstances occurred with the *L. gibbus* species in Bunaken Marine Park, North Sulawesi, where the paucity of large fish in the catch suggested that the area may have been overfished. This scenario can happen because there are no laws limiting the minimum size of snapper that can be fished, and because the supply of younger fish is subjected to intense pressure (**Holloway *et al*., 2015**). In addition, changes in size might result from differences in growth rates, recruitment methods, exploitation levels, and fishing gear utilized (**Mallawa and Amir, 2019**).

The correlation coefficient for total length and standard length of *L. gibbus* was 0.960, which is the greatest. **Soliman *et al*. (2018)** discovered comparable results in L. quinquelineatus species. The PCA analysis identified two principal components, PC1 and PC2. PC1 provided 87.7% to the diversity of the fish species' morphometric features, while PC2 contributed 3.2%. Meanwhile, On PC1, total length and standard length is the significant morphometric variable for determining the diversity of morphometric features among *L. gibbus species*. On PC2, the significant morphometric variable is the distance between the ventral fin and the end of fin origin.

Meristic characteristics such as "pectoral-fin soft ray", "dorsal-fin spine" and "dorsal-fin soft ray" in *L. gibbus* species are quite variable. Meanwhile, the meristic characters of "anal-fin spine" and "anal-fin soft ray" showed a consistent amount. The Manokwari population displayed a greater variation in the number of "dorsal-fin spines," whereas the populations of Jayapura, Nabire, Biak, and Numfor displayed the same characteristics. In the Western Central Pacific, **Anderson *et al.* (2001)** measured meristic L. gibbus species and found 16-17 pectoral-fin soft rays, X dorsal-fin spines, 13-14 dorsal-fin soft rays, III anal-fin spines, and 8 anal-fin soft rays. Several other investigations have reached the same conclusion, namely that several members of the family *Lutjanus* possessed the same number of anal-fin spines (Table 10).

Table 10. Meristic Characteristics of the family Lutjanus.

	***L. Goreensis* (Fakunmoju *et al*., 2014)**	***L. Agennes* (Fakunmoju *et al*., 2014)**	***L. rivulatus* (Karna *et al*., 2018)**	***L. erythropterus* (Sarkar *et al*., 2021)**	***L. erythropterus* (Barman and Mishra, 2013)**	***L. fulvus* (Sarkar *et al*., 2021)**
Pectoral-fin soft ray	-	-	15	17	15–17	16
Dorsal-fin spine	X	X	X	XI	X–XI	X
Dorsal-fin soft ray	14	14	15	14	12–14	14
Anal-fin spine	III	III	III	III	III	III
Anal-fin soft ray	8	8	8	9	9	8

The difference in morphometric characters of the *L. gibbus* species in the waters of northern Papua indicates a diversity of phenotypes. Phenotype variety is a form of adaptation to various habitat features. This type of adaptation is referred to as phenotypic plasticity (**Chapman 2015**). Food availability is a factor that causes morphological differences (**Abaad *et al.*, 2016**). When food supply fluctuates or is abundant, the effect of availability on fluctuations in body size metrics (jaw depth, body depth, and fork length) has been documented in detail (**Abaad *et al.*, 2016; Jacobson *et al.*, 2018**). Additionally, the size of the prey devoured influences the morphology of the fish (**Paul *et al.* 2017**). In addition, it has been demonstrated that the nutritional value of diet affects the morphology of snapper (**Barley *et al*., 2017**). According to the findings of **Bailey's (2021)** study, *L. bohar* and *L. gibbus* grow larger and are in better health when they ingest fish and squid, which are high-energy foods. **Olsson and Eklov (2005)** found that habitat complexity can lead to phenotypic plasticity and physical changes between individuals of the same species occupying various habitats. Fish will adopt the most optimal morphology to avoid predators, find food and swim. Pelagic fish, for instance, may have longer, slender bodies for speedy swimming, whereas identical species in more complex benthic/reef settings have deeper bodies, larger heads, and wider gapes (**Mihalitsis and Bellwood 2019**).

The results of Pearson Correlation analysis and dendogram reconstruction showed that populations of *L. gibbus* in northern Papua waters were strongly correlated and had a high level of similarity of morphometric characters. Character relationships and a high degree of resemblance show that morphometric structures are not produced at each place. The morphometric similarity between populations of the same species is a result of the same environmental factors. In addition, interbreeding between individuals because of migration and movement of larvae between populations produces a high degree of morphological similarity. The results of our investigation indicate that there is no morphometric structure among *L. gibbus* species in the waters of northern Papua. We assume that the *L. gibbus* species in several study areas in the waters of northern Papua are part of the same population, but this assumption needs to be proven through molecular studies such as phylogenetic and genetic analyses across snapper populations from Papua. The results of **Zamroni *et al.* (2021)** showed that morphometrically, *L. malabaricus* from Biak-Nabire waters was part of the same population as *L. malabaricus* from Raja Ampat waters.

CONCLUSION

In conclusion, reports on the morphometric diversity and phenotypic relationships of Red Snapper (*L. gibbus*) species in the waters of northern Papua are relatively new. Several morphometric characteristics of *L. gibbus* species exhibit a positive and statistically significant relationship, as shown by the present study. Total length and standard length have a correlation coefficient of 0.96, which is quite high. Total length, standard length, and the distance between the ventral fin and the end of fin origin are morphometric characteristics that determine the variation among *L. gibbus* species individuals. The reconstruction of the dendogram in the cluster analysis revealed that the morphometric characteristics of the five studied populations share a high degree of similarity, between 99.67 and 99.98. Based on these results, we conclude that the populations of *L. gibbus* from the five study sites are morphologically and genetically related. However, molecular research is required to ensure connectivity between populations. The morphometric data provide preliminary information to support future management, conservation, and enhancement decisions regarding the genetic resources of the *L. gibbus* species in the northern Papua waters.

ACKNOWLEDGEMENTS

We would like to thank the Ministry of Education, Culture, Research and Technology for funding this study through a research scheme with DIPA Directorate of Research, Technology and Community Service Directorate General of Higher Education, Research and Technology Ministry of Education, Culture, Research and Technology Number: 235/E5/PG.02.00.PT/2022. Research contract number No. 235/E5/PG/02.00.PT/2022 (dated May 30, 2022) and derivative contract No. 190.c/UN42.15/PG/2022 (June 7, 2022).

REFERENCES

Anderson, W.D.Jr. and Allen, G.R. (2001). Lutjanidae. Jobfishes. p. 2840-2918. In K.E. Carpenter and V. Niem (eds.) FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Vol. 5. Bony fishes part 3 (Menidae to Pomacentridae). FAO, Rome. Available online at http://www.fao.org/docrep/009/x2401e/x2401e00.htm

Allen, G.R.; White, W.T. and Erdmann, M.V. (2013). Two new species of snappers (Pisces: Lutjanidae: Lutjanus) from the Indo-West Pacific. Journal of the Ocean Science Foundation, 6: 33-51. DOI: 10.5281/zenodo.1036813

Aryani, N.; Nuraini and Suharman, I. (2013). Morphological characterization of Baung Fish (*Hemibagrus nemurus*) aquatic habitat on the different method based truss morfometrics. Journal of Fisheries and Aquaculture, 4 (3): 139-142. Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid = BPJ0000265

Abaad, M.; Tuset, V.M.; Montero, D.; Lomberte, A.; Otero-Ferrer, J.L. and Haroun, R. (2016). Phenotypic plasticity in wild marine fishes associated with fish-cage aquaculture. Hydrobiologia, 765 (1): 343–358. DOI: 10.1007/s10750-015-2428-5.

Awad, J.E.I.E. and Ouizgani, H.E. (2022). Some morphometric and meristic parameters of the Moroccan Atlantic anchovy *Engraulis encrasicolus* (Linnaeus, 1758). Egyptian Journal of Aquatic Biology & Fisheries, 26 (3): 59-73. DOI:10.21608/EJABF.2022.236285

Barman, R.P.; Das, A. and Mishra, S.S. (2013). On the occurrence of crimson snapper, *Lutjanus erythropterus* (Perciformes: Lutjanidae) from West Bengal, India. Records of the Zoological Survey of India, 113 (2): 81–84. Available online at http://faunaofindia.nic.in/PDFVolumes/records/113/02/0081-0084.pdf

Brraich, O.S. and Akhter, S. (2015). Morphometric characters and meristic Counts of a Fish, *Crossocheilus latius latius* (Hamilton-Buchanan) from Ranjit Sagar Wetland, India. International Journal of Fisheries and Aquatic Studies, 2 (5): 260-265. Available online at https://www.fisheriesjournal.com/archives/2015/vol2issue5/PartE/2-5-74-228.pdf

Barley, S.; Meekan, M.G. and Meeuwig, J.J. (2017). Species diversity, abundance, biomass, size and trophic structure of fish on coral reefs in relation to shark abundance. Marine Ecology Progress Series, 565: 163–179. DOI: 10.3354/meps11981.

Bailey, A.S. (2021). Genetic and morphometric variation of two focal snapper species (*Lutjanus bohar* and *Lutjanus gibbus*) in the Chagos Archipelago. [Thesis] Oxford Brookes University, Oxford. [England].

Bal, H.; Yanik, T. and Türker, D. (2021). Assessment of morphological variation between stocks of bluefish, *Pomatomus saltatrix* (Actinopterygii, Perciformes, Pomatomidae), in the Aegean Sea, Black Sea, and Sea of Marmara. Acta Ichthyologica et Piscatoria, 51 (1): 85-94. DOI: 10.3897/aiep.51.63319

Chapman, L.J. (2015). Low-Oxygen Lifestyles BT - Extremophile fishes: ecology, evolution, and physiology of teleosts in extreme environments. In: Riesch R, Tobler M, Plath M (eds) Cham: Springer International Publishing. DOI: 10.1007/978-3-319-13362-1_2.

Fakunmoju, F.A.; Akintola, S.L.; and Ijimakinde, B. (2014). Comparative analysis of the morphometric and meristic character of Lutjanidae from Lekki and Badagry Lagoons in Lagos State Nigeria. IOSR Journal of Agriculture and Veterinary Science, 7 (1): 81-88. DOI:10.9790/2380-07158188

Gonzalez-Martinez, A.; Lopez, M.; Molero, H.M.; Rodriguez, J.; González, M.; Barba, C. and García, A. (2020). Morphometric and meristic characterization of native Chame Fish (*Dormitator latifrons*) in Ecuador using multivariate analysis. Animals, 10:1805. Available online at https://doi.org/10.3390/ani10101805

Hossain, M.A.R, Nahiduzzaman, Md.; Saha, D.; Khanam, Mst.U.H. and Alam, M.S. (2010). Landmark-Based morphometric and meristic variations of the endangered carp, Kalibaus *Labeo calbasu*, from stocks of two isolated Rivers, the Jamuna and Halda and a Hatchery. Zool Stud, 49 (4):556-563. Available online at http://zoolstud.sinica.edu.tw/Journals/49.4/556.pdf

Heino, M. (2014). Quantitative Traits. In: Cadrin SX, Karr LA, Mariani S (eds) Stock Identification Methods: Applications in Fishery Science. 2nd Edition. Academic Press – Elsevier, London, UK.

Holloway, C.J.; Bucher, D.J. and Kearney, L. (2015). A Preliminary Study of the Age and Growth of Paddletail Snapper *Lutjanus gibbus* (Forsskål 1775) in Bunaken Marine Park, North Sulawesi, Indonesia. Asian Fisheries Science, 28: 186-197. DOI:10.33997/j.afs.2015.28.4.005

Izzo, C.; Ward, T.M.; Ivey, A.R.; Suthers, I.M.; Stewart, J.; Sexton, S.C. and Gillanders, B.M. (2017). Integrated approach to determining stock structure: implications for fisheries management of sardine, Sardinops sagax, in Australian waters. Reviews in Fish Biology and Fisheries, 27 (1): 267-284. DOI: 10.1007/s11160-017-9468-z

Jacobson, P.; Gårdmark, A.; Östergren, J. and Casini, M. (2018). Size-dependent prey availability affects diet and performance of predatory fish at sea: a case study of Atlantic salmon. ECOSPHERE, 9 (1): e02081. DOI:10.1002/ecs2.2081

Karna, S.K.; Manna, R.K.; Panda, D.; Manas, H.M.; Mukherjee, M. and Suresh, V.R. (2018). Occurrence of Blubberlip snapper, *Lutjanus rivulatus* (Cuvier, 1828) from Chilika lagoon, India. Indian Journal of Geo Marine Sciences, 47 (08): 1633-1635. Available online athttp://nopr.niscpr.res.in/bitstream/123456789/44766/1/IJMS%2047(8)%201633-1635.pdf

Mihalitsis, M. and Bellwood, D.R. (2019). Morphological and functional diversity of piscivorous fishes on coral reefs. Coral Reefs, 38 (5): 945–954. DOI: 10.1007/s00338-019-01820-w.

Mallawa, A. and Amir, F. (2019). Population dynamic of Narrow-barred spanish mackerel (*Scomberomorus commerson*) in Bone Bay waters South Sulawesi Indonesia. AACL Bioflux, 12: 908–917 Available online at http://www.bioflux.com.ro/docs/2019.908-917.pdf

Nama, S.; Bhushan, S.; Ramteke, K.; Jaiswar, A.; Nayak, B.; Pathak, V. and Akter, S. (2022). Stock structure analysis of Upeneus vittatus based on morphometric, meristic and otolith shape analysis along the Indian coast. Iranian Journal of Fisheries Sciences, 21(1): 93-103. DOI: 10.21203/rs.3.rs-1426133/v1

Nayman. (1965). Growth and Ecology of Fish Population. J Anim Ecol, 20: 201 - 219.

Narejo, N.T. (2010). Morphometric characters and their relationship in *Gudusia chapra* (Hamilton) from Keenjhar lake (Distt: Thatta), Sindh. Pak. J. Zool, 42(1):101-104.

Olsson, J. and Eklöv, P. (2005). Habitat structure, feeding mode and morphological reversibility: Factors influencing phenotypic plasticity in perch. Evolutionary Ecology Research, 7(8): 1109– 1123. Available online at https://www.diva-portal.org/smash/get/diva2:158847/FULLTEXT01.pdf

Paul, M.; Pradit, S.; Hajisamae, S.; Prengmak, P.; Hisam, F. and Chaibundit, S. (2017). Relationships of body lengths with mouth opening and prey length of nemipterid fishes (Regan, 1913) in the Gulf of Thailand. The Egyptian Journal of Aquatic Research, 43(4): 297–302. DOI: 10.1016/j.ejar.2017.11.001.

Prihatiningsih.; Kamal, M.M.; Kurnia, R. and Suman, A. (2017). Length-Weight relationship, food habits, and reproduction of humpback red snapper (*Lutjanus gibbus*; family Lutjanidae) in the Southern Part of Banten Waters. BAWAL Widyariset Perikanan Tangkap, 9(1):21. DOI:10.15578/bawal.9.1.2017.21-32

Prihatiningsih.; Kamal, M.M.; Kurnia, R. and Suman, A. (2020). The spawning season, growth, and mortality of humpback red snapper (*Lutjanus gibbus* (Forsskal, 1775) in the Southern Banten waters, Indonesia. AACL Bioflux, 13(2):1079-1089. Available online at http://www.bioflux.com.ro/docs/2020.1079-1089.pdf

Pakro, A.; Mallawa, A.; Sudirman. and Amir, F. (2020). Population dynamic of red snapper (*Lutjanus gibbus*) at Alor waters East Nusa Tenggara Province, Indonesia. The 2nd International Conference of Animal Science and Technology. IOP Conf. Series: Earth and Environmental Science, 492(1): 012091 DOI:10.1088/1755-1315/492/1/012091

Randall, J.E.; Williams, J.T.; Smith, D.G.; Kulbicki, M.; Tham, G.M.; Labrosse, P.; Kronen, M.; Clua, E.; Mann, B.S. (2003). Checklist of the shore and epipelagic fishes of Tonga. Atoll Research Bulletin 502 (497). (497) DOI:10.5479/si.00775630.502.1

Rawat, S.; Benakappa, S.; Kumar, J.; Naik, K.; Pandey, G. and Pema, C. (2017). Identification of fish stocks based on truss morphometric: A review. Journal of Fisheries and Life Sciences, 2(1): 9–14. Available online at https://www.fishlifesciencejournal.com/download/2017/v2.i1/9/9.pdf

Reiss, H.; Hoarau, G.; Dickey-Collas, M. and Wolff, W.J. (2009). Genetic population structure of marine fish: mismatch between biological and fisheries management units. Fish and Fisheries, 10(4): 361-395. DOI: https://doi.org/10.1111/j.1467-2979.2008.00324.x

Soliman, F.M.; Mehanna, S.F.; Soliman, H.A. and Baker, T.S. (2018). Meristic and morphometric characteristics of five-lined snapper, *Lutjanus quinquelineatus* (Bloch, 1790) from the Red Sea, Egypt. Egyptian Journal of Aquatic Biology & Fisheries, 22(1):41-48. DOI: 10.21608/ejabf.2018.7723

Soliman, H.A.M.; Soliman, F.M. and Baker, T.S. (2020). Morphological and Genetic Relationship of two Closely-Related Species of Snappers (Family: Lutjanidae) from Egyptian Red Sea. Sohag J. Sci, 5(3):15-21. DOI: 0.21608/sjsci.2020.233187

Sarkar, P.; Islam, Md.J.; Habib, A.H.M.S.; Neogi, A.K and Habib, K.A. (2021). Two new records of Snapper (Perciformes, Lutjanidae) from Saint Martin's Island, Bangladesh. J. Ocean Univ. China, 20(2): 439-444. DOI.org/10.1007/s11802-021-4566-x

Zamroni, A.; Kembaren, D.D.; Ernawati, T.; Purwanto.; Satria, F.; Nurdin, E.; Mardiani, S.R. and Budiarti, T.W. (2021). A Genetic and Morphometric Study on Red Snapper and Grouper in Fisheries Management Area 715. A Case Study on Malabar Blood Snapper (*Lutjanus malabaricus*) and Leopard Coral Grouper (*Plectropomus leopardus*). Prepared by Research Institute for Marine Fisheries - MMAF and USAID Sustainable Ecosystems Advanced Project. Jakarta, Indonesia. 60 p.

Zhang, S.; Li, M.; Zhu, J.; Xu, S. and Chen, Z. (2021). An Integrated Approach to Determine the Stock Structure of Spinyhead Croaker Collichthys lucidus (Sciaenidae) in Chinese Coastal Waters. *Frontiers in Marine Science* 8. DOI: 10.3389/fmars.2021.693954