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CHEMICAL AND GRANULOMETRIC PARAMETERS OF BOTTOM SEDIMENTS IN THE ASSESSMENT OF FLOODPLAIN WATER BODIES OF THE LOWER BUG RIVER

PARAMETRY CHEMICZNE I GRANULOMETRYCZNE OSADÓW DENNYCH W OCENIE ZBIORNIKÓW WODNYCH TERENÓW ZALEWOWYCH DOLNEGO BUGU

Abstract: Usefulness of basic chemical and granulometric parameters of bottom sediments in the assessment of successional stage and condition of floodplain water bodies was analyzed, as well as some aspects of nutritional quality of bottom sediments. *Organic matter* (OM), nitrogen and phosphorus content and granulometric parameters differed between permanent and temporary, as well as between old and young water bodies. In some habitats despite of relatively low C/N ratio and high OM content sediments were not favourable for detritivores. Organic matter content in sediments of floodplain water bodies may be used in the assessment of C_{org} and N with high probability.

Keywords: floodplain water bodies, bottom sediments, granulometry, organic matter, C/N ratio

Riverine floodplains are regarded as one of the most heterogenous and dynamic ecosystems [eg 1, 2]. Despite some transformations (especially flood control embankments construction) the lower Bug River floodplain retained relatively high diversity of habitats [3, 4 and literature cited there]. The lower Bug River valley is characterized by the occurrence of numerous water bodies differing in hydrological connectivity, permanence of flooding and representing various successional stages. Previous investigations conducted in floodplain water bodies by the author concerned the occurrence, diversity and abundance of molluscs, environmental factors shaping malacocoenoses, as well as possibility of using aquatic molluscs in describing a condition and successional stage of these habitats.

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Bottom sediments, especially their organic matter content and granulometry have been found to be useful in characterizing floodplain water bodies [eg 5, 6]. Grain size distribution can be used as the record of hydrologic dynamics, whereas organic matter content may reflect ecosystem metabolism.

Nutritional quality of bottom sediments, especially organic matter contained in their upper layer, may be very important factor for macrozoobenthos, including molluscs, but data are rather scarce. High organic matter content in bottom sediments may be unfavourable for bottom macrofauna, eg when its decomposition leads to anoxic conditions. Composition of decaying matter and its nutritional value change during decomposition processes [eg 7–9]. C/N ratio in bottom sediments is frequently used to describe the quality of food. Food quality is negatively correlated with the C/N ratio. Critical C/N value of about 17 was recognized by Bretschko and Leichtfried [10], whereas Tockner and Bretschko [6] proposed even lower C/N value (below 15) as indicating digestible matter.

The aim of the present study was evaluation of usefulness of basic chemical and granulometric analyses of bottom sediments in the assessment of successional stage and condition of floodplain water bodies of a lowland river. Some aspects of nutritional quality of bottom sediments were also analyzed.

Materials and methods

Samples of bottom sediments were collected in the years 2007–2009 in 113 water bodies located within the lower Bug river valley, between 190 and 50 km of the river course counting from the mouth (52°21.520′–52°41.991′ N, 21°36.379′–22°50.820′ E) and within the terminal section, where the Bug River constitutes a part of the Zegrzynski Reservoir (52°31.333′–52°31.289′ N, 21°12.326′–21°12.404′ E). Study sites were located within fragments of natural floodplain, the 'active' floodplain constrained by the flood control embankment and the 'former' floodplain situated outside the embankment. They represented earlier and advanced successional stages, as well as temporarily and permanently flooded habitats. Their geographic co-ordinates were measured with GPS.

The samples of bottom sediments were dried in *ca* 105 °C to the constant weight. Grain sizes were determined by sieving technique (grain size fractions: < 0.063, 0.063–0.1, 0.1–0.2, 0.2–0.5, 0.5–1.0, 1.0–2.0, > 2.0 mm). *Mean grain size* (GSS) and *sorting degree* (GSO) being a measure of substrate heterogeneity were calculated with a graphic method [11].

Organic matter (OM) content in bottom sediments was determined as loss of weight on ignition (ashed in 530 °C for 4 hours). *Organic carbon* (C) and *total nitrogen* (TN) content in a chosen part of the samples were measured using elemental analyzer CHNS+O (model 1108, Fisons Instruments) in the Centre for Ecological Studies, PAS. In the other samples organic carbon content was assessed based on the relation between organic matter content determined as loss of weight on ignition and C content measured with elemental analyzer CHNS+O. The Ca concentration was determined by titrimetric method.

Subsamples of bottom sediments were digested with persulphate [10] enabling simultaneous determination of nitrogen and phosphorus. In resulting solutions *Kjeldahl* *nitrogen* (KN) was determined with the indophenol blue method [12] and phosphorus with molibdenum blue method with ascorbic acid as a reducing agent [13], using spectrophotometer (Novaspec 2, Pharmacia LKB). C/N ratio was calculated in bottom sediments to describe the quality of food.

Regression analysis (Statistica 6.0) was used to describe the relations between organic carbon and organic matter (OM), total nitrogen (TN) and Kjeldahl nitrogen (KN), organic matter and total nitrogen. Nonparametric Kruskal-Wallis ANOVA was applied to compare the analyzed parameters of bottom sediments in water bodies differing in permanence of flooding and successional stage owing to not normal distribution of variables.

Results

Organic matter content in bottom sediments of the investigated water bodies, as well as N and P concentrations ranged within broad limits: 0.36 to 76.61 % d.m., 0.13–24.80 $mg \cdot g^{-1}$ and 0.05–4.83 $mg \cdot g^{-1}$ d.m. respectively. In temporary habitats significantly higher mean values of these parameters were stated than in permanent ones (Fig. 1A, B, C, $p < 0.05$), however no significant differences were found between habitats representing advanced successional stages in both permanence groups. Within permanent water bodies OM, N and P concentrations were significantly higher in older ones than in those representing earlier successional stages ($p < 0.01$), whereas such differences were not observed within temporary habitats.

C/N ratio ranged from about 8 to over 40, mean value amounted to 14.72 ± 3.92. It was similar in water bodies representing earlier and more advanced successional stages, as well as in permanent and temporary habitats (Fig. 1D). In most of the investigated habitats (about 85 %) C/N ratio did not exceed 17 recognized as critical value for food quality [10].

The Ca concentration in bottom sediments ranged from 1.20 to 76.15 $mg \cdot g^{-1}$ d.m., mean value was significantly higher in permanent water bodies as compared to temporary ones (Fig. 1E, $p = 0.004$), the difference was especially distinct within older habitats.

Granulometric composition of sediments varied between water bodies. Generally sandy fractions ($0.1 < \varphi < 0.5$ mm) dominated (Fig. 2A). Significantly higher percentage of sand was found in younger permanent habitats than in older ones ($p = 0.0001$). The share of coarse particles (with the diameter > 1mm) ranged from 1.1 to 69.5 % with higher values in older water bodies, especially permanent ones (Fig. 2B). High organic matter content in coarse fraction (Fig. 2C) showed, that it consisted mainly of coarse particulate organic matter (CPOM).

Mean substrate particle size ranged from 0.08 to 1.7 mm (mean value ±SD was 0.46 ± 0.28). It was significantly higher in older water bodies as compared to young ones ($p = 0.0000$, Fig. 2D). Sorting degree ranged from 0.23 to 2.48 (with the mean value of 1.29 ± 0.44). Generally lower values (ie better sorting) were found in young water bodies as compared to old and usually more isolated ones ($p = 0.012$). Within young habitats sediments in permanent water bodies were better sorted than in temporary ones ($p = 0.057$) (Fig. 2E). Over 75 % of the investigated habitats had badly or very badly sorted sediments (i.e. sorting degree was ≥ 1).

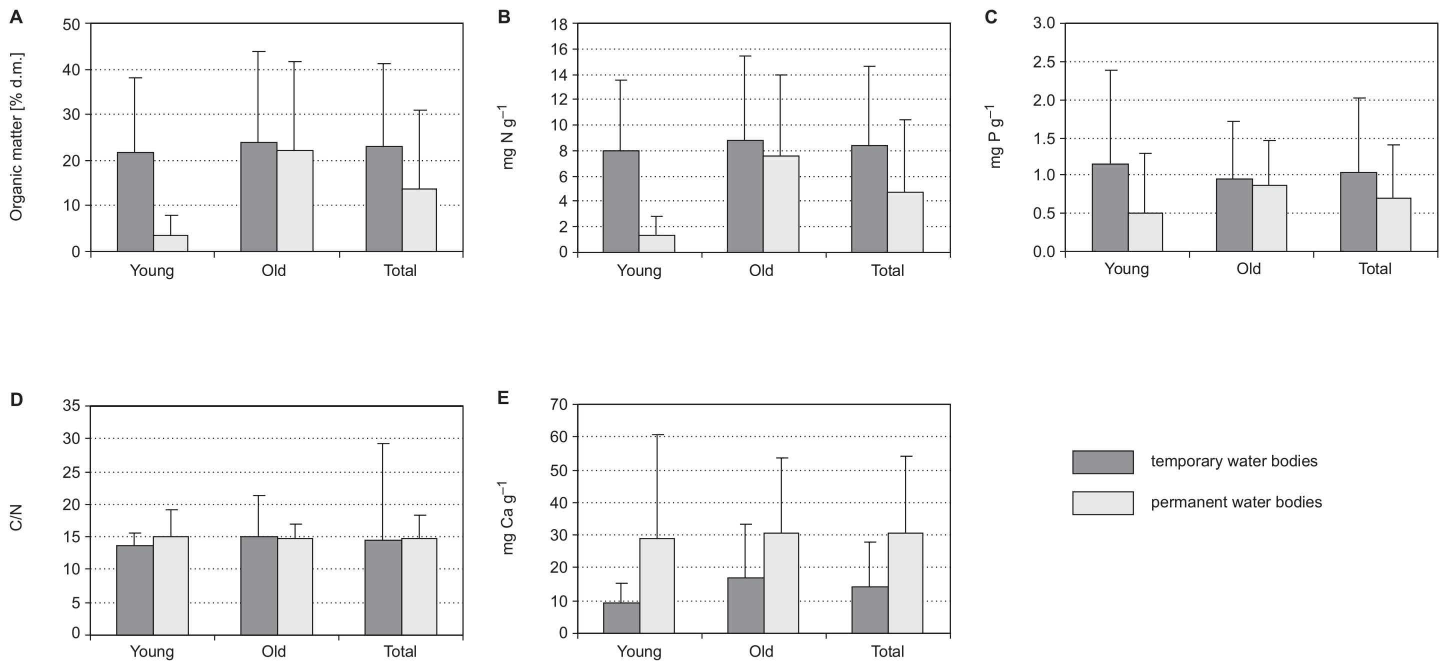

Fig. 1. Mean values (±SD) of chemical parameters of bottom sediments in water bodies differing in successional stage (young and old) and permanence of flooding (temporary and permanent): organic matter content(A), concentration of nitrogen (B) and phosphorus (C), C/N ratio (D), concentration of Ca (E)

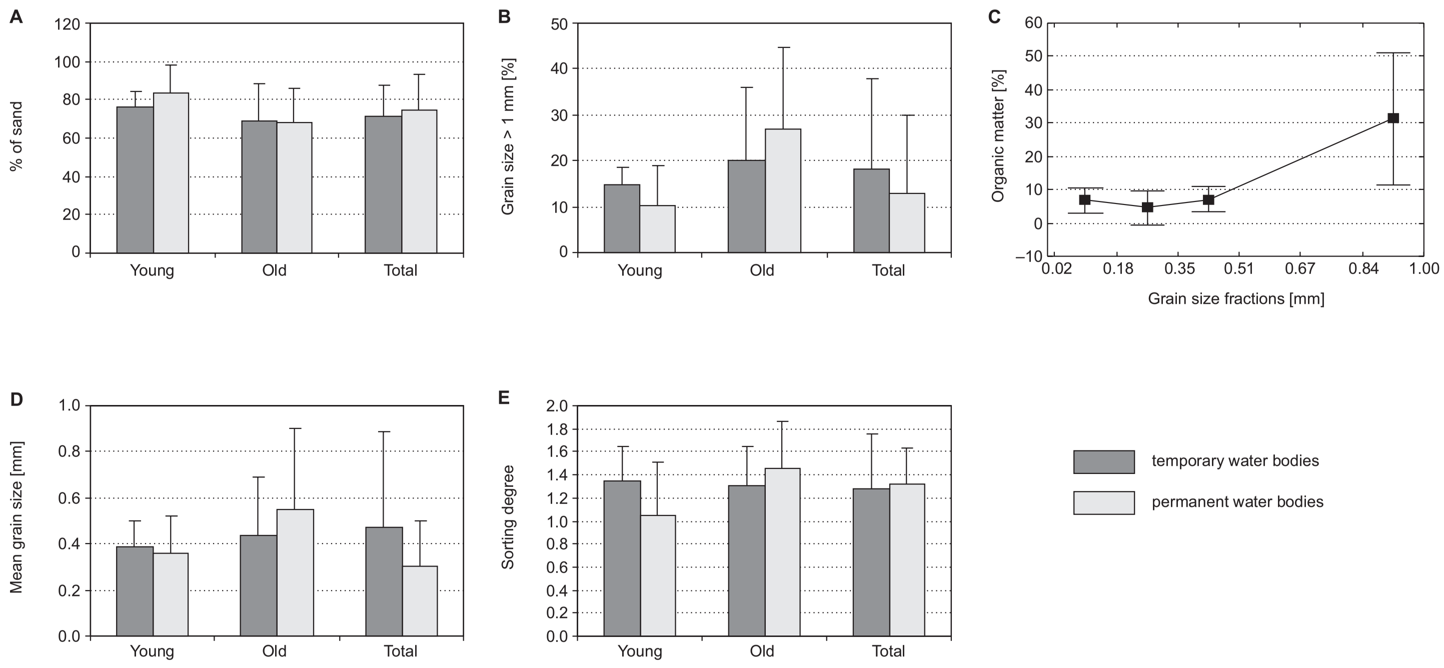

Fig. 2. Fig. 2. Granulometric parameters of bottom sediments in water bodies differing in successional stage (young and old) and permanence of flooding (temporary and permanent): percentage of sand (A), contribution of grain size fraction > 1 mm (B), organic matter content in different grain size fractions (C), mean grain size (D), sorting degree (E)

The relation between organic C and organic matter (Fig. 3A) was described by the equation: C = 0.50 OM + 0.01 (R^2 = 0.96). Organic matter seems to be a good predictor of organic carbon in bottom sediments of the investigated water bodies containing a wide range of organic carbon (0.18–39.84) % d.m.

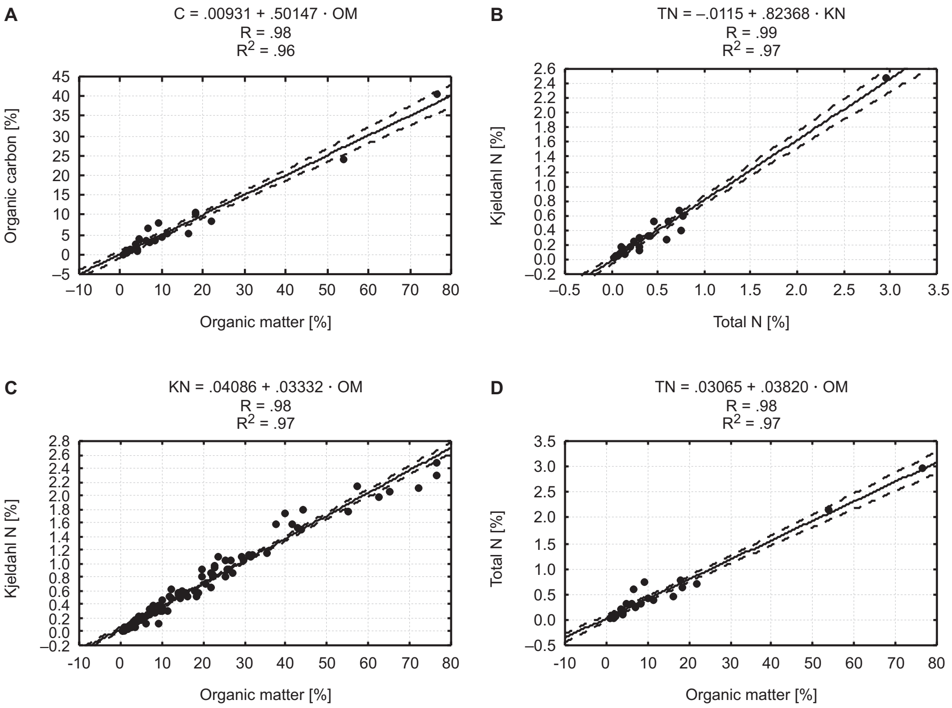

Fig. 3. The relationship between organic carbon and organic matter (A), Kjeldahl N and total N (B), KN and OM (C), TN and OM (D) in the investigated sediments

The relation between KN and TN (Fig. 3B) was described by the equation: KN = 0.82 TN – 0.01 (R^2 = 0.97). Kjeldahl method recovered approximately 82 % of total nitrogen in the investigated sediments. KN can be a reliable predictor of TN in sediments containing a wide range of KN (0.01–2.48) % d.m.

The relations between KN and OM, as well as TN and OM (Fig. 3C, D) were described by the equations: KN = 0.03 OM + 0.04 and TN = 0.04 OM + 0.03. The high determination coefficients (R^2 = 0.97 in both relations) indicate that it is possible to estimate KN and TN concentrations using OM content (measured as loss of ignition) with high probability.

Discussion

The range of organic matter (and organic carbon) and nitrogen content in sediments of the investigated water bodies was wider, than reported from a number of aquatic environments and marsh soils [eg 5, 6, 14]. Concentrations of phosphorus were relatively high as compared to lake sediments [15] and similar to the values found in wetlands [16].

Relatively high content of organic matter, nitrogen and phosphorus in substratum of temporary water bodies and in permanent ones representing advanced successional stages may be related to the presence of much remains of *Carex* spp. and another wetland plants in the former habitats, as well as remains of aquatic macrophytes, woody debris and leaf litter in the latter ones. Decomposition of such kind of detritus proceeds relatively slowly [eg 17–19].

The values of C/N ratio in sediments of a majority of the investigated water bodies were comparable to the data from peat bogs, some lakes and small water bodies [6, 20–22], as well as marsh soils [23, 24]. The cause of relatively uniform C/N ratio found in habitats representing different successional stages and permanence of flooding may be related to the parallel decomposition of hydrocarbonic and nitrogenous compounds [5]. C/N values in most of the investigated bottom sediments were lower than C/N ratio in vascular plants (ie > 20 according to [8, 9]). C/N ratio in celulose-rich vascular plants may decrease during diagenesis owing to considerable contribution of microorganisms to N content in coarse detritus [9] or selective degradation of carbon-rich sugars and lipids [eg 8]. An increase of nitrogen content in some vascular plant detritus during later stages of decomposition was observed [7], but it occurred mostly as non-labile humic nitrogen, which is not available to consumers. It follows, that relatively low values of C/N ratio occurring in old detritus cannot be regarded as a measure of nutritional value, but rather the stage of humification. Relatively low C/N ratios in sediments of some water bodies may suggest a subequal mixture of algal and vascular plant contributions. C/N ratio in algae is usually much lower than in vascular plants [eg 8].

Detritivorous invertebrates feed on fresh, labile detritus [25]. As the ratio of microbial biomass to plant tissue increases, detritus become more nutritious for them [26]. Some animals consuming detritus use rather microorganisms not dead plant tissues [27, 28]. During aging deposited organic matter is transformed from relatively labile forms to less assimilable heterocyclic aromatic forms typical of mature humic material [7]. The proportion of organic matter resistant to degradation and biologically unavailable is much higher in anoxic conditions [29] which frequently occur in water bodies with sediments rich in OM. Old and refractory materials (structurally complex and aromatic macromolecules, eg lignin and complex lipids) resist anaerobic decomposition [30].

Some habitats investigated in the present study hold poor malacofauna [31] despite relatively low C/N ratio and high organic matter content. Mollusc species richness was lowest, when organic matter content in bottom sediments was high (ie > 40 % d.m., Fig. 4A). The highest abundance of molluscs was found in habitats with medium organic matter content in bottom sediments (ie 5–40 % d.m., Fig. 4B). Bottom sediments of older water bodies contain much refractory matter and humic substances, which are indigestible to most detritivores [26]. Relatively high abundance of malacofauna in some temporary water bodies, especially young ones reported by the author [32] may be related to higher nutritional quality of detritus within these habitats. High protein content and nutritional value of detritus were found especially by the end of waterless period [33], thus in the beginning of hydroperiod in temporary water bodies the highest food quality occurs.

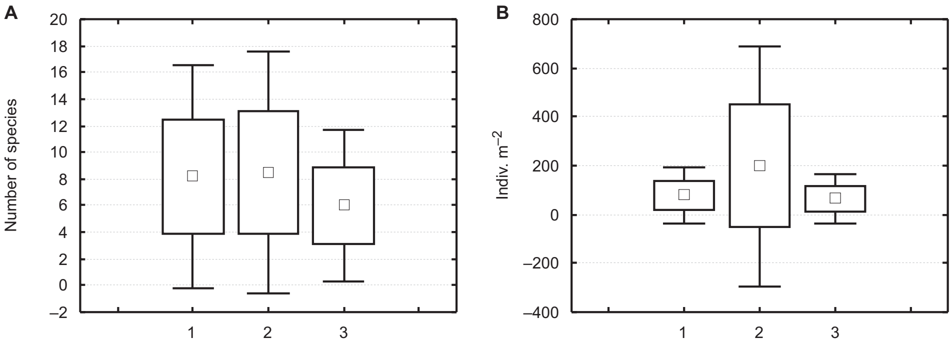

Fig. 4. Number of species (A) and density of molluscs (B) dependence on OM content (%) in sediments. OM content was expressed in 3 classes: 1 – < 5 %, 2 – 5–40 %, 3 – > 40 % d.m.. Numbers of mollusc species and their densities in the investigated water bodies according to the earlier study of the author [31]

Mean grain size and sorting degree of the analyzed sediments indicated low hydrologic dynamics and considerable heterogeneity of substratum in most of the investigated water bodies. It was consistent with the results of Rostan et al [5], who reported the lowest heterogeneity of sediments in frequently connected floodplain waters. The highest organic matter content found in large size fractions (> 1 mm) and relatively high content of organic matter in sediments of more isolated water bodies (temporary or older permanent ones) confirm the results of Tockner and Bretschko [6], who found that in isolated water bodies particular organic matter was mostly composed of CPOM and relative contribution of organic matter was positively correlated with the degree of isolation of floodplain waters.

Conversion factor for estimating organic carbon from organic matter in bottom sediments of the investigated water bodies was in close agreement with the values published for bottom sediments of abandoned river channels, as well as wetland and upland soils [5, 23 and literature cited there]. There was high compatibility between organic matter and organic carbon, as well as total N and Kjeldahl N, which makes possible using OM in the assessment of organic carbon and KN in the assessment of TN concentration in bottom sediments. This may be useful in monitoring, where simplicity and low costs of analyses are important. Strong relation between OM measured as lost of ignition and concentration of TN, as well as between OM and KN enables the assessment of nitrogen (TN and KN) concentration basing on OM content in sediments.

Conclusions

1. Permanent habitats representing advanced successional stages contained significantly more organic matter, N and P in bottom sediments, than young ones. It was

related to accumulation of detritus with the age of water body. This rule did not apply to temporary habitats, where large amounts of fresh detritus derived from vascular plants occurred.

2. Sediments of the investigated water bodies were mostly characterized by considerable heterogeneity resulting from low hydrological connectivity or isolation.

3. The highest contribution of organic matter in the grain size fraction of > 1 mm indicates, that this fraction is mainly composed of CPOM.

4. In some habitats despite of relatively low C/N ratio and high OM content bottom sediments were not favourable for detritivores because of low digestibility. This was the case of old water bodies.

5. High compatibility between organic matter and organic carbon, as well as total N and Kjeldahl N makes possible using OM in the assessment of organic carbon and KN in the assessment of TN concentration in bottom sediments. Strong relation between OM measured as lost of ignition and concentration of TN and KN enables the assessment of N concentration basing on OM content in sediments.

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PARAMETRY CHEMICZNE I GRANULOMETRYCZNE OSADÓW DENNYCH W OCENIE ZBIORNIKÓW WODNYCH TERENÓW ZALEWOWYCH DOLNEGO BUGU

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Abstrakt: Analizowano przydatność podstawowych chemicznych i granulometrycznych badań osadów dennych w ocenie stadium sukcesji oraz kondycji zbiorników wodnych terenów zalewowych, jak również niektóre aspekty jakości pokarmowej osadów. Zawartość materii organicznej, azotu i fosforu oraz parametry granulometryczne osadów dennych różniły się w zbiornikach trwałych i okresowych, a także w zbiornikach starych i młodych. W niektórych biotopach pomimo stosunkowo niskiego stosunku C/N i wysokiej zawartości materii organicznej osady były niekorzystne dla detrytusożerców. Zawartość materii organicznej w osadach zbiorników terenów zalewowych może być z dużym prawdopodobieństwem wykorzystywana w ocenie zawartości C i N.

Słowa kluczowe: zbiorniki wodne terenów zalewowych, osady denne, granulometria, materia organiczna, stosunek C/N