Morphometric and meristic variations among five populations of *Sardinella lemuru* Bleeker, 1853 from waters of Bali Strait, northern and southern-east Java and their relation to the environment

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Abstract. The variation of morphometric and meristic characters among five populations of *Sardinella lemuru* and its environment was studied in waters of Bali Strait, northern and southern-east Java. Fish and hydro-oceanography samples were collected during transition and southeastern monsoon seasons (March-June) 2017 directly at five fishing grounds of *S. lemuru*. The fish was caught by gillnet. In the same time hydro-oceanography data have been recorded by using AAQ1183C sensor. Clustering analysis was carried out to examine the grouping of *S. lemuru* based on the morphometric and meristic characteristics. Furthermore, length-weight relationship and hydro-oceanography data were analyzed using Principal Component Analysis (PCA). The result shows that there were found two population groups based on morphological characteristics of five population of *S. lemuru* of Bali Strait, Northern and Southern-East Java waters. Further, the environmental parameters, mainly chlorophyll-*a*, pH, DO and water temperature affect morphological characteristics. This study suggested that environment factors play an important role in controlling the variety of fish phenotypes that are likely to affect the condition of its stock in the waters.
Key Words: *Sardinella lemuru*, morphometric, meristic, fish stock, environment.

Introduction. *Sardinella lemuru* belongs to the family Clupeidae. The fish is rich in Omega-3 content that is good to prevent cancer or coronary diseases (Khoddami et al 2009; Mahrus et al 2012). *S. lemuru* became the main commodity catch in Bali Strait with 90% of total catch (Hendiarti et al 2005). It is broadly scattered in the east Indian Ocean and western Pacific region. In Indonesia, this fish can be found in the north and south waters of Java, the Bali Strait and the waters around Sumatra Island (Sartimbul et al 2010).

Knowledge about fish stock structure in waters is very important to support effective and sustainable fisheries' management (Turan 2004). The stock of *S. lemuru* in the waters is highly variable and is influenced by the environment. Study of *S. lemuru* stock with population dynamics approach conducted by Pet et al (1997) during 1990-1992 shows that based on age structure and migration pattern, *S. lemuru* in East Java waters consists of two different stocks, North Java stock and Indian Ocean stock. North Java stock is found in fish caught from Probolinggo waters, while the Indian Ocean stock is found in fish from Sendang Biru/South Malang and Bali Strait.

Currently, the number of *S. lemuru* is dwindling in a significant rate, as shown by the decreasing quantity of catch. During the period between 2005 and 2014, *S. lemuru* experienced fluctuations in catch and tended to decline. The continuous decline occurred in 2009-2012 from the catch of 108.772 tons to 19.663 tons (Figure 1) (Kepmen-KP 2016). Until now, the cause of the disappearance of *S. lemuru* is still unclear, whether it is caused by the behavior of overfishing or migration. Therefore, further analysis of *S. lemuru* stocks and the prediction of migratory patterns should be conducted.

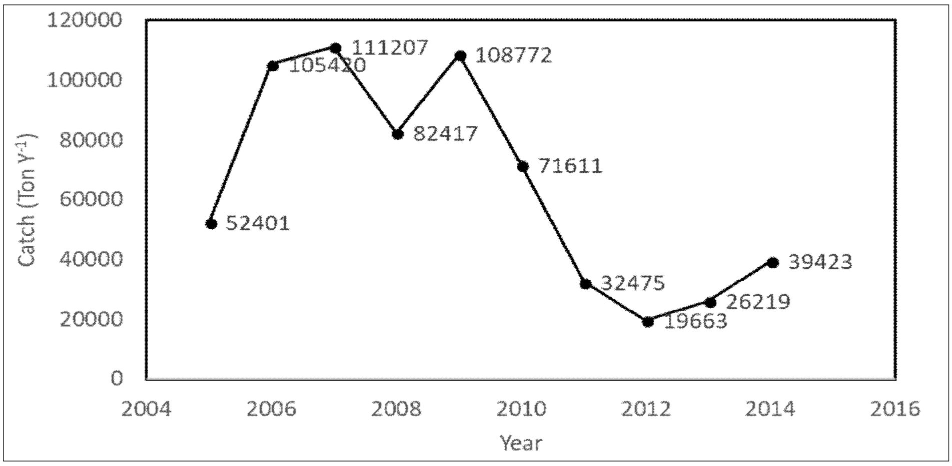

Figure 1. *S. lemuru* catch trend (2005-2014) of Fisheries Management Area of Republic of Indonesia No. 573 (WPPNRI 573) includes Java and Bali (Kepmen-KP 2016).

The environment becomes one of the factors that can affect the variation of fish phenotypes that are likely to affect the condition of its stock in the waters. It is most apparent in fish with different phenotypes, i.e. differences in morphometric characters (Turan 2004; Savriama et al 2017). Thus, the morphological approach can be used as a first step in identifying stocks and predicting fish migration patterns (Giducos et al 2015). The morphological approach used includes morphometric and meristic characteristics and has been widely used and shows success in describing stock conditions (Turan 2004; Hossain et al 2010). Therefore, this study aims to identify the stock of *S. lemuru* caught on 5 fishing grounds in East Java waters and Bali Strait and suspect migration pattern based on morphological approach.

Material and Method. Sampling of *S. lemuru* was conducted in March-June (transition and southeast monsoon seasons) 2017 at 5 fishing grounds in East Java waters, including Probolinggo (-7.63011^o and 113.22533^o), Bali Strait (-8.47504^o and 114.38102^o), Puger (-8.44091^o and 113.59098^o), South Malang (-8.43407^o and 122.68415^o) and Prigi waters (-8.34903^o and 111.81619^o) (Figure 2). Along with *S. lemuru* sampling, hydro-oceanographic data (water temperature, salinity, pH, dissolved oxygen - DO, and chlorophyll *a*) were taken at each fishing ground. Generally, fish sampling for this kind of research is only done at fish landing sites or fishing ports (Pet et al 1997; Setyohadi et al 2016), but in this study the fish samples were obtained directly from the fishing ground. The purpose of fish data collection in the fishing ground is to ensure that fish samples and hydro-oceanographic data taken originated from the same location. Sampling of *S. lemuru* is done by using ¾-1 inch mesh size gill net made from polyethylene material, which is a rectangular passive capturing device with a larger number of horizontal mesh nodes than vertical. Length and depth gill nets are 200 m and 12 m, respectively. Gill net is equipped with a balanced buoy and sinker in accordance to the target fish swimming layer (ACIAR 2006; Sartimbul el al 2016a).

As explained in the background, when this study was performed, *S. lemuru* were very hard to find, probably due to the prolonged La Niña and El Niño phenomenon from 2010 to 2016 (Sartimbul et al 2016b), which became one of the major hurdles in sample *S. lemuru* collection. Due to this limitation, the *S. lemuru* samples used in this study were only 100 in total, or 20 fish per fishing ground. Furthermore, the process of morphological identification conducted in the laboratory is done using standard equipment that includes a static ruler, tweezers and digital scales.

To complement the *S. lemuru* habitat data, hydro-oceanography data was required. The hydro-oceanographic data collection was performed with Aqua quality sensor (AAQ1183C) product of Alec Ltd. Japan which was set in waters with average depth reaching 5 meters in each fishing ground or adjusted with upper gill nets depth during operated. AAQ1183C was an effective water quality measurement tool because it is a relatively modernized compact and light-weight (1.5 kg) multi-parameter water quality meter which has nine kinds of sensors that can record parameters of waters such as depth, temperature, conductivity, conductivity (fresh water), salinity, turbidity, chlorophyll *a*, DO and pH. In addition, this tool is encompassed with data logger that is able to store data with interval 0.2 until 1.5 second (http://www.nijin.com.tw/sf/JFE/AAQ1183C/AAQ1183C-e.htm). Subsequent fish samples and hydro-oceanography data were analyzed at the Hydrobiology Laboratory, Faculty of Fisheries and Marine Sciences, Brawijaya University, Malang, Indonesia.

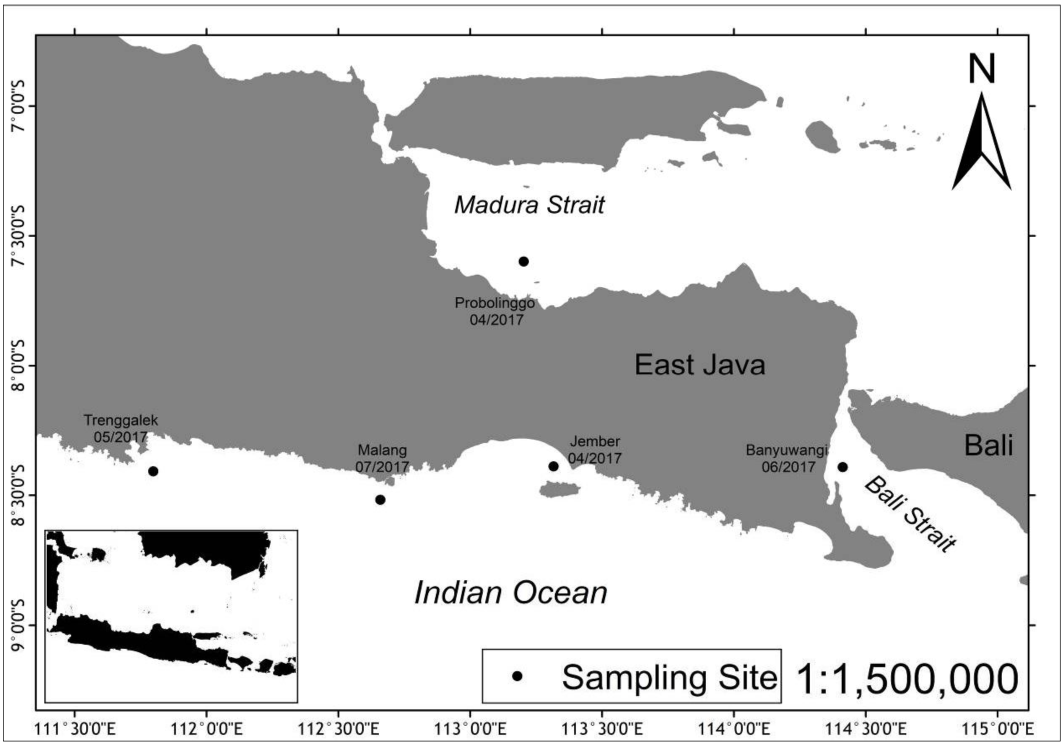

Figure 2. Sampling sites of *S. lemuru* and water quality parameters. The 5 sampling sites are Prigi (Trenggalek), South Malang, Puger (Situbondo), Bali Strait, and Probolinggo.

Identification of morphological characteristics. Measurement of morphological characteristic includes morphometric characters and meristic characters (Smith 1945; Kartika 2013; Taqwin et al 2014). The measured morphometric characters include total length (TL), standard length (SL), fork length (FL), predorsal length (PreDL), orbital length (OrbL), eye length (EyeL), caudal predorsal length (CpedL), head length (HdL), snout length (SntL), post orbital length (POL), head height (HH), body height (BH), cheek height (CH), under eye height (UEH), dorsal fin base length (DBL), anal fin base length (ABL), dorsal fin height (DFH), anal fin height (AFH), pectoral fin length (PFL), ventral fin length (VFL), maxilla base length (MXBL), mandibulla base length (MNBL), while for meristic observations we counted the ray of the fins on *S. lemuru*, as dorsal, pectoral, anal, ventral and caudal fin, and also scale of linea lateralis (LL). The scheme of the morphometric measurements of *S. lemuru* can be seen in Figure 3.

Data analysis. Morphometric and meristic data analysis of *S. lemuru* was done by clustering method or grouping of morphological characteristics from 100 *S. lemuru* individuals obtained from five fishing grounds based on similarity or likeness. This hierarchical clustering analysis is commonly used to analyze data that has considerable variation using Euclidian distance matrix, to make it easier to learn the pattern (Emery & Thomson 1997). The final result obtained from hierarchical clustering analysis, the K-means clustering applied to show the pattern of *S. lemuru* grouping based on morphology obtained from five fishing grounds. Furthermore, to know the parameters of hydro-oceanography most influential on the length and weight variations of *S. lemuru*, Principal Component Analysis (PCA) analysis was conducted using statistical software SPSS.

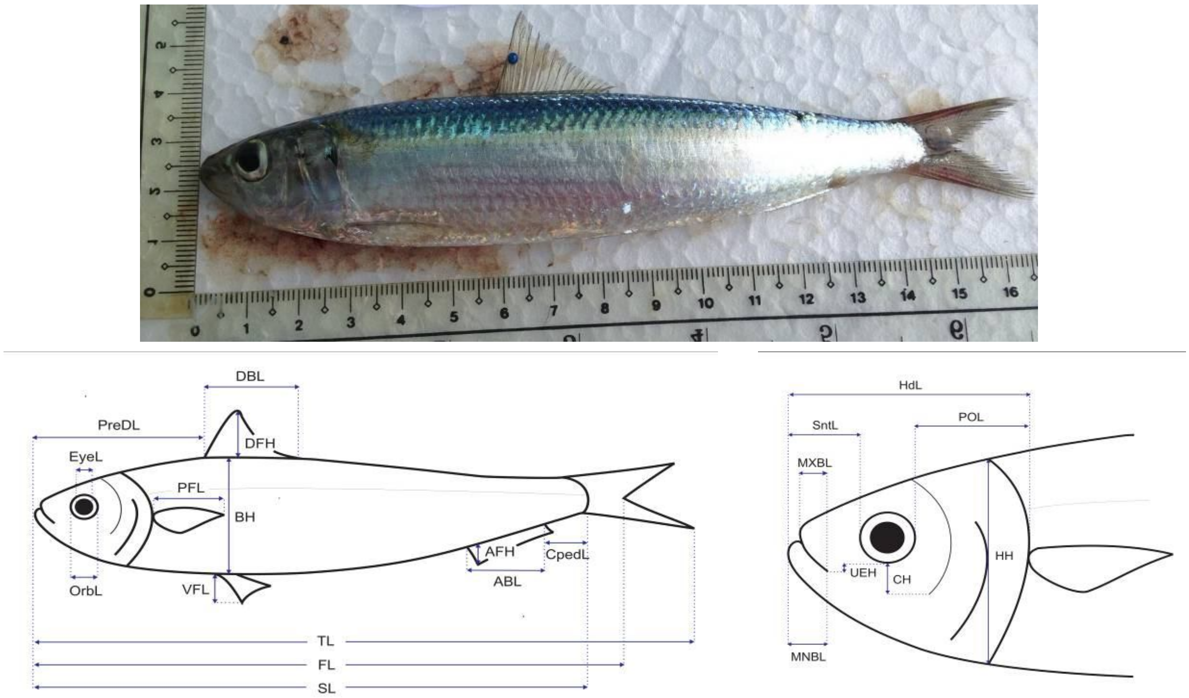

Figure 3. *Sardinella lemuru* (upper panel). Illustration of morphometric characters measurement methods for whole individual and head section (left and right lower panel respectively).

Results and Discussion. Observations on the morphology of *S. lemuru* from all sampling sites show similarity with compressed body shape and blueish-green body color on the dorsal (upper) part and silvery on the ventral (lower) part. *S. lemuru* had superior mouth type, terminal shape and forked tail shape with homocercal type as similarly described by Luceño et al (2014) and Wujdi et al (2016).

The results of morphometric and meristic characters measurement of *S. lemuru* are listed in Tables 1 and 2.

Based on morphometric measurements, it was obtained that the length average of *S. lemuru* caught at five fishing grounds of East Java waters ranged between 11 and 17 cm. It was also found that *S. lemuru* caught in the fishing ground of South Malang and Bali Strait was smaller (11-12 cm) than that caught from other three fishing grounds. The small size of *S. lemuru* of both South Malang and Bali Strait can be categorized as "*protolan". Protolan* is a local term commonly used for *S. lemuru* with size between 11 and 15 cm in Muncar area (Banyuwangi: see Figure 1) of Bali Strait (Wudianto & Wujdi 2014). The differences in size of fish might be due to differences in nutrient availability in each fishing ground (Setyohadi et al 2016). ANOVA test showed that the sampling sites difference has an effect on morphometric characteristics of *S. lemuru* ($p < 0.05$).

Besides identification purposes, morphometric and meristic characteristics are also commonly used for grouping (clustering) method of fish populations (Nasution et al 2004). Based on the morphometric and meristic characteristics, *S. lemuru* of East Java waters were clustered to be two major groups, group 1 and 2. The group 1 consisted of *S. lemuru* caught in the waters of Puger, Prigi and Probolinggo, while the group 2 was *S. lemuru* caught in Bali Strait and South Malang (Figure 4). This current study proofed well with the past study done by Pet et al (1997) with added another two sampling sites, Prigi and Puger for sampling site enhancement. Pet et al (1997) have determined that group 1 (North Java population group) is only consisted of Probolinggo sampling site, and group 2 (Indian Ocean population group) is composed of Bali Strait and South Malang sampling sites.

Table 1

Morphometric characters measurement of *S. lemuru* (Mean±SD measured in cm)

Morphometric characteristic	*Location*				
	Prigi	*South Malang*	*Puger*	*Bali Strait*	*Probolinggo*
	Mean±SD	*Mean±SD*	*Mean±SD*	*Mean±SD*	*Mean±SD*
TL	16.51±0.30	11.50±0.22	16.02±0.50	11.89±1.75	17.97±0.49
FL	14.84±0.30	10.30±0.33	14.40±0,52	10.64±1.67	16.06±0.48
SL	14.14±0.31	9.72±0.22	13.68±0,49	10.01±1.43	15.24±0.41
PreDL	5.98±0.15	4.20±0.10	5.57±0,23	4.44±0.58	6.74±0.29
OrbL	0.80±0.00	0.72±0.04	0.77±0,05	0.68±0.10	0.86±0.04
EyeL	0.40±0.00	0.30±0.00	0.38±0,08	0.34±0.05	0.41±0.04
CpedL	1.16±0.07	1.18±0.32	1.23±0,12	0.80±0.23	1.24±0.26
HdL	3.43±0.07	2.36±0.18	3.00±0,15	2.42±0.36	3.86±0.39
SntL	1.14±0.12	0.68±0.04	1.03±0.18	0.80±0.05	1.28±0.21
POL	1.50±0.07	0.92±0.08	1.25±0.08	0.94±0.26	1.87±0.18
HH	2.37±0.10	1.70±0.07	2.87±0.19	1.75±0.27	2.49±0.19
BH	3.07±0.21	2.72±0.08	3.53±0.14	2.39±0.46	4.03±0.29
CH	0.88±0.10	1.16±0.05	0.83±0.08	0.76±0.13	1.08±0.08
UEH	0.78±0.22	0.70±0.00	0.43±0.08	0.30±0.11	0.49±0.22
DBL	1.86±0.21	1.64±0.17	1.82±0.12	1.37±0.24	2.01±0.13
ABL	1.83±0.15	1.52±0.22	1.87±0.10	1.32±0.29	2.11±0.16
DFH	1.92±0.10	1.56±0.19	1.58±0.12	1.21±0.15	1.88±0.39
AFH	0.54±0.10	0.52±0.11	0.40±0.00	0.36±0.08	0.59±0.11
PFL	2.08±0.16	1.30±0.28	2.08±0.04	1.48±0.23	2.19±0.15
VFL	1.04±0.05	1.02±0.04	1.15±0.05	0.88±0.11	1.13±0.08
MXBL	0.94±0.07	0.70±0.00	0.77±0.14	0.59±0.12	1.11±0.10
MNBL	1.18±0.11	0.88±0.04	0.57±0.10	0.47±0.08	1.37±0.10

Table 2

Meristic characters count of *S. lemuru*

Meristic characteristic	*Location*				
	Prigi	*South Malang*	*Puger*	*Bali Strait*	*Probolinggo*
	Mean±SD	*Mean±SD*	*Mean±SD*	*Mean±SD*	*Mean±SD*
D hard	2.89±0.60	2.20±0.45	2.17±0.41	2.0±0.00	2.25±0.44
D soft	12.89±0.78	13.00±2.45	12.83±0.75	14.4±0.68	12.9±0.97
P hard	2.33±0.50	2.00±0.00	1.33±0.82	2.00±0.00	2.05±0.76
P soft	11.11±1.69	10.20±0.45	12.83±0.75	13.95±1.43	11.95±1.50
A soft	13.78±1.30	14.80±0.84	16.50±0.84	13.65±2.06	14.20±1.74
V hard	1.56±0.73	1.40±0.55	1.17±0.41	1.00±0.00	1.90±0.45
V soft	7.33±0.71	9.00±1.22	6.50±1.05	8.25±0.44	7.10±0.72
C hard	3,33±1.00	2.80±1.10	3.67±0.82	4.00±0.00	2.55±0,69
C soft	12.78±0.97	17.20±1.79	14.67±1.63	16.00±1.45	12.25±1.62
LL	50.00±2.00	36.40±1.52	41.33±3.67	35.75±329	50.00±2.66

D - dorsal fin; P - pectoral fin; A - anal fin; V - ventral fin; C - caudal fin.

The size differences of the *S. lemuru* population caught in five sampling sites let them grouped into two separate groups, group 1 and 2. Standard-length difference of this fish is linked to significantly differences in morphometric characters. Furthermore Muchlisin (2013) revealed that environmental factors, such as water habitat, could affect the morphology of fish as a form of fish adaptation due to water environment changes. Indeed, environmental factors such as temperature, salinity and currents can affect the different characteristics associated with the number of parts in the fish body (Dewantoro 2001). Although the meristic character is the result of gene expression, however the environmental component may also modify the expression of characters mainly during the larval development period (Smith et al 2002). In this case environmental factors have a considerable effect on fish growth (Checkley Jr. et al 2017).

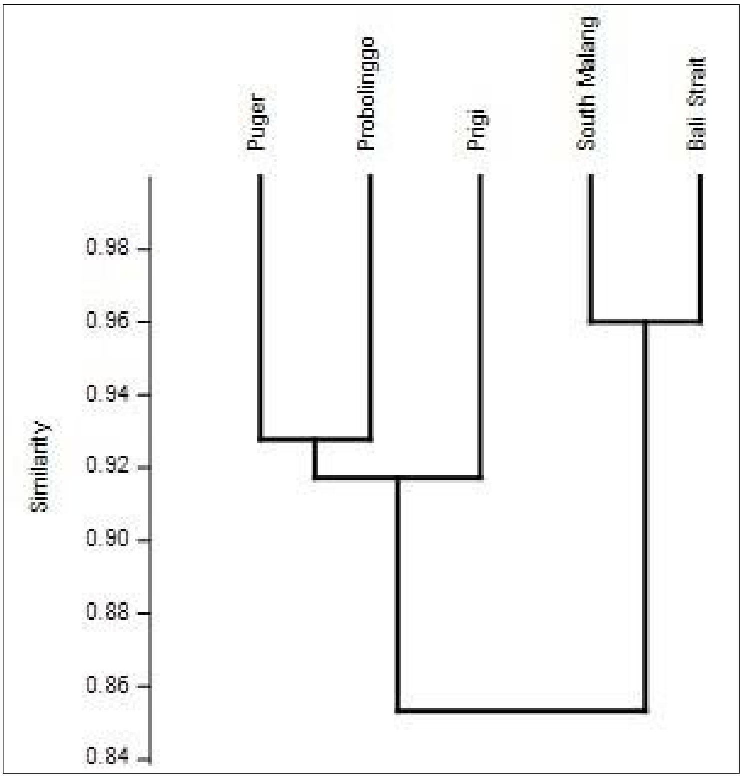

Figure 4. Dendrogram of morphometric and meristic characters of *S. lemuru* caught in East Java waters. It shows that *S. lemuru* population of East Java waters grouped into two clusters.

Furthermore, the result of water quality measurement among five fishing ground of *S. lemuru* are presented in Table 3. The result showed that the range of water temperature at five sampling sites was 29-30°C with a fairly stable salinity as 32 psu. Chlorophyll-*a* concentration showed large variation among five sampling sites, where Bali Strait was found as the highest chlorophyll-*a* (5.96 mg m^{-3}) concentration, while Probolinggo waters was the lowest (0.28 mg m^{-3}) concentration.

Table 3

Hydro-oceanography data at five sampling sites

Sampling sites	*Hydro-oceanography data*				
	Temp (°C)	*Sal (psu)*	*pH*	*DO (mg L^{-1})*	*Chl-a (mg m^{-3})*
Prigi	29.17±2.90	32.10±0.23	8.14±0.004	7.13±0.06	1.60±0.74
South Malang	29.12±0.02	32.80±0.03	8.10±0.00	7.84±0.04	0.91±1.23
Puger	29.47±0.10	32.14±0.64	8.17±0.005	7.53±0.04	2.04±1.03
Bali Strait	27.63±0.36	32.70±0.11	8.89±0.01	8.82±0.14	5.96±1.39
Probolinggo	30.06±0.80	32.41±0.26	8.53±0.030	7.75±0.09	0.28±0.02

Subsequently, the Principal Component Analysis (PCA) of the hydro-oceanography factors on the length and weight relationship of *S. lemuru* are presented in Table 4 and Figure 5. The correlation-based PCA shows the first component highly affect characteristics of *S. lemuru* at East Java. It described a gradient from salinity at the negative score to Chlorophyll a, pH, length, DO, weight, and temperature at the positive score. The second component indicated the variability of all variables.

Hydro-oceanography data and length-weight variables were plotted into PCA diagram as shown by Figure 5. It showed that Component 1 and 2 explained 50.69% and 43.13% of the total variance, respectively. Therefore, those two components explain 93.82% of the total variance of hydro-oceanography data and length-weight variables.

Chlorophyll-*a*, pH, and DO have the strongest correlation. Length and weight have strong correlation with temperature. While, salinity has a weak correlation with other variables.

Table 4
PCA component matrix of hydro-oceanography data and length-weight relationship of five sampling sites

Variables	*Component matrix*[a]	
	PC1	*PC2*
Length	0.790	0.551
Weight	0.886	0.386
Chl-*a*	0.955	-0.199
Salinity	-0.981	0.167
pH	0.946	-0.319
DO	0.823	-0.552
Temperature	0.776	0.428

Extraction Method: Principal component Analysis; [a] Two components extracted.

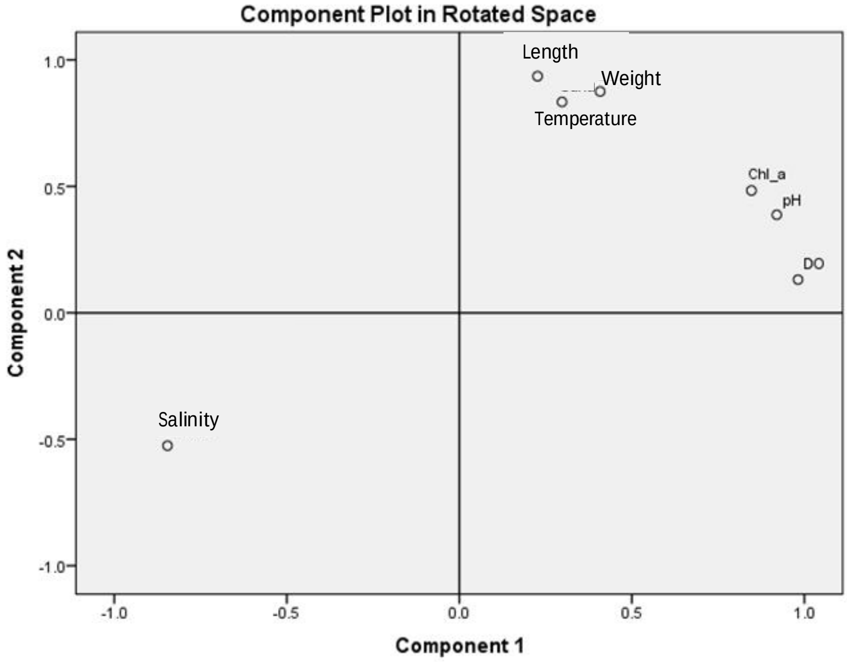

Figure 5. Principle Component Analysis (PCA) diagram of hydro-oceanography data and length-weight variables. All variables have strong correlation with length-weight variables. Component 1 (50.69% explained variance) and Component 2 (43.13% explained variance).

The waters of the Bali Strait as endemic habitat of *S. lemuru* are rich of nutrients due to the high upwelling intensity, so that the chlorophyll-*a* content is also higher than the north and south waters of East Java (Sartimbul et al 2010). Chlorophyll-*a* rich water are usually supplied primarily by coastal, wind-driven upwelling or rivers (Checkley Jr. et al 2017). Even Bali Strait is typically abundant of nutrients, however in this case, the timing of sampling is more important than the richness of fishing ground alone. Because there is 3-month lagged from abundance of chlorophyll-*a* toward *S. lemuru* availability as revealed by Sartimbul et al (2010). The current samples of *S. lemuru* were caught in Bali Strait in June or early season of southwest monsoon (southeast monsoon: June, July, and August). During this season, strong wind prevails from Australia leading to cause upwelling along West Java, South Java, Bali and Nusa Tenggara (Hendiarti et al 2005). It will give impact to fish catch three-month later due to grazing process in its food chain (Sartimbul et al 2010). Furthermore, in winter (northwest monsoon season), zooplankton is less abundant (Somoue 2004), fish eat little and reduce its mass. This weight loss stops with the recovery of food and condition improved in the spring (transition season) with a greater or lesser time lag between years (Checkley Jr. et al 2017).

Conclusions. This study proofs well the past study with enhancement of sampling areas. It is suggested that there are two groups of *S. lemuru* population based on morphological analysis. Group 1 consists of South Malang and Bali Strait, while group 2 consists of Puger, Prigi and Probolinggo. These two groups are classified due to the different size of *S. lemuru* (length and weight) which were mainly influenced by chlorophyll-*a* concentration, pH then DO and temperature during transition and southeastern monsoon seasons in the southern waters of East Java. The environment seems to be one of the factors that can affect the variety of fish phenotypes and played an important role controlling the fish stock in the waters. By applying morphological method alone does not proof the best method in *S. lemuru* stock analysis. Therefore, other methods such as molecular biology will be a good chance to be applied for future study.

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