*Mar. Res. Indonesia Vol. 40, No. 1, 2015: 23−31*

# AMPHIPOD DISTRIBUTION IN THE SOFT-BOTTOM SUBTIDAL ZONES OF JAVA ISLAND IN RELATION TO SEDIMENT TYPES

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Received: June 2015 Accepted: December 2015

## ABSTRACT

Amphipods inhabit many marine benthic habitats and have an important ecological role. However, there is a lack of information about Indonesian amphipod diversity and distribution, especially in the shallow subtidal sediments of Probolinggo and Tangerang. During the transition to the monsoon season in September 2014, eight subtidal stations were sampled in Bayeman (Probolinggo) on East Java and seven subtidal stations were sampled in Kramat Kebo (Tangerang) in West Java. A total of 7346 amphipods individuals were collected, comprising five genera. Genus *Photis* was the most abundant group, followed by *Grandidierella* and *Synchelidium*. Multivariate analyses of these data indicated that sampling location and sediment granulometry were major determinants of distribution and composition of amphipods in Probolinggo and Tangerang.

**Keywords**: Indonesian Amphipods, Distribution, Sediment Types, Java

## INTRODUCTION

Some studies have reported on the global patterns of the macrobenthic communities (Rodil *et al.*, 2006), but globally, only a small portion of marine habitats have been sampled for macrofauna including amphipods (Snelgrove, 1998). To date, Lowry (2013) stated that more than 10,000 amphipod species have been described. Amphipods (Peracarida, Crustacea) represent one of the most diverse taxa of Crustacea (Marques & Bellan-Santini, 1990) and are among the most diverse and numerically dominant organisms of soft-bottom benthic faunas (Prato & Biandiolino, 2005). Amphipods play an important role in the structuring of benthic assemblages (Duffy & Hay, 2000). Amphipods also function as an important source of food for other benthic animals and important commercial fishes (Beare & Moore, 1996). The distribution and abundance of amphipods inhabiting marine sediments are influenced by a number of abiotic factors, such as waves, primary productivity (Snelgrove & Butman, 1994), sediment composition (De Grave, 1999), sediment type and depth (Hoey *et. al.*, 2004).

Probolinggo and Tangerang are special and complex estuarine systems, comprised of varied sedimentary habitats and inhabited by rich benthic fauna. Both areas also hold great economic and social importance. Amphipod fauna of the Probolinggo and Tangerang are little known, and few studies have been done to describe the diversity, distribution and composition of amphipods there. Thus, the main objectives of this paper were : (1) to characterize the composition and distribution of the amphipods fauna in



*DOI : 10.14203/mri.v40i1.68*

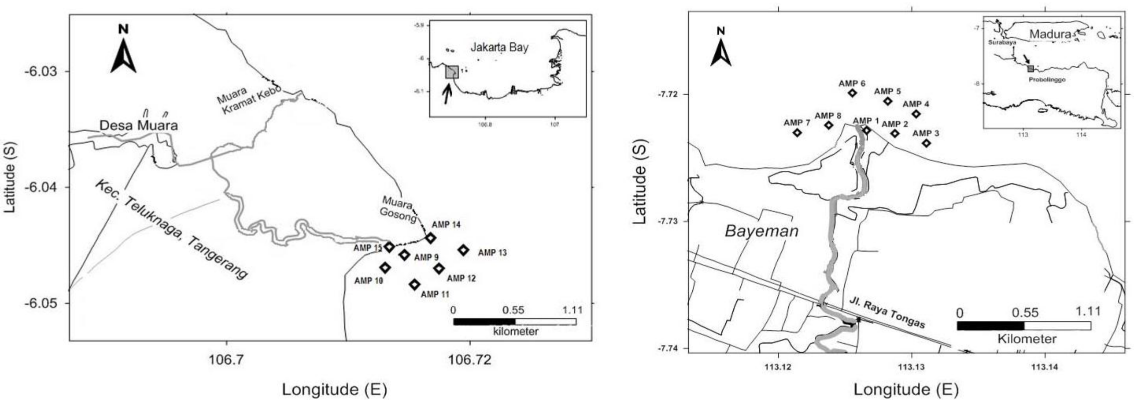


**Fig 1.** Sampling stations, Kramat Kebo-Tangerang (top), Bayeman-Probolinggo region (bottom)

the sub tidal soft-bottom ecosystems of Probolinggo and Tangerang; and (2) to study the influence of sediment types on the distribution patterns of amphipods. This study will not only provide baseline data and update existing information on benthic amphipods, but also increase our knowledge on the biodiversity of Indonesian amphipods.

## MATERIALS AND METHODS

### Study Area

The study area comprised two locations, namely Probolinggo and Tangerang. Samples were collected in eight stations in Probolinggo (coded Amp 1 to Amp 8), and seven stations (coded Amp 9 to Amp 15) in the Tangerang region (Fig. 1).

#### Sample Collection and Processing

Quantitative sampling was carried out during September 2014 at Bayeman in Probolinggo and Kramat Kebo in Tangerang by using a Smith McIntyre grab with a sampling area of 0.25 $m^2$ per grab. Three replicates were taken at each station, over a total area of 0.75 $m^2$. These samples were sieved through a 0.5 mm sieve, and the fauna was preserved in 10% neutral buffered formalin (i.e. 3.7%-4.0% formaldehyde in phosphate buffered saline), containing a Rose Bengal solution as a staining agent to facilitate sortation and identification of the fauna later at the laboratory. Amphipods were sorted under a binocular microscope (NIKON, SMZ 1500), then preserved in 70% ethanol, and then identified to genus level and counted. The system of classification proposed by Bellan-Santini *et al.* (1998) was followed in the identification process. An additional sediment sample was taken by using a Smith McIntyre grab at each station for determining granulometric composition. Sediment characteristics were analysed and grouped following Wentworth (1922).

### Data Analysis

Several diversity indices were calculated by PRIMER 5 (Clarke & Warwick, 2001) for each sampling station, namely: total abundance ($N$), number of species ($S$) and the Shannon–Wiener diversity index ($H'$), Simpson index ($\lambda$), Pielou eveness index ($J'$) (Marques, 2008). For any given site, species with ≥ 4% of total abundance were considered to be dominant (Field *et al.*,1982).

The structure of the amphipod community was investigated using multivariate techniques provided by PRIMER software v5 (Clarke & Warwick, 2001). The Bray-Curtis coefficient is more accurate compared to others (Bloom, 1981) and was hence used to calculate the resemblance matrix. The log (X+1) transformation was applied to the raw data prior to analysis in order to minimise the contribution of the most abundant species (Ysebaert *et al.*, 2002).

From the resemblance matrix, classification and ordination of sampling stations were performed. The classification of sampling stations was performed by cluster analysis based on the Unweighted Pair-Group Method using Arithmethic Averages (UPGMA), while the ordination was calculated based on Non-metric Multi-Dimensional Scaling (nMDS).

In addition, One-way Analysis of Similarities (ANOSIM) was applied for location, grain type and salinity factors. On ANOSIM, sampling stations were grouped into two locations, namely Tangerang (T) and Probolinggo (P), while for the salinity factor, sampling stations were assembled to Saline (S) if the salinity was bigger than 30 psu, and Brackish (B) if the salinity was equal or less than 30 psu. The grain factor represented sediment characteristics, sampling stations were convened to two groups, the first was the Silt-clay (SC) group if the the sediment had more than 70% Silt-clay, and the second was Sand (S) group if the sediment contained less than 70% Silt-clay.

## RESULTS

### Sediments

Sediments were dominated mainly by silt clay in most stations from the Probolinggo region, and sand was dominant in most of the Tangerang sampling stations (Table 1 & Table 2).

**Table 1.** Sediment characteristics of Bayeman (Probolinggo)

| Station | Percentage (%) | | | | |
|---|---|---|---|---|---|
| | Cobbles | Pebbles | Granules | Sand | Silt-Clay |
| Amp 1 | 2.30 | 2.30 | 5.01 | 17.11 | 75.57 |
| Amp 2 | 0.33 | 0.33 | 0.92 | 26.61 | 72.14 |
| Amp 3 | 0.09 | 0.09 | 0.14 | 6.96 | 92.81 |
| Amp 4 | 0.04 | 0.04 | 0.1 | 17.67 | 82.19 |
| Amp 5 | 9.34 | 9.34 | 5.45 | 73.31 | 11.91 |
| Amp 6 | 16.61 | 16.61 | 3.16 | 73.22 | 7.00 |
| Amp 7 | 1.66 | 1.66 | 0.61 | 27.22 | 70.51 |
| Amp 8 | 3.74 | 3.74 | 2.85 | 55.91 | 37.5 |

**Table 2.** Sediment characteristics of Kramat Kebo (Tangerang)

| Station | Percentage (%) | | | | |
|---|---|---|---|---|---|
| | Cobbles | Pebbles | Granules | Sand | Silt-Clay |
| Amp 9 | 0.00 | 0.00 | 0.00 | 54.19 | 45.81 |
| Amp 10 | 0.00 | 0.00 | 0.09 | 56.77 | 43.15 |
| Amp 11 | 0.00 | 0.00 | 0.05 | 68.70 | 31.25 |
| Amp 12 | 0.00 | 0.00 | 0.00 | 95.69 | 4.31 |
| Amp 13 | 0.00 | 0.00 | 0.00 | 95.32 | 4.68 |
| Amp 14 | 0.00 | 0.41 | 0.54 | 56.03 | 43.02 |
| Amp 15 | 0.00 | 0.14 | 0.52 | 63.41 | 35.93 |

**Table 3.** Number of species (*S*), total abundance per $m^2$ and 0.75 $m^2$ (*N*), Shannon Wiener's diversity index (*H'*, $log_2$), Pielou index (*J'*), Simpson index ($\lambda$) for each sampling station in Probolinggo and Tangerang

| Station | S | N ($m^2$) | N (0.75$m^2$) | *H'* | J' | λ |
|---|---|---|---|---|---|---|
| Amp 1 | 2 | 14 | 10.5 | 0.985 | 0.985 | 0.510 |
| Amp 2 | 3 | 26 | 19.5 | 0.893 | 0.563 | 0.672 |
| Amp 3 | 2 | 7 | 5.25 | 0.863 | 0.863 | 0.592 |
| Amp 4 | 2 | 7 | 5.25 | 0.985 | 0.985 | 0.510 |
| Amp 5 | 1 | 7 | 5.25 | 0.000 | 0 | 1.000 |
| Amp 6 | 4 | 19 | 14.25 | 1.813 | 0.906 | 0.313 |
| Amp 7 | 3 | 15 | 11.25 | 1.242 | 0.784 | 0.502 |
| Amp 8 | 2 | 16 | 12 | 0.896 | 0.896 | 0.570 |
| Amp 9 | 2 | 194 | 144.75 | 0.083 | 0.083 | 0.980 |
| Amp 10 | 1 | 1037 | 777.75 | 0.000 | 0 | 1.000 |
| Amp 11 | 1 | 2989 | 2241.75 | 0.000 | 0 | 1.000 |
| Amp 12 | 2 | 39 | 29.25 | 0.391 | 0.391 | 0.858 |
| Amp 13 | 1 | 854 | 640.5 | 0.000 | 0 | 1.000 |
| Amp 14 | 1 | 1349 | 1011.75 | 0.000 | 0 | 1.000 |
| Amp 15 | 1 | 774 | 580.5 | 0.000 | 0.985 | 1.000 |

## The Diversity of Amphipods

The present data set allowed the identification of 7346 amphipod individuals comprising five genera. The most abundant genera were *Photis* (7249 and 98.7% abundance), *Grandidierella* (0.65%), *Synchelidium* (0.45%) and *Melita* (0.2%). Values of univariate measurements are shown in Table 3. The lowest abundance values were recorded at Probolinggo (St. Amp 3, 4 & 5 with 7 ind./$m^2$), while the highest numbers were recorded at Tangerang (Table 3; highlighted in yellow). The number of species varied between 1 (St. Amp 5, Amp 10, 11, 13, 14 & 15) and 4 (St. Amp 14); diversity ranged from 0 (St. Amp 5, 10, 11, 13, 14 & 15) and 1.26 (St. Amp 6). The highest diversity of amphipods was found in St. Amp 6 with *H'* value of 1.813. In general, the diversity of amphipods in the Probolinggo region was higher than Tangerang with *H'* average value of 0.96 ± 0.50 and 0.07 ± 0.15, respectively. Although amphipod abundances were higher in Tangerang compared to Probolinggo stations, amphipod species were not evenly distributed. The condition was shown by low Pielou index (*J'*) values and high Simpson index *(λ)* (Table 3).

## Multivariate Analysis

Cluster analysis was carried out by applying the Bray Curtis Similarity Index with group average. The analysis showed at least three major clusters, namely group I, II and III (Fig. 2).

Group I contained all stations from Kramat Kebo-Tangereang with 60.37% similarity, while the stations on group II mostly comprised samples sites from the Bayemen-Probolinggo region with 46.35% similarity, however two stations in the

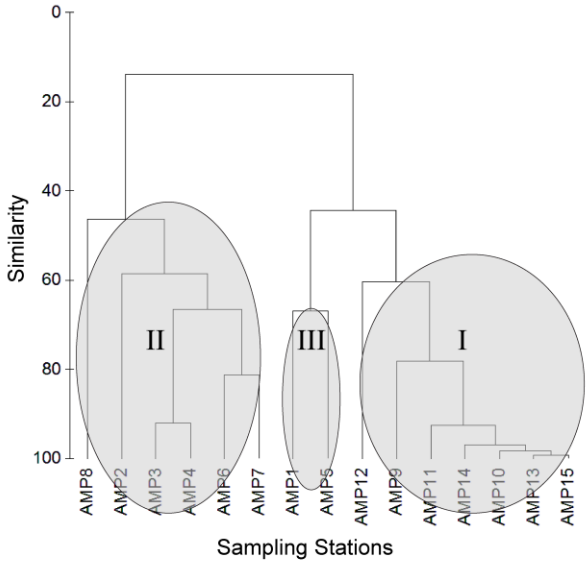


**Fig 2**. Amphipods in Probolinggo and Tangerang as determined by cluster analysis based on Bray–Curtis similarity coefficient

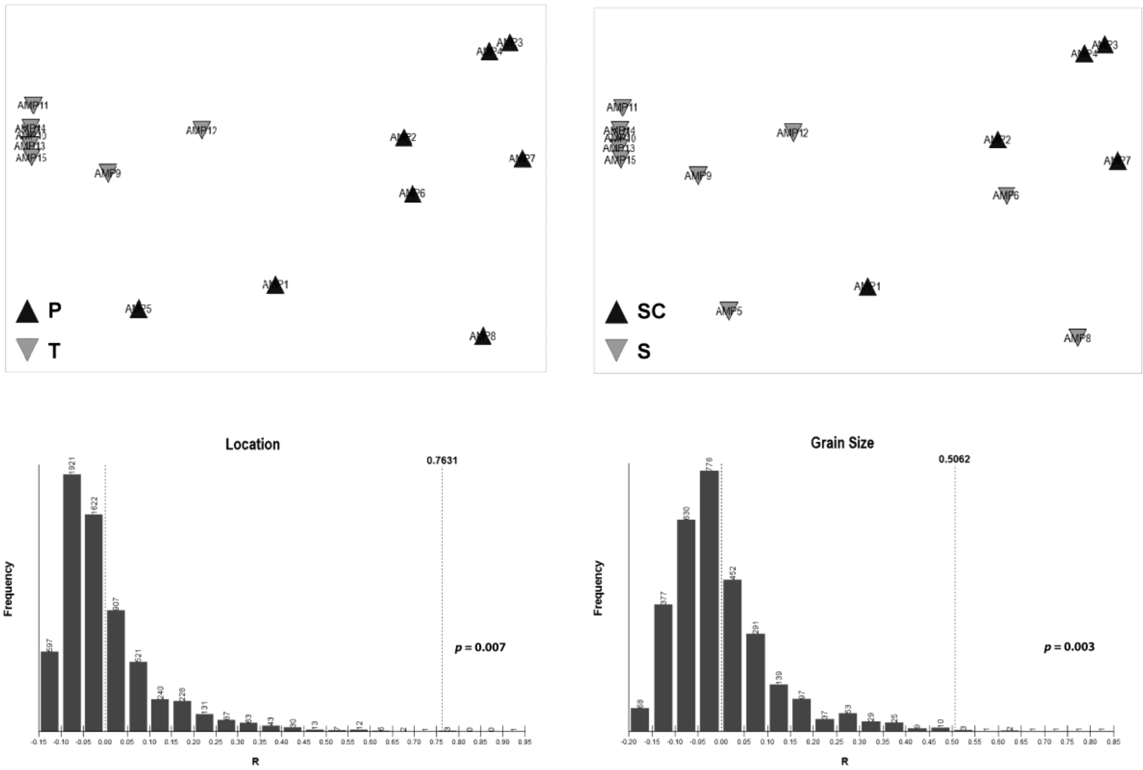


**Fig 3.** Non-metric Multi-Dimensional Scaling on factors: location (top left), grain size of sediment (top right), and Analysis of Similarities on factors: location (bottom left), grain size (bottom right)

Probolinggo region, namely Amp 1 and Amp 5 belonged to Group III and had 66.84% similarity.

The nMDS ordination showed similar results with cluster analysis (Fig. 3). The ANOSIM test of amphipod abundance based on factors: grain size and sampling location, showed significant differences ($p$ < 0.01). ANOSIM on the location factor resulted in higher global R than the grain factor, where the values were 0.763 and 0.506 for location and grain size respectively (Fig. 3). However, ANOSIM on the salinity factor did not show significant different between the Saline and Brackish water group ($p$ > 0.05, data not shown).

## DISCUSSION

### Distribution of amphipods in relation to sediment type

Significant relationships between the density/diversity of amphipods and sediment types were detected. Based on the average value of the Shanon-Wiener diversity index, the Probolinggo region had higher diversity than the Tangerang region. This condition was concordant to what had been previously reported for the Portuguese coast (Marques and Bellan-Santini, 1990).

These results can be attributed to higher organic matter in silt clay sediments (Carvalho *et al.*, 2006; Sousa *et al.*, 2007), which is an important food resource for benthic communities (Rodríguez-Graña *et al*., 2008). Furthermore, the finer sediments also reflect low levels of physical disturbance (Nicholls *et al*., 1998). Therefore, both food availability and reduced disturbance may allow for the existence of an abundant amphipod community.

Conversely, our findings on amphipod fauna in the Tangerang region showed higher density despite a predominantly sandy sediment type. This finding related to the domination of *Photis* spp. (7231 individuals) compared to five individuals for other genera (*Melita* and *Synchelidium*). Photis domination at Tangerang region could be attributed to the high amount of decaying algae that was available on this subtidal substrate. The fact that most Photidae species prefer to live in tubes constructed using sand or organisms, such as macroalgae, explained this finding (Souza-Filho & Serejo, 2010; Myers & Lowry, 2003). In addition, high density *Photis* spp. in sandy bottoms was also reported in the southern Portugese coast (Carvalho *et al*., 2012).

To our knowledge, this is the first description of amphipod communities of Bayeman (Probolinggo) and Kramat Kebo (Tangerang). This is particularly important since these two locations have similar substrata characteristics as Segara Anakan Lagoon (Cilacap) where benthic organisms became important living natural resources, and hence had economical potential for its local population (Nordhaus *et al.*, 2009). Besides fishing, dredging, eutrophication and aquaculture are known to threaten these highly diverse habitats (Hall-Spencer *et al.*, 2006). There have been no previous publications regarding the amphipod communities associated with the sediment type in these locations, thus we could not compare our data findings with previous data. However Sanders (1969) stated that there have been several attempts to examine diversity in different habitats and, in general, estuaries tend to have relatively low diversity and tropical environments are thought to be generally species rich. It has also been suggested that higher biological diversity maybe associated with higher sediment grain diversity (Etter & Grassle, 1992). Thus, it is reasonable to expect that the habitat for sedimentary fauna is defined largely by the surface sediment (Grange, 1977) and sediment grain size (Connell, 1978).

Gray (1968) also found low species diversity in areas with high current action and coarse sediments, where the sediment was too loose and unstable for construction of permanent burrows. Furthermore, habitat diversity tends to promote biological diversity as well (Connell, 1978).

### Ecological patterns of dominant taxa: *Photis* spp.

In the present study, the most abundant genus (*Photis* spp.) accounted for 98.7% of the total density. There is a variety of *Photis* spp. found in oceans all around the world (Barnard,

1962) from cold to tropical waters. They usually inhabit shallow waters less than 200 m in depth (Barnard & Karaman 1991). The dominance of *Photis* spp. might be biased due to genus level identification employed in this study. However, according to McKinney (1980) the dominance of Photids was common in soft-bottom communities. Myers & Lowry (2003) said that most species of Photidae live in tubes constructed using sand, mud or organisms such as macroalgae, coral rubble and sponges. Some of them also inhabit mollusc shells, and Snelgrove (1998) suggested that they have a key role as food for many secondary consumers.

### Biogeographic notes of Major Genus: *Photis* spp.

Regional biogeographical syntheses of amphipods have been assembled for different areas of the world, but global syntheses are hindered by several problems. Firstly, the huge areas of the oceans necessitate very limited and uneven coverage, and most areas are poorly sampled. Secondly, another problem is the lack amount of funds and expertise needed to process available samples. Thirdly, some species that had been previously assumed to be cosmopolitan were in fact species complexes (Snelgrove, 1998).

Despite a lack of species-by-species syntheses over broad scales, several generalizations can be made about amphipod distribution. Amphipods are often expected to have an endemic tendency due to their limited dispersal capacity, resulting both from the direct development and from reduced swimming capacity (Marques and Bellan-Santini, 1990). There were only two records on the genus *Photis* from Indonesian waters. Pirlot (1938) reported *Photis* spp. from Dongala, Celebes and *Photis dolichommata* from Siboga. The latest finding on Indonesian photis were *Photis cavimana* and *Photis longicaudata* at Bunaken, 18 years ago by Ortiz & Lalana (1997). After those findings, there are no recent publications/information/reports on this genus from Indonesian waters.

## CONCLUSION

There were 7346 amphipods individuals comprising five genera found at Bayeman (Probolinggo) and Kramat Kebo (Tangerang), collected during the transition to the monsoon in September 2014. Overall, this study revealed that their distribution was affected by grain size and sampling location.

The methods of linking community patterns to environmental variables used in this study were developed mainly to assess the effects of pollution on benthic community structure. In the present context, it was shown that these methods are useful in showing the importance of environmental factors in regulating community structures.

## ACKNOWLEDGEMENTS

The authors want to express their gratitude to the "*Kajian Penggunaan Biota Uji Untuk Mendeteksi Pencemaran di Ekosistem Pesisir*" project team (Dr. Zainal Arifin, Onny, Lestari, Dede, Rachma, Deny, Eston, Dwi H., Abdul R., Riyana S., M. Taufik K., Khozanah, Edward) for their invaluable help with many tasks, including sample collection, and Singgih P. for sediment characterization. This study was a part of the "*Kajian Penggunaan Biota Uji Untuk Mendeteksi pencemaran Di Ekosistem Pesisir*" Project**,** supported by DIPA 2014 Research Center for Oceanography-LIPI.

# REFERENCES

Barnard, J. L. 1962. Benthic marine amphipoda of southern california: families aoridae, photidae, ischyroceridae, corophiidae, podoceridae. *Pacif. Nat*., 3,1-72.

Barnard, J. L. & Karaman, G. S. (1991). *The families and genera of marine gammaridean amphipoda (except marine gammaroidea) part 2* (pp. 419-866). Australia : Records of The Australian Museum.

Beare, D. J. & Moore, P.G. (1996). The distribution, growth and reproduction of Pontocrates arenariusand P. altamarinus (Crustacea: Amphipoda) at Millport, Scotland. *J. Mar. Biol. Assoc. UK.*, 76, 931–950. doi: http://dx.doi.org/10.1017/S0025315400040893

Bellan-Santini, D.; Karaman, G.; Ledoyer, M.; Myers, A.; Ruffo, S.; Vader, W. (1998). The Amphipoda of the Mediterranean. Part 4: Localities and Map, Addenda to Parts 1-3, Key to Families, Ecology, Faunistics and Zoogeography, Bibliography, Index. *Mém. Inst. Océangr. Monaco*., 13 (4), 815–950.

Bloom, S. A. (1981). Similarity Indices in Community Studies: Potential Pitfalls. *Mar. Ecol. Prog. Ser.,* 5, 125-128.

Carvalho, S., Gaspar, M.B., Moura, A., Vale, C., Antunes, P., Gil, O., Cancela da Fonseca L, Falcão M. (2006). The use of the marine biotic index AMBI in the assessment of the ecological status of the Óbidos lagoon (Portugal). *Mar. Pollut. Bull.*, 52, 1414–1424. doi: 10.1016/j.marpolbul.2006.04.004

Carvalho, S., Cunha, M.R., Pereira, F., Pousão-Ferreira, P., Santos, M.N., Gaspar, M.B., 2012. The effect of depth and sediment type on the spatial distribution of shallow soft-bottom amphipods along the southern Portuguese coast. *Helgol. Mar. Res*., 66, 489–501. doi: 10.1007/s10152-011-0285-9

Clarke, K. R. & Warwick, R. M. (2001). *Change in marine communities: an approach to statistical analysis and interpretation*. Plymouth, United Kingdom, PRIMER-E Ltd.

Connell, J. H. (1978). Diversity in tropical rainforests and coral reefs. *Science.*, 199, 1302-1310.

De Grave, S. (1999). The infuence of sedimentary heterogeneity on within maerl bed differences in infaunal crustacean community. *Estuar. Coast. Shelf. Sci.*, 49, 153–163. doi: 10.1006/ecss.1999.0484

Duffy, J. E. & Hay, M. E. (2000). Strong impacts of grazing amphipods on the organization of a benthic community. *Ecol. Monogr.*, 70, 237–263. doi: 10.1890/0012-9615(2000)070[0237:SIOGAO]2.0.CO;2

Etter, R. J. & Grassle, J. F. (1992). Patterns of species diversity in the deep sea as a function of sediment particle size diversity. *Nature*., 360, 576-578. doi: 10.1038/360576a0

Field, J. G., Clarke, K. R. , Warwick, R. M. (1982). A practical strategy for analysing multispecies distribution patterns. *Mar. Ecol. Prog. Ser.,* 8, 37–52.

Grange, K. R. (1977). Littoral benthos-sediment relationships in manukau harbour, New Zealand. N. Z. *J. Mar. Fresh. Res.*, 11(1), 111-23. doi: 10.1080/00288330.1977.9515664

Gray, J. S. (1968). *The ecology of marine sediments*. Cambridge: University Press, 180 pp.

Hall-Spencer, J., White, N., Gillespie, E., Gillham, K., Foggo, A. (2006). Impact of fish farms on maerl beds in strongly tidal areas. *Mar. Ecol. Prog. Ser.*, 326,1–9.

Lowry, J. K. (2013). Amphipoda. In: Lowry, J. K. (ed.), World amphipoda database. Accessed through: World Register of Marine Species (WoRMS) at http://www.marinespecies.org/aphia.php?p=taxdetails&id=1135.

Marques, J. C. (2008). *Coastal and estuarine environments*. Encyclopedia of Ecology. S. E. J. Fath and D. Brian (pp. 619-630). Amsterdam :Elsevier B.V.

Marques, J. C, Bellan-Santini, D. (1990). Benthic amphipod fauna (Crustacea) of the Portuguese coast: biogeographical considerations. *Mar. Nat.*, 3, 43–51.

McKinney, L. D. (1980). The genus photis (crustacea: amphipoda) from the texas coast with the description of a new species, *Photis melanicus*. *Contrib. Mar. Sci.*, 23, 57-61.

Myers, A. A. & Lowry, J. K. (2003). A phylogeny and a new classification of the Corophiidea Leach,1814 (Amphipoda). *J. Crust. Biol.*, 23(2), 443–485. doi: 10.1163/20021975-99990353

Nicholls, R. J, Birkemeier, W.A., Lee, G. (1998). Evaluation of depth of closure using data from

Duck, NC, USA. *Mar. Geol.*, 148, 179–201. doi: 10.1016/S0025-3227(98)00011-5

Nordhaus, I., Hadipudjana, F. A., Janssen, R., Pamungkas, J. 2009. Spatio-temporal variation of macrobenthic communities in the mangrove-fringed Segara Anakan lagoon, Indonesia, affected by anthropogenic activities. *Reg Environ Change*., 9, 291–313. doi: 10.1007/s10113-009-0097-5

Ortiz, M & Lalana, R. (1997). Amphipoda, In: M. GUTU (Co-ordination), Results of the zoological expedition organized by "Grigore Antipa" museum in the indonesian archipelago (1991). I. peracarida (crustacea). *Trav. Mus. Natl. Hist. Nat.*, 38, 29-113.

Prato, E. & Biandiolino, F. (2005). Amphipod biodiversity of shallow water in the Taranto seas (north-western Ionian Sea). *J. Mar. Biol. Assoc. UK.*, 85, 333–338. doi: http://dx.doi.org/10.1017/S0025315405011239h

Rodil, I. F., Lastra, M., Sánchez-Mata, A. G. (2006). Community structure and intertidal zonation of the macroinfauna in intermediate sandy beaches in temperate latitudes: north coast of Spain. *Estuar. Coast. Shelf. Sci.*, 67, 267–279. doi:10.1016/j.ecss.2005.11.018

Rodríguez-Graña, L., Calliari, D., Conde, D., Sellanes, J., Urrutia, R. (2008). Food web of a SW Atlantic shallow coastal lagoon: spatial environmental variability does not impose substantial changes in the trophic structure. *Mar. Ecol. Prog. Ser.*, 362, 69–83. doi: 10.3354/meps07401

Sanders, M. L. (1968). Marine benthic diversity: a comparative study. *Am. Nat.*, 102, 243–282.

Snelgrove, P. V. R. (1998). The biodiversity of macrofaunal organisms in marine sediments. *Biodivers. Conserv.*, 7, 1123–1132. doi:10.1023/A:1008867313340

Snelgrove, P. V. R. & Butman, C.A. (1994). Animal sediment relationships revisited: Cause versus effect. *Oceanogr. Mar. Biol. Ann. Rev.*, 32, 111-177.

Sousa, R., Dias, S., Freitas, V., Antunes, C. (2007). Subtidal macrozoobenthic ssemblages along the River Minho estuarine gradient (northwest Iberian Península). *Aquat. Conserv. Mar. Freshw. Ecosyst.*, 18, 1063–1077. doi: 10.1002/aqc.871

Souza-Filho, J. F. & Serejo, C. S.(2010). Two new species of the family Photidae (Amphipoda: Corophiidea: Photoidea) from Brazilian waters, with description of Rocasphotis gen. nov.', *J. Nat. Hist.*, 44 (9), 559-577. doi:10.1080/00222930903471118

Wentworth, C. K. (1922). A scale of grade and class terms for clastic sediments. *J. Geol.*, 30 (5), 377-392.

Ysebaert , T., Meire, P., Herman, P. M. J., Verbeek, H. (2002). Macrobenthic species response surfaces along estuarine gradients: prediction by logistic regression. *Mar. Ecol. Prog. Ser.*, 225, 79–95. doi:10.3354/meps225079