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Wetland classification and inventory in Lithuania

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Abstract The different conceptions of wetlands and their classifications as well as their definitions in Lithuania are represented in this paper. According to existing databases, Lithuanian wetlands are represented by: suo wetlands, peatlands, lentic, lotic, and marine/coastal wetlands. The harmonisation of the Ramsar classification system with the traditional classifications of Lithuanian wetlands is emphasised. The distribution of the distinguishable wetland types is identified. The following Ramsar inland and man-made wetland types are found in Lithuania: non-forested and forested peatlands (9.9% area of Lithuania), seasonal pools on mineral soils and tree-dominated wetlands (>13.92% area of Lithuania), permanent freshwater lakes (1.27% area of Lithuania), permanent freshwater marshes/pools (0.08% area of Lithuania), aquaculture ponds (0.18% area of Lithuania), ponds (0.16% area of Lithuania), water storage areas (0.3% area of Lithuania), excavations (0.04% area of Lithuania), permanent rivers/streams/creeks, seasonal streams/creeks (~0.69% area of Lithuania), canals and drainage ditches (0.11% area of Lithuania), and permanent inland deltas (0.01% area of Lithuania). The authors identified the following types of Ramsar marine/coastal wetlands in Lithuania: permanent shallow marine waters (0.09% area of Lithuania), sand, shingle or pebble shores (94 km marine and 77.89 km lagoon shores), coastal freshwater lagoons (0.52% area of Lithuania).

Keywords *Ramsar wetlands type • Wetlands classification • Lithuanian wetlands*

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INTRODUCTION

Dry and waterlogged areas are often distinguished during landscape investigations as well as when planning territory management and protection. Permanently or seasonally wet organic and mineral soils are attributed to wet terrains. The diversity of such soils, as well as their associated water bodies, and their impact on various landscapes determine the need to classify them at the national, regional, and international geographic scales.

In Lithuania as in other countries, the interest in wet terrains was triggered by their production functions: peat harvesting and the use of drained wetlands for agricultural and forestry purposes. These purposes lie at the basis of the Lithuanian classification and inventory of wetland resources and predetermine the directions of their investigations. The economic motive of wetland investigations dominated until the second half of the 20th century when the importance of wetlands for landscape stability, protection of habitats, plants, and animals, and reduction of greenhouse gas emissions was recognised. The new ecological conception of wetlands was promoted by the Ramsar Convention of 1971 which suggested the new definition and classification of wetlands. According to the traditional notion, the term "wetlands" was applied to waterlogged soils. According to the new classification, wetlands also encompass seasonally and permanently submerged inland areas and shallow coastal waters. Yet even today, the traditional and the new notions of wetlands and wet terrains distinguished by the old

and the new classifications are confused or taken as identical. This happens because the inventory of the wetland resources often is based on national and even departmental definitions and classifications of wetlands. This cumbers the adjustment of the national legislation to the Ramsar Convention.

There was no common term that could characterise both permanently and seasonally wet areas in scientific literature until the beginning of the 20th century. In Lithuania, a specific term describing such a type of landscape appeared just at the end of the 20th century. However, its conception is still ambiguous. Therefore, the rising international importance of wetlands at the national and international levels drives the imperative to harmonise the notion of wetlands and their classifications used in different countries and regions (Cowardin *et al.* 1979; Zoltai, Vitt 1995). The conception of a wetland was developed by the Ramsar Convention (Convention on Wetlands... 1971). The classification of wetlands appeared later (Ramsar Classification... 2001). Terminological confusion regarding wetlands is caused by an insufficient harmonisation of the Ramsar Convention principles and traditional classifications of wetlands in Lithuania. For example, the wetlands are treated as mires in some state documents. Traditionally, this term was used to describe peatlands with a peat layer more than 30 cm thick whose formation has not been disturbed by anthropogenic activity. Such terminological ambiguity leads to inaccurate wetland resources assessment and spatial planning.

Wetlands have a particular influence on water quality that depends on the type of wetland, on its morphological parameters, soil structure, vegetation etc. In this article, five landscape classes of wetlands are distinguished and described according to hydrodynamic and reduction-oxidation conditions. They are the following: suo wetlands, peatlands, lentic and lotic wetlands, marine/coastal wetlands. All these wetlands are compared to the Ramsar classification s.

The main goal of this article is to evaluate the distribution of wetlands in Lithuania and adapt the Ramsar classifications on this basis.. In order to achieve this goal, the following tasks were set: (1) to compare the existing Lithuanian and Ramsar classification wetlands types; it is suggested that the Ramsar classification was adapted to Lithuanian conditions; (2) to describe the distribution of Lithuanian wetlands according to Ramsar classifications; (3) to evaluate the area occupied by different wetland types in the river basins and sub–basins.

METHODOLOGY

Recent GIS databases and data sets have been used for the delineation of wetlands and for the evaluation of their state and distribution in Lithuania. Additional information was found in various cadastre, topographic, and orthophotographic maps. Peatlands (all areas with peat layer >30 cm deep) were calculated according to the data of following digital databases and datasets: Soil Database of Lithuania (Soil database... 2010) at a scale of 1: 10 000 (further – Dirv_DB10LT), State Forest Cadastre of Lithuania (further – forest cadastre) and Map of Peatlands and Mires in Lithuania at a scale of 1:200 000 (Wetlands... 2005).

There are two types of peatlands in the Ramsar classification: non-forested and forested ones. Areas of forested peatlands were distinguished according to the forest cadastre data (wood-cutting areas were classified as forested areas). Drained peatland areas were delineated according to the forest cadastre data and the database of Lithuanian drained land and flooded areas (Database of Lithuanian land... 2008; further – Mel_DB10LT) as well as data of ditches and canals from the Geo-referencing database of Lithuania at a scale of 1:10 000 (Geo-referencing basis... 2010;. further – GDB10LT).

According to the Ramsar classification, wetlands on mineral or organic soils with a thin (<30 cm) peat layer (suo wetlands) comprise alluvial meadows and seasonally flooded or wet forests. Agricultural areas with poorly functioning drainage systems are not distinguished in this classification. An area of alluvial meadows (floodplains covered by meadow vegetation) could not be accurately calculated in Lithuania because of lack of GIS data. Areas of seasonally flooded and wet forests on mineral or peat soils (where the peat layer is less than 30 cm thick) were determined according to the forest cadastre data: drained forests were determined according to the data on ditches (GDB10LT) and the drained areas data (Mel_DB10LT).

There are nine types of natural wetlands which could be assigned to lentic ecosystems (standing water bodies) in the Ramsar classification system. Three of them are found in Lithuania: permanent inland deltas, permanent freshwater lakes, permanent freshwater marshes/pools. There are man-made wetlands distinguished in the Ramsar system; 6 types of man-made wetlands could be assigned to lentic ecosystems in Lithuania: aquaculture ponds, seasonally flooded agricultural land, water storage areas, excavations, and wastewater treatment areas. This classification is not harmonised with the surface water classifications recently used in Lithuania. Traditionally, there are no marshes distinguished in Lithuania. Lakes are supposed to be naturally formed water bodies, regardless of their depth or size. Seasonally flooded agricultural land – polders (especially properly maintained ones) and wastewater treatment areas have never been considered to be wetlands.

Lentic wetlands were delineated according to GDB10LT database (version 2010), applying attribute data and additional information. Many types of lentic wetlands (lakes, ponds, excavations and aquaculture ponds) were identified in this way. There was no possibility of calculating polders and wastewater treatment

areas according to the existing data. Wastewater treatment areas were calculated along with ponds.

A part of the Nemunas River delta from Rusnė to Curonian Lagoon (Kuršių Marios) should be classified as permanent freshwater marshes and water bodies without small area lakes and ponds (area<8 ha), according to the Ramsar classification. Its total area is meant to cover about 85.4 ha. However, there are wetlands which could be assigned to alluvial meadows, polders etc. in this area. For example, Lake Krokų Lanka and the Atmata stream section from Krokų Lanka to Kniaupas Bay belongs to the category of permanent inland deltas. Therefore, only oxbow lakes and ponds situated in the Nemunas River delta were classified as permanent freshwater marshes/pools in this study.

There are three types of lotic ecosystems in the Ramsar system: permanent rivers, seasonal rivers, canals, and drainage ditches. Rivers, streams, drainage ditches, and canals were delineated according to the GDB10LT database (2010), applying attribute data and additional information in the analysis. The challenge was that natural watercourses are not clearly separated from the man-made ones in the database. The data were visually reviewed and revised using aero–photographic maps, focusing on features of an unidentified type. Surface areas of non-polygon watercourses (<12 m thick) were calculated using the width measurements recorded in the GDB10LT. The drainage ditch is wider than the watercourse bed. Therefore, considering the technological characteristics of the trenching, the surface area of non-polygon drainage ditches was calculated equating the average width as 1 m.

The next challenge was to quantify separate sections of the seasonal streams and creeks. These are not identified in databases; therefore, another method was used. Research studies of minimum annual flow in Lithuania have shown that in most cases, runoff is seasonally interrupted in streams with lengths of <3 km. The total length of the seasonal streambeds was calculated after the elimination of the streams with lengths of >3 km from the total stream network (Gailiušis *et al.* 2001), determined according to the GDB10LT in this study. The average width of these streambeds was about 3.1 m.

There are three types of Ramsar classification marine/coastal wetlands found in Lithuania: permanent shallow marine waters; sand, shingle or pebble shores; coastal freshwater lagoons. Permanent shallow marine waters were determined according to a 6-m isobath, which is marked in the Geological Atlas of the Baltic Sea Shores of Lithuania (Bitinas *et al.* 2004). The data about the Lithuanian coastline were taken from the GDB10LT database. The Klaipėda Strait boundaries were revised according to ortho–photographic maps (2010) – ORT10LT. The state border in the Baltic Sea was delineated according to the Borderland Plan, certified by the Government of the Republic of Lithuania on May 30, 2007 (Act No. 548).

The boundary between the coastal freshwater lagoons and permanently flooded delta wetlands is a straight delineation from Ventė Cape to Liekai Cape. Therefore, Gaurynė Bay is designated as flooded delta wetland. The coordinates of these capes are the following (in LKS-94 coordinate system): Ventė Cape – 321749E/6137514N and Liekai Cape – 322981E/6122758N (Russian Federation territory). The line mentioned above crosses the state's boundary at the point with coordinates – 322602E/6127297N. The state border in the Curonian Lagoon was delineated according to the Borderland Plan, certified by the Government of the Republic of Lithuania on May 30, 2007 (Act No. 548). The lagoon coastline was taken from GDB10LT database.

The distribution of the different wetland types in Lithuania was analysed according to the database covering the Lithuanian river and stream basins and sub-basins (Database of Lithuanian Rivers'... 2004). The division of Lithuanian river basins is were river basin means the area of land from which all surface run-off flows into the sea at a single river mouth (Water Framework Directive 2000). There are four levels of river and stream basins distinguished in the database of Lithuanian river basins and sub-basins: river basin districts (RBD), basins, sub-basins, and small streams basins. Only the two biggest river basins (Nemunas and Lielupė) are divided into sub-basins. All basins and sub-basins of the streams are divided into small stream basins, 244 in total. There are 4 RBD in Lithuania. The sub-basins of the small tributaries of the Baltic Sea were joined into the one basin of the Lithuanian Baltic seacoast and were attached to the Nemunas RBD (Fig. 1).

To calculate the relative extent of wetlands in Lithuania, the total area of the Republic of Lithuania (including the Curonian Lagoon) was used for the ratio, according to the State Enterprise Centre of Registers data. is 65 278 km^2.

DEFINITION AND CLASSIFICATION OF WETLANDS

The term *"wetland"* was used for the first time as a synonym for the term *"swamp"* by J. O. Wright (Wright 1907). This term has gradually come into common scientific usage only in the second half of the 20th century. In Lithuania, a common term describing the permanently or seasonally wet land was first used by land reclamation engineers (Zelionka 1967). All permanently or seasonally wet areas (seasonally wet mineral soils or organic soils with a thin peat layer and wet forests and wetlands) were called *"šlapios žemės"*. However, this term did not include open water bodies, such as lakes, ponds, rivers, streams etc. Later on, a landscape, where the water is the main factor for the surrounding environmental formation (Howard-Williams 1985; Cowardin *et al.* 1979; Tiner 1991),

Fig. 1 The division of Lithuanian river basins according to the Water Framework Directive. Compiled by M. Pileckas, 2011.

was called *"šlapynės"* (Kilkus 1998; Mierauskas *et al.* 2005) or *"šlapžemės"* (Identification and Mapping... 2006) in Lithuania. Although such a landscape is usually referred to as *"šlapynės"* in a contemporary scientific literature, a uniform concept does not exist.

Some researchers (Kilkus 1998) understood the term "*wetland*" as mineral or peaty soils. In this case, wetlands could only be considered to be areas with permanently or seasonally wet soils: wet mineral soils, wet soils with a thin peat layer and peatlands. However, this is only a part of wetlands classification distinguished in Ramsar Convention. Permanently or seasonally waterlogged territories such as lakes, ponds, rivers streams, ditches do not fall into this category.

All wet or waterlogged inland or coastal areas, i.e. all wetlands indicated in the Ramsar classification system, are called *"wetlands" (Lith. šlapynės)* in this work. According to their impact on water quality and ecosystems, they are divided into five groups: peatlands, suo wetlands, lentic wetlands, lotic wetlands and marine/coastal wetlands.

Lack of a unified international classification system causes a lot of problems. Contemporary national, regional, and international classifications (Dugan 1990; Hollis *et al.* 1992; Scott, Jones 1995) are often difficult to compare with each other. There is no officially unified wetland classification in some countries (e.g. Lithuania). Specialists of different fields use different terms to identify the same objects. For example, traditionally *"durpynas"* is a peat mining site. However, all peatlands with a peat layer >30 cm thick before drainage and <20 cm thick after drainage are also called *"durpynas"* in Lithuania. Although larger peatlands generally are mire complexes that are composed of several types of peatlands, they are often characterised as a single category: raised bog, fen, etc.

DISTRIBUTION OF WETLANDS

Inland wetlands occupy 26.24% of Lithuania's territory, while near-natural wetlands cover 12.39%. The largest area (13.42% of Lithuania's territory) is occupied by suo wetlands; the smallest area – by lotic wetlands, 0.8%. Marine/coastal wetlands cover 397.6 km² of Lithuania's waters. Inland wetlands are not equally distributed among Lithuanian river basins. However, they are distributed more equally compared with the distribution of other wetland groups and types. Wetlands occupy an average area in the Nemunas and the Lielupė basins, respectively 25.5 % and 26.79 % (Fig. 2, Table 1). Wetlands cover the largest area in the Nemunėlis sub-basin and in the Šventoji (Baltic Sea tributary) sub-basin. The smallest area occupied by wetlands is in the sub-basin of the small tributaries of the Lielupė River.

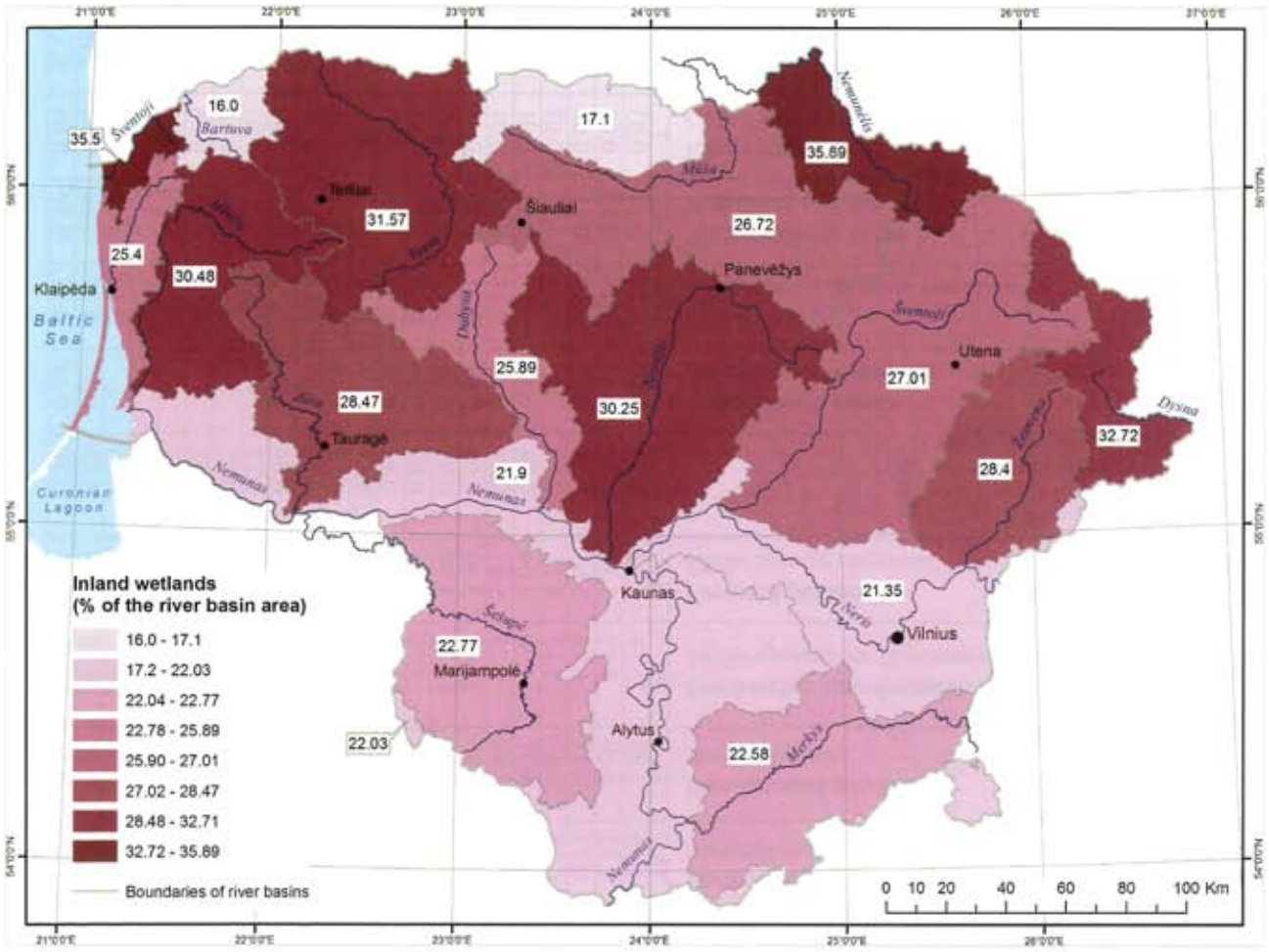


Fig. 2 Distribution of continental (inland) wetlands (% of the basin area). Compiled by M. Pileckas, 2011.

Five wetlands in Lithuania were listed in the Ramsar List of Wetlands of International Importance: Žuvintas, Čepkeliai, Kamanos, and Viešvilė mire complexes (strict nature reserves) and river delta (Regional Park). Two mire complexes are due to be added to this list. In total, it is 1% of Lithuania's area or about 7.7% of the area of natural and semi-natural inland wetlands.

Distribution of peatlands

According to different sources, the area occupied by Lithuanian mires and peatlands can vary widely: 2433 km² (Montanarella *et al.* 2006), 3520 km² (Strategy and action ... 2003), 4826 km² (Tamošaitis *et al.* 1997), 6097 km² (Motuzas *et al.* 2009). According to our assessment, peatlands cover 9.9% of Lithuanian territory (Table 2). The area occupied by peatlands in neighbouring countries is very similar: 10.4% in Latvia (Šnore 1997), 11.5% in Belarus (Bambalov 1997).

Fens dominate among Lithuania's peatlands, covering 7.7% of the state's territory, while raised bogs occupy only 0.76%. Based on the previous data, our assessment gives considerably larger area to mixed and transitional peatland type – 1.44% of the state's territory. The total area of Lithuanian mires (natural and semi natural peatlands) is 1781.2 km² or 27.6% of the total peatland area. Most of these are fens (61%); raised bogs occupy only 16%.

The total area of disturbed (drained, exploited, or abandoned) peatlands is 4679.2 km². The biggest part of this area are the drained deforested peatlands. Most of them are used for agricultural purposes. A quarter of the country's peatlands consists of drained forested peatlands.

Peatlands are not equally distributed among Lithuanian river basins. The average area of peatlands is found in the Nemunas basin. The area of peatlands in the Lielupė basin is slightly less than the average. The biggest area of peatlands is found in the Daugava basin and the Žeimena sub-basin. The smallest area of peatlands are in the Bartuva, the the sub-basins of the small tributaries of the Lielupė, and the Šventoji (Baltic Sea tributary) basin.

The distribution of mires is similar to that of all peatlands. Most mires are found in the Daugava, 7.5% of the river basin area. The area of the mires of the Nemunas basin is 2.9%. The remaining wetland areas are smaller in the other river basins. The smallest area of mires was found in the Bartuva basin, only 0.5 %. The Žeimena (7.9 %), the Merkys (4.3 %) and

Table 1 Distribution of the wetlands (%) in Lithuanian rivers' basins and sub-basins.

River basin Sub-basin	Area Km²	**All inland wetlands, including human-made** *Visos vidaus šlapynės, įskaitant dirbtines*	***Inland wetlands**** *Sausumos (vidaus) šlapynės*								**Human-made wetlands*** *Dirbtinės šlapynės*					
			Total	**Permanent inland deltas** *Pastoviai užlietos deltos*	**Permanent freshwater marshes/pools** *Gėlavandeniai maršai ir <8ha ploto ežerai*	**Rivers/ streams/ creeks** *Upės, upeliai, išdžiūstančios vagos*	**Permanent freshwater lakes (over 8 ha)** *Neišdžiūstantys gėlieji ežerai (>8 ha)*	**Non forested peatlands** *Atviri durpynai*	**Freshwater, tree-dominated wetlands** *Miška apaugusios šlapžemės (šlapi miškai)*	**Forested peatlands** *Miška apaugę durpynai*	**Total**	**Aquaculture ponds** *Žuvininkystės tvenkiniai*	**Ponds** *Kūdros ir <8 ha ploto tvenkiniai*	**Water storage areas** *Tvenkiniai (>8 ha)*	**Excavations** *Užlieti karjerai*	**Canals and drainage channels, ditches** *Kanalai ir grioviai*
				L	T	M, N	O	U	Xf	Xp		1	2, 8	6	7	9
Nemunas	46 635	25.50	24.67	0.02	0.10	0.72	1.33	5.85	12.39	4.27	0.83	0.20	0.16	0.34	0.03	0.10
Nemunas & small tributaries	9184	21.90	20.59	0.10	0.13	1.41	1.32	5.10	9.19	3.34	1.31	0.14	0.18	0.87	0.03	0.09
Merkys	3799	22.58	21.85	-	0.07	0.35	0.93	8.43	6.44	5.63	0.73	0.45	0.08	0.15	0.00	0.05
Neris & small tributaries	4267	21.35	20.64	-	0.09	0.81	0.79	5.63	9.17	4.15	0.70	0.27	0.21	0.13	0.03	0.07
Žeimena	2776	28.40	27.85	-	0.34	0.26	6.25	8.07	4.90	8.04	0.56	0.39	0.10	0.02	0.01	0.05
Šventoji	6789	27.01	26.17	-	0.15	0.45	2.53	7.82	9.75	5.47	0.84	0.19	0.17	0.36	0.01	0.11
Nevėžis	6140	30.25	29.62	-	0.03	0.59	0.07	3.87	21.46	3.60	0.64	0.03	0.12	0.30	0.06	0.13
Dubysa	1966	25.89	25.16	-	0.05	0.56	0.26	6.35	12.21	5.74	0.73	0.19	0.23	0.15	0.05	0.11
Šešupė	4770	22.77	22.17	-	0.04	0.49	1.15	6.98	9.95	3.55	0.60	0.11	0.20	0.17	0.01	0.10
Jūra	4005	28.47	27.55	-	0.02	0.59	0.05	3.23	21.15	2.50	0.91	0.37	0.19	0.19	0.03	0.12
Minija	2940	30.48	29.89	-	0.05	0.81	0.60	4.04	21.07	3.32	0.59	0.06	0.19	0.11	0.09	0.14
Lithuanian seaside rivers	1098	25.40	24.43	-	0.03	0.59	0.05	4.82	17.62	1.32	0.98	0.26	0.19	0.19	0.07	0.26
Prieglius	75	22.03	21.79	-	0.34	0.19	5.18	10.11	2.25	3.71	0.24	-	0.16	-	0.00	0.08
Venta	5138	31.57	30.73	-	0.04	0.63	0.61	5.45	18.88	5.13	0.84	0.23	0.17	0.22	0.08	0.13
Šventoji (by the Sea)	390	35.50	34.78	-	0.01	0.76	-	2.37	29.84	1.80	0.72	-	0.15	0.33	0.07	0.17
Bartuva	749	16.00	15.07	-	0.01	0.61	0.03	2.71	11.00	0.71	0.92	-	0.30	0.49	0.00	0.14
Lielupe	8949	26.79	26.25	-	0.01	0.72	0.37	3.81	16.69	4.65	0.53	-	0.09	0.25	0.08	0.11
Lielupė small tributaries	1751	17.10	16.68	-	0.00	0.66	0.02	1.43	12.37	2.20	0.42	-	0.10	0.16	0.06	0.10
Mūša	5296	26.72	26.09	-	0.01	0.75	0.45	3.95	16.83	4.09	0.63	-	0.09	0.34	0.09	0.11
Nemunėlis	1902	35.89	35.52	-	0.03	0.69	0.47	5.58	20.27	8.48	0.36	-	0.10	0.08	0.05	0.13
Daugava	1871	32.72	32.01	-	0.19	0.30	7.59	9.05	6.76	8.12	0.72	0.38	0.13	0.08	0.04	0.08
Total:	65 278	26.24	25.46	0.01	0.08	0.69	1.27	5.53	13.42	4.37	0.78	0.18	0.16	0.30	0.04	0.11

*Classification of wetlands (inland, human made) is taken from Ramsar classification.

Table 2 Natural (mires) and drained peatlands.

Human impact on wetlands	Peatlands type	Area. km²	% in Lithuania
Natural	Wet forests	1232.2	1.9
	Deforested wetlands	549.0	0.8
Total:		*1781.2*	*2.7*
Drained	Forested drained peatlands	1621.6	2.5
	Deforested drained peatlands	2834.3	4.3
	Peats quarries	223.3	0.4
Total:		*4679.2*	*7.2*
All peatlands		***6460.4***	***9.9***

the Šventoji (3.8 %) sub-basins could be called the largest mire areas in the Nemunas basin. This can be explained because of the more natural landscape of East Lithuania.

Distribution of suo wetlands

Suo wetlands could be called *"šlapžemės"* in Lithuanian (Povilaitis *et al.* 2011). They include wet forests and meadows with permanently or seasonally wet mineral soils and soils with peat layer less than 30 cm thick. Wet forests are seasonally wet or waterlogged areas overgrown with trees, characterised with good aeration conditions and mineral-rich surface water or groundwater. A peat layer is absent or is very thin. Wet meadows are recently developed deforested wetlands without a peat layer or one up to 30 cm.

Forests, including wood-cutting areas, occupy 32.5% of total area in Lithuania (Numerical data of Lithuanian state forest 2010). The bigger portion of them is occupied by dry forests. The area occupied by wet forests varies greatly among published sources. According to our assessment, these forests cover about 13.42% of Lithuania. Non-drained forests constitute the biggest portion of them (Table 3).

Table 3 Drained and non-drained suo wetlands.

Wetland type	Human impact on wetland	Area, km²	% in Lithuania
Wet forests	Drained	3850	5.9
	Non-drained	4911	7.52
Total:		*8761*	*13.42*
Wet meadows*	Non-drained	-	-
	Drained	-	-
Total:		>317	>0.5
All wetlands		***>9078***	***>13.92***

* – There are no data bases for determining the area of wet meadows.

Wet forests are distributed through Lithuania very unevenly. The greatest extentof them is concentrated in central, north and west Lithuania, dominated by soils with low water-permeability. Wet forests occupy the biggest area in the Šventoji basin (a Baltic Sea tributary). The smallest area is covered by wet forests in the Prieglius basin and Žeimena sub-basin (see Table 1).

The comparison of the peatlands and wet forest areas showed a dependence represented by a linear direct relationship between two variables that can vary in different basins and sub-basins. A direct linear relationship between the area of wet forests and peatlands was indicated in the basins of the Daugava, the Šventoji, the Prieglius, and in the sub-basins of small tributaries of the Nemunas and the Neris ($p= 0.01$; $R^2=0.914$). An inverse linear relationship between the area of wet forests and peatlands was indicated in the basins of the Lielupė, Venta, and Bartuva, and sub-basins of the Mūša, Nemunėlis, Nevėžis, Šventoji, Žeimena, Merkys, Šešupė, Dubysa, Jūra, Minija, and small tributaries of the Lielupė ($p= 0.001$; $R^2=0.817$).

The accurate assessment of wet and seasonally flooded meadow areas is limited to the existing databases, but lacking in GIS data. Natural meadows can occur only in flooded areas in Lithuania, although some authors pointed out the existence of natural terrestrial grasslands (Valodka, Balčiauskas 2001). Meadows and natural pastures occupy 4971 km² in Lithuania. 317 km² are occupied by the flooded meadows of the Nemunas River Delta (Lower... 2006). Considerable area of flooded meadows can be found in the other Nemunas River sections, as well as near other rivers and streams. However, data about that is not available.

Distribution of lentic wetlands

According to the Ramsar classification system, lentic ecosystems are divided into natural (permanent freshwater lakes, permanent freshwater marshes/ pools etc.) and man-made (aquaculture, ponds, water storage areas, wastewater treatment areas etc.). This classification is uncommon in Lithuania, because traditionally standing water bodies were considered to be lakes and ponds.

Lake (*Lith. ežeras*) is a body of natural standing inland surface water. Traditionally, lakes are classified according to morphometrical parameters in Lithuania. There are 2850 lakes >0.5 ha in Lithuania (Kilkus 1989). The number of lakes grows with the decline in the lake surface area. The number of natural lakes in Lithuania reaches 6000 with the total area of 914 km² (Kilkus 1998). According to our assessment, there are 6714 lakes of various size in Lithuania with the total area of 884.2 km² (Table 4). This area does not include Antalieptė, Elektrėnai, Aukštadvaris, Bagdononys and Kapčiamiestis hydropower reservoirs (all classified as water storage areas) Lake Lampėdžiai (classified as an excavation) and Lake Krokų Lanka (classified as a permanent inland delta). The first quartile includes lakes with areas ranging from 0.002 to 0.055 ha, the second quartile includes lakes with areas from 0.055 to 3 ha in size, and the third quartile covers the lakes with the areas up to 3530 ha.

According to the Ramsar system, lakes over 8 ha are assigned to permanent freshwater lake classes, while lakes below 8 ha are permanent freshwater marshes/ pools. Such classifications of lakes in Lithuania have not been applied until now. According to this system, there are 1083 permanent freshwater lakes and 5630 lakes, classified as permanent freshwater marshes and pools (Table 4).

Permanent inland deltas should be assigned to the lentic wetlands category and have not been distinguished in Lithuania until now. Permanent inland deltas occupy a part of the Nemunas River Delta, as well as the neighbouring areas of the Curonian Lagoon, the Gaurynė Bay and Kniaupas Bay, whose hydrological and hydrochemical characteristics are mostly influenced by the water of the Nemunas River. Therefore, the part of Gaurynė Bay (only on Lithuania's area) and Kniaupas Bay (54.2 km^2), Atmata stream from Krokų Lanka to Kniaupas Bay (0.9 km^2), and the whole Lake Krokų Lanka (7.9 km^2) should be classified as permanent inland deltas (Table 4).

Table 4 Natural and human-made lentic wetlands.

Human impact on wetland	Wetland type	Area. km^2	% in Lithuania
Human-made	Ponds (A<8 ha)	101.3	0.16
	Water storage area (A>8 ha)	199.0	0.30
	Excavations	27.1	0.04
	Aquaculture ponds	114.7	0.18
Total:		*442.1*	*0.68*
Natural	Lakes (A<8 ha). according Ramsar-permanent freshwater marshes/pools	53.2	0.08
	Permanent freshwater lakes (A>8 ha)	831.0	1.27
	Total:	*884.2*	*1.35*
	Permanent inland deltas	63.0	0.1
Total:		*947.2*	*1.45*
All lentic wetlands:		***1389.3***	***2.13***

The largest man-made lentic wetlands are ponds that are assigned to the category of water storage areas in the Ramsar system. They are created by damming the rivers and streams of their flow. According to their origin, the affluent lakes could also be assigned to this category. These are the Antalieptė, Elektrėnai, Aukštadvaris, Bagdononys, and Kapčiamiestis Hydropower reservoirs. However, they are considered lakes in several databases. The other type of water body is created by damming the rivers and streams of pond and water storage areas to form a fluvial water reservoir. The largest fluvial water reservoir is Kauno Marios, 6350 ha in extent. There are 354 fluvial water reservoirs and ponds > 5 ha in size in Lithuania with a total area of 228 km^2 (Povilaitis *et al.* 2011). According to our assessment, there are 358 ponds and water storage areas, excluding fish ponds, >8 ha in size in Lithuania. Fish ponds and excavations are also assigned to the man-made lentic wetlands category. According to our assessment, there are 1252 fish ponds of various sizes and 1804 excavations. Lake Lampėdžiai is considered an excavation.

The remaining man-made lentic waters should be assigned to the category of man-made ponds *(Lith. kūdros)* of the Ramsar classification system. There are 107 495 ponds of this kind. Most of them (105 012) are small ponds with an average area of 6.2 acres. The total area of these small ponds is 66.1 km^2. Wastewater treatment areas are also assigned here, because there was no possibility of calculating them separately.

The spatial distribution of the lentic wetlands is greatly influenced by the lakes and water storage areas. The Nemunas basin could be characterised by the average area of lentic wetlands, 2.17% of total basin area, whereas the area covered by lentic wetlands in the Lielupė basin is really small, 0.81% of total basin area. The biggest area of lentic wetlands was determined to be in the Daugava basin, 8.42%, and in the Žeimena sub-basin, 7.09 %. The smallest area of lentic wetlands was found in the sub-basins of small tributaries of the Lielupė, only 0.34%.

Distribution of lotic wetlands

Lotic wetlands, including rivers, streams, canals, drainage canals, and ditches, are distinguished among the other wetlands as a separate group, characterised by specific hydrodynamic conditions and their origin. Traditionally, there are no seasonal or intermittent streams distinguished in Lithuania, though some upper reaches of streams go seasonally dry. Seasonal and intermittent streams and creeks are distinguished as a separate wetland type in this article.

Due to favourable climatic and hydrological conditions, rivers, and streams, with the exception of some upper reaches, are perennial in Lithuania. According to our assessment, the total length of rivers, streams, and creeks in Lithuania is 43 207 km, calculated from a river network density of 0.66 km / km^2. The area of riverbed surface is about 450 km^2. This is 26% more compared to the earlier assessment (Gailiušis *et al.* 2001). Approximately one half of the riverbed area, about 213 km^2, is >12 m in width and are represented as polygon features in GDB10LT. Their total length is 5 172 km. The broadest riverbeds belong to the Nemunas, at 92.2 km^2, and the Neris, 23.7 km^2. The total area covered by riverbeds narrower than 12 m is 237 km^2 and the average width is 6.2 m.

The flow ceases during the dry period in some upper reaches of the rivers, or their beds go fully dry. However, no precise information about the number of

such streams is available. Streams shorter than 10 km usually go dry. The total length of such riverbeds is 18 842 km (Gailiušis *et al.* 2001). If we suppose that the average area of their riverbeds is 1 m, the calculated result of wetlands assigned to the seasonal or intermittent streams and creeks would be about 19 km² (Table 5).

Table 5 Natural and human-made lotic wetlands.

Human impact on wetland	Wetland type	Area, km²	% in Lithuania
Human-made	Ditches and channels	69,1	0,11
Natural	Permanent streams	~431	~0,66
	Seasonal or intermittent streams and creeks	~19	~0,03
Total:		*~450*	*~0,69*
All lotic wetlands:		***~519,1***	***~0,8***

According to our assessment, there are 64 508 km of man-made watercourses in Lithuania. The vast majority of them are drainage ditches. There are only a few canals in Lithuania (the largest one is King William canal). The average density of the man-made watercourses is 0.99 km / km^{-2}. The spatial distribution of lotic wetlands is mainly influenced by the density of the watercourses and riverbeds of large rivers. River basins with the highest density of watercourses are also characterized by the biggest area of lotic wetlands (thse are in northern and western Lithuania). The biggest area of lotic wetlands was determined to be in sub-basins of the small tributaries of the Nemunas (with Nemunas riverbeds) (1.51%). The smallest area of lotic wetlands was calculated to be in the Prieglius basin (0.27%) and Žeimena sub-basin (0.31%).

Marine/coastal wetlands

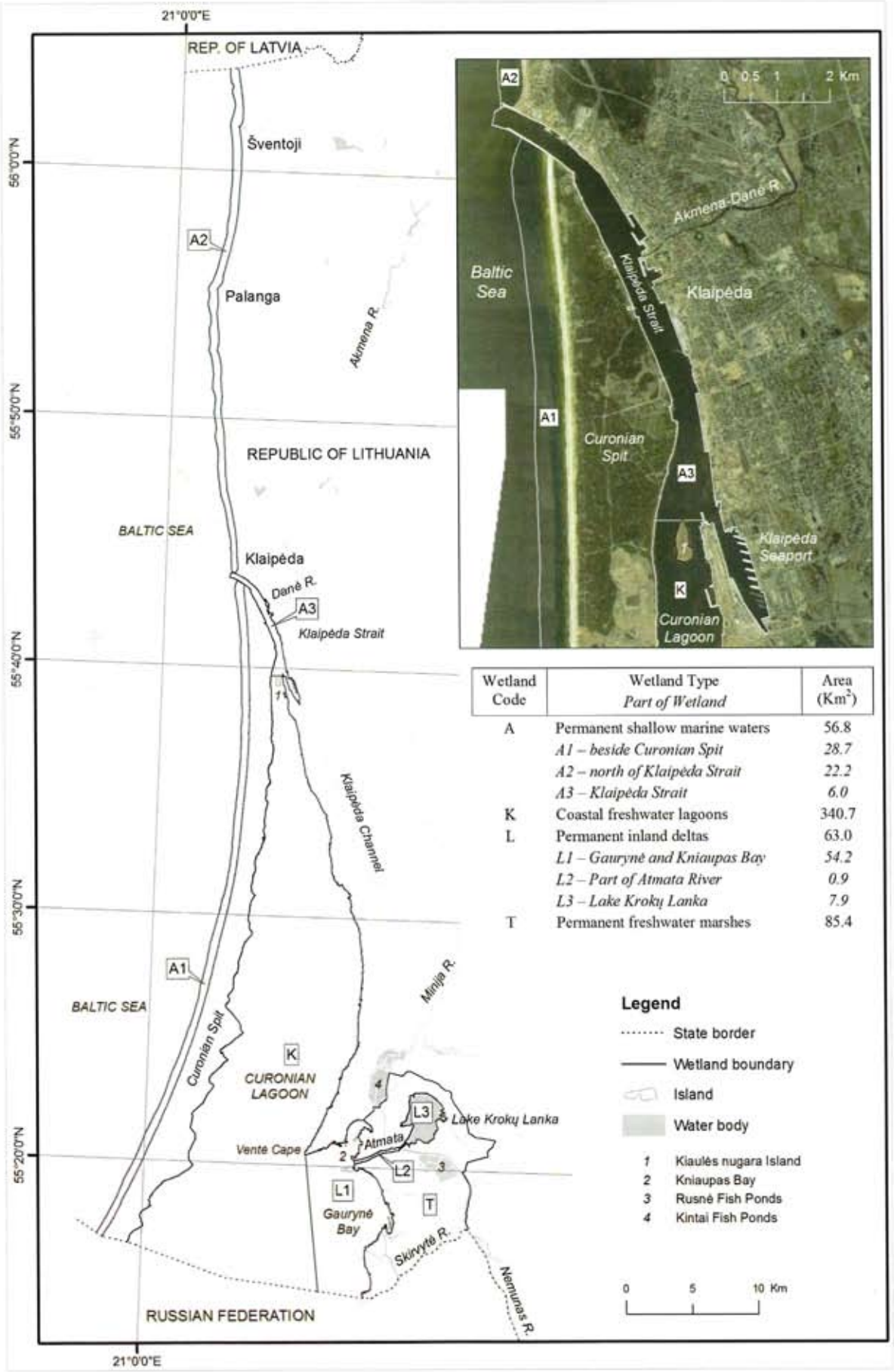
There are 12 types of marine/coastal wetlands in the Ramsar classification system. Three of these are found in Lithuania: permanent shallow marine waters, sand, shingle, or pebble shores, and coastal freshwater lagoons (Fig. 3).

Permanent shallow marine waters are situated less than six m deep. They occupy the water area along the western coast of the Curonian Spit (Kuršių Nerija) and stretch from the Klaipėda Strait towards the border of Latvia. They are found also from the sea port gates in the Klaipėda Strait to the Kiaulės Nugara island. The total area of this group is 56.8 km², including 6 km² belonging to the water area of Klaipėda Strait (Fig. 3). The average width of the shallow marine water belt is 554 m along the western coast of the Curonian Spit and 567 m going northwards from the Klaipėda Strait. Despite an almost equal width in both sections, the bottom relief differs greatly between them. There are narrow and long bottom relief waves, valleys up to 7-8 m deep, and crests up to 3 m high, parallel with the seashore situated along the coastal zone of the Curonian Spit. The sea bottom deepens gradually beyond a 6-m isobath. Heading northwards from the Klaipėda Strait, the bottom relief waves are perpendicular to the shore and they are more apparent beyond the 6-m isobath.

Sand, shingle, or pebble shores extend 94 km from the Lithuanian border with the Kaliningrad Region of Russia to the Latvian border, including 52 km of the shore along the Curonian Spit and 42 km to the continental coast (Gudelis 1998). The coast of the Curonian Spit situated along the Curonian Lagoon could also be called a shore type of wetlands. The length of this coast in the Lithuanian territory reaches 77.89 km, including 60.59 km of a naturally formed coast and 17.3 km of a quay strengthened with concrete (Grigelis *et al.* 2007). 21 littoral cells are distinguished in the Curonian Spit coastal zone along the Curonian Lagoon. However, based on the sediment source and transfer, the coastal zone could be divided into two types: dune or translocation cells. Dune littoral cells are characterised by aeolian sediment input and distribution down-drift (usually northwards) from the source. Sediment transfer from the erosion sites to the accretion sites characterises the translocation cells (Povilanskas, Taminskas 2004).

The northern part of the Curonian Lagoon belongs to Lithuania. The bigger part of Curonian Lagoon should be considered coastal freshwater lagoon wetlands. However, the smaller part of the Curonian Lagoon – Gaurynė Bay and Kniaupas Bay –should be assigned to inland wetlands – permanent inland deltas according to hydrological characteristics (Fig. 3). According to our assessment, the Curonian Lagoon occupies 394.9 km² of Lithuania's territory. Excluding the permanent inland deltas (Kniaupas and Gaurynė Bays), the coastal freshwater lagoons occupy 340.7 km² within Lithuania.

Sediments from the Nemunas River considerably decrease the area of the Curonian Lagoon. At the beginning of the 20th century, the area of the Curonian Lagoon was 1619 km² (Kres 1911; Pratje 1931). It decreased to 1610 km² in 1955, and amounted to only 1584 km² in 1970 (Červinskas 1972). Due to the growth of the frontal part of the delta (the so-called avandelta) of the Nemunas River, the area of the Curonian Lagoon continued to decrease. However, this rate slowed down from 9.8 ha to 8.4 ha per year during the past 50 years (Žilinskas, Jarmalavičius 2001). The current area of the Curonian Lagoon is 1572.5 km² according to the GDB250LT. It should be mentioned, that the shoreline of the Curonian Lagoon is not very precise in this database, especially within the territory of Russian Federation. According to more precise data (that of the GDB10LT in Lithuania and satellite images of the Russian Federation), the current area of the Curonian Lagoon is 1570.7 km².



Wetland Code	Wetland Type *Part of Wetland*	Area (Km^2)
A	Permanent shallow marine waters	56.8
	A1 – beside Curonian Spit	*28.7*
	A2 – north of Klaipėda Strait	*22.2*
	A3 – Klaipėda Strait	*6.0*
K	Coastal freshwater lagoons	340.7
L	Permanent inland deltas	63.0
	L1 – Gauryně and Kniaupas Bay	*54.2*
	L2 – Part of Atmata River	*0.9*
	L3 – Lake Krokų Lanka	*7.9*
T	Permanent freshwater marshes	85.4

Fig. 3 Coastal wetlands, permanently flooded deltas and freshwater marshes. Compiled by M. Pileckas, 2011.

DISCUSSION

Five landscape groups of wetlands are distinguished according to hydrodynamic and oxidation-reduction conditions: peatlands, suo, lentic, lotic, and marine/coastal wetlands. Wetland types of each landscape group are compared with those of the Ramsar classification system. The area occupied by peatlands in Lithuania (a total of 9.9% of total state area) is very similar to that in neighbouring countries, although it is indicated to be an abnormally small percentage in some literary sources. The bigger portion of peatlands is drained. The mires occupy less than a third of all peatlands. Forested peatlands dominate among them.

Suo wetlands occupy the biggest portion of all Lithuania's wetlands. Due to the structural peculiarities of existing data, the area of wet meadows was the most difficult to determine in the group of suo wetlands. The wet forested suo wetlands were more accurately determined. The area occupied by wet forests correlates quite well with peatlands in some river basins and sub-basins. The direct linear relationship between the areas of wet forests and peatlands is found in a large part of the Baltic Uplands, and an inverse linear relationship is in the remaining part of the country.

The landscape of lentic wetlands occupies an area 11 times smaller than the waterlogged wetlands (peatlands and suo wetlands). Permanent freshwater lakes (with an area >8 ha) predominate among them (64% of the total area of lentic wetlands). Recently, rapid growth of small man-made and disturbed lentic wetlands has been observed. However, the natural lentic wetlands predominate and compose 69% of the total area of the lentic wetlands.

The smallest class of wetlands is that of lotic wetlands. Permanent streams predominate and compose about 83%. According to existing databases, it is difficult to accurately assess the surface area of these wetlands; it is not possible to distinguish regulated stream sections from ditches in some places, there is no information about the width of non-areal riverbeds, and there is no information about the intermittent streams sections.

There are three types of marine/coastal wetlands found in Lithuania: permanent shallow marine waters; sand, shingle, or pebble shores; coastal freshwater lagoons. The largest area is occupied by coastal freshwater lagoons (about 86% of the marine/coastal wetland area). The detection of the boundaries of this wetland type is complicated by two circumstances: the lack of information about the limits of sand, shingle, or pebble shores in the Curonian Lagoon, and the difficulty in determining the western part of permanent inland deltas. A separate research study should be devoted to the determination of permanent freshwater marshes in Lithuania.

CONCLUSIONS

In Lithuania, as in other countries, the studies of wetlands used to be stimulated by the possibility of their economic utilisation: peat mining, use of drained areasfor forestation and agricultural purposes, and the use of inland waters for fisheries, as energy resources, etc. Expectations of economic utilisation served as a basis for traditional classifications and their application in databases of wetlands. In the course of time, attitudes towards wetlands have changed. Their regulation function has gained priority over economic uses. For this reason, existing classifications do not meet modern requirements. The Ramsar classification system seems to be a better choice, yet the databases available in Lithuania lack information about some types of wetlands distinguished by the Ramsar classifications. On the other hand, even the notion of wetlands often differs from the one declared by the Ramsar Convention.

The present work is the first attempt to adapt the Ramsar classification system to Lithuanian conditions and to inventory wetland resources on the basis of the adapted wetland types. Yet a more precise evaluation of the number and distribution of Lithuanian wetlands requires the improvement of the available databases and creation of new ones using the Ramsar system.

According to the adapted Ramsar classification system, the waterlogged and seasonally submerged meadows and forests with a thin peat layer (suo wetlands) have been determined to be the dominant type of wetlands in Lithuania. What would have been the larger part of the wetlands, with a thicker peat layer (peat bogs), has been drained. Other types of wetlands occupy considerably smaller areas.

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