Acrocephalus 32 (150/151): 135–141, 2012
doi: 10.2478/v10100-011-0006-0

# Detecting habitat changes using MODIS EVI images: a case study of Spoonbill *Platalea leucorodia* in Croatia

## Ugotavljanje sprememb v habitatih z uporabo posnetkov MODIS EVI: vzorčna študija žličarke *Platalea leucorodia* na Hrvaškem

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The breeding population of Spoonbill *Platalea leucorodia* in Croatia, estimated at 154–275 breeding pairs, is classified as Endangered. The main reason for the unfavourable status is loss of breeding/feeding habitats. The purpose of the study was to detect changes in the habitat types previously assessed as important for Spoonbill's feeding. The study area was chosen for two reasons: (1) the alluvial wetlands of the central part of the Sava River hold the biggest colony of Spoonbills in Croatia, and (2) availability of data on feeding ecology of Spoonbills along alluvial wetlands of the Sava River. We used the MODIS (Moderate Resolution Imaging Spectroradiometer) Enhanced Vegetation Index (EVI) as the main indicator for the changes in habitat structure along critical habitats for Spoonbills. The analysis identified areas with significant changes in EVI for habitat types important for feeding of the Spoonbills during the 2000–2008 period. Pastures, especially those with high wetness potential, changed in significant percentage despite conservation efforts in this habitat type. Changes in EVI were detected on ca. 9% of the pastures. For that reason we urge for better monitoring of the Spoonbill's feeding habitats "in situ" and more specified characterisation of the reasons for the detected changes.

**Key words:** Spoonbill, *Platalea leucorodia*, satellite, habitat changes, CORINE, MODIS, Sava River
**Ključne besede:** žličarka, *Platalea leucorodia*, satelit, spremembe v habitatih, CORINE, MODIS, reka Sava

### 1. Introduction

Habitat changes caused by humans are one of the main reasons for changes in population size and/or distribution of numerous species (Tryjanowski 2005). Vegetation and its structure is dynamic, changing constantly over space and time (Coops *et al.* 2009) due to natural processes of succession, but also the human-induced changes in agriculture, forest management and climate. Along river valleys, vegetation changes can be caused by water level, seasonal flooding regime, meteorological conditions and by the intensity of grazing and mowing (Bernstead *et al.* 1999). Some types of habitats, like natural wetlands, are disappearing throughout the world (Hollis 1992, Bellio *et al.* 2009, Yuan & Zhang 2010), resulting in declining populations of bird species. Similar situation is in Croatia where drainage of wetland areas and coastal lagoons are recognised as one of the major threats for these habitats in the country, following by shifts in agriculture and different urbanisation processes. Today, the Croatian wetlands still cover 7% of the country's total territory according to the State Institute for Nature Protection.

The European population of Eurasian Spoonbill *Platalea leucorodia* is characterised by large and fluctuating range size with patchily distributed breeding areas. At the global level, it is declared as

Least Concern (BirdLife International 2009) with the status of rare species in Europe with a total population of 8,900–15,000 pairs. Species suffered large declines during the 1970–1990 period, but today most of the European countries are reporting stable or significantly increasing populations (BirdLife International 2004). The Croatian population was estimated at 100–150 breeding pairs during last decades of the 20th century (BirdLife International & EBCC 2000). Stable population was confirmed with another assessment of 100–220 breeding pairs (Radović *et al.* 2003) and 80–180 breeding pairs (BirdLife International 2004). It was classified as Endangered in the Red Book of Endangered Birds in Croatia (Radović *et al.* 2003). The latest assessment by Triplet *et al.* (2008) speaks of 154–275 breeding pairs. Even though the methods for making presented assessments are not quite transparent they can be regarded as indicators of at least stable population. Birds that breed in Croatia are part of the Pannonian population with specific dispersing history (Schneider-Jacoby *et al.* 2001) due to the drastic changes in breeding habitat. The main historic and present threat for Spoonbills is the loss of habitat for feeding and breeding (Triplet *et al.* 2008). These habitats have been drained, regulated, destroyed and polluted for years, with breeding sites being especially affected by the disappearance of reed swamps (BirdLife International 2009). For that reason monitoring of the Spoonbill population should be comprised, also, with simultaneous monitoring of breeding and foraging habitats.

There are several processes that influence the spatial distribution of birds such as competition, predation, disease, disturbance at foraging and breeding places (Frederick *et al.* 2009) and availability of food. Like other species, Spoonbills select resources and microhabitats in wetland areas according to their availability. Precise Spoonbill's foraging places are very difficult to delineate spatially. The reason for that is a need for specific conditions of feeding habitats that change rapidly, and the fact that suitable feeding grounds are a very dynamic category. On local scale, bird abundance depends on availability, density and distribution of those temporally suitable foraging ground (Romano *et al.* 2005). Choice of foraging habitats is interrelated with specific vegetation density and type. For Spoonbills, they are mostly placed on muddy, clay or fine sand substrates with water level of up to 30 cm (Boileau & Plichon 2002). Due to Spoonbill's characteristic way of feeding on small fishes and crustaceans with movements of bill from side to side (Müller 1988), these requirements are fulfilled along the Sava River on flooded pastures, temporarily drained fishponds and other seasonal wetlands having different importance at the different part of the year (Schneider-Jacoby 1993, Schneider-Jacoby *et al.* 2001).

There are several problems associated with the monitoring of the foraging habitats for species like Spoonbills. Firstly, suitability of habitats for foraging depends on local hydrological conditions, and that can change quickly. Another issue is the placement of the breeding colony near the country border, and potential feeding grounds extend to the neighbouring countries, too. In case of lack of thematic layers from a neighbouring country, this can disable the standard GIS analysis and stop further planning process of natural resources with geographic that numerous authors consider crucial (Buldgen *et al.* 1994, Qiu 2009, Junge *et al.* 2010). Additional reason why we wanted to test this approach was the recommendation of OECD (2003) that monitoring of birds and their habitats should be made, also, by remote sensing data. Bird habitat mapping by using remote sensing data (Sader *et al.* 1991, Thibault *et al.* 1998) or derivation of habitat data to map bird distributions (Palmeirim 1988, Debinski *et al.* 1999) is becoming standard nowadays. The result of such habitat mapping can be used further for more adequate management of important habitats (Saveraid *et al.* 2001). It is already recognised that monitoring of habitats using remote sensing is possible in the case where the habitat preferences for the key species are known (Prins *et al.* 2005), as is the case with Spoonbills, and should be used as a first indicator of possible population changes.

In this paper we wanted to investigate whether the significant changes occurred in habitat classes of the CORINE land cover (CLC) that are already known to be important for Spoonbills in the most important breeding area in Croatia. We attempted to estimate the role of habitat modifications detected in the area and, additionally, to promote comprehensive monitoring of the habitats important for target species.

## 2. Materials and methods

### 2.1. Study area

The analysis of Enhanced Vegetation Index (EVI) changes during the 2000–2008 period was performed in the cross-border area along the Sava River floodplain (Figure 1). EVI, which is responsive to canopy structural variations, including leaf area index (LAI), canopy type, plant physiognomy, and canopy architecture, is one of the results of MODIS (Moderate Resolution Imaging Spectroradiometer)

mission. This area was chosen due to its importance for the Spoonbill population in Croatia. The area holds the biggest Spoonbill colony in the region and for that reason the changes in its feeding habitats would affect a significant part of the population. This is a transitional territory, between two important bird areas in Croatia, and has already been suggested as future SPA areas (1) Lower Sava Basin and (2) Jelas field with fishponds and inundated pastures along the Sava River. The selected area partly contains Lonjsko field (part of the Lower Sava Basin) – the biggest retention in Croatia with vast area of wet meadows and pastures mixed with ponds, oxbows, small rivers and canals as well as transitional zone between floodplain and traditional agriculture. Study area covers, also, part of the Jelas field with fishponds and inundated pastures along the Sava River area. Most comprehensive research on feeding habitats for Spoonbills (Schneider-Jacoby 1993) was conducted along the Lonjsko field area. Land cover classes (Level 3), which are according to the CORINE project (CEC 1991) already known to be important for Spoonbills, are swamps (411), swamps and water stands (512) and pastures (321), and these three classes have been given special attention in this paper. Main threats for the Spoonbills in the area, among others, are drainage of wetlands, loss of fishponds and hunting (Radović *et al.* 2003).

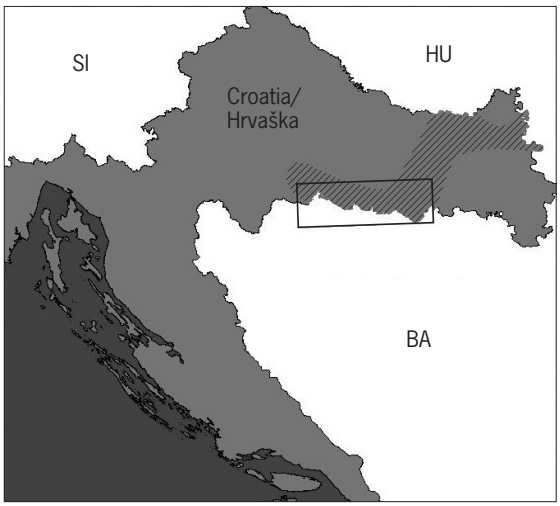


**Figure 1:** Breeding range of Spoonbill *Platalea leucorodia* (hatched) (Radović *et al.* 2003) with study area in Croatia (frame) depicted

**Slika 1:** Gnezditveni areal žličarke *Platalea leucorodia* (šrafirano) (Radović *et al.* 2003) s prikazanim območjem raziskave na Hrvaškem (okvir)

### 2.2. Analyses

The pixel-by-pixel analysis of the changes in habitat structure for important feeding grounds for Spoonbills was made using MODIS EVI (MOD13Q1) images that were downloaded from the NASA website (http://modis.gsfc.nasa.gov). The images are a 16- day composites with spatial resolution of 250 m. The original hdf formats of the images were transformed into geotif format and projected into 33 UTM zone. Manipulation and processing of satellite images were controlled from R software. For manipulating with downloaded MODIS images we needed several packages (e.g. rgdal, RCurl). After re-projecting the images into local geographic coordinate system and extraction of spatial subset of interest for the April 2000–November 2000 period, we tested the difference in the means of the distributions for the EVI with the equivalent images from 2008. Comparisons were made iteratively on pixel by pixel basis.

As the main indicator of changes in vegetation structure we used the change in mean value of the EVI spectral layer of the images. Due to the known distributions of EVI for natural vegetation that, for given period of the year (April–November) approximately follows normal distribution, we used *t*-test. After attaining *P*-values for every pixel we extracted pixels with probability of changes taking place that was greater than 95%. We aimed to analyse whether the habitats important for Spoonbills, especially pastures, have the same probability of changing as other habitat classes or that probability differs.

This analysis was performed according to the CLC classification as well as according to wetness index of the pixel. All the statistical analyses were performed with R programming environment using SAGA geoprocessor functions for zonal analysis of grids, which means the descriptive values for target grids in dependence of the land cover classes used as separate zones. Wetness index grid was, also, prepared with SAGA software (version 2.0.4) and this is a potential of pixel to contain and keep water derived from Digital Elevation Model (grid with values for mean elevation on each pixel). The contingency table analysis for testing the independence of the data (area of the habitats changed per category) was performed with two sided $\chi^2$ test.

## 3. Results

The analysis revealed pixels with probability that changes in Enhanced Vegetation Index that occurred between 2000 and 2008 exceed 95%. The mean

**Table 1:** Obtained probability of change of the mean value of Enhanced Vegetation Index (EVI) between 2000 and 2008 for CORINE land cover classes (Level 3) important for Spoonbills *Platalea leucorodia* in Croatian part of the study area

**Tabela 1:** Izračunana verjetnost sprememb v povprečni vrednosti izboljšanega vegetacijskega indeksa (EVI) med letoma 2000 in 2008 za kategorije pokrovnosti in rabe tal CORINE (3. nivo), ki so pomembne za žličarke *Platalea leucorodia* v hrvaškem delu območja raziskave

| CLC code/ koda | CLC class name/ Ime CLC kategorije | Mean EVI change/ Povprečna sprememba EVI | S.E./ Standardna napaka | Area/ Površina (ha) | Area changed/ Sprememba površine (ha) |
|---|---|---|---|---|---|
| 231 | Pastures / Pašniki | 0.351 | 0.227 | 3,368 | 300 |
| 512 | Water stands / Mirujoča voda | 0.458 | 0.216 | 1,431 | 56 |
| 411 | Swamps / Celinska barja | 0.478 | 0.279 | 581 | 25 |

probability values of change per every CLC class for the Croatian part of the study area are given in Table 1, revealing that wet pastures are more threatened by structural change than dry ones. The analysis of change probability of pixels classified as pastures along research areas revealed that there are no differences in the probability of change when compared to other habitat classes together ($\chi^2$ test = $9e^{-4}$, df = 1, $P$ = 0.976, C.I. = –0.012–0.011, two-sided test) with odds ratio of 0.9888 C.I. (0.776–1.259). But this is not the case of pastures with highest level of wetness index ($\chi^2$ test = 4.346, df = 1, $P$ = 0.037, C.I. = 0.00265, two-sided test) with odds ratio of 0.001 C.I. (0.001–0.002), the most important potential feeding habitats for Spoonbills.

The results of contingency table analysis for detection of changes in mean EVI value on pastures between 2000 and 2008, according to the value of wetness index of the pixel, are presented in Table 2. The highly significant $\chi^2$ test for the proportions revealed non-independent structure of the table ($\chi^2$ = 214.5, df = 3, $P = 2.2e^{-16}$, two-sided test).

## 4. Discussion

Results of the presented analysis revealed where along the Sava River there is a high probability that changes in EVI in the 2000–2008 period occurred. Swamps and water stands, beside pastures, the most important habitats for Spoonbills have similar and high mean value of probability of change in EVI during the 2000–2008 period. This analysis revealed changes in 4% of swamps and water stands (CLC 411 and 512 respectively) and on ca. 9% of pastures (CLC 231). Although we did not detect in what direction the changes went, the obtained result should not be ignored. With respect to changes in water stands and swamps we are positive that this result, at least partially, reflects the succession process that is unavoidable a result of problems in economic profitability/ sustainability of extensive fish production in Croatia (Schneider-Jacoby 2003). The majority of fish farms have reduced their production or completely shifted to hunting related activities. The possible reason for the fact that the breeding population of Spoonbill is stable and has even been slowly increasing during the last decade can be due to the fact that the population still did not reach the carrying capacity of the area (Schneider-Jacoby *et al.* 2001) and for that reason the reduction of habitat's feeding capacity is still not detectable in the breeding population. We anticipate more drastic changes in those habitats in the future and this can have a major impact on the Spoonbill population in Croatia not only due to disturbance on feeding grounds in spring and autumn when fishponds constitute most important feeding places for Spoonbills in Croatia (Schneider-Jacoby *et al.* 2001), but will cause a permanent loss of important feeding grounds.

Pastures are recognised as habitat of the greatest importance for the preservation of a number of animal and plant taxa at the international (Nikolov 2010, Verhulst 2004) and national levels (Official Gazette 2006 & 2009) and should as such be in the focus of conservation activities and preservation actions. Despite that, this analysis revealed that pastures in the Lower Sava Basin do not have a lower value of the probability of change in EVI values than other habitat types in the studied area. The highest probability of change was detected for the pastures with the highest wetness potential in the area. During the last few decades, a significant amount of pastures in Europe has been transformed with diverse processes like land drainage, agricultural improvement and conversion to arable cultivation (Smith 2009). The changes detected in this study on pastures are very likely connected with the abandonment of breeding

**Table 2:** Results of contingency table analysis for detection of changes in mean EVI value between 2000 and 2008 according to the pixels classified as pastures versus other habitats. Both categories are divided into two levels: (1) high wetness index "wet", where wetness index value ranged from 11–12, and (2) lower wetness index "dry" with wetness index value less than 11

**Tabela 2:** Rezultati analize s kontingenčno tabelo za ugotavljanje sprememb v povprečni vrednosti EVI med letoma 2000 in 2008 v skladu s piksli, uvrščenimi kot pašniki v primerjavi z drugimi habitati. Obe kategoriji sta razdeljeni na dve ravni: (1) visok indeks vlažnosti ("vlažen"), kjer je bila vrednost indeksa med 11 in 12, in (2) nižji indeks vlažnosti ("suhi"), z vrednostmi manjšimi od 11

| Two-way analysis of pastures vs. other habitats/ Dvosmerna analiza pašniki vs. drugi habitati | Odds ratio EVI change / Razmerje obetov za spremembo EVI | C.I. for odds ratio EVI change/ Interval zaupanja za razmerje obetov za spremembo EVI |
|---|---|---|
| "Wet" pastures vs. other "wet" habitats/ "Vlažni" pašniki vs. drugi "vlažni" habitati | 1.346 | 0.746–2.431 |
| "Wet" pastures vs. "dry" pastures/ "Vlažni" pašniki vs. "suhi" pašniki | 1.568 | 0.868–2.831 |
| "Wet" pastures vs. other "dry" habitats/ "Vlažni" pašniki vs. drugi "suhi" habitati | 2.735 | 1.514–4.938 |
| Other "wet" habitats vs. "dry" pastures/ Drugi "vlažni" habitati vs. "suhi" pašniki | 1.164 | 0.645–2.103 |
| Other "wet" habitats vs. other "dry" habitats/ Drugi "vlažni" habitati vs. drugi "suhi" habitati | 2.031 | 1.125–3.668 |
| "Dry" pastures / other "dry" habitats/ "Suhi" pašniki vs. drugi "suhi" habitati | 1.744 | 0.966–3.150 |

of grazing animals and domestic pigs as well as with the severe problem of uncontrolled expansion of invasive plant species *Amorpha fruticosa*, especially along the open habitats like pastures with high wetness potential. The consequence of transitions of the Croatian economy, subsidiary policy and uncertain profit of agricultural production is the abandonment of different traditional activities that were in line with conservation of different taxa. Although there are some activities beginning to take place in Lonjsko polje Nature Park that should raise the number of grazing animals on pastures within the Park, the number of animals is not even close that from several decades ago. Furthermore, the Spoonbill's feeding grounds are threatened by large infrastructural projects and changes in water management measures that will permanently change the water regime in the area (Schneider-Jacoby 2006) and consequently the dynamics of the Spoonbill's feeding places availability.

Indeed, we do not think that the proposed procedure could replace the standard monitoring of the species habitats, but we do strongly believe that it could be a useful tool for a large scale monitoring of the areas where changes in habitat structure occurred in habitats important for target species and where detailed field research should be organised.

**Acknowledgments:** This study was prepared under the grants No. 119-0000000-3169 and No. 119-1012682-1221 of the Croatian Ministry of Science, Education and Sports.

## 5. Povzetek

Gnezditvena populacija žličarke *Platalea leucorodia*, ki je na Hrvaškem ocenjena na 154–275 gnezdečih parov, je v tej državi uvrščena med ogrožene vrste (EN). Poglavitni vzrok za njen neugodni status je izguba gnezditvenih in prehranjevalnih habitatov. Namen pričujoče študije je bil ugotoviti spremembe v habitatnih tipih, ki so bili predtem ocenjeni kot pomembni za prehranjevanje teh ptic. Območje raziskave je bilo izbrano zaradi (1) dejstva, da v aluvialnih mokriščih osrednjega dela reke Save gnezdi največja kolonija žličark na Hrvaškem, in (2) razpoložljivosti podatkov o prehranjevalni ekologiji žličark v aluvialnih mokriščih vzdolž reke Save. Kot glavni kazalec sprememb v strukturi kritičnih habitatov za žličarke je bil uporabljen tako imenovani izboljšani vegetacijski indeks (EVI) spektroradiometra MODIS (Moderate Resolution Imaging Spectroradiometer). Z analizo so bila ugotovljena območja s pomembnimi spremembami v vegetacijskem indeksu za habitatne tipe, ki so

pomembni za prehranjevanje žličark v obdobju 2000–2008. V pomembni meri so se spremenili pašniki, še posebno tisti z velikim vlažnostnim potencialom, in to kljub naravovarstvenim naporom, vloženim v tem habitatnem tipu. Spremembe v vegetacijskem indeksu so bile ugotovljene na 9 % pašnikov. To pa je razlog, da nujno potrebujemo boljši monitoring prehranjevalnega habitata žličark in situ, a tudi natančnejšo opredelitev vzrokov za ugotovljene spremembe.

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Arrived / Prispelo: 30. 3. 2011
Accepted / Sprejeto: 19. 3. 2012