



Identification coral reef diatom using scanning electron microscope at Nature Reserve Pulau Sempu (NRPS), East Java

Sayyid Afdhal El Rahimi¹, Adrian Kryk², Sulastri Arsad², Oktiyas Muzaky Luthfi^{2,3,*}, Andik Isdianto³ and M. Azurea Bahri Luthfi³

¹Department of Marine Science, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh, Indonesia

²Institute of Marine and Environmental Sciences, University of Szczecin, ul. Mickiewicza 16a, 70-383 Szczecin, Poland

³Faculty of Fisheries and Marine Sciences, Universitas Brawijaya, Jl. Veteran, Malang, 65145, Indonesia

ARTICLE INFO

Keywords:

Hard coral
Cocconeis
Psammodictyon
Pulau Sempu
Diatom

DOI: 10.13170/depik.13.1.29516

ABSTRACT

Diatom, Bacillariophyceae, has an important role in environmental support because these algae contribute to 25% of the oxygen supply globally and each year represent 40% of primary production by fixed carbon using photosynthesis. Diatom samples were obtained from 3 different sites in around NRPS. Cleaning diatoms analyzed using SEM for describe ultrastructure in diatom valves. Three dominant diatoms Cocconeidaceae and Bacillariaceae from the south Java Sea (Indian Ocean). Basic information regarding the diversity of diatoms, and the success of photoautotrophic micro-algae that can be found both in marine and freshwater habitats, is very important to describe the role of each taxon from an ecology perspective in the future. Samples are taken from the substrate of 3 stations in Nature Reserve Pulau Sempu and prepared in the laboratory for scanning electron microscopy photographs. Clear and detailed features diatom frustule of SEM photograph reveal a schild diatom (Cocconeis) and panduriform diatom (Psammodictyon) are dominating taxa in NRSP areas.

Introduction

Coral reef ecosystem is a forest in marine environment that supports another biota by providing shelter, food and breeding sites. This complex ecosystem also become important for protecting the coast from abrasion, providing goods and services, protein sources and also economic revenue for tourism activity (Bellwood *et al.*, 2019; Harborne *et al.*, 2017; Riniwati *et al.*, 2019). This ecosystem builds by various marine organisms that scleractinian coral as a major structure since their deposit carbonate as a building block (DeVantier *et al.*, 2006; Waheed *et al.*, 2015). Coral reefs in East Java can be found scattered throughout the South and North coasts of East Java. On the south coast, which is directly adjacent to the Indian Ocean, coral can be found from the Banyuwangi, Jember, Prigi areas, to the Malang area. The average coral cover in southern

East Java is 25-30% (Luthfi & Rendy, 2018; Luthfi *et al.*, 2019). Coral reefs in the south are mostly found in the reef flat to reef crest areas. The coral reefs in these waters are composed of massive corals including Porites, Goniastrea, Favia and Favites. Also found Acropora, Pocillopora, Seriatopora and Montipora. Meanwhile, on the north coast of East Java, corals as the main constituent of coral reefs can be found in Banyuwangi, Situbondo and the Madura Strait. Coral cover in northern East Java also showed poor performance, with an average live coral cover of 31.6% (Asadi & Andrimida, 2017; Herawati *et al.*, 2022; Hidayah & Nuzula, 2019; Samuel *et al.*, 2021).

Coral can live well and requires appropriate environmental support, such as high-water clarity, pH 7.9 - 8.3 (Gagliano *et al.*, 2010), salinity 29-35 ppt (Coles & Jokiel, 2018), DO > 4.8 mg/L (Altieri *et al.*, 2017) and low nutrients (D'Angelo & Wiedenmann,

* Corresponding author.

Email address: oktiyas.luthfi@pbd.usz.edu.pl

2014). This is in contrast to the water conditions required by algae in general. So that only certain algae and microalgae can survive in the coral reef ecosystem. Likewise with diatoms.

Research on diatoms from coral reef ecosystems is still not too much, from Réunion and Rodrigues Islands Indian Ocean (Al-Handal et al., 2016; Riaux-Gobin et al., 2012), Basra coast, Iraq (Al-Handal et al., 2018), Juan de Nova coral island Western Indian Ocean and Tuamotu archipelago, Pacific (Witkowski et al., 2022), Great Barrier Reef, Australia (Gottschalk et al., 2007), Guam (Christopher S Lobban et al., 2012), and Indonesia (Risjani et al., 2021). Recent research from Kryk et al. (2021) described a new species of diatom from Tiga Warna, E. Java. From the Thousand Islands a new species has also been described (Prasetya et al., 2019). There is also a new genus described in the early 20th century by naturalists as a result of expeditions such as those carried out by Hustedt (1931-1959) who gave the species name *Mastogloia lata* from the island of Miang Besar, Borneo (East Kalimantan) (Pennesi et al., 2013, 2016).

The waters in Nature Reserve Pulau Sempu and its surroundings have not received the attention of researchers in Indonesia, so far there have only been 2 publications providing information on diatoms in the southern Malang region. This study aims to provide basic information about the type or genus of diatoms in the Sempu Island nature reserve and its surroundings as well as information on the diversity of coral reef species in the southern Malang area.

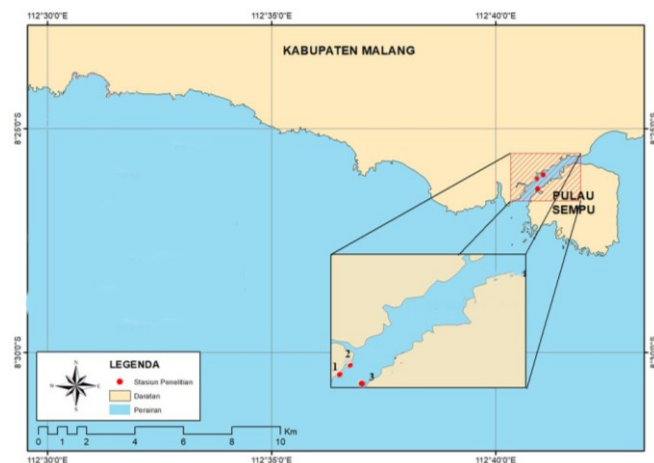


Figure 1. Research location in NRPS. Sampling sites were Tiga Warna (1), Kondang Buntung (2) and Pulau Sempu (3)

Materials and Methods

Location and time of research

The research was conducted June 2022 in Nature Reserve Pulau Sempu which 3 sampling stations, they were Pulau Sempu, Kondang Buntung and Tiga Warna. The sampling point can be seen in Figure 1. The local name of station in Pulau Sempu is Teluk Semut which has short beach with montiporids and acroporids dominate in the sea water. Tiga warna and Kondang Buntung located in adjacent of Teluk Semut, both of sites had wider beach and more diverse of scleractinian coral.

Diatom sampling

Samples were taken from coral reef habitat, namely sand, dead coral and macro algae, using a 50 ml falcon bottle. In order for diatom metabolism to be maintained while in the sample bottle, ¼ falcon bottles are emptied for air space. Furthermore, the samples were stored in the laboratory at room temperature and not exposed to direct sunlight.

For cleaning calcium carbonate, the samples then soak into a beaker glass of 250 ml and added 10% of HCl. After the bubbles were gone, the samples were washed 3 times using distilled water. Furthermore, samples were boiled using peroxide (H₂O₂) 37% for 5 hours in total to remove organic material in the samples in a hot plate at 250 °C. After the samples were cleaned, then were washed with distilled water 5 times. The clean sample materials kept in 15 ml bottles samples (Battarbee & Berglund, 1986; Bodén, 1988; Gersonde & Wefer, 1987).

For SEM, suspensions of clean material were dropped into Whatman Nuclepore filter membrane size 5 µm and mounted into SEM specimen stubs 12.5 mm. furthermore samples were coated with 20 nm of gold using a Quorum Q 150OT ES Turbo-Pumped Sputter Coater. Diatoms were observed using a Hitachi SU 8010 scanning electron microscope (SEM) at the University of Rzeszów.

Results

The results showed that there were 3 diatoms identified using SEM, namely *Coconeis* sp. cf. *mascarenica*, *Psammodictyon* sp1 and *Psammodictyon* sp2. *Coconeis* sp. cf. *mascarenica* was found in Kondang Buntung with valve length and width of 15.57 x 8.15 µm (Figure 2A) and 14.33 x 7.83 µm (Figure 2B). *Psammodictyon* sp 1 was found in Pulau Sempu and *Psammodictyon* sp 2 was found in Tiga Warna with valve length and width of 14.3 x 7.12 and 14.45 x 3.62 µm (Figure 2 C, D).

Cocconeis sp cf. *mascarenica* (Figure 2 A, B) is seen sternal valve (SV) of diatoms. The sternum is elliptical in shape with not too wide in size and the striae tend to be towards the apices. No poles found in apex. Figure 2C is an internal view of *Psammodictyon*

sp 1, showing the areolae of the diatom valves in the form of confined pores with a size of 200-300 nm. Valve in oblique view showing epithecal valve,

hypothecal valve, raphe, valvocopula, and cingulum (Figure 2D).

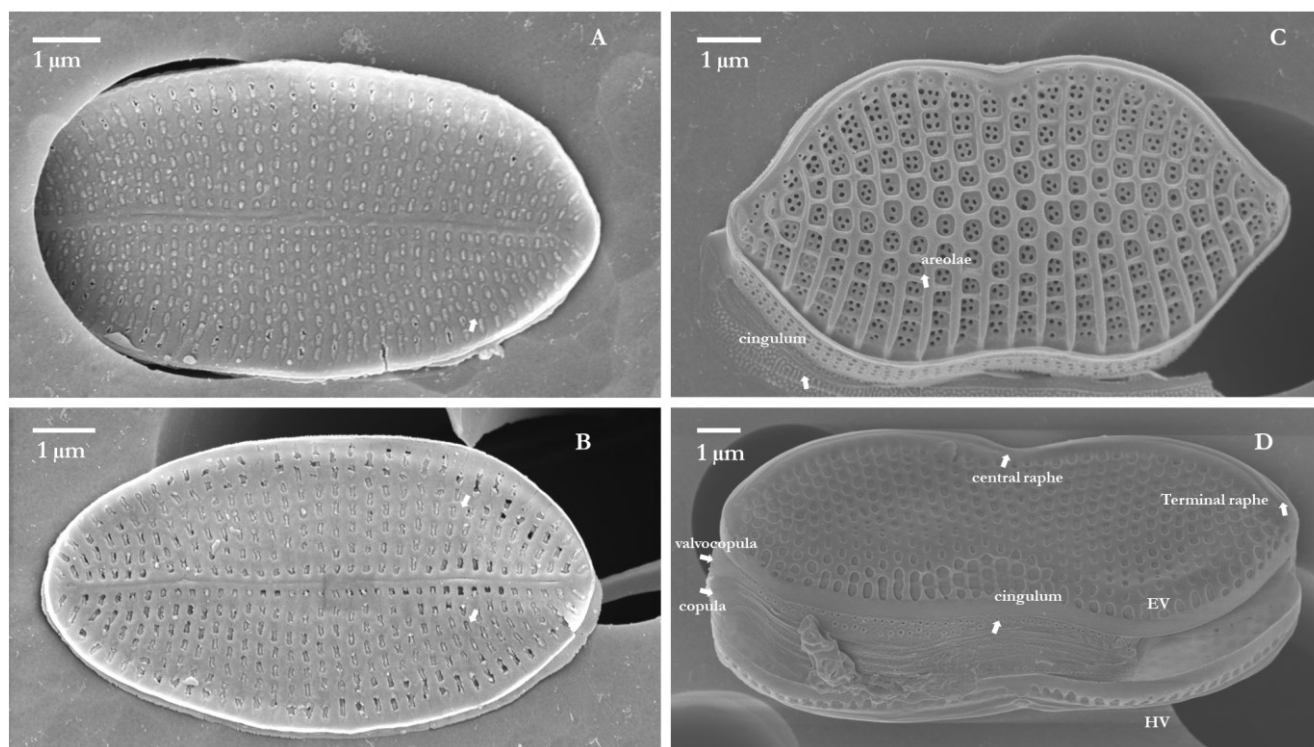


Figure 2. External view of diatom valve *Cocconeis* diatom lacking raphe and uniseriate striae show on white arrows (A, B); oblique view of internal valve of *Psammodictyon* diatom with clear areolae (arrow) and broken cingulum (arrow) (C); and tilt view of diatom frustule show ornamental characters of valve and girdle band. The bigger valve is called as epivalve (EV) and smaller valve is known as hypovalve (HV). Valvocopula is direct cingulum attach valve and copula is silica band made. The position of raphe is eccentric (D).

Discussion

Habitat and function diatom in ecology

Diatom is a photosynthetic unicellular alga that has an internal skeleton made from SiO₂ (silica) (Mann, 2010; Williams & Kocielek, 2011). And now the diatom has been classified as class Bacillariophyceae. Diatom is easily be found in both fresh and marine habitats (Risjani et al., 2021), also in the maximum photic zone, 100 m (Schvarcz et al., 2022). Furthermore, diatoms are responsible for marine primary production of about 25% (Vardi, 2008), comprising food for herbivores since diatoms are rich in lipids (Hussein & Abdullah, 2020).

Cocconeis sp. cf. *mascarenica*

The genus *Cocconeis* was first described by Ehrenberg (1838) in his first compendium book entitled *Infusionsthierchen*. The name refers to the shape of the frustule diatom which is similar to a shield or schild in German (Romero & Jahn, 2013). In general, diatoms from this genus are categorized as monoraphid diatoms where only one of the valves has a raphe, or it is also called heterovalvar, where

one of the valves has different ornamentation (Pappas & Gordon, 2021). Another common feature of these diatoms is their elliptic shape and sandle-like shape. On all sides the valve has striae grooves which are uniseriate in shape because they only have one column of areolae (Romero, 2011).

Cocconeis diatoms are epiphytic which means these diatoms live in other algae or higher plants. About 8 species were found living on the leaves of seagrass *Posidonia oceanica* at Ischia Island in Italy (De Stefano et al., 2000). Others report said some diatom such as *C. heteroidea* has lived on seaweed surface and *C. caulerpacola* was living on green alga *Caulerpa taxifolia* known as an algae killer (Car et al., 2012; Suzuki et al., 2001). Moreover, *Cocconeis* also known as epilithic and epipsammic diatom since also can be found in rock surface and attached to the grain of sand (Hafner et al., 2018; Riaux-Gobin et al., 2011). As monoraphid, the raphe valve (RV) side attaches to the substrate and sometimes made a single layer foul at the surface of the substrate (Molino et al., 2009; Sullivan, 2019).

Psammodictyon sp1 and sp2

The genus *Psammodictyon* was described by Round *et al.*, (1990) for the extent the genus *Nitzschia*. The first species was *Psammodictyon panduriforme* based on *Nitzschia* sect. *Panduriformes* (Lobban, 2015). The Nitzschioid group has 11 genera which have main characteristics: bilateral symmetry both apical and transapical axes, raphe eccentric and some have keel (Round *et al.*, 1990). The special features for this genus are the panduriform shape of valves as on genus *Tryblionella*, raphe arranged eccentric or in edge of the valve, the areolae are large in size with variations in shape such as round, polygonal and irregular in shape. The occlusions also are found in areolae (Yang *et al.*, 2020).

Psammodictyon was reported originally from marine habitats (Round *et al.* 1990) and minor from freshwater (Yang *et al.*, 2020). To date, 15 species belong to this genus which has 11 species from marine and 4 from freshwater (Kociolek *et al.*, 2021). The differences in environments or habitat influence the size of marine diatoms which have larger comparing freshwater diatoms (Litchman *et al.*, 2009). Nutrient and mixed layer depth (MLD) of water also had a role in diatom size. High phosphorus supply in the freshwater area, in general, and lack of MLD contribute to the small size of the diatom.

Conclusion

Diatoms in NR Pulau Sempu have not been revealed much by researchers. In this study, 3 species of pennate diatoms from the families Bacillariaceae and Cocconeidaceae were obtained. More photos of diatoms from SEM results are needed to be able to identify diatoms to the species level, because there are many details of the frustule ornament of each diatom species that must be observed. Future research will open up a lot of diatom biodiversity in NR Sempu Island.

Acknowledgments

We thank the member of Acropora Universitas Brawijaya for assistance during the fieldwork and also our sincere to the anonymous reviewers for their insightful comments on this manuscript.

References

Al-Handal, Y. Adil, P. Compere, C. Riaux-Gobin. 2016. Marine benthic diatoms in the coral reefs of Reunion and Rodrigues Islands, West Indian Ocean. *Micronesica*, 3: 1-78.
Al-Handal, Y. Adil, E.W. Thomas, C. Pennesi, C. 2018. Marine benthic diatoms in the newly discovered coral reefs, off Basra coast, Southern Iraq. *Phytotaxa*, 372(2): 111-152.
Altieri, A.H., S.B. Harrison, J. Seemann, R. Collin, R.J. Diaz, N. Knowlton, N. 2017. Tropical dead zones and mass mortalities on coral reefs. *Proceedings of the National Academy of Sciences*,

114(14): 3660-3665.
Asadi, M.A., A. Andrimida, 2017. Economic valuation of coral reefs ecosystem of Bangsrang, Banyuwangi, Indonesia. *ECOSOFiM (Economic and Social of Fisheries and Marine Journal)*, 4(2): 144-152.
Battarbee, R.W., B.E. Berglund. 1986. Handbook of Holocene palaeoecology and palaeohydrology. In *Diatom analysis* (pp. 527-570). Wiley New York.
Bellwood, D.R., R.P. Streit, S.J. Brandl, S.B. Tebbett, 2019. The meaning of the term 'function' in ecology: A coral reef perspective. *Functional Ecology*, 33(6): 948-961.
Bodén, P. 1988. Epipsammic diatoms as borers: an observation on calcareous sand grains. *Sedimentary Geology*, 59(1-2), 143-147.
Car, A., A. Witkowski, S. Dobosz, D.D. Burfeind, A. Meinesz, N. Jasprica, M. Ruppel, K.J. Kurzydowski, T. Płociński. 2012. Description of a new marine diatom, *Cocconeis caulerpacola* sp. nov. (Bacillariophyceae), epiphytic on invasive *Caulerpa* species. *European Journal of Phycology*, 47(4): 433-448.
Coles, S.L., P.L. Jokiel. 2018. Effects of salinity on coral reefs. In *Pollution in tropical aquatic systems* (pp. 147-166). CRC Press.
D'Angelo, C., J. Wiedenmann. 2014. Impacts of nutrient enrichment on coral reefs: new perspectives and implications for coastal management and reef survival. *Current Opinion in Environmental Sustainability*, 7: 82-93.
De Stefano, M., D. Marino, L. Mazzella, 2000. Marine taxa of *Cocconeis* on leaves of *Posidonia oceanica*, including a new species and two new varieties. *European Journal of Phycology*, 35(3): 225-242.
DeVantier, L.M., G. De'Ath, E. Turak, T.J. Done, K.E. Fabricius. 2006. Species richness and community structure of reef-building corals on the nearshore Great Barrier Reef. *Coral Reefs*, 25(3): 329-340.
Gagliano, M., M.I. McCormick, J.A. Moore, M. Depczynski. 2010. The basics of acidification: baseline variability of pH on Australian coral reefs. *Marine Biology*, 157(8): 1849-1856.
Gersonde, R., G. Wefer. 1987. Sedimentation of biogenic siliceous particles in Antarctic waters from the Atlantic sector. *Marine Micropaleontology*, 11(4): 311-332.
Gottschalk, S., S. Uthicke, K. Heimann. 2007. Benthic diatom community composition in three regions of the Great Barrier Reef, Australia. *Coral Reefs*, 26(2): 345-357.
Hafner, D., A.N.A. Car, N. Jasprica, T. Kapetanović, I.D. Radić. 2018. Relationship between marine epilithic diatoms and environmental variables in oligotrophic bay, NE Mediterranean. *Mediterranean Marine Science*, 19(2): 223-239.
Harborne, A.R., A. Rogers, Y.M. Bozec, P.J. Mumby, 2017. Multiple stressors and the functioning of coral reefs. *Annual Review of Marine Science*, 9: 445-468.
Herawati, E.Y., P.D., Samuel, D. Arfiati, R.K. Pratiwi, Z.N. Inayah. 2022. Jenis-Jenis Terumbu Karang Yang Tumbuh Pada Rumah Ikan Di Perairan Pasir Putih, Situbondo, Jawa Timur. *Prosiding Seminar Nasional Perikanan Dan Kelautan*, 9(1): 31-37.
Hidayah, Z., N.I. Nuzula. 2019. Pemetaan Sebaran Terumbu Karang Studi Kasus Selat Madura, Jawa Timur. *Jurnal Kelautan Tropis*, 22(2): 127-134.
Hussein, H.A., M.A. Abdullah. 2020. Anticancer compounds derived from marine diatoms. *Marine Drugs*, 18(7): 356.
Kociolek, J.P., S. Blanco, M. Coste, L. Ector, Y. Liu, B. Karthick, M. Kulikovskiy, N. Lundholm, T. Ludwig, M. Potapova, F. Rimet, K. Sabbe, S. Sala, E. Sar, J. Taylor, B.V. de Vijver, C.E. Wetzel, D.M. Williams, A. Witkowski, J. Witkowski. 2021. DiatomBase. *Psammodictyon* D.G. Mann in F.E. Round, R.M. Crawford & D.G. Mann, 1990. Accessed at: <http://www.diatombase.org> on 2022-12-07
Kryk, A., A. Witkowski, L. Ribeiro, J.P. Kociolek, S. Mayama, R.J. Wróbel, Y. Risjani, Yunianta, J. Bemiasa, E. Bemanaja. 2021. Novel Diatoms (Bacillariophyta) from tropical and temperate marine littoral habitats with the description of *Catenulopsis* gen. nov., and two *Catenula* species. *Diatom Research*, 36(3): 265-280.
Litchman, E., C.A. Klausmeier, K. Yoshiyama. 2009. Contrasting size evolution in marine and freshwater diatoms. *Proceedings of the National Academy of Sciences*, 106(8): 2665-2670.

- Lobban, C.S. 2015. Benthic marine diatom flora of Guam: new records, redescription of *Psammodictyon pustulatum* n. comb., n. stat., and three new species (*Colliculoamphora gabgabensis*, *Lauderia excentrica*, and *Rhoiconeis pagoensis*). *Micronesica*, 2: 1-49.
- Lobban, C.S., M. Schefter, R.W. Jordan, Y. Arai, A. Sasaki, E.C. Theriot, M. Ashworth, E.C. Ruck, C. Pennesi. 2012. Coral-reef diatoms (Bacillariophyta) from Guam: new records and preliminary checklist, with emphasis on epiphytic species from farmer-fish territories. *Micronesica*, 43(2): 237-479.
- Luthfi, O.M., V.W. Rendy. 2018. Keanekaragaman Karang Keras dan Ikan Terumbu Di Pantai Papuma Jember, Jawa Timur. *Jurnal Biologi Udayana*, 22.
- Luthfi, O.M., D. Akbar, M.G. Ramadhan, M. Rohman, N.K. Wahib. 2019. Studi Komparatif Tutupan Living dan Non Living Substrat Dasar Perairan Pulau Sempu Kabupaten Malang Menggunakan Metode Reef Check. *JFMR (Journal of Fisheries and Marine Research)*, 3(2): 127-134.
- Mann, D.G. 2010. Discovering diatom species: is a long history of disagreements about species-level taxonomy now at an end? *Plant Ecology and Evolution*, 143(3), 251-264.
- Molino, P.J., E.R. Campbell, R. Wetherbee, R. 2009. Development of the initial diatom microfouling layer on antifouling and fouling-release surfaces in temperate and tropical Australia. *Biofouling*, 25(8): 685-694.
- Pappas, J. L., R. Gordon. 2021. Are Mantle Profiles of Circular Centric Diatoms a Measure of Buckling Forces During Valve Morphogenesis? *Diatom Morphogenesis*, 231-250.
- Pennesi, C., M. Poulin, F. Hinz, T. Romagnoli, M. De Stefano, C. Totti. 2013. Comparison of two new species of *Mastogloia* (Bacillariophyceae) with other small members of section *Ellipticae*. *Phytotaxa*, 126(1): 1-21.
- Pennesi, C., M. Poulin, C. Totti. 2016. Phylogenetic relationships and biogeography of the diatom genus *Mastogloia* (Bacillariophyceae): Revision of the section *ellipticae* including the description of new taxa. *Protist*, 167(2): 148-173.
- Prasetya, F.S., R. Gastineau, M. Poulin, C. Lemieux, M. Turmel, A.D. Syakti, Y. Hardivillier, I. Widowati, Y. Risjani, I. Iskandar. 2019. *Haslea nusantara* (Bacillariophyceae), a new blue diatom from the Java Sea, Indonesia: morphology, biometry and molecular characterization. *Plant Ecology and Evolution*, 152(2): 188-202.
- Riaux-Gobin, C., P. Compère, A.Y. Al-Handal. 2011. Species of the *Cocconeis peltoides* group with a marginal row of unusual processes (Mascarenes and Kerguelen Islands, Indian Ocean). *Diatom Research*, 26(4): 325-338.
- Riaux-Gobin, C., O.E. Romero, P. Compère, A.Y. Al-Handal. 2012. Small-sized *Achnanthes* (Bacillariophyta) from coral sands off Mascarenes (Western Indian Ocean). *Acta Botanica Hungarica*, 54: 3-4.
- Riniwati, H., N. Harahab, Z. Abidin. 2019. A vulnerability analysis of coral reefs in coastal ecotourism areas for conservation management. *Diversity*, 11(7): 107.
- Risjani, Y., A. Witkowski, A. Kryk, E. Górecka, M. Krzywda, I. Safitri, A. Sapar, P. Dąbek, S. Arsad, E. Gusev. 2021. Indonesian coral reef habitats reveal exceptionally high species richness and biodiversity of diatom assemblages. *Estuarine, Coastal and Shelf Science*, 261: 107551.
- Romero, O.E. 2011. Morphological study of the genus *Cocconeis* Ehrenberg (Bacillariophyceae) collected during the 1897-1899 Belgian Antarctic Expedition.
- Romero, O.E., R. Jahn. 2013. Typification of *Cocconeis lineata* and *Cocconeis euglypta* (Bacillariophyta). *Diatom Research*, 28(2): 175-184.
- Round, F.E., R.M. Crawford, D.G. Mann. 1990. *Diatoms: biology and morphology of the genera*. Cambridge university press.
- Samuel, P.D., C.S.U. Dewi, N.F.U. Azmi, M.C. Anam, D.P. Imas, D.N. Setyorini, D.F. Hariani, R. Fatmawati. 2021. Coral Reefs Health Status in the East Java: a Case Study in Banyuwangi, Situbondo, Probolinggo. *Research Journal of Life Science*, 8(2): 66-74.
- Schvarcz, C.R., S.T. Wilson, M. Caffin, R. Stancheva, Q. Li, K.A. Turk-Kubo, A.E. White, D.M. Karl, J.P. Zehr, G.F. Steward. 2022. Overlooked and widespread pennate diatom-diazotroph symbioses in the sea. *Nature Communications*, 13(1): 1-9.
- Sullivan, T. 2019. Cell shape and surface colonisation in the diatom genus *Cocconeis*—an opportunity to explore bio-inspired shape packing? *Biomimetics*, 4(2): 29.
- Suzuki, H., T. Nagumo, J. Tanaka. 2001. Morphology of the marine epiphytic diatom *Cocconeis heteroidea* (Bacillariophyceae). *Phycological Research*, 49(2): 129-136.
- Vardi, A. 2008. Cell signaling in marine diatoms. *Communicative & Integrative Biology*, 1(2), 134-136.
- Waheed, Z., H.G.J. van Mil, M.A. Syed Hussein, R. Jumin, B.G. Ahad, B.W. Hoeksema. (2015). Coral reefs at the northernmost tip of Borneo: an assessment of scleractinian species richness patterns and benthic reef assemblages. *PloS One*, 10(12): e0146006.
- Williams, D.M., J.P. Kociolek. 2011. An overview of diatom classification with some prospects for the future. *The Diatom World*, 47-91.
- Witkowski, A., C. Riaux-Gobin, A. Kryk, T. Płociński, I. Zglobicka, K. Kurzydłowski. 2022. *Xenobennettella coralliensis* a new monoraphid diatom genus characterized by the alveolate sternum valve with cavum, observed from coral reef habitats. *PeerJ*, 10, e13977.
- Yang, Q., T. Liu, P. Yu, J. Zhang, J.P. Kociolek, Q. Wang, Q. You. 2020. A new freshwater *Psammodictyon* species in the Taihu Basin, Jiangsu Province, China. *Fottea*, 20: 144-151.
- El Rahimi, S.A., A. Kryk, S. Arsad, O.M. Luthfi, A. Isdianto, M.A.B. Luthfi. 2024. Identification coral reef diatom using scanning electron microscope at Nature Reserve Pulau Sempu (NRPS), East Java. *Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan*, 13(1): 19-23.