II. ECOMONITORING

STUDY OF THE DYNAMICS OF FLOATING REED ISLANDS IN SREBARNA LAKE FOR THE PERIOD 1992-2014, BASED ON SATELLITE, GROUND AND GPS DATA

Iva Ivanova

Abstract. This study is about the dynamics of floating reed islands in Srebarna Lake during the period 1992 - 2014. Srebarna Lake is part of Natura 2000, European ecological network. Srebarna Lake is declared as Srebarna Biosphere Reserve by UNESCO, and categorized as a supported reserve.

Floating reed islands are important for the breeding of different water bird species, some of which are endangered species. They are unique for Europe as water bird habitats and they are presented only in Srebarna Lake and the Danube Delta. Focused research on the area and spatial variability of the floating reed islands have not been performed yet due to their difficult accessibility and the lack of data about their dynamics. Study of the floating reed islands dynamics (absolute and relative motion) could be done only by high-tech methods, based on remote sensing from space, using appropriate sensors to register parameters of this unique kind of unsystematic landscape units. The results from this research have been grouped in specialized geodatabase. A methodology for studying the dynamics of area, size, and location changes of the floating reed islands has been proposed. Based on this methodology the quantitative results for habitat's ecodynamics in Srebarna Lake have been received. A coefficient of relative area (KM), showing the attitude of the habitats to the area of central water body have been introduced which is used as quantitative assessment of this habitat's dynamics. The results of the study have been used in monitoring management plans of Srebarna Biosphere Reserve. Tracking the floating reed islands attitude is essential for investigating the dynamics of these specific habitats for endangered bird species nesting.

Key words: floating reed islands, dynamics, satellite data, monitoring.

Introduction

The supported biosphere reserve Srebarna is situated on the bank of the Danube River between 391 and 393 river km, 18 km west of the town of Silistra (44°07 N, 27°04 E; UTM grid NJ 08) and altitude between 10 m и 13.2 m) [1].

In nature-conservation aspect the Srebarna reserve was established as a nature reserve in 1948 and designated as wetland of international importance under the Ramsar Convention in 1975. In 1977 it was recognized as a Biosphere Reserve under UNESCO's Program as a site of the world's natural and cultural heritage [2]. Since 1999 its status has been changed to that of a supported reserve (Ordinance № RD) [3].

The Srebarna Biosphere Reserve is characterized by a relatively rich floristic and phytoecological diversity.

The floating reed islands in Srebarna Lake are objects of this study. They are specific drifting habitats of the reed in places with greater depth of the water, which for Bulgaria can be found only at Srebarna Lake. They occupy the central part of the reserve and they are surrounded of water surface.

Floating reed islands are specific formations of floating fragments of soil, decaying leaves, roots and stems of reeds, located in water areas with water depth in excess of 2 m. They represent a layer with a thickness of 1-6 m, which are constructed from a combination of the reed rhizomes and roots and other aquatic plants, mixed with the organics and salts.

Floating reed islands are two types: mobile - moving under the action of water and air currents; fixed - still attached to the bottom by cane rhizomes. They are capable of modification in the water level to carry out vertical movements to form a water layer below them, which is an excellent environment for certain fish species [4].

Initially reed islands are immobile. Rise in the water level, they are separated from the shore or the bottom of the water basin and become floating reed islands of different sizes and shapes, which under the influence of water and air currents moving along the surface of the pond.

Floating reed islands are important for breeding of different species of water birds, some of which are endangered species. In Europe the floating reed islands as habitat for water birds are only presented in Srebarna Lake and the Danube Delta [5].

Thirteen types of habitats on the area of the reserve and its surroundings have been determined [6]. In Srebarna Lake and its neighbors 173 species of birds, 57 from which are listed in the Bulgarian Red Book (1985), have been found, 78 of the bird's species are with European nature-conservation importance (SPEC). The only Bulgarian colony of Dalmatian pelicans (Pelecanus crispus) is situated in the reserve [2, 5].

Reasons for this are their difficult accessibility and the lack of data on their performance. Remote sensing methods make it possible to explore the movement on the islands for multiple years.

The aim of this study is the dynamics of form, size and location of the floating reed islands over the years in Srebarna Lake based on satellite, terrestrial and GPS data. To realize this aim the following tasks has been solved:

1. Creation of database of satellite, terrestrial and GPS data. Georeferencing data, generating digital elevation models and separate vector layers required for the study.

2. Creation an archive of topographic maps of the studied lake.

3. Develop a methodology for studying the spatial and temporal variations of the floating reed islands.

4. Examination and analysis of changes in the area, shape, and location of the floating reed islands for the period 1992 – 2014.

Methodology

Determining the state of Srebarna Lake includes: location, identification and discrimination of the lakes, floating reed islands, rivers, canals, villages [2].

For a quantitative assessment of the state of floating islands is necessary that all output data to be digitized and georeferenced. This means that the selected images and map data must be attached (georeferenced) to the same coordinate system. They are georefenced in **UTM** (**U**niversal **T**ransversal **M**ercator- **35T**), WGS 84, 35[7].

The spectral reflectance of vegetation is dynamic and depends on the conditions of falling and reflection of solar radiation and the condition of the objects themselves - soil moisture, vegetation period. (Fig.3)

Object information is obtained based on their spectral reflectance characteristics, the nature of which is essential for the selection of the wavelength range, which uses remote sensing to this study [2, 8].

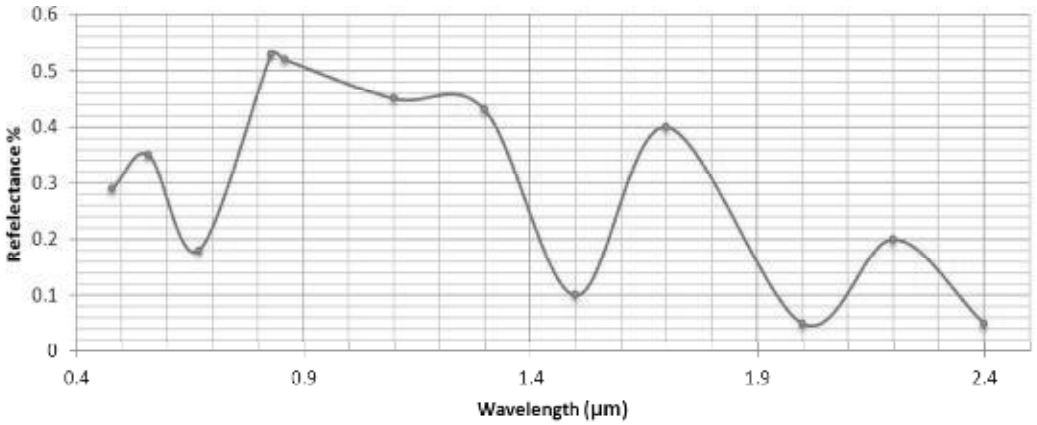

Fig.1. Spectral reflectance of vegetation in Srebarna Lake (Landsat satellite, 2000)

Floating reed islands as plant formations are recognized from satellite images in the visible and infrared range of the spectrum. In the infrared range of the spectrum they can be most strongly identified.

For proposed study the following tasks were performed:

-georeferencion of the satellite and ground data towards a unified coordinate basis

- generation of the corresponding vector layers: floating reed islands, water surface and water areas

-a time interval for studying the motion of the center of the floating reed islands' location has been defined.

The digital elevation model of the area is generated on the basis of the topographic map's contour lines. The river web and the villages in separate layers has been vectorizated and they have been combined with the digital elevation model of the relief (DEM). The topical map with the three layers of the river web, the villages and the canals, combined with DEM indicates the position of the lake on the territory of the region under research [7].

Satellite data for the time period 1992-2014 are used. At Table 1 the satellites which have provided the aerospace information in the correspondent years were given.

Table 1. Satellite data sources for Srebarna Lake

Satellite	Year	Data
Landsat 5-TM	1992	September 4
Landsat 7-ETM	2000	June 14
IKONOS	2001	April 6
IKONOS	2005	April 5
Aerial image	2011	July
Landsat 8	2013	June 2
Landsat 8	2014	August 16

As the floating reed islands are actually geometrical figures, the coordinates of their location have been defined by analogy with the method of defining the center of mass where instead of the mass the area has been used (based on coordinates of a centroid method). The equations for calculating the coordinates of the floating islands' center are

$$C_x = \frac{\sum A_i x_i}{\sum A_i} \quad (1)$$

$$C_y = \frac{\sum A_i y_i}{\sum A_i} \quad (2)$$

where x_i is the distance from the center of the net's square with area A_i to the coordinate axis Y, and y_i - the distance from the center of the net's square with area A_i to the coordinate axis X_i, C_i (x_i, y_i,) are the centers of the net's basic cells with area A_i.

A coefficient of relative area of habitats to central water body (KM), showing the attitude of the habitats to the area of the central water body, have been introduced which is a quantitative assessment of this habitat's dynamic.

This method of determining the coordinates makes it possible to trace all possible cases of movement (absolute and relative). Because in practice between these two types of movement there is no sharp boundary the method is optimal as it provides a quantitative assessment of actual performance.

Results

The location of the floating reed islands in 2000 compared to 1992 is shown on Fig. 2a. There are differences in the area of the islands: the floating reed islands are broken as a result of increase the water level in 2000, the number of islands have been increased to 14 compared to 1992 where has been observed only four relatively large islands. The area of the islands has been reduced for this period of time - it has been decreased by 39.72 ha. The area of central water body in 2000 is 110.81 ha - it has been increased by 3.97 ha.

Fig. 2b. shows a comparative analysis of the position of the islands in 2001 compared with their position in 2000. There were no significant dynamics. The number of floating reed islands in 2000 was 14 and in 2001 - 18. There were no mergers and significant increases in the areas. The area of the islands in 2000 was 109.85 ha, and next year has been decreased by 19.92 ha and has become 89.92 ha. The area of central water body also has been decreased by 1.84 ha. The figure shows that there is movement, the floating reed islands have been moved to the East-Northeast.

The location of floating islands in 2001 compared to 2005 is shown on the next figure 2c. Significant changes in total areas have not been observed. In 2005 has been observed tearing the islands and forming smaller ones. Their numbers have been increased to 34, while in 2001 their numbers have been 8.

On Fig. 2d. is shown a digital model of the location of the floating reed islands in 2005 compared with that in 2011. The number of floating reed islands in 2005 was 34. In 2011 the number of floating reed islands was 35. Their corresponding areas were: 121.65 ha in 2005 and 172.09 ha in 2011. The total area has been increased in the period of five years with 50.44 ha, which increase is mainly due to the two larger islands in the lake, designated as K1 and K5.

Comparison of the state of the floating reed islands in 2011 and 2013 is shown in Fig. 2e. The area of the island in 2013 was 163.62 ha, the area has been decreased by 8.46 ha compared to the year in 2011 when she was 172.09ha. The number of the islands in 2013 has been decreased in comparison

with their number in 2011 to 16; has not been observed small and scattered islands as this in 2011, where their number was 35.

In 2014 the total area of the floating reed islands is 193.42 ha (Fig. 2f). The area has been increased slightly compared to the previous year. There were no major differences in the shape, number and location of the islands for the observed years. The area of central water body has decreased to 123.27 ha in 2014. Movement on the islands for the period of one year is not registered.

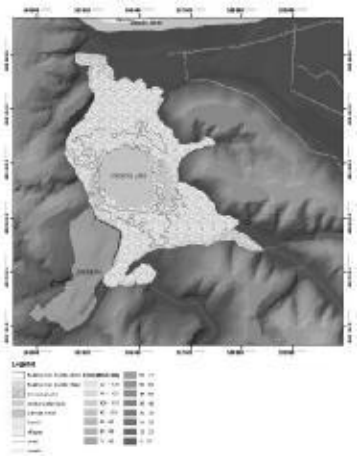

Fig. 2a Position of floating reed islands based on a comparison of 1992 to 2000

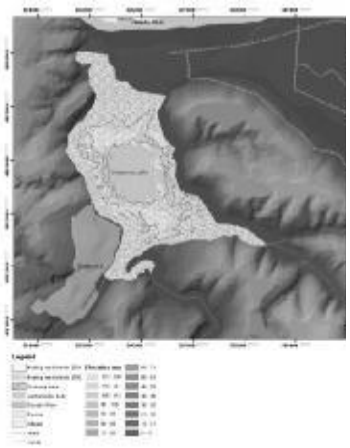

Fig. 2b Position of floating reed islands based on a comparison of 2000 to 2001

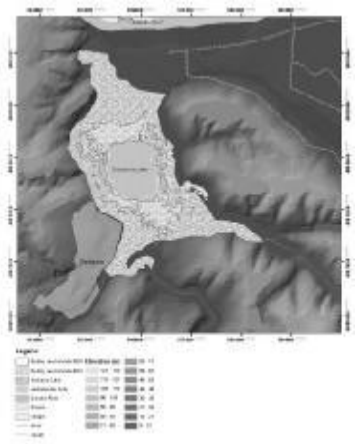

Fig. 2c Position of floating reed islands based on a comparison of 2001 to 2005

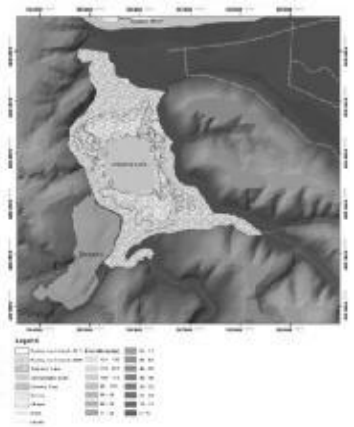

Fig. 2d Position of floating reed islands based on a comparison of 2005 to 2011

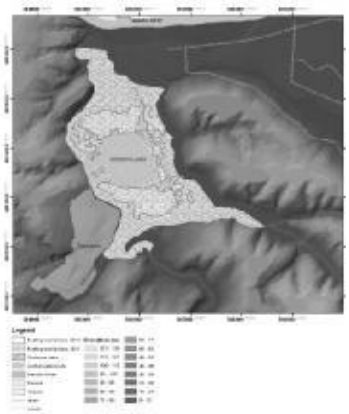

Fig. 2e Position of floating reed islands based on a comparison of 2011 to 2013

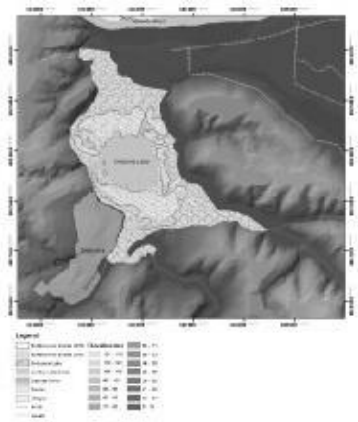

Fig. 2f Position of floating reed islands based on a comparison of 2013 to 2014

Total areas of floating reed islands and central water body during the studied years are given in Table 2. As shown on Table 2 and Fig. 3 the largest total area of the floating reed islands has been observed in 1992, when has been registered a drought in Srebarna Lake. Then their total area is 507.11 ha. During the remaining years of observation the areas of the islands are relatively constant but some increase in their areas has been observed.

Table. 2. Areas of the floating reed islands and central water body (ha) in Srebarna Lake (1992-2014)

Year	Area of the floating reed islands [ha]	Area of central water body [ha]
1992	507.11	106.84
2000	109.85	110.81
2001	89.92	108.97
2005	121.65	110.62
2011	172.09	170.96
2013	163.62	138.50
2014	193.42	123.27

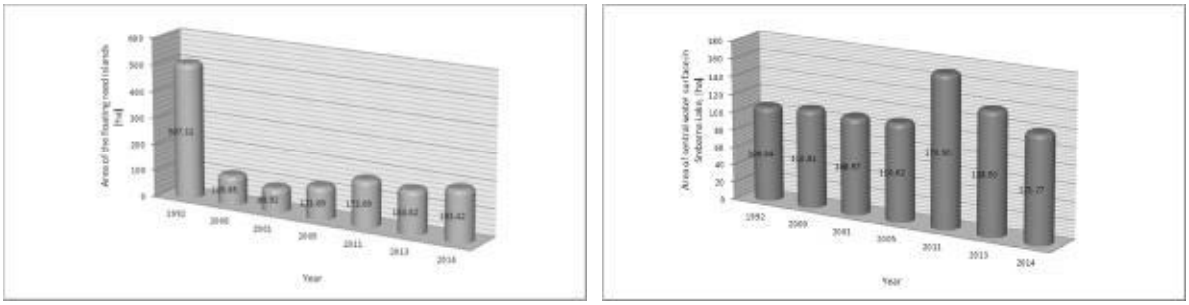

Fig. 3 Area of a) floating reed islands, b) central water body in Srebarna Lake for the period 1992 – 2014

To examine the movement of some floating island in the territory of Srebarna Lake, is necessary to track their location and change over the years during the period 1992-2014. For this purpose some islands have been selected which have relatively stable form and are clearly distinctive in different years. In this case five of these islands have been chosen which are classified in different classes, designated as K1, K2, K3, K4 and K5. (Fig.3)

A ratio coefficient of their relative area to the area of central water body in the lake (KM) has been determined. (Table 3) [2].

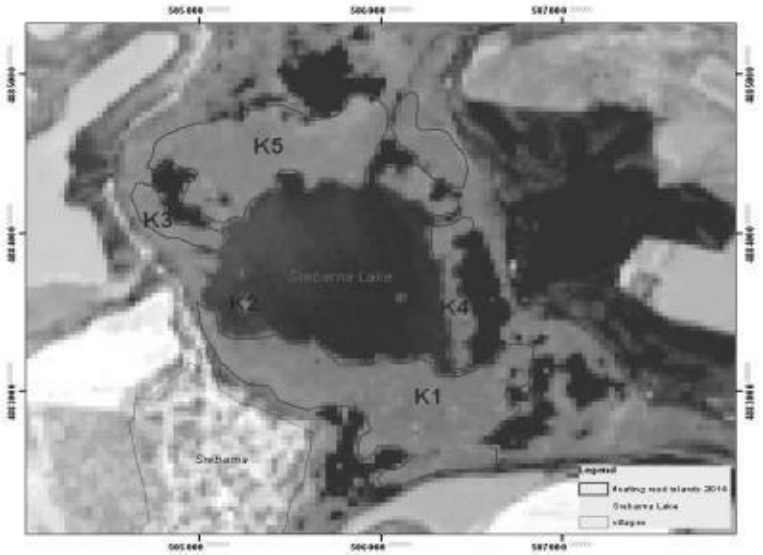

Fig. 3. Scheme available to the floating islands surveyed, Landsat 2014

Table 3. Area of floating reed islands and the coefficient of relative area of habitat to central water body

Year	K1		K2		K3		K4		K5	
	Area, [ha]	KM %	Area, [ha]	KM %	Area, [ha]	KM %	Area, [ha]	KM %	Area, [ha]	KM %
1992	232.91	217	-	-	-	-	3.22	3	268.49	250
2000	42.31	38	5.28	4	3.27	2	3.30	3	34.60	30
2001	63.70	58	4.50	4	3.19	3	4.68	4	59.30	54
2005	42.02	37	5.26	5	2.35	2	3.75	3	40.12	36
2011	61.72	36	1.58	0.9	6.82	1	8.96	5	59.33	34
2013	60.55	43	3.34	2	8.97	7	9.95	7	51.92	37
2014	98.18	74	0.94	1	7.99	9	6.88	8	58.61	75

The coefficient of the relative area of habitat to central water body (KM) indicates the attitude of the habitat to the area of the central water body. KM is a quantitative assessment of the dynamics of habitats (floating reed islands) in Srebarna Lake. For K1 and K5 islands KM is highest in 1992, when has been seen lowest water level in Srebarna Lake.

Movement of the floating islands can be traced by determining the location of the islands in coordinates and determine their centers on the basis of the chosen methodology and after that monitoring of the change in the situation of their centers. For this purpose graphics coordinate system (x, y) in meters has been built. The movement of floating reed islands and their direction are visible on next table (Table 4) and figures (Fig.4a, b, c, d, e).

Table 4. Movement the location of the center of the floating reed islands

Year	Movement the location of the center of the floating reed islands, [m]				
	K1	K2	K3	K4	K5
1992-2000	250	20	65	120	200
2000-2001	200	90	50	130	200
2001-2005	40	250	50	60	150
2005-2011	150	250	110	285	80
2011-2013	30	300	40	20	40
2013-2014	20	110	80	83	26

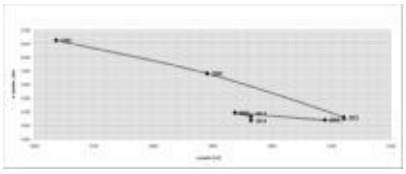

Fig. 4a Change of position of the center of the floating island K1

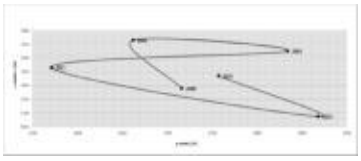

Fig. 4b Change of position of the center of the floating island K2

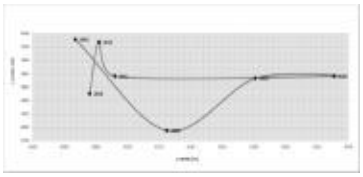

Fig. 4c Change of position of the center of the floating island K3

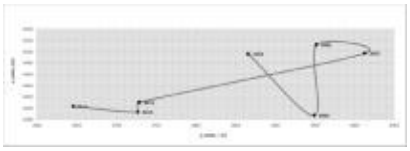

Fig. 4d Change of position of the center of the floating island K4

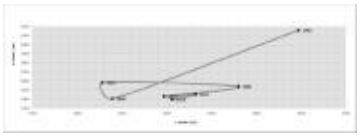

Fig. 4e Change of position of the center of the floating island K5

As shown in these figures the displacement of the center of the islands over the years is very dynamic. Floating reed island K1 is located in the Southern part of the lake. The maximum displacement of its center is observed for the period 1992 -2000, he has been displaced with 250 m.

Floating reed island K2 (Northwest part of the lake) is not observed in 1992, the reason for this is his merging with another island (probably has been merged with floating reed island K5). Significant movements for this island have been observed in 2001 and 2005, and for the period 2011 - 2013, when the floating island has been moved 300 meters to the Southeast.

Floating reed island K3, located in the Northwest part of the lake in 1992, also has not been observed. The most significant movement was observed for the period 2005 - 2011, the floating reed islands has been moved 110 meters to the West.

Floating reed island K4, located in the Eastern part of the Srebarna Lake, has been displaced notably for the period 2005 - 2011, he has been moved with 285 meters to the Southwest. In 1992, the floating reed islands K5 has been merged with a floating island K3. The most significant shift of the center of the island has been seen in the period 2000 -2005.

The movement of the floating reed islands (see Fig.4a, b, c, d, e) has been estimated on the basis of the chosen method and then the change of the position of their centers has been studied. Certain movements of these floating reed islands can be observed. Dominant directions of floating islands' movements are Northwest and Southeast.

Conclusion

Based on the proposed methodology to study the dynamics of changes in shape, size and location of the floating reed islands, quantitative results for habitats ecodynamic in Srebarna Reserve have been received.

As results of this study the change in the area of the floating reed islands and their total area were established, depending on fluctuations in water levels of the lake and the degree of surface agitation. The area of the floating reed islands increases at low water levels, smooth water surface and merger of some of the islands, and increased in the case of high water levels in the lake, large water fluctuations and rupture of the islands

A coefficient of relative area of habitat to central water mirror (KM) has been determined. These results from the calculation of KM can be used in in monitoring management plans of Srebarna Biosphere Reserve

Changes in the shape and direction of the floating reed islands are casual.

Based on the results of this study the dominant factor in the change of area, shape and location of the floating reed islands is water fluctuant levels in Srebarna Lake.

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ИЗСЛЕДВАНЕ ДИНАМИКАТА НА ПЛАВАЩИТЕ ТРЪСТИКОВИ ОСТРОВИ В ПОДДЪРЖАНИЯ РЕЗЕРВАТ „СРЕБЪРНА“ ЗА ПЕРИОДА 1992-2014 г. НА БАЗАТА НА СПЪТНИКОВИ, НАЗЕМНИ И GPS ДАННИ

Ива Иванова

Резюме. Работата е свързана с изследване състояние и динамиката на плаващите тръстикови острови в езерото Сребърна за периода от 1992 г. до 2014 г.

Плаващите тръстикови острови имат изключително важно значение за гнездането на различни видове водолюбиви птици, някои от които застрашени видове. Те са уникални за Европа като местообитания на водолюбиви птици, представени единствено в езерото Сребърна и делтата на р. Дунав. Целенасочени изследвания върху площните и пространствени изменения на плаващите тръстикови острови досега почти не са провеждани. Причини за това са трудната им достъпност и липсата на данни за тяхната динамика. За изследване динамиката (като абсолютно и относително движение) на плаващите тръстикови острови е използвана възможността, която предоставят високотехнологичните методи, базирани на дистанционни изследвания от космоса с помощта на сензори с подходящи за целта параметри за този вид несистемни ландшафтни единици. Резултатите от изследването са обединени в специализирана геобаза данни. Предложена е методика за изследване динамиката в измененията на формата, площта и местоположението на плаващите тръстикови острови. Получени са количествени резултати за екодинамиката на местообитанията в Биосферен Резерват „Сребърна“. Въведен е коефициент на относителната площ на местообитанията спрямо централното водно огледало (КМ), показващ отношението на площта на местообитанието към площта на централното водно огледало, който е количествен показател за оценка за динамиката на местообитанията. Тези резултати за стойностите на КМ се използват в плановете за управление на резервата както и за постоянен мониторинг на местообитанията. Проследяването на динамиката на плаващите тръстикови острови има съществено значение за проследяване динамиката на специфични местообитания за гнездането на застрашени видове птици.

Ключови думи: плаващи тръстикови острови, динамика, сателитни данни, мониторинг.

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