

Sexual Maturity and Macronutrient Contents in *Diopatra* sp. (Onuphidae, Polychaeta) Maintained at Different Salinity Levels

by Eko Setio Wibowo

Submission date: 28-Mar-2023 03:09PM (UTC+0700)

Submission ID: 2048889881

File name: 49188-170015-1-PB.pdf (327.7K)

Word count: 4746

Character count: 25035

Sexual Maturity and Macronutrient Contents in *Diopatra* sp. (Onuphidae, Polychaeta) Maintained at Different Salinity Levels

Eko Setio Wibowo^{1*}, Mellya Rizki Pitriani¹, Farida Nur Rachmawati¹, Untung Susilo¹,
Eko Setiyono¹, Atang¹, Phuping Sucharitakul², Joko Pamungkas³

¹¹
¹Faculty of Biology, Jenderal Soedirman University
Jl. dr. Soeparno No. 63, Purwokerto 53122, Indonesia

²School of Environment, Tsinghua University
Beijing 100084, China

⁶
³Research Center for Biosystematics and Evolution, National Research and Agency Innovation
Jl. Raya Jakarta-Bogor Km. 46, Cibinong 16911, Indonesia
Email: tio_eko@yahoo.co.id

Abstract

Diopatra sp. (Onuphidae, Polychaeta) is an economically important polychaete species commonly used as a fishing bait by local anglers in Cilacap, Central Java Province. Some biological aspects of this local species, however, have not been studied yet. The aim of this research was to see the effect of salinity levels on the sexual maturity and the macronutrient contents of the animals. *Diopatra* specimens in the present study were collected from the intertidal mangrove habitats of Jeruklegi Village, Cilacap, in sexually immature condition. The worms were then transported to the laboratory and were maintained in containers with four different salinity levels, 10, 15, 20 and 25 ppt over the next two months. The sexual maturity of the animals were observed based on the presence or absence of coelomic gametes. Proximate analysis was performed to determine macronutrient contents of the animals. The effect of salinity levels on the animals' sexual maturity and macronutrient contents was analyzed using one-way ANOVA. The results showed that salinity levels did not significantly affect the sexual maturity level of *Diopatra* worms ($p > 0.05$). Similarly, they did not affect the protein and fat contents, but impacted the carbohydrate content of the animals ($p < 0.05$). The protein and the fat contents in *Diopatra* sp., i.e. 41–43% and 6–9%, respectively, met the amount required to be used as shrimp broodstock and fish feeds. While the species has the potential for use in local aquaculture, the annual reproductive cycle as well as the identity of the species, however, require further research.

Keywords: Annelida, aquaculture, proximate analysis, reproduction

Introduction

¹⁵
Diopatra (Audouin and Edwards, 1833) is the only genus of the family Onuphidae whose members possess spiral branchiae (Budaeva and Fauchald, 2011). Members of this genus occur worldwide in both temperate and tropical regions. The animals, dwelling in a solitary tube, typically inhabit intertidal and subtidal areas of estuaries with soft sediment despite some species being reported to occur at greater depths (Berke, 2022).

Some *Diopatra* species have high economic importance as they are commercially used as fishing baits by anglers. The most popular and exploited one is the European species *Diopatra neapolitana* Del. Chiaje, 1841. Other Asian species include *D. aciculata* (Knox and Cameron, 1971) and *D. sugokai* (Izuka, 1907), in Japan, as well as *D. clapedii* Grube, 1878, in Malaysia. In Cilacap, Central Java

Province, Indonesia, *Diopatra* worms are also used as fishing bait by local anglers (Wibowo et al., 2022) – the animals are called 'lur umah' in the local language, which means a worm with housing. The worms were initially identified as *D. neapolitana* by Purwati et al. (2020), but the occurrence of this European species in Indonesian waters is highly unlikely considering the long distance between the two geographic regions. In such case, a detailed taxonomic work will reveal the identity of the species; for example, the worms *D. neapolitana* in Malaysia were later identified as *D. clapedii* by Idris and Arshad (2013).

Diopatra worms were obtained generally rely on digging from their natural habitat. For instance, approximately 4.3 million individuals of *D. neapolitana* may be annually harvested by worm diggers in Portugal's Canal de Mira (Ria de Aveiro estuary) with an economic value of more than EUR

*) Corresponding author
© Ilmu Kelautan, UNDI

<https://ejournal.undip.ac.id/index.php/ijms>
DOI: 10.14710/ik.ijms.28.1.49-56

Received : 26-09-2022
Accepted : 13-02-2023

325,000 (Cunha et al., 2005). In Cilacap, an experienced worm digger may collect about 100 individuals of *Diopatra* sp. within a few hours of work. The digger exclusively trades the animals in his house – not in a traditional market – IDR 1000 per individual (pers. obs.). These activities are concerning because they may threaten the sustainability of the species with potentially detrimental effects on the natural environment, therefore mariculture can be proposed to be the solution. Despite some biological aspects of *Diopatra* sp. that have been studied by Wibowo et al. (2022), initial information regarding reproductive aspects and macronutrient contents of this species is still lacking. The aim of this research was to study the sexual maturity levels and the macronutrient contents of *Diopatra* sp. maintained at different salinity levels.

Materials and Methods

Diopatra worms, as well as the substrate and the seawater were collected from the intertidal mangrove habitats of Jeruklegi Village, Cilacap Regency, Central Java Province, during a low tide. All the worms obtained were sexually immature. The type of the substrate was clay, with a composition of 3–6% sand, 15–18% silt and 74–79% clay, with 4–8% C-organic content and 8–14% organic matter.

Experimental design

The laboratory work was conducted between January and March 2022. The substrate was placed in 12 containers, each of which measures 20 x 30 x 25 cm. The containers were then grouped into four different water salinity treatments, i.e. 10, 15, 20 and 25 ppt (freshwater was used to dilute the seawater obtained from the field). The containers containing substrate and saline water were then aerated and left for one week to stabilize the salinity. Three individuals of *Diopatra* sp. were put and maintained in each container (the worms were acclimatized for one week and weighed prior to the treatment) and were fed with D0 ornamental fish feed (2% of the worm's body weight) once a week over the following two months. This treatment was replicated five times.

Sexual maturity observation

The sexual maturity of *Diopatra* worms were observed based on the presence or absence of coelomic gametes. The gametes were taken out of the coelomic cavity by cutting off the anterior part of the animals. The part was then pressed on an object glass to release the gametes (if the gametes present). The gametes were dripped using saline water taken from the animals' container, and were observed under a compound microscope with 100x magnification. The diameter of the worms' oocytes

was measured using a calibrated micrometer. The proportion between the numbers of sexually mature and immature worms per salinity treatment was calculated by using the following formula:

$$\text{Percentage (\%)} = (\text{number of sexually mature worms per salinity} / \text{number of total worms per salinity}) \times 100\%$$

Macronutrient content measurement

To measure the macronutrient contents, wet *Diopatra* worms were weighed using a balance with an accuracy of 0.0001 g. The animals were then dried in an oven at a temperature of 80°C. After a constant weight was achieved, the animals were mashed and stored at a room temperature for a further proximate analysis (Sudarmadji et al., 1998).

Statistical analysis

The significance of salinity effects towards the proportion between sexually mature and immature *Diopatra* worms, as well as the macronutrient contents of the animals, was analyzed using one-way ANOVA. The analysis was performed using Minitab.

Results and Discussion

Sexual maturity

Our experiment demonstrated that after two months 40 and 33% of *Diopatra* worms maintained in the containers with salinity levels of 10 and 15 ppt, respectively, were sexually mature, whereas 66 and 73% of the animals maintained in the containers with salinity levels of 20 and 25 ppt were sexually mature. The rest of the animals were undetermined (no gametes were observed in the coelom) and considered sexually immature. In this stage, no morphological differences were noticed between males and females, which is in line with the study by Pires et al. (2012) on *D. neapolitana*.

This study found that several female *Diopatra* worms maintained in the containers with salinity levels of 10 and 20 ppt were in sexually submature and mature stages. The oocytes' shape was rounded, and the diameter of the oocytes in the sexually submature worms ranged between 200 and 210 µm with an average of 205.8 µm, whereas sexually mature worms had oocytes with a diameter ranging between 220 and 230 µm with an average of 225.4 µm (Figure 1A.). These findings are in agreement with the study of Purwati et al. (2020) in which *Diopatra* worms collected from Cilacap showed different levels of sexual maturity based on the diameter of the oocytes. The oocyte diameters of the sexually submature and mature female worms were below

200 µm and 208–240 µm, respectively, and the cells did not appear to have nurse cells. The shape and the diameter range of *Diopatra*'s oocytes in the present study were also similar to the larger oocytes of *D. neapolitana* investigated by Pires *et al.* (2012), i.e. rounded with a diameter of 140–240 µm. The study also clarified that nurse cells were only observed in smaller oocytes with a diameter of up to 160 µm; larger cells did not have nurse cells attached. Having a diameter of around 200 µm, oocytes should be released from the coelom into the water column (Dagli *et al.* 2005).

The male gametes of *Diopatra* worms were much smaller than the oocytes and were in the cluster and tetrad stages (Figure 1B.). In the former stage, the spermatid cells were fused and were inactive, while in the latter stage the cells were fused in a group of four and started to move actively. Mature sperms of the animals, which were characterized as having a long tail attached to a spherical, short and rounded head in *D. neapolitana* (Conti *et al.*, 2005; Pires *et al.*, 2012), were not found in this study.

Unlike *Diopatra* sp. from Jeruklegi, the reproductive cycle in the European *D. neapolitana* has been well-studied. Annually, the beginning of gametogenesis took place in spring, i.e. March or April, while the spawning period typically occurred from the end of spring in May to the end of summer in August – the amount of mature oocytes during this period were peaked, and the mature sperms had the highest mobility. The gametogenic inactivity period, thereafter, lasted from the end of autumn in November to the end of winter in February (Pires *et al.*, 2012). The reproductive cycle of the Javanese *Diopatra* sp. in the present work may be different considering that Indonesia only has two different seasons, i.e. rainy and dry. A monthly sampling over one year is hence necessary to see the reproductive pattern of this local species.

Although higher salinity levels seem to result in more sexually mature worms, statistical analysis shows that salinities did not significantly affect the sexual maturity level of the animals ($P > 0.05$) (Figure 2A.). This finding is in line with the study by Wibowo *et al.* (2021) in which variations in salinities did not significantly affect the proportion between sexually mature and immature *Nereis* worms (family Nereididae). While sexually immature *Diopatra* sp. possibly had not naturally entered the reproductive period, the result of this study was also biased from wounded worms, which were found in all the experimental containers. These worms typically lost the posterior part of their body and during the study were found to be regenerating this part – the

regenerating area was pink and whitish yellow (Figure 1C). Regeneration of lost body parts can adversely impact reproduction as the worms tend to use their energy for regenerating their parts rather than producing gametes (e.g. Pires *et al.*, 2015).

Macronutrient contents

Our proximate analysis revealed that *Diopatra* worms collected from Jeruklegi mostly comprised protein (41–43%) followed by carbohydrate (24–29%), ash (16–21%), fat (6–9%) and fiber (1–3%) as presented in Table 1. The protein content of the animals (41–43%) was almost similar to the Malaysian *Diopatra*, i.e. around 49% (Selvam, 2021) – the worms were identified as *D. neapolitana* by the author, yet the identification needs to be rechecked as the occurrence of this species in Asian waters is highly unlikely due to the long distance between European and Malaysian waters (e.g. Idris and Arshad, 2013; Berke, 2022). Compared to some local polychaete species, the protein content of *Diopatra* worms in this study was rather lower than that of *Nereis* sp. (family Nereididae) collected from Randusanga Village in Brebes, i.e. about 52% (Rachmad and Yuwono, 2000), and Jeruklegi, i.e. 60–66% (Wibowo *et al.*, 2019) and 47–51% (Wibowo *et al.*, 2020^a). It was also lower than that of female epitokes of wawo worms (family Eunicidae) collected from Ambon, i.e. about 54% (Pamungkas, 2015). The protein content of *Diopatra* sp. was nonetheless almost similar to that of *Dendronereis pinnaticirris* Grube, 1878 (family Nereididae), i.e. 32–43% (Wibowo *et al.*, 2020^b).

The fat content of *Diopatra* sp. from Jeruklegi (6–9%) was three to four times lower than that of the Malaysian *Diopatra* (approximately 24%) (Selvam, 2021). It was also much lower than that of some local species including *Nereis* sp. collected from Randusanga, i.e. nearly 30% (Rachmad and Yuwono, 2000), and Jeruklegi, i.e. 12–22% (Wibowo *et al.*, 2020^a), as well as the female epitokes of wawo worms, i.e. about 11% (Pamungkas, 2015). The fat content of *Diopatra* worms from Jeruklegi was nevertheless rather similar to that of *Nereis* sp. collected from the same area by Wibowo *et al.* (2019), i.e. 6–11%, and *D. pinnaticirris*, i.e. 2–9% (Wibowo *et al.*, 2020^b).

The carbohydrate content of *Diopatra* sp. from Jeruklegi (24–29% in the form of non-nitrogen extract matter) was similar to that of the Malaysian *Diopatra*, i.e. about 24% (Selvam, 2021), but much lower than that of *D. pinnaticirris*, i.e. 39–50% (Wibowo *et al.*, 2020^b). The content was however higher than that of *Nereis* sp. studied by Wibowo *et al.* (2019, 2020^a), i.e. 14–22% and 1–10%, respectively, and the female epitokes of wawo worms, i.e. about 12% (Pamungkas, 2015).

This study suggested that the levels of protein and fat in *Diopatra* worms from Jeruklegi may be suitable for using as shrimp broodstock and fish feeds since both feeds typically have more than 40% of protein and about 10% of fat. A number of polychaete species, especially members of the genera *Nereis* and *Glycera*, have been used for feeding crustaceans and fishes as the use of these worms ensures sufficient nutrition for reared broodstock as well as significantly stimulates the development of the animals' gonads (e-Costa *et al.*, 2003). Several European species such as *Arenicola marina* (Linnaeus, 1758) and *A. defodiens* Cadman and Nelson-Smith, 1993, from the family Arenicolidae, as well as *Alitta virens* (Sars, 1835) and *Hediste diversicolor* (Müller, 1776) from the family Nereididae – both species were previously known as *Nereis virens* and *N. diversicolor*, respectively – are recognized as commercial species and have been cultivated to meet the market demand (e-Costa *et al.*, 2003).

In Indonesia, initial studies on the potential of polychaete worms for aquaculture use have been limited to the Javanese *Nereis* sp. collected from several estuarine habitats in Central Java Province. The worms were used to feed two species of shrimps,

including the giant freshwater prawn *Macrobrachium rosenbergii* (De Man, 1879) and the giant tiger prawn *Penaeus monodon* Fabricius, 1798. The results of the studies showed that the shrimps fed with feed containing the worms had better growth and higher survival rates than those fed with other feed (Yuwono *et al.*, 1993, 1994, 1995; Rachmad and Yuwono, 2000; Yuwono, 2005). This is due to the fact that the worms contained high essential amino and fatty acids required by the shrimps to grow (Rachmad and Yuwono, 2000; Yuwono, 2005; Yuwono *et al.*, 2005).

Besides *Nereis* sp., the Javanese *Eunice* sp. from the family Eunicidae (Yuwono *et al.*, 2005) and *Diopatra* sp. (present study) also have the potential for use as feed in aquaculture due to their relatively high protein and fat contents. The latter two species, however, are still poorly studied despite an initial research on some biological aspects of *Diopatra* by Wibowo *et al.* (2022). The identity of these three Javanese species also remains unknown to date that further taxonomic investigations are required; they may represent new records or even new species considering that polychaete taxonomic studies in the southern coast of Java have been limited (Pamungkas and Glasby, 2019).

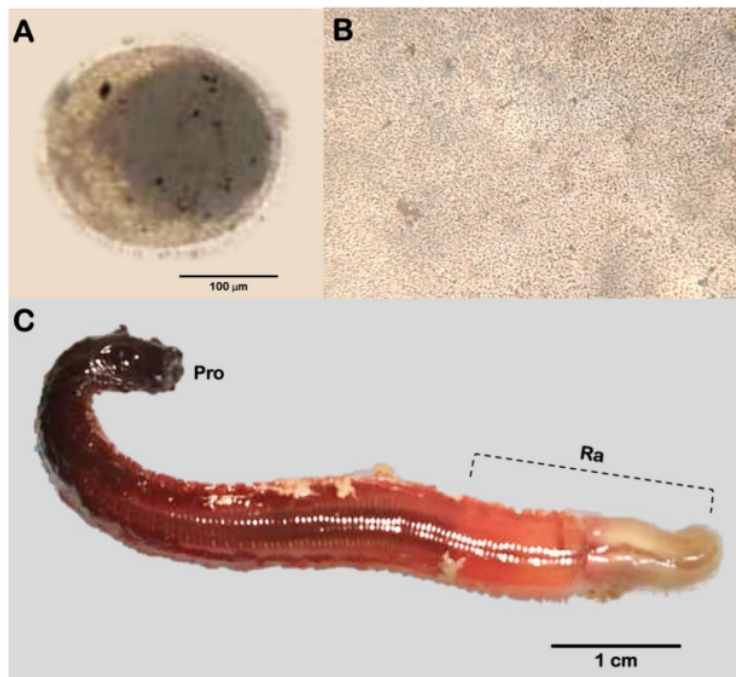
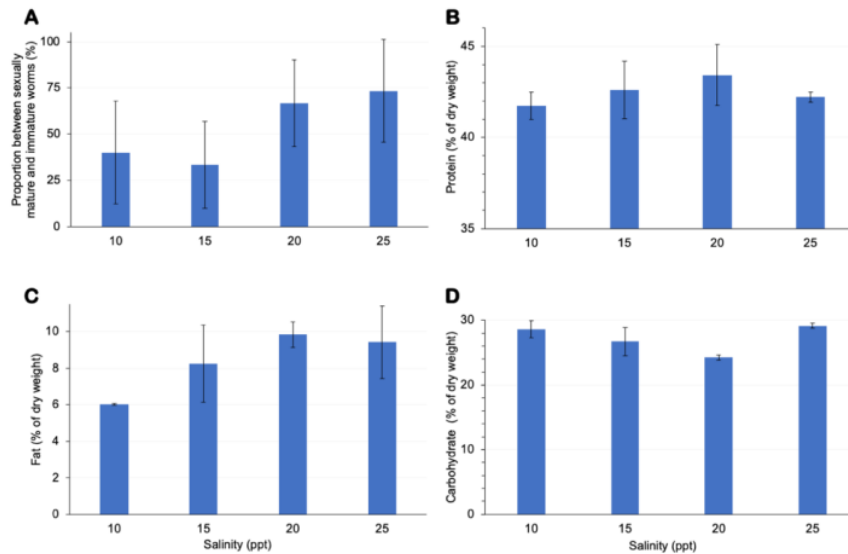


Figure 1. A mature oocyte (ovum) of *Diopatra* sp. from Jeruklegi, Cilacap (A), spermatids of the animals in the tetrad stage (B), *Diopatra* sp. regenerating the anterior part of the body (C). Pro, prostomium; Ra, regenerating area

Table 1. Results of the proximate analysis of *Diopatra* sp. from Jeruklegi Village, Cilacap

Salinity	Dry weight (%)	Water (%)	Protein*	Fat*	Carbohydrate*	Fiber*	Ash*
10	89.91	10.09	41.74	6.02	28.59	2.72	20.92
15	90.40	9.60	42.61	8.26	26.70	1.40	21.03
20	90.78	9.22	43.42	9.84	24.24	1.83	20.67
25	89.10	10.90	42.22	9.42	29.11	3.24	16.00

* in % of dry weight

**Figure 2.** Proportion between sexually mature and immature worms (A), average protein (B), fat (C) and carbohydrate contents (D) of *Diopatra* worms maintained at four different salinity levels.

Statistical analysis indicates that salinity levels did not affect the protein and fat contents ($P > 0.05$; Figure 1B & C), but affected the carbohydrate content of the animals ($P < 0.05$; Figure 1D). Both the lowest and the highest carbohydrate contents were found in the worms maintained at the salinity levels of 20 and 25 ppt, respectively (Figure 1D). Despite this, carbohydrates generally do not appear to be essential for shrimp broodstock diets (Irena et al., 2013). The water salinity was reported to have more impact on the regenerative capacity of the worms; it was the most responsible environmental factor influencing the regenerative capacity of *D. neapolitana* compared to pH and temperature (Freitas et al., 2015; Pires et al., 2015). Macronutrient contents of polychaetes generally depend on various factors such as the species (the contents vary between species), the diet (what they eat), the sexual maturity level (sexually mature worms tend to have a higher protein content due to the presence of gametes in their body cavity) and the method of proximate analysis used (e.g.

Kjeldahl vs Biuret methods for protein analysis and the determination of carbohydrate content) – see a comparison of the macronutrient contents of various commercially important polychaete species by Selvam (2021). A particular range of salinity levels (between 15 and 40 ppt), however, are required for *Diopatra* worms to live (Hakkim, 1975).

Conclusion

Salinity levels did not significantly affect the sexual maturity level of *Diopatra* worms collected from Jeruklegi. They also did not affect the protein and fat contents, but impacted the carbohydrate content of the animals. The levels of protein and fat in *Diopatra* sp. in the present work, i.e. 41–43% and 6–9%, respectively, were suitable for using as shrimp broodstock and fish feeds. *Diopatra* sp. has the potential use in local aquaculture. The annual reproductive cycle and the identity of the species, however, requires further research.

Acknowledgement

We would like to thank everyone involved in this study. This research was funded by DIPA BLU UNSOED.

References

- Audouin, J.V. & Milne, E.H. 1833. Classification des Annélides et description de celles qui habitent les côtes de la France (Part 2). *Ann. Sci. Nat.*, 1(28): 187–247. <https://doi.org/10.5962/bhl.title.part.8010>
- Berke, S.K. 2022. A review of *Diopatra* Ecology: Current knowledge, open questions, and future threats for an ecosystem engineering Polychaete. *Biology*, 11: p.1485. <https://doi.org/10.3390/biology11101485>
- Budaeva, N. & Fauchald, K. 2011. Phylogeny of the *Diopatra* generic complex with a revision of *Paradiopatra* Ehlers, 1887 (Polychaeta: Onuphidae). *Zool. J. Linn. Soc.*, 163(2): 319–436. <https://doi.org/10.1111/j.1096-3642.2011.00701.x>
- Cadman, P.S. & Nelson-Smith, A. 1993. A New Species of Lugworm, *Arenicola defodiens* sp. nov. *J. Mar. Biol. Assoc. U.K.*, 73(1): 213–224. <https://doi.org/10.1017/S0025315400032744>
- Conti, G., Loffredo, F. & Lantini M.S. 2005. Fine structure of the spermatozoon of *Diopatra neapolitana* (Polychaeta, Onuphidae). *Zoomorphology*, 124: 155–160. <https://doi.org/10.1007/s00435-005-0002-9>
- Cunha, T., Hall, A. & Queiroga, H. 2005. Estimation of the *Diopatra neapolitana* annual harvest resulting from digging activity in Canal de Mira, Ria de Aveiro. *Fish. Res.*, 76(1): 56–66. <https://doi.org/10.1016/j.fishres.2005.05.008>
- Dağlı, E., Ergen Z. & Çinar, M.E. 2005. One-year observation on the population structure of *Diopatra neapolitana* Delle Chiaje (Polychaeta, Onuphidae) in Izmir Bay (Aegean Sea, eastern Mediterranean). *Mar. Ecol.*, 26: 265–272. <https://doi.org/10.1111/j.1439-0485.2005.00055.x>
- De Man, J.G. 1879. On some species of the genus *Palaemon* Fabr. with descriptions of two new forms. *Notes from the Leyden Museum*, 41: 165–184.
- Delle-Chiaje, S. 1841. Descrizione e notomia degli animali invertebrati della Sicilia citeriore osservati vivi negli anni 1822–1830. Batteli & Co., Naples. <https://doi.org/10.5962/bhl.title.10031>
- e-Costa, P.F., Passos, A.M. & da Fonseca, L.C. 2003. Polychaetes and their potential use in aquaculture. *J. World Aquac.*, 34(3): 41–44.
- Fabricius, J.C. 1798. Supplementum Entomologiae Systematicae. Hafniae: Proft et Storck: 1-572.
- Freitas, R., Coelho, D., Pires, A., Soares, A.M.V.M., Figueira, E. & Nunes, B. 2015. Preliminary evaluation of *Diopatra neapolitana* regenerative capacity as a biomarker for paracetamol exposure. *Environ. Sci. Pollut. Res.*, 22(17): 13382–13392. <https://doi.org/10.1007/s11356-015-4589-1>
- Grube, A.E. 1878. Annulata Semperiana. Beiträge zur Kenntniss der Annelidenfauna der Philippinen nach den von Herrn Prof. Semper mitgebrachten Sammlungen. Mémoires l'Académie Impériale des Sciences de St. Pétersbourg (série 7), 25(8): 1–300. <https://doi.org/10.5962/bhl.title.85345>
- Hakkim, V.M. 1975. Salinity tolerance of *Diopatra neapolitana* Delle Chiaje: Annelida-Polychaeta. *Indian J. Mar. Sci.*, 4: 99–101.
- Idris, I. & Arshad, A. 2013. Checklist of polychaetous annelids in Malaysia with redescription of two commercially exploited species. *Asian J. Anim. Vet. Adv.*, 8: 409436. <https://doi.org/10.3923/ajava.2013.409.436>
- Izuka, A. 1907. On two new species of the eunicid annelids. *The Zoological Magazine*, 19: 139–143
- Knox, G.A. & Cameron, D.B. 1971. Port Phillip Bay Survey 1957–1963, Victoria, Australia. Part 2(4) Polychaeta. *Mem. Mus. Vic.*, 32: 21–42. <https://doi.org/10.24199/j.mmv.1971.32.04>
- Linnaeus, C. 1758. Systema Naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Editio decima, reformata (10th revised edition), 1: 824 pp. <https://doi.org/10.5962/bhl.title.542>
- Meena, D.K., Das, P., Akhtar, M.S., Sekar, M. & Kumar, S. 2013. Broodstock nutrition and management in Crustacean. aquafind.com/articles/Broodstock-Nutrition-InCrustacean.php

- Müller, O.F. 1776. Zoologiæ Danicæ Prodromus, seu Animalium Daniæ et Norvegiæ indigenarum characteres, nomina, et synonyma imprimis popularium. Havniæ (Copenhagen), Hallageri. <https://doi.org/10.5962/bhl.title.13268>
- Pamungkas, J. 2015. Species richness and macronutrient content of wawo worms (Polychaeta, Annelida) from Ambonese waters, Maluku, Indonesia. *Biodivers. Data J.*, 3: e4251. <https://doi.org/10.3897/BDJ.3.e4251>
- Pamungkas, J. & Glasby, C.J. 2019. Status of polychaete (Annelida) taxonomy in Indonesia, including a checklist of Indonesian species. *Raffles Bull. Zool.*, 67: 595–639.
- Pires, A., Figueira, E., Moreira, A., Soares, A.M.V.M. & Freitas, R. 2015. The effects of water acidification, temperature and salinity on the regenerative capacity of the Polychaeta *Diopatra neapolitana*. *Mar. Environ. Res.*, 106: 30–41. <https://doi.org/10.1016/j.marenvres.2015.03.002>
- Pires, A., Gentil, F., Quintino, V. & Rodrigues, A. M. 2012. Reproductive biology of *Diopatra neapolitana* (Annelida, Onuphidae), an exploited natural resource in Ria de Aveiro (Northwestern Portugal). *Mar. Biol.*, 33(1): 56–65. <https://doi.org/10.1111/j.1439-0485.2011.00463.x>
- Purwati, I., Rachmawati, F.N. & Wibowo, E.S. 2020. Aspek-aspek reproduksi cacing *Diopatra neapolitana* di Cilacap. *BioEksakta: J. Ilmiah Biologi Unsoed*, 2(3): 440–448. <https://doi.org/10.20884/1.bioe.2020.2.3.3494>
- Rachmad, B. & Yuwono, E. 2000. Pertumbuhan dan laju makan serta efisiensi protein pada post larva udang windu yang diberi pakan mengandung tepung cacing *lur*. *Makalah Seminar Nasional Biologi XVI*. ITB, Bandung.
- Sars, M. 1835. Beskrivelser og lagttagelser over nogle moerkelige eller nye i Havet ved den Bergenske Kyst levende Dyr af Polypemes, Acalephernes, Radiaternes, Annelidernes og Molluskernes classer, med en kort Oversigt over de hidtil af Forfatteren sammesteds fundne Arter og deres Forekommen. [book]. Thorstein Hallagers Forlag hos Chr. Dahl, R.S. <https://doi.org/10.5962/bhl.title.13017>
- Selvam, S.B. 2021. Proximate analysis of bait polychaetes from Port Dickson, Malaysia as prospectus replacement for aquaculture feed. *Int. J. Forest Animal Fish. Res.*, 5(1): 25–39. <https://doi.org/10.22161/ijfaf.5.1.4>
- Sudarmadji, S., Haryono, B. & Suhardi. 1998. Analisa Bahan Makanan dan Pertanian. Liberty Jogjakarta kerjasama dengan PAU Pangan dan Gizi UGM, Jogjakarta.
- Wibowo, E.S., Atang, Puspitasari, I.G.A.A.R. & Palupi, E.S. 2021. Pertumbuhan, retensi protein dan perkembangan gonad *Nereis* sp. dengan salinitas dan pakan berbeda. *Al-Kauniyah: J. Biologi*, 14(2): 304–312.
- Wibowo, E.S., Puspitasari, I.G.A.A.R., Atang & Pamungkas, J. 2022. Biological aspects of *Diopatra* sp. Onuphidae, Polychaeta) collected from mangrove habitats of Jeruklegi, Cilacap Regency. *Depik: J. Ilmu-Ilmu Perairan, Pesisir dan Perikanan*, 11(3): 299–305. <https://doi.org/10.13170/depik.11.3.25787>
- Wibowo, E.S., Palupi, E.S., Puspitasari, I.G.A.A.R., & Atang. 2019. Metabolism and nutritional content of Polychaeta *Nereis* sp. with maintenance salinity and different types of feed. *Ilmu Kelautan: Indonesian Journal of Marine Sciences*, 24(3): 113–120. <https://doi.org/10.14710/ik.ijms.24.3.105-112>
- Wibowo, E.S., Puspitasari, I.G.A.A.R., Palupi, E.S. & Atang. 2020^a. The potential of *Nereis* sp. (Polychaete) as prawn feed at the coastal farming of Jeruklegi, Cilacap. *IOP Conf. Ser.: Earth Environ. Sci.*, 550(1): 12030. <https://doi.org/10.1088/1755-1315/550/1/012030>
- Wibowo, E.S., Yuwono, E., Sukardi, P. & Siregar, A.S. 2020^b. Survival rate, growth, and chemical content of *Dendronereis pinnaticirris* (Polychaeta, Nereidae) in maintenance with different feeds and substrates. *Ilmu Kelautan: Indonesian Journal of Marine Sciences*, 25(2): 75–84. <https://doi.org/10.14710/ik.ijms.25.2.75-84>
- Yuwono, E. 2005. Kebutuhan nutrisi crustacea dan potensi cacing *lur* (*Nereis* sp., Polychaeta) untuk pakan udang. *J. Pemb. Pedesaan*, 5(1): 42–49.
- Yuwono, E., Nganroo, N.R. & Sahri, A. 1995. Kultur cacing *lur* dan pemanfaatannya untuk pakan udang. Laporan RUT3, Lembaga Penelitian, Unsoed, Purwokerto.
- Yuwono, E., Sahri, A. & Sugiarto. 2005. Asistensi teknis pengembangan budidaya cacing *lur* di PT Birulaut Katulistiwa, Lampung. Laporan Penelitian, Lembaga Penelitian Unsoed, Purwokerto.

Yuwono, E., Soesilo, U., Haryadi, B., Rachmawati, F.N. & Ida, S.B. 1993. Studi pemanfaatan *Nereis* sp. sebagai pakan udang galah *Macrobrachium rosenbergii* de Man skala laboratorium. Laporan Penelitian, Fakultas Biologi, Unsoed, Purwokerto.

Yuwono, E., Soesilo, U., Sahri, A., Widhiono, I. & Martodigdo, S. 1994. Pemanfaatan limbah pemintalan sutera alami untuk pakan udang *Macrobrachium rosenbergii* de Man. Laporan Penelitian, PPLH Unsoed, Purwokerto.

Sexual Maturity and Macronutrient Contents in Diopatra sp. (Onuphidae, Polychaeta) Maintained at Different Salinity Levels

ORIGINALITY REPORT

10%
SIMILARITY INDEX

%
INTERNET SOURCES

10%
PUBLICATIONS

%
STUDENT PAPERS

PRIMARY SOURCES

- 1 Ajib Setyo Arifin, Rafifa Maricha Putri Erisa, Muhammad Suryanegara. "Sea and Ship Waves Spectrum Measurement Using Wireless Sensor Network in Java Sea", 2018 Second World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4), 2018
Publication 1%
- 2 Adília Pires. "Reproductive biology of Diopatra neapolitana (Annelida, Onuphidae), an exploited natural resource in Ria de Aveiro (Northwestern Portugal) : Reproductive biology of Diopatra neapolitana", Marine Ecology, 03/2012
Publication 1%
- 3 Andrés Arias, Hannelore Paxton, Nataliya Budaeva. "Redescription and biology of Diopatra neapolitana (Annelida: Onuphidae), a protandric hermaphrodite with external spermaducal papillae", Estuarine, Coastal and Shelf Science, 2016 1%

4

Bruno Nunes. "Chapter 546 Ecotoxicological Effects of the Drug Paracetamol: A Critical Review of Past Ecotoxicity Assessments and Future Perspectives", Springer Science and Business Media LLC, 2020

Publication

1 %

5

Lola De Cubber, Sébastien Lefebvre, Charline Fisseau, Vincent Cornille, Sylvie Marylène Gaudron. "Linking life-history traits, spatial distribution and abundance of two species of lugworms to bait collection: A case study for sustainable management plan", Marine Environmental Research, 2018

Publication

1 %

6

Julianus Kinho, Suhartati, Husna, Faisal Danu Tuheteru et al. "Conserving Potential and Endangered Species of *Pericopsis mooniana* Thwaites in Indonesia", Forests, 2023

Publication

1 %

7

A. Pires, V. Quintino, F. Gentil, R. Freitas, A.M. Rodrigues. "Reproductive biology of a brooding *Diopatra* species: *Diopatra marocensis*", Estuarine, Coastal and Shelf Science, 2012

Publication

1 %

8

E S Wibowo, I G A R Puspitasari, E S Palupi, Atang. " The Potential of . (Polychaete) as

<1 %

Prawn Feed at the Coastal Farming of Jeruklegi, Cilacap ", IOP Conference Series: Earth and Environmental Science, 2020

Publication

9

Lucia De Marchi, Victor Neto, Carlo Pretti, Etelvina Figueira et al. "Physiological and biochemical impacts of graphene oxide in polychaetes: The case of Diopatra neapolitana", Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology, 2017

Publication

<1 %

10

Sarah K. Berke. "A Review of Diopatra Ecology: Current Knowledge, Open Questions, and Future Threats for an Ecosystem Engineering Polychaete", Biology, 2022

Publication

<1 %

11

Farida Nur Rachmawati, Untung Susilo. " Biochemical composition of tropical eel McClelland, 1844 in Freshwater and Estuary ", E3S Web of Conferences, 2021

Publication

<1 %

12

Ranilson de Souza Bezerra, Augusto César Vasconcelos de Freitas, Fábio Marcel da Silva Santos, Wagner Cotroni Valenti et al. "Digestive proteases from wild and farmed male morphotypes of the Amazon river prawn

<1 %

(Macrobrachium amazonicum)", Journal of Crustacean Biology, 2014

Publication

13

R Naufalin, R Wicaksono, Erminawati, P Arsil, V Z Khusna. "Physicochemical Analysis Of Gouramy Fish Sausage With Kecombrang Edible Coating Addition", IOP Conference Series: Earth and Environmental Science, 2019

Publication

<1 %

14

Adília Pires, Etelvina Figueira, Anthony Moreira, Amadeu M.V.M. Soares, Rosa Freitas. "The effects of water acidification, temperature and salinity on the regenerative capacity of the polychaete Diopatra neapolitana", Marine Environmental Research, 2015

Publication

<1 %

15

Asmaa H. Elgetany, Hendré Rensburg, Martin Hektoen, Conrad Matthee, Nataliya Budaeva, Carol A Simon, Torsten H. Struck. " Species delineation in the speciation grey zone—The case of (Annelida, Onuphidae) ", Zoologica Scripta, 2020

Publication

<1 %

16

Gilberto Bergamo, Orlemir Carrerette, João Miguel de Matos Nogueira. "Continuous and non-seasonal reproductive cycle of the alien species Diopatra neapolitana (Onuphidae,

<1 %

17

María Ana Tovar - Hernández, Nuria Méndez,
Tulio Fabio Villalobos - Guerrero. "Fouling
polychaete worms from the Southern Gulf of
California: Sabellidae and Serpulidae",
Systematics and Biodiversity, 2009

Publication

18

Nenengsih Verawati, Nur Aida, Assrorudin
Assrorudin, Andre Wijayanto. "Pengaruh
Konsentrasi Agar-Agar Terhadap Karakteristik
Kimia dan Sensori Permen Jelly Buah Mangga
Kweni (*Mangifera odorata* Griff)", AGRITEKNO:
Jurnal Teknologi Pertanian, 2020

Publication

19

H. van Rensburg, C. A. Matthee, C. A. Simon. "
Moonshine worms (: Onuphidae, Annelida) in
the Knysna Estuary, South Africa; taxonomy
and distribution ", Journal of the Marine
Biological Association of the United Kingdom,
2020

Publication

20

Hannelore Paxton. "A new species of *Diopatra*
(Annelida: Onuphidae) from Namibia,
southwestern Africa", Marine Biodiversity,
2016

Publication

<1 %

<1 %

<1 %

<1 %

21 Masaharu Izawakatsu. "On the ecology and distribution of freshwater planarians in the Japanese islands, with special reference to their vertical distribution", Hydrobiologia, 1965 $<1\%$
Publication

22 Pat Hutchings. Invertebrate Systematics, 2000 $<1\%$
Publication

23 Renewable Energy and Sustainable Technologies for Building and Environmental Applications, 2016. $<1\%$
Publication

Exclude quotes On

Exclude matches < 5 words

Exclude bibliography On