Genetic Similarity of Commerson’s Anchovy across Segara Anakan Cilacap Assessed Using Randomly Amplified Polymorphic DNA (RAPD) Markers

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ABSTRACT

Segara Anakan areas can be divided into three different regions according to their salinity. Salinity differences suggested that Commerson’s anchovy population in that area can be divided into three subpopulations due to genetic differences. Genetic differences among subpopulation can be assessed through a population genetic study using random amplified polymorphic DNA. This study aims to evaluate the genetic variation and differences of Commerson’s anchovy (Stolephorus commersonnii) collected at three different water salinities in Segara Anakan estuary Cilacap Indonesia. Total genomic DNA was isolated using the Chelex method. Genetic diversity and differences were assessed using RAPD markers and were analyzed statistically using an analysis of molecular variance, as implemented in Arlequin software. The results showed that high genetic diversity was observed within the subpopulations. However, no significant genetic differences were observed among subpopulations which indicate genetic similarity. A high number of offspring are likely to cause high genetic variation within subpopulations. Adult and larvae migration is the cause of genetics similarity across Segara Anakan. Another impressive result is that water salinity did not affect the genetic characteristic of Commerson’s anchovy. Genetic similirarity of Commerson’s anchovy indicates that Segara Anakan forms a single genetic conservation unit.

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Introduction

Commerson’s anchovy (Stolephorus commersonnii) or locally known as Ikan Teri, is widely distributed fish. It has a geographic distribution from the Indian Ocean to the Fiji Islands. Commerson’s anchovy is a pelagic fish inhabit coastal areas and brackish water. It lives in a massive colony in the water column from 0 meters up to 50 meters depth (Froese & Pauly, 2019). Therefore, it is not surprising that
Commerson's anchovy is abundant in Segara Anakan, Cilacap, Central Java, Indonesia (Nuryanto et al., 2017).

Segara Anakan is an estuary ecosystem directly adjacent to the Indian Ocean. It is a semi-closed aquatic ecosystem separated from the Indian Ocean by the Nusakambangan Island in the western part of Cilacap City. The Segara Anakan has two openings; one in the eastern areas (East Plawangan) and one in the west regions (West Plawangan). Those openings make both Plawangan areas are much affected by seawater input and have high salinity. Water salinity in both locations is ranging from 12 to 28.5 parts per trillion (ppt) (Nugroho et al., 2020; Sastranegara et al., 2020). Conversely, the central areas have salinity ranging from 6 ppt to 25 ppt (Nuryanto et al., 2017). A recent data collected by Sastranegara et al. (2020) proved that the lagoon has water salinity below 10 ppt, with the range between 3 ppt to 6.5 ppt. It’s mean that lagoon areas have water salinity below the ecological requirement of Commerson’s anchovy, that is and salinity conditions ranging from 19.6 to 32 ppt (Froese & Pauly 2019). However, Suprastini et al. (2014) and Nuryanto et al. (2019a) reported that Commerson’s anchovy is also highly abundant in the lagoon areas of Segara Anakan.

Previous studies reported contradictive result about the impact of salinity on the fish genetic constituent. On the one hand, Catanese et al. (2016), had found that offshore (low salinity) anchovy population was genetically different to inshore (high salinity) population. Even Whitehead et al. (2011) observed significant genetic differences among populations without an obvious salinity barrier. On the other hand, Regmi et al. (2016) and Moore et al. (2018) noted that there was no significant relationship between salinity gradient and genetic structure of mosquitofish. Therefore, it is interesting to elucidate which population genetic pattern has occurred on Commerson's anchovy (Stolephorus commersonnii) that live in different water salinities in Segara Anakan Cilacap.

Molecular characteristics of a population can be evaluated using RAPD markers (Nuryanto & Susanto, 2010; Sari et al., 2014). Previous studies proved that RAPD is a reliable marker for molecular characterization in fish (Kusmini et al., 2011; Gustiano et al., 2013). A previous study by Muharam et al. (2012) observed that two strains of goldfish (Cyprinus carpio) have different molecular characteristic based RAPD markers. A survey by Kusmini et al. (2016) showed different RAPD profiles among three distinct populations of Barbonimus schwanenfeldii. Other studies also reported similar results when applying RAPD markers on the molecular characterization of various species. For example, Kristanto et al. (2017) on kissing gourami (Helostoma temminckii), Mulyadi et al. (2017) on the hybrid of Osteochilus hasselti and Cyprinus carpio), and Hayuningtyas et al. (2016) on three generations of rainbow kurumoi (Melanotaenia parva).

An earlier study proved that no genetic differences on the population of Commerson’s anchovy from Segara Anakan Cilacap based on PCR RFLP cytochrome c oxidase 1 gene (Nuryanto et al., 2019a) and suggested that S. commersonnii formed a single population in Segara Anakan. In contrast, Nuryanto & Sastranegara (2013) reported a different molecular characteristic among Polymesoda erosa subpopulation across Segara Anakan with different heavy-metal concentration as revealed by PCR RFLP COI gene markers. Assuming that genetic constituent is strongly affected by the ecological condition and referring to previous studies by Whitehead et al.
(2011), Catanese et al. (2016), and Moore et al. (2018) it seems that different molecular markers, ecological factor, and species might show a different population genetic pattern of organisms. Therefore, we are suggested that RAPD markers and different salinity in the areas of Segara Anakan might show a different pattern of population genetic compared to Nuryanto et al. (2019a).

This study aims to evaluate the genetic variation and differences of Commerson's anchovy (Stolephorus commersonnii) collected at three different water salinities in Segara Anakan estuary Cilacap Indonesia. This research is expected to provide information population genetic pattern of S. commersonnii in Segara Anakan. The information is essential for fishing management and conservation effort in Segara Anakan Cilacap.

Materials and Methods
Research location and times

Fish samples were collected from three different areas, namely east parts, middle parts, and the lagoon parts of Segara Anakan (Figure 1). A total of 20 fish samples were analyzed from each area. The DNA isolation and amplification were conducted at the Animal Taxonomy Laboratory, Biology faculty, Jenderal Soedirman University. The study was conducted for six months, starting from February 2019 until August 2019.

DNA Isolation

DNA isolation was carried out using the Chelex method (Walsh et al., 2013). The reaction was performed in a mixture of 100 µL of Chelex 5%, 5 µL of dithiothreitol 0.1M, and 4 µL of proteinase-K, which was put into a 1.5 ml microtube size. The mixed solution was made for ten samples at a time, so six microtubes of 1.5 mL were used. The mixed solution is then homogenized with a vortex machine for 30 seconds. After being homogeneous, the mixed solution was divided into 60 new 1.5 mL microtubes of 109 µL.

The RAPD markers amplification

Random Amplified Polymorphic DNA (RAPD) markers were amplified with the following procedures. At the preliminary steps, the markers were amplified using 23 of primers. Based on the preliminary results, 4 RAPD primers were selected (Table 1) and were used to analyze the population genetic of S. commersonnii samples. The primer was selected based on non-contamination and produce clear and strong bands, as shown from preliminary research.

| Name   | Nucleotide sequence 5’-3’ |
|--------|-------------------------|
| OPA 08 | GTGACGTAGG               |
| OPA 20 | GTTGCGATCC               |
| OPAH 08| TTCCCGTGCC              |
| GEN 14 | CGCATTCGCC              |

The PCR reaction was carried out with a volume of 25 µL. The mixed solutions for one reaction consisted of 17.6 µL ddH2O, 2.5 µL 10X PCR buffer, 1.25 µL MgCl2 50 mM, 1 µL dNTPs, 1.5 µL primer, 0.15 µL Taq polymerase, and 1 µL DNA template. PCR amplification was performed in thermal condition as follow. The pre-denaturation stage was conducted at a temperature of 95°C for 2 minutes and followed by 35 cycles. The cycles were as follow. Denaturation conditions at a temperature of 95°C for 45 seconds, annealing for 45 seconds with the
temperature adjusted based on the melting temperature (Tm) for each used primer (Table 1), elongation at 72°C for 1 minute, then proceed with final elongation at 72°C for 5 minutes.

**Electrophoresis and DNA visualization**

Electrophoresis was carried out for DNA isolation and PCR amplification products and was done in 1.5% of agarose gel. Electrophoresis was run on 80 volts and 400 mA for 70 minutes. The isolation and PCR products were visualized under a UV transilluminator and documented using 16-megapixel cameras.

**Data Analysis**

The genetic variations of Commerson’s anchovy were estimated based on polymorphism (Θ), gene (h), and locus (π) diversity values. Genetic differences among subpopulations were evaluated using Fst and variance component values and compared to their p-value. The polymorphism was analyzed mathematically by dividing an allele by all observed alleles and presented as allele percentage and then compared to the per cent value available in Hartl & Clark (1997). Gene and locus diversities and molecular differences among subpopulations were analyzed statistically. The used statistical tool was an analysis of molecular variance (AMOVA). The analysis was performed in Arlequin ver. 3.5 (Excoffier & Lischer, 2010). Before the variance analysis was conducted, the band pattern data were converted to binary data 0:1 (0= no RAPD bands; 1= RAPD bands are present).

**Results and Discussion**

**Genetic variation**

Polymorphism analysis showed that RAPD markers of Commerson’s anchovy showed variable values. East subpopulation had a polymorphism value of 78.21%. Lagoon subpopulation has a value of 66.67%, and middle subpopulation has of 80.77% (Table 2). The obtained values indicate that the used RAPD markers are highly polymorphic for all the three subpopulations. It was because they have the most common allele frequency at a locus in the subpopulation of less than 95%. Hartl & Clark (1997) have stated that a locus is referred to as polymorphic if the most common allele has a frequency below 95%.

High polymorphisms of RAPD markers obtained in the present study are similar to reported results in the previous research in several fish species. For example, high polymorphisms of RAPD markers were observed in goldfish (Muharam et al., 2012), kissing gourami (Kristanto et al., 2017), and rainbow kurumoi (Hayuninftyas et al., 2016). Even, Nuryanto & Susanto (2010) observed high polymorphisms of RAPD markers in *Polymesoda erosa* (Bivalvia) from Segara Anakan Cilacap. Based on the present and those previous studies results, it can be noted that high polymorphisms of RAPD markers are common phenomena in a wide range of animals.

**Table 2. Polymorphism and genetic diversity**

| Areas    | Θ (%)  | h     | π      |
|----------|--------|-------|--------|
| East     | 78.21  | 1 ± 0.02 | 0.23 ± 0.12 |
| Middle   | 80.77  | 1 ± 0.02 | 0.25 ± 0.13 |
| Lagoon   | 66.67  | 1 ± 0.02 | 0.19 ± 0.10 |

Note: Θ = Polymorphism  
$h = Haplotype diversity$  
$π = Locus diversity$

It can be seen in Table 2 that the examined subpopulations have a different value of polymorphisms. The phenomenon could be due to that each subpopulation lives in a habitat with different water salinity (East and Middle areas have high salinity, while lagoon areas have low salinity). Our argument was based on the report by Catanese et
that water conditions, such as salinity, might become a chemical barrier for the populations. Table 2 also shown that all three subpopulations have high and similar gene diversity values. The value was of 1 ± 0.0158. The value indicates that Commerson’s anchovy has high genetic diversity within subpopulations because of the value close to 1. According to Nuryanto et al. (2019b), gene diversity value of 1 indicates high gene diversity of a population. High gene diversity of the population based on RAPD markers was also reported in giant gourami (Sari et al., 2014) and Polymesoda erosa from Segara Anakan (Nuryanto & Susanto, 2010).

Comparison to other studies showed that the present study obtained a higher gene diversity than that of Indian anchovy (Stolephorus indicus) studied by Sukumaran et al. (2019), and European anchovy (Engraulis encrasicolus) (Viñas et al., 2014).

Locus diversity (π) was ranged from 0.19 ± 0.10 in lagoon subpopulation to 0.25 ± 0.13 in the middle subpopulation. The detail values for all subpopulations are presented in Table 2. The values indicate that all S. commersonnii subpopulations in the Segara Anakan have a high locus diversity of RAPD markers because of the values higher than 0.1. According to Nuryanto et al. (2019b), locus diversity of 0.1 indicated high locus diversity. Loci diversity, as obtained in the present study was higher than Indian anchovy (S. indicus), and European anchovy (Viñas et al., 2014; Sukumaran et al., 2019).

Genetic variability that occurs can be caused by mutations, random mating, migration, and recombination (Melian et al., 2012). A population that has a fast reproductive rate and produces a large number of offspring tends to have a high level of genetic variation because it allows random interbreeding.

Interbreeding between populations might increase genetic diversity because of genetic recombination (Melian et al., 2012). Therefore, it is reasonable that the present study observed high genetic diversity because Commerson’s anchovy is among fish species with high reproductive rates and produces an enormous number of offspring in one spawning. According to Froese & Pauly (2019), Comerson’s anchovy belongs to the Clupeoid group that lives in a large school. These fish groups also have fast reproductive property. Moreover, it can produce a large number of offspring, mature before one year, and spawn throughout the year. It is suggested that all those reproductive properties of Commerson’s anchovy have contributed to a high genetic variation in anchovy (S. commersonnii) subpopulations from Segara Anakan.

Genetic difference analysis

Pairwise comparison showed no genetic differences among the three anchovy subpopulations in Segara Anakan despite lives in different levels of water salinity. Genetic similarity was indicated by a variance component value of 0.00 and the fixation index (Fst) of 0.00 among subpopulations (p-value 1.000). According to the result presented in Table 3, it is undoubted to state that S. commersonnii in the Segara Anakan formed a single genetic conservation unit.

| Source of variation | d.f | Sum of squares | Variance components |
|---------------------|-----|----------------|---------------------|
| Among populations   | 2   | 1              | 0.00 Va             |
| Within populations  | 57  | 28.50          | 0.50 Vb             |
| Total               | 59  | 29.50          | 0.50                |
| Fst                 | 0.00| 1.00           |                     |
| p-value             |     |                |                     |

It can also be seen in Table 3 is that variation has occurred within subpopulations (Vb = 0.500). That data supports the result of gene diversity and
locus diversity analysis that high molecular variation was observed within subpopulations, as explained in the previous section. The phenomena could be because the salinity values within each subpopulation are also high, which lead various alleles to adapt to that condition.

Comparison to previous studies suggested that high genetic diversity within subpopulations is common in various animals and using variable molecular markers (Chandra et al., 2010; Nuryanto & Susanto, 2010, Nuryanto & Sastranegara, 2013; Sari et al., 2014).

This study observed that water salinity does not significantly affect the genetic constituent of Commerson’s anchovy in the Segara Anakan. It is proven by no statistical difference in the variance component among subpopulations and extremely low Fst values (p-value 0.000, Table 3). This result consistent with and strengthen the previous study using the PCR-RFLP COI marker by Nuryanto et al. (2019a) that genetic homogeneity was observed in Commerson’s anchovy in Segara Anakan. Similar results were also reported by Damerau et al. (2012), that low and even absence of molecular differences among populations are common in marine fish.

This study obtained a different result from Catanese et al. (2016), which shows that differences in water salinities could affect the level of genetic diversity. The differences because both studies be explained at least by two arguments. Fist, the present study used Commerson’s anchovy as a research object, while Catanese et al. (2016) used European anchovy. Different species will have a different response to environmental conditions. That difference might cause in different genetic response as a result of different natural selection factors. Second, the present study used RAPD as a molecular marker, whereas Catanese et al. (2016) used SNPs markers. The SNPs markers have a high rate of mutation. That condition could be the cause of molecular differences among herring populations, which are collected from different water salinity ecosystems.

The absence of molecular differences among Commerson’s anchovy subpopulations in East, central, and the lagoon areas indicates high gene flow. Gene flow can be caused by the euryhaline nature of anchovies that can live in waters with low to high salt levels (Silva et al., 2014a). This tolerant trait makes anchovies have a wide distribution in the waters. Broad distribution is also supported by migration, both in adult fish and their planktonic larvae (Silva et al., 2014b). Migration of adult anchovy often occurs in feeding areas (feeding ground) (Catanese et al., 2016). Migration in adult anchovy also occurs when the fish will spawn. Anchovy will migrate from the estuarine area to the area near the beach to spawn. Planktonic larvae of anchovies will then migrate back to the estuarine site until the juvenile and adult phases (Correa-Herrera et al., 2017). Based on the nature of S. commersonnii, the difference in water salinity between East areas and Lagoon areas does not inhibit anchovy migration. Beside, geographic distance east areas and lagoon might also not be a barrier to anchovy distribution. The distribution of planktonic larvae can also be facilitated by tidal waters (Silva et al., 2014a). Eastern areas directly connected to the ocean and high tides could carry anchovy planktonic larvae to the middle and lagoon areas (Nuryanto and Sastranegara, 2013).

No genetic differences among the three subpopulations of Commerson’s anchovy populations (S. commersonnii) across Segara Anakan indicate that Commerson's anchovy across Segara
Anakan forms a single gene pool. In term of conservation, the result proved that *S. commersonnii* constituted a single genetic conservation unit across Segaara Anakan and suggested a single policy for Segara Anakan Conservation. However, further research using more sensitive molecular markers, such as microsatellite, is still needed to obtain a comprehensive figure about population genetic of Commerson’s anchovy populations in Segara Anakan. It is because complete information will provide a strong scientific basis for the management of Commerson’s anchovy fishery in the Segara Anakan or even generally for conservation Segara Anakan as an aquatic ecosystem.

**Conclusion**

This study concludes that high genetic variations were observed at three subpopulations of anchovy (*S. commersonnii*) in Segara Anakan Cilacap. There is no genetic differences among subpopulations indicate that Segara Anakan, Cilacap formed a single genetic conservation unit.

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**References**

Catanese, G., Borme, D., Watteaux, R., Montes, I., Barra, M., Rumolo, P., Genovese, S., Nardelli, B. B., Botte, V., Mazzocchi, M. G., Di Capua, I., Iriondo, M., Estonba, A., Ruggeri, P., Tirelli, V., Iudicone, D., Caputo-Barucchi, V., Basilone, G., Bonanno, A., & Procaccini, G. (2016). Insights on the Drivers of Genetic Divergence in the European Anchovy. *Scientific Reports*, 7, 4180.

Chandra, G., Saxena, A., & Barat, A. (2010). Genetic diversity of two riverine populations of Eutropiichthys vacha (Hamilton, 1822) using RAPD markers and implications for its conservation. *Journal of Cell and Molecular Biology*, 8(2), 77-85.

Correa-Herrera, T., Barletta, M., Lima, A. R. A., Jimenez-Segura, L. F., & Arango-Sanchez, L. B. (2017). Spatial Distribution and Seasonality of Ichthyoplankton and Anthropogenic Debris in a River Delta in the Caribbean Sea. *Journal of Fish Biology*, 90(4), 1356-1387.

Damerau, M., Matschiner, M., Salzburger, W., & Hanel, R. (2012). Comparative Population Genetics of Seven Notothenioid Fish Species Reveals High Levels of Gene Flow Along Ocean Currents in the Southern Scotia Arc, Antarctica. *Polar Biology*, 35(7), 1073-1086.

Excoffier, L. & Lischer, H. E. (2010). Arlequin suite ver 3.5: a new series of programs to perform population genetics analyses under Linux and Windows. *Molecular Ecology Resources*, 10(3), 564-67.

Froese, R. & Pauly, D., Editors. (2019). FishBase. World Wide Web electronic publication.www.fishbase.org, version (12/2019).

Gustiano, R., Oktaviani, T., Soelistiowati, D. T., Kusmini, I. I., Wahyutomo, & Huwoyon, G. H. (2013). Analysis of Genotype Variation and Truss
Morphometric of Three Populations of Snakehead Fish \textit{(Channa striata} (Bloch, 1793). \textit{Berita Biologi}, 12(3), 325-333

Hartl, D. L., & Clark, A. G. (1997). \textit{Principles of population genetics}. 3rd ed. Sunderland: Sinauer Associates.

Hayuningtyas, E. P., & Kadarini, T. (2016). Keragaman Genotipe Tiga Generasi Ikan Rainbow Kurumoi \textit{(Melanotaenia parva)} Hasil Domestikasi Berdasarkan RAPD. \textit{Jurnal Riset Akukultur}, 11(2), 107-114.

Kristanto, A. H., Subagja, J., Cahyanti, W., & Arifin, O. Z. (2017). Evaluasi Variasi Fenotipe dan Genotipe Populasi Ikan Tambakan dari Kalimantan Tengah, Jawa Barat, dan Jambi dengan Truss Morfometrik dan Random Amplified Polymorphic DNA (RAPD). \textit{Jurnal Riset Akuakultur}, 12(3), 203-211.

Kusmini, I. I., Gustiano, R., & Mulyasari. (2011). Genetic Characterization of Kelabau Fish \textit{(Osteochilus kelabau)} from Several Locations in West Kalimantan Using RAPD (Random Amplified Polymorphism DNA) Method. \textit{Berita Biologi}, 10(4), 449-454.

Kusmini, I. I., Gustiano, R., Radona, D., Prakoso, V. A., Putri, F. P., & Prihadi, T. H. (2016). Karakterisasi Fenotipe dan Genotipe Tiga Populasi Ikan Tengadak, \textit{Barbomyrus schwanefeldii}. \textit{Jurnal Riset Akuakultur}, 11(3), 2017-216.

Melian, C. J., Alonso, D., Allesina, S., Condit, R. S., & Etienne, R. S. (2012). Does Sex Speed Up Evolutionary Rate and Increase Biodiversity? \textit{PLoS Computational Biology}, 8(3), e1002414.

Moore, C. S., Ruocchio, M. J., & Blakeslee, A. M. H. (2018). Distribution and Population Structure in the Naked Goby \textit{Gobiosoma Bosc} (Perciformes: \textit{Gobiidae}) Along a Salinity Gradient in Two Western Atlantic Estuaries. \textit{PeerJ}, 6, e5380.

Muhammad, E. G., Buwono, I. D., & Mulyani, Y. (2012). Analaisis Kekerabatan Ikan Mas Koi \textit{(Cyprinus carpio koi)} dan Ikan Mas Majalaya \textit{(Cyprinus carpiocarpio)} Menggunakan Metode RAPD. \textit{Jurnal Perikanan dan Kelautan}, 3(3), 15-23.

Mulyadi, G. K., Buwono, I. D., & Subhan, U. (2017). Analisis Kekerabatan Genetik Hibrid Ikan Nilem \textit{(Osteochilus hasselti)} dan Ikan Mas \textit{(Cyprinus carpio L)} Menggunakan PCR-RAPD. \textit{Jurnal Perikanan dan Kelautan}, 3(1), 42-47.

Nugroho, L. A., Piranti, A. S., & Sastranegara, M. H. (2020). Plankton Community and Water Quality During Maximum Tidal Range in Segara Anakan Cilacap. \textit{IOP Conf. Series: Earth and Environmental Science}, 593, 012020.

Nuryanto, A., Dewi, R. E., & Pramono, H. (2019a). Genetic Homogeneity of Commerson's Anchovy \textit{(Stolephorus commersonnii)} in Segara Anakan Cilacap Central Java Inferred from PCR-RFLP Marker. \textit{Biogenesis}, 7(1), 14-23.

Nuryanto, A., Komalawati, N., & Sugiharto. (2019b). Genetic Diversity Assessment of \textit{Hemibagrus nemurus} from Rivers in Java Island, Indonesia Using COI Gene. \textit{Biodiversitas}, 20(9), 2707-2717.

Nuryanto, A., Pramono, H., & Sastranegara, Moh. H. (2017). Molecular Identification of Fish
Larvae from East Plawangan of Segara Anakan, Cilacap, Central Java, Indonesia. *Biosaintifika*, 9(1), 33-40.

Nuryanto, A. & Sastranegara, M. H. (2013). Molecular Characterization of *Polymesoda erosa* (Solander, 1786) Inhabits Two Different Habitats. *Bionatura-Jurnal Ilmu Hayati dan Fisik*, 15(3), 184-89.

Nuryanto, A. & Susanto, AH (2010). Genetic Variability of *Polymesoda erosa* Population in the Segara Anakan Cilacap. *Biotropia*, 17(1), 22-30.

Regmi, B., Douglas, M. R., Anthonysamy, W. J. B., Doglas, M. E., & Leberg, P. L. (2016). Salinity and Hydrological Barriers Have Little Influence on Genetic Structure of the Mosquitofish in a Coastal Landscape Shaped by Climate Change. *Hidrobiologia*, 777, 209-223.

Sari, A. K., Nuryanto, A. & Susanto, A. H. (2014). Karakterisasi Beberapa Strain Gurami (*Osphronemus gouramy* Lac.) menggunakan Marka RAPD. *Scripta Biologica*, 1(1), 113-16.

Sastragengara, M. H., Widyartini, D. S., Fitriana, I., & Rani,K. M. (2020). The Plankton Composition from the Lagoon to the Marine Entrance at the West Part of Segara Anakan Mangrove Ecosystem in Cilacap. *IOP Conf. Series: Earth and Environmental Science*, 550, 012021

Silva, G., Horne, J. B., & Castilho, R. (2014a). Anchovies Go North and West Without Losing Diversity: Post-Glacial Range Expansions in a Small Pelagic fish. *Journal of Biogeography*, 41(6), 1171-1182.

Silva, G., Lima F. P., Martel, P., & Castilho, R. (2014b). Thermal Adaptation and Clinal Mitochondrial DNA Variation of European Anchovy. *Proceedings of the Royal Society B*, 281, 20141093.

Sukumaran, S., Sebastian, W., Francis, K. X. & Gopalakrishnan, A. (2019). Contemporary and Historic Patterns of Intraspecific Diversity in Indian Anchovy, *Stolephorus indicus*, from Indian Peninsular waters. *Genetica*, 147(3-4), 259-67.

Suprastini, Ardli, E.R. & Nuryanto, A., 2014. Diversitas dan Distribusi Ikan di Segara Anakan Cilacap. *Scripta Biologica*, 1(2), 147-51.

Vinas, J., Sanz, N., Penarrubia, L., Araguas, R. M., Manin, J. L. G., Roldan, M. I., Pla, C. (2014). Genetic population structure of European anchovy in the Mediterranean Sea and the Northeast Atlantic Ocean using sequence analysis of the mitochondrial DNA control region. *ICES Journal of Marine Science*, 71(2), 391-97.

Walsh, P. S., Metzger, D. A. & Higuchi, R. (2013). Chelex 100 as a Medium for Simple Extraction of DNA for PCR-Based Typing from Forensic Material. *Biotechniques*, 54(3), 134-39.

Whitehead, A., Roach, J. L., Zhang, S., & Galvez, F. (2011). Genomic mechanisms of evolved physiological plasticity in killifish distributed along an environmental salinity gradient. *PNAS*, 108(15), 6193–6198.