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Preliminary Data on the Bioturbation Activity of *Hediste Diversicolor* (Polychaeta, Nereididae) from the Loire Estuary, France

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Abstract: The ragworm *Hediste diversicolor* (O. F. Müller, 1776) plays a key role in the estuarine water-sediment interface. This scientific project comes under the framework of the International network Nereis Park Experiment gathering 27 laboratories from all over the world. The experiments were carried out concurrently in spring 2007 using a common protocol. In the Loire estuary, the samples were collected in the intertidal zone of the Saint-Nazaire Bridge. During the field experiment, we estimated the surface area of the burrow walls (Sb) value varied from Sb = 0.26 $m^2.m^{-2}$ to 2.18 $m^2.m^{-2}$ (mean Sb = 0.75 $m^2.m^{-2}$), and the pumping rate (Pr) value from Pr = 0.9 $l.d^{-1}m^{-2}$ to 7.7 $l.d^{-1}$ m^{-2} (mean value Pr = 2.7 $l.d^{-1}m^{-2}$). The density and the biomass of *H. diversicolor* populations largely controlled the amount of reworked sediment. In the laboratory, we estimated the pseudo-diffusive mixing, Db value varied from Db = 1.2 to 1.6 (mean Db = 1.5). The non-local transport (r) from the upper layers to the bottom of the tubes varied from r = 1 to 7.2 (mean r = 4.3). A positive relationship could be established between Db and the temperature while on the contrary a negative relationship could be established between the Db and biomass. It seems that small individuals are more efficient reworkers than big ones.

Keywords: Bioturbation, Burrow walls, Pumping rate, *Hediste diversicolor*, Loire estuary.

INTRODUCTION

The ragworm *Hediste diversicolor* (O.F. Müller, 1776) is a widespread species of coastal lagoons and estuaries from Morocco to Scandinavia. *H. diversicolor* is a major link in food webs and has an economic value as bait for fishing in several European countries [1]. In the Loire estuary, the benthic fauna was studied by [2-4]. The population dynamics of *H. diversicolor* was first studied by [5, 6]. More recently the populations of *H. diversicolor* were studied in the Authie and Seine estuaries [7-9].

H. diversicolor plays a key role in the physical, chemical and biological properties of the marine water-sediment interface. The influence of *H. diversicolor* on biogeochemical processes has been assigned mainly to their sediment reworking and bioirrigation activities. The works on the bioturbation of *H. diversicolor* are not very numerous [10-15]. Such studies on *H. diversicolor* were carried out using luminophores [16, 17].

The aim of this work is to gather initial data on the bioturbation activity of *H. diversicolor* in the Loire estuary. During the field experiment, we assessed the surface of the burrow walls and the pumping rate of *H. diversicolor*. In the laboratory, we used a gallery-diffusors model [13] to estimate the pseudo-diffusive mixing and the non-local transport. The experience was carried out in spring 2007 using a common protocol. This project was carried out within the framework of the Nereis Park Experiment, an international network gathering 27 laboratories all over the world.

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MATERIAL AND METHODS

The survey was carried out in 2007 in the Loire estuary. The sampling site is located in the southern part of the Loire estuary (Latitude 47.26406, Longitude -2.16928) close to St-Nazaire in the polyhaline zone. Specimens *of H. diversicolor* were collected using a spade at a depth of approximately 25 cm in the intertidal zone. The samples were collected from the mud sand community and included *Heteromastus filiformis, Hydrobia ulvae* and *Scrobicularia plana* (Fig. **1**).

The surface sediment (0-5 cm) was sieved with a 1 mm mesh with no water being added. Some sieved sediment was saved for Organic Matter (OM) and grain-size distribution analysis. Four core tubes were filled with a 15-cm high column of sieved sediment.

The core tubes had a diameter of 10 cm. The remainder of the cores (~10 cm) was filled with seawater from the sampling site and the cores were left for a week with aerated seawater under *in situ* temperature. Twelve individuals were necessary for the experiment. They were weighted and measured (length). Four individuals were introduced in each of the first three cores; the last core, which contained no organisms, served as a control core. The cores were acclimatized in the aerated seawater system for a week (12:12 dark light cycle with an *in situ* temperature of 17°C). A suspension of each luminophore dose with a little water

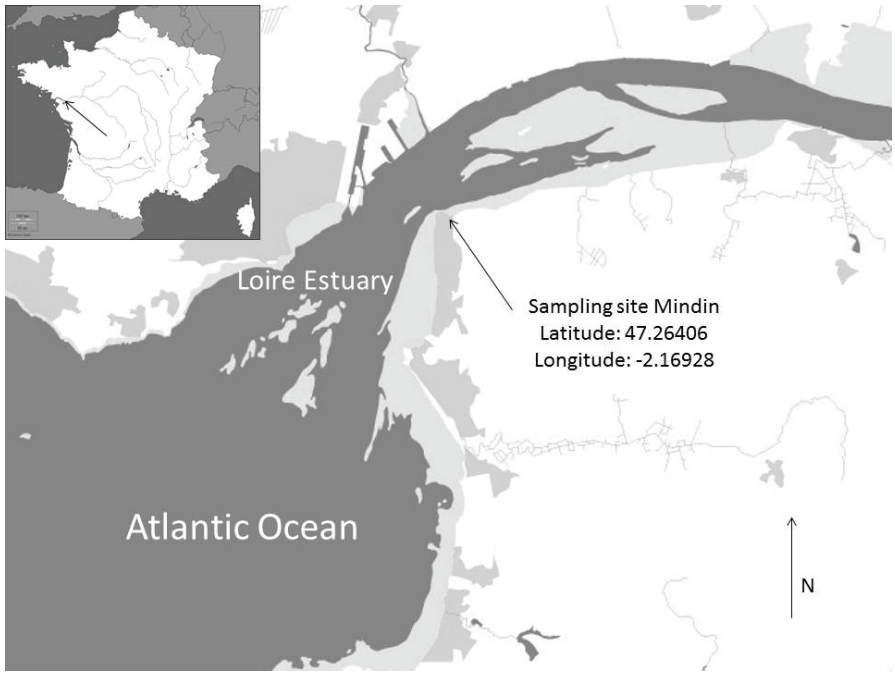


Fig. (1). Location of the sampling site of *Hediste diversicolor* in the Loire estuary, France.

was added to the overlying water of each core. After 10 days of incubation, the overlying seawater was removed by siphoning. The sediment was sectioned vertically into 0.5 cm-thick layers from the surface down to 2 cm depth, and then into 1 cm-thick layers down to 15 cm for *Hediste* cores (only down to 5 cm for the control core). Each sediment layer was freeze-dried and then homogenized. We used a gallery-diffusors model [13] with the peudso-diffusive mixing (Db) in the region of intense burrowing activity (surface) and non-local transport (r) from the upper layers down to the tube bottom.

RESULTS AND DISCUSSION

Field Experiment

The densities of the population of *H. diversicolor* observed in the Loire estuary varied from N = 300 to 2,560 ind.m^{-2}. The mean annual density of *H. diversicolor* was N = 900 $\pm$ 534 ind.m^{-2} with two peaks, the first one with N = 2,560 ind.m^{-2} in April and the second one with N = 1,280 ind.m^{-2} in September. A decrease in the density was observed in February with N = 304 ind.m^{-2} and November with N = 528 ind.m^{-2}. The mean annual biomass is $\overline{B}$ = 9.1 g.m^{-2}. The biomass shows temporal variations with a maximum of B = 26.0 g.m^{-2} in August. Lower values were obtained in January with B = 1.2 g.m^{-2} and February with B = 1.3 g.m^{-2}. The decrease in the density and biomass in winter is linked to the mortality of adults and the increase in spring to the recruitment of juveniles.

During the field experiment, we estimated the Surface of the burrow walls (Sb) varied from Sb = 0.26 m^2.m^{-2} to 2.18 m^2.m^{-2} (mean Sb = 0.75 m^2.m^{-2}), and the Pumping rate (Pr) from Pr = 0.9 l to 7.7 l. d^{-1}m^{-2} (mean value Pr = 2.7 l.d^{-1}m^{-2}) (Fig. **2**).

`The bioturbation activity of *H. diversicolor* is directly connected to the density of the population. *H. diversicolor* is capable of pumping large volumes of water into the sediment. The properties of the pumping action were studied

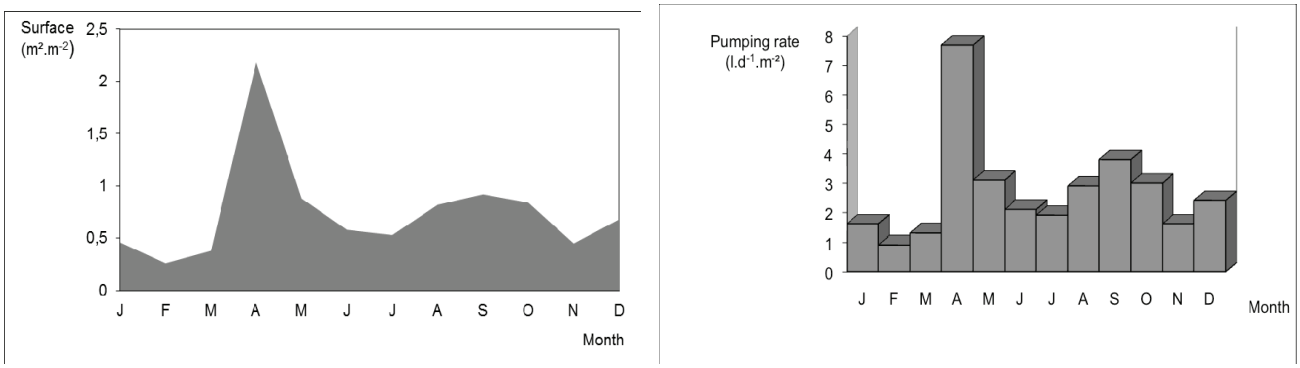


Fig. (2). Temporal variations in the Surface of burrows (Sb in m^2.m^{-2}) and Pumping rate (Pr in l.d^{-1}.m^{-2} mudflat surface) of *Hediste diversicolor* from the Loire estuary.

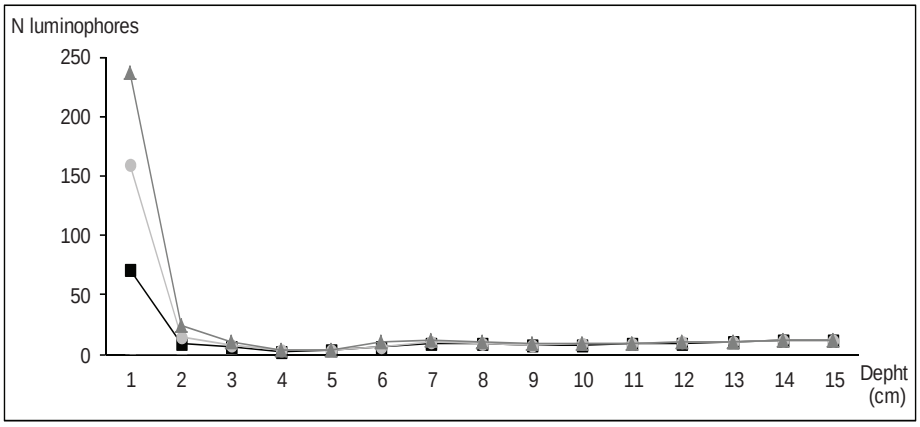


Fig. (3). Depth profiles (cm) of the number of luminophores for the three cores containing Polychaete *Hediste diversicolor* from the Loire estuary.

in *H. diversicolor* [18]. It was found that *H. diversicolor* pumps about 40 l of water per ml oxygen consumed. The pumping rate for a population of 2,400 ind.m^{-2} was estimated to 9.8 m^3 d^{-1} or 10 times the whole water column daily. A natural population with 1,000 to 3,000 ind.m^{-2} may pass a volume corresponding to a water column of 3 to 9 m through their burrows each day [19].

Laboratory Experiment

Twelve individuals of *H. diversicolor* were necessary for the three experiments (four individuals in each core). They were measured and weighted before the experiment. Length varied from L = 5.0 to 7.5 cm and Weight from W = 0.29 to 0.73 g. The depth profiles of luminophores for the three cores were different for each core (Fig. **3**).

The gallery diffuser model was used to assess the core containing *H. diversicolor*. The pseudo-diffusive mixing (Db) in the region of intense burrowing activity was estimated. A significant difference of the bio-diffusion was observed between the three cores. The Db value varied from Db = 1.2 to 1.6 (mean Db = 1.5). The non-local transport (r) from the upper layers to the bottom of the tubes was calculated. The r value varied from r = 1 to 7.2 (mean r = 4.3) (Table **1**).

Table 1. Parameters of Bioturbation Activity of *Hediste diversicolor* from the Loire Estuary with the Pseudo-Diffusive Mixing (Db) and the non-local transport (r)

Core	Db	r	Depth max
Core 1	1.6	7.2	11.5
Core 2	1.2	1.0	8.5
Core 3	1.6	4.6	9.5
Mean value	1.5	4.3	9.8

The results observed in the Loire estuary are among the highest values observed in the North Atlantic regions. The Db mean value is Db = 1.5 in the Loire estuary, and varies from Db = 0.8 in Scotland to 1.7 at Venice, Italy. The mean r value is r = 4.3 in the Loire estuary, and varies from r = 2.45 at Rostock, Germany to r = 11.0 at Aberdeen in the United Kingdom.

The optimal temperature of sediment reworking observed during the Nereis Park Experiment is 21°C for *H. diversicolor*. The optimal temperature of sediment reworking activity occurred at 13°C for *Neanthes virens* in the Saint Lawrence Estuary, Canada [20]. *N. virens* is a cold stenothermic species and *H. diversicolor* a eurythermic species [21]. There is a positive relationship between Db and temperature. On the contrary, there is a negative relationship between Db and biomass. It seems that small individuals are more efficient reworkers than big ones. Small animals are more active on the surface. The highest bio-diffusion due to *H. diversicolor* was shown by Mermillod-Blondin *et al.* [16, 17] in comparison with benthic invertebrates as *Cerastoderma edule* and *Corophium volutator*. In the case of *H. diversicolor,* the biogeochemical nature of the sediment depends on the balance of metabolite production rates, removal and oxidation due to *H. diversicolor* bioturbation activity [10].

The nereid *H. diversicolor* constructs burrows and is considered a gallery diffuser [22]. Gallery-diffusor animals produce particle diffusion in the layer with very dense gallery systems and a bio-transport (non-local transport) at the end of the burrows [13]. The transport of sediment from the deeper sediment to the sediment-water interface represents a mechanism whereby organic matter can be recycled by animals. *H. diversicolor* inhibits anaerobic metabolism and alters sediment S cycles, although to various extents. A study of behavioural response (ventilation rate, duration of ventilation, length of pauses…) of three closely related nereid polychaetes (*H. diversicolor*, *N. succinea* and *N. virens*) to various levels of sulphide exposure did not show much variation under HS exposure for *H. diversicolor*. The only significant response was a decreased duration of rest periods at high HS concentration. *H. diversicolor* removed most HS from the burrow in less than 10 min due to the high ventilation rate of this species [23].

To conclude, the density and the biomass of *H. diversicolor* populations largely controlled the amount of sediment reworked. The classification of Pearson & Rosenberg [24] using four modes of functional traits (feeding mode, mobility mode, degree of mobility and mode

of feeding habit) aimed to link marine benthic community and benthic habitats. Pearson [25] shows that our knowledge is good enough to partition the benthic infauna into functional groups, which are then used to explain changes along organic enrichment gradients. Infauna (bioturbation and grazing) benthic microalgae and pore-water nutrients appear to be key components in a biogeochemical network in shallow water of estuarine systems [26]. The redistribution of particles by *H. diversicolor* occurs in bouts of activity (every 100 min) that are associated with burrow construction, maintenance and the repositioning of the upper region of the burrow during the establishment of new connections with the sediment-water interface [27]. There was a significant relationship between the bio-volume of macrobenthos and the diffusion coefficient of surface sediment, suggesting that the bio-volume of macrobenthos could be used as an indicator to predict the bioturbation capacity of estuarine sediment [28].

CONFLICT OF INTEREST

None declared.

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REFERENCES

[1] Scaps P. A review of the biology, ecology and potential use of the common ragworm *Hediste diversicolor* (O.F. Müller) (Annelida: Polychaeta). Hydrobiologia 2002; 470: 203-18.

[2] Marchand J. Bionomie benthique de l'estuaire de la Loire. I: Observations sur l'estran maritime de la mer à Cordemais. Revue Travaux Institut des Pêches Maritimes 1972; 36: 47-67.

[3] Marchand J, Gascuel D. Seasonal dynamics of the zoobenthic communities in the mesohaline zone of the Loire estuary (France). Hydrobiologia 1988; 160: 129-39.

[4] Robineau B. Caractérisation des peuplements macrozoobenthiques de l'estuaire de la Loire. Vie et Milieu 1987; 37: 67-76.

[5] Gillet P. Biomasse, production et dynamique des populations *de Nereis diversicolor* (annélide polychète) de l'estuaire de la Loire (France). Oceanologica Acta 1990; 13: 361-71.

[6] Gillet P, Torresani S. Structure of the population and secondary production of *Hediste diversicolor* (O.F. Müller, 1776), (Polychaeta, Nereididae) in the Loire estuary, Atlantic coast, France. Estuar Coast Shelf Sci 2002; 56: 621-8.

[7] Durou C, Smith BD, Roméo M, *et al.* From biomarkers to population response in *Nereis diversicolor*: assessment of stress in estuarine ecosystems. Ecotoxicol Environ Saf 2007; 66: 402-11.

[8] Gillet P, Mouloud M, Durou C, Deutsch B. Response of *Nereis diversicolor* population (Polychaeta, Nereididae) to the pollution impact – Authie and Seine estuaries (France). Estuar Coast Shelf Sci 2007; 76: 201-10.

[9] Denis L, Boust D, Thouvenin B, *et al.* Dynamic diagenic modelling and impacts of biota. Amiard-Triquet C, PS. Rainbow. Eds. In "Environmental assessment of estuarine ecosystems: a case study". USA: CRC Press Taylor and Francis 2009.

[10] Banta GT, Holmer M, Jensen MH, Kristensen E. Effects of two polychaete worms *Nereis diversicolor* and *Arenicola marina*, on aerobic and anaerobic decomposition in a sandy marine sediment. Aquatic Microbial Ecol 1999; 19: 189-204.

[11] Kristensen E. Impact of polychaetes (*Nereis* spp. and *Arenicola marina*) on carbon biogeochemistry in coastal marine sediment. Geochem Trans 2001; 2: 17-30.

[12] Biles CL, Paterson DM, Ford RB, Solan M, Raffaelli DG. Bioturbation ecosystem functioning and community structure. Hydrol Earth Syst Sci 2002; 6: 999-1005.

[13] François F, Gerino M, Stora G, Durbec JP, Poggiale JC. A functional approach to sediment reworking by gallery forming macrobenthic organisms: modelling and applications with the polychaete *Nereis diversicolor.* Mar Ecol Prog Ser 2002; 229: 127-36.

[14] Fernandes S, Meysman FJR, Sobral P. The influence of Cu contamination on *Nereis diversicolor* bioturbation. Mar Chem 2006; 102: 148-58.

[15] Fernandes S, Sobral P, Costa MH. *Nereis diversicolor* effect on the stability of cohesive intertidal sediments. Aquat Ecol 2006; 40: 567-79.

[16] Mermillod-BF, François-CF, Rosenberg R. Biodiversity of benthic invertebrates and organic matter processing in shallow marine sediments: an experimental study. J Exp Mar Biol Ecol 2005; 315: 187-209.

[17] Mermillod-BF, Rosenberg R, François-CF, Norling K, Mauclaire L. Influence of bioturbation by three benthic infaunal species on microbial communities and biogeochemical processes in marine sediment. Aquat Microbiol Ecol 2004; 36: 271-84.

[18] Riisgard HU. Suspension feeding in the polychaete *Nereis diversicolor*. Mar Ecol Prog Ser 1991; 70: 29-37.

[19] Koretsky C, Meile MC, Van Cappellen P. Quantifying bioirrigation using ecological parameters: a stochastic approach. Geochem Trans 2002; 3: 17-30.

[20] Ouellette D, Desrosiers G, Gagne JP. *et al.* Effects of temperature on in vitro sediment reworking processes by a gallery biodiffusor, the polychaete *Neanthes virens*. Mar Ecol Prog Ser 2004; 266: 185-93.

[21] Kristensen E. Factors influencing the distribution of nereid polychaetes in Danish coastal waters. Ophelia 1988; 29: 127-40.

[22] Christensen B, Vendel A, Kristensen E. Carbon and nitrogen fluxes in sediment inhabited by suspension-feeding (*Nereis diversicolor*) and non suspension-feeding (*N. virens*) polychaetes. Mar Ecol Prog Ser 2000; 192: 203-17.

[23] Miron G, Kristensen E. behavioural response of three nereid polychaetes to injection of sulphide inside burrows. Mar Ecol Prog Ser 1993; 101: 147-55.

[24] Pearson TH, Rosenberg, R. Feast and famine: structuring factors in marine benthic communities. In: Gee JHR, Giller PR Eds. The 27th symposium of the British Ecological Society, Aberystwyth. Oxford: Blackwell Scientific Publications 1986; pp. 373-95.

[25] Pearson TH. Functional group ecology in soft-sediment marine benthos: the role of bioturbation. Oceanogr Mar Biol Annu Rev 2001; 39: 233-67.

[26] Engelsen A, Sunbäck K, Hulth S. Links between bottom-water anoxia, the polychaete *Nereis diversicolor*, and the growth of green-algal mats. Estuar Coast 2010; 33: 1365-76.

[27] Schiffers K, Teal LR, Travis JMJ, Sola M. An open source simulation model for soil and sediment bioturbation. Plos One 2011; 6: e28028.

[28] Qin XB, Sun HW, Wu JZ, Wang RN, Sun TH. Bioturbation of macrobenthos on estuarine sediment. Ying Yong Sheng Tai Xu Bao 2010; 21: 458-63.