

András Márkus<sup>1</sup>, Zoltán Kenyeres<sup>2</sup>, Norbert Bauer<sup>3</sup>, Sándor Tóth<sup>4</sup>,  
Tamás Sáringer-Kenyeres<sup>5</sup>, Gyula Sáringer

<sup>1</sup>EcoMap L.P., Hungary

<sup>2</sup>Acrida Conservational Research L.P., H-8300 Tapolca, Deák F. u. 7, Hungary

<sup>3</sup>Hungarian Natural History Museum, Department of Botany, H-1087 Budapest, Könyves K., krt. 40, Hungary

<sup>4</sup>H-8420 Zirc, Széchenyi u. 2, Hungary

<sup>5</sup>St-Art Chem L.P., H-8360 Keszthely, Vak Bottyán u. 37, Hungary

## THE CAPABILITIES AND CONFINES OF GIS TECHNOLOGY IN THE MAPPING OF THE MOSQUITO BREEDING SITES OF THE BASE REVELATION IN A BACKGROUND PATTERN

Márkus A., Kenyeres Z., Bauer N., Tóth S., Sáringer-Kenyeres T., Sáringer G. **Możliwości i ograniczenia metody GIS w kartowaniu miejsc rozmnażania komarów na podstawie pól podstawowych.** Przedstawiono metodykę kartowania obszarów rozmnażania owadów przy pomocy technologii komputerowych, pozwalających na zlokalizowanie takich potencjalnych punktów. Proponowana metodyka jest oparta na badaniach przeprowadzonych w latach 2006–2008 w okolicach Balatonu (Węgry). Obszary rozmnażania komarów stwierdzono na podstawie analizy 620 wskaźników (biotycznych i abiotycznych parametrów środowiska i biotycznych charakterystyk zbiorowisk owadów) oraz 8348 źródeł literaturowych, dotyczących. Praktyczne korzyści wynikające z takich badań geograficznych polegają na możliwości dosyć dokładnego wskazania miejsc rozmnażania, które należy zneutralizować chemicznie, minimalizując szkody wyrządzone środowisku.

Маркуш А., Кеньереш З., Бауер Н., Тот С., Шарингер-Кеньереш Т., Шарингер Г. **Возможности и ограничения ГИС-технологий в картировании мест размножения комаров на основе базовых участков.** В статье предлагается методика картирования участков размножения насекомых с помощью компьютерных технологий, позволяющих селективно выявлять такие потенциальные участки. Предлагаемая методика базируется на локальном исследовании, проведенном в 2006–2008 годах в окрестностях озера Балатон (Венгрия). Участки размножения комаров выявлялись (картировались) на основании анализа 620 показателей (абиотических и биотических параметров среды, биотических характеристик сообществ насекомых) и 8348 литературных источников, касающихся проблемы. Практическая польза подобных географических исследований заключается в возможности более точного указания мест размножения, которые следует обрабатывать химически, с минимизацией ущерба для окружающей среды.

### Abstract

This paper gives a methodological protocol for the mapping and evaluation of breeding sites of mosquitoes and the structure of the GIS which makes it possible for the selective BTI treatment of their habitats. The suggested method is based on a case study carried out between 2006 and 2008 in the Balaton Region (Hungary). Mosquito breeding sites were studied based on 620 current (abiotic and biotic characteristics of the breeding sites, biotic characteristics of the mosquito communities) and 8348 literary samples. The practical importance of the results is that the geographically exact patch maps of the mosquito breeding sites make it possible for the detailed planning of the BTI treatments and the minimization of the environmental side effects.

### INTRODUCTION

Nowadays, due to the production of base maps of mosquito breeding sites and with the speed of map resolutions together with the implementing of selective and environmentally effect minimized BTI treatments, the topologically correct patch mapping is essential – which means that GIS methods and databases are used. Although colour-infrared (CIR) aerial photography has been used to identify the larval habitats for the first time in 1971 by NASA (HAY et al., 1998), nowadays the use of aerial photographs is typically used in many fields of research; the potential of the geo-information systems in mapping mosquito breeding sites is rarely exploited. For a long time, the use of picture editing softwares were typical (e.g. BOURGEOIS, CAISSIE, 1997) in the breeding site mapping tasks. Recently, the GIS technology has come to the fore in the mapping of

mosquito breeding sites. Besides this, identification by manual interpretation of the aerial photographs and the predicting methods were also tested in connection with the mapping of the larval habitats in the last decade (HAY et al., 1998; THOMAS, LINDSAY, 2000; LACAUX et al., 2007; SZABÓ et al., 2008). However, publications about case studies in this field of science are relatively rare (e.g. HAY et al., 1998; SRIVASTAVA et al., 2001, 2003; HAUSBECK, 2004; ZOU et al., 2006; LACAUX et al., 2007; SCHÄFER, 2008).

Aerial photographs taken in appropriate time for depiction of the mosquito habitats (out of vegetation period, flooded breeding sites etc.) are usually very reliable for the objectives, but those photographs used in the allocation of the teaching areas, and in the predicting methods by field work are frequently incompetent. This is caused by a temporary shift in character of the breeding sites; these are often in a dry period during field work. Our results gave a solution for this problem with a new method based on revelation of the background pattern. Through our hypothesis based on the community-characteristics of mosquitoes (KENYERES et al., 2008) but moreover the connections between the pattern of mosquito communities and the vegetation patterns (BAUER et al., 2008) and the exact topologically breeding-site map of the mosquitoes can be produced by special vegetation mapping and the use of geo-information methods. The raising of this issue can be justified by the fact that we could not find any examples for the use of the available GIS methods adopted for the mosquito breeding site mapping in Hungary where the fauna of the mosquitoes is mid-rich. The case study in Hungary is also proved by the fact that there are many recreational areas in the country (e.g. Lake Balaton, Lake Tisza, Dunakanyar, Lake Velence) where the presence and population density of the mosquito species received special attention. At the same time, the minimizing of the environmental effects become more and more important along with the law and social attitudes too.

The basic examinations were carried out in the administrative areas of Alsópáhok, Cserszegtomaj, Gyenesdiás, Hévíz, Keszthely and Vonyarcvashegy (Hungary, Zala County, Balaton Region). It was revealed that the structural features of the larval mosquito communities and their background pattern together with the further development of the most objective and quickest mapping methods, the scope of experiences within our working group were fully applied. The results of the more than decade long field research by Sándor Tóth and Gyula Sáringer (TÓTH, 2004, 2006) were also very useful to our work. Thus our additional faunistical synopsis gives

exact quantitative information about the Hungarian mosquito fauna, based on larval occurrences.

In this paper, summarized fauna data (from frequency and seasonal point of view), the basic connections between the patterns of mosquito communities and vegetation patterns (see detailed in BAUER et al., 2008), together with a methodological protocol for the mapping and evaluation of breeding sites of mosquitoes and the structure of the GIS has made it possible for the selective treatment of the spots given.

## METHODS

From 2006 to 2008 the administrative area of Alsópáhok, Cserszegtomaj, Gyenesdiás, Hévíz, Keszthely and Vonyarcvashegy (Hungary, Zala County, Balaton Region) there has been data collected from 620 samples of mosquito breeding sites (point data). The following data were recorded: **(I) Abiotic characteristics:** (1) geographic co-ordinates; (2) pH value, (3) water temperature, (4) level of water pollution (5 step scale, estimated), (5) water depth, (6) transparency (5 step scale, estimated), (7) character (continuous, temporary, or casual), (8) typological class of the breeding site water body; **(II) Biotic characteristics** of the breeding site: (1) presence of pondweed vegetation, (2) coverage of pondweed vegetation, (3) coverage of the breeding water (5 step scale, estimated), (4) shading of the water body (5 step scale, estimated), (5) plant communities and characteristic plant species of the breeding site (Vegetation I = hydrophyta species, Vegetation II = helophyta species), (6) habitat type around the breeding site (code of the National Habitat Classification System – NHCS); **(III) Biotic characteristics of the mosquito communities:** (1) density of larvae (number of larvae/litre), (2) qualitative and (3) quantitative conditions of the larval communities. The data is written on the datasheets linked to the sampling sites.

On the base of field-born GIS data and the evaluation of aerial photographs the breeding site map of the mosquitoes with 496 patches was produced. We linked the sample points of the data collection to the patches on the map and with this method the patch definitions were born (more sampling spot to one patch and more sampling date are possible). The definitions of the patches became complete with each given category on the base of using different deducted values and categorisations with empirical backgrounds. The categories grouped on base experiences were: (1) for the mosquito communities characteristic habitat types (primarily different habitat types) drawn together on different levels; (2–5) the importance of the breeding sites in spring, sum-

mer, autumn and winter; (6) the importance of the breeding sites from the viewpoint of treatment on the base species composition; (7) the most characteristic surface area of the breeding site; (8) the type of surface change at the breeding site (see detailed in KENYERES et al., 2008).

The polygons of the mosquito breeding sites were produced with the ArcGIS 9.1 (1999–2004) and ArcPad 7.0 (2000–2005) soft-ware with digitalisation on a 1:10 000 scale topographic maps and orthophotos (geographically exact, orthorectified aerial photos) in the Hungarian National Grid coordinate system. The producing and visualisation of the exact points and patch maps were tested with all of the available background images to get the best results.

## RESULTS

### Faunistical and ecological results

The summarized faunistical results (density, frequency, relative frequency etc.) are given in Table 1. The data of which is depicted in Table 1 which originates from a huge database. These data were not exclusively collected during the field work of current study, but contain many literary data (TÓTH, 2004, 2006). Table 2 shows basic phenology of the Hungarian mosquito species which is based on the above mentioned database.

Connections between the patterns of mosquito communities and the vegetation patterns were studied statistically by us (see detailed in BAUER et al., 2008). Results of these researches showed that:

Table 1. Qualitative and quantitative features of the analysed mosquito database based on presence data of 194.825 specimens belonging to 45 species [anthropophilous species are marked; RF=relative frequency; NPS=Number of presences in samples; RNPS=Rank of number of presences in samples; A/S=Average specimen number per sample; RAN=Rank of specimen number per sample]

Tabela 1. Ilościowe i jakościowe cechy analizowanej bazy danych o owadach, opierające się na analizie 194.825 okazów, należących do 45 gatunków (zaznaczone są gatunki antropofilne, RF = częstotliwość względna, NPS = liczba przypadków w analizowanym zespole, RNPS – stopień liczebności (ranking) okazów w analizowanych zespołach, A/S = średnia liczba okazów na zespół, RAN = stopień liczebności (ranking) okazów na zespół)

	Species	N	%	RF	NPS	RNPS	A/S	RAN
1.	<i>Culex pipiens</i>	66796	34,285	0,34285	2926	1.	22,83	1.
<b>2.</b>	<b><i>Aedes vexans</i></b>	<b>25282</b>	<b>12,977</b>	<b>0,12977</b>	<b>1757</b>	<b>4.</b>	<b>14,39</b>	<b>2.</b>
3.	<i>Culiseta annulata</i>	16247	8,339	0,08339	1849	3.	8,79	7.
4.	<i>Anopheles maculipennis</i>	13605	6,983	0,06983	2513	2.	5,41	15.
<b>5.</b>	<b><i>Ochlerotatus sticticus</i></b>	<b>9130</b>	<b>4,686</b>	<b>0,04686</b>	<b>1070</b>	<b>8.</b>	<b>8,53</b>	<b>8.</b>
<b>6.</b>	<b><i>Culex modestus</i></b>	<b>8470</b>	<b>4,347</b>	<b>0,04347</b>	<b>1161</b>	<b>7.</b>	<b>7,30</b>	<b>11.</b>
<b>7.</b>	<b><i>Aedes cinereus</i></b>	<b>7066</b>	<b>3,627</b>	<b>0,03627</b>	<b>1369</b>	<b>6.</b>	<b>5,16</b>	<b>17.</b>
<b>8.</b>	<b><i>Ochlerotatus cantans</i></b>	<b>6278</b>	<b>3,222</b>	<b>0,03222</b>	<b>660</b>	<b>10.</b>	<b>9,51</b>	<b>6.</b>
9.	<i>Ochlerotatus cataphylla</i>	6208	3,186	0,03186	525	14.	11,82	4.
10.	<i>Anopheles claviger</i>	5769	2,961	0,02961	1465	5.	3,94	26.
<b>11.</b>	<b><i>Ochlerotatus annulipes</i></b>	<b>5339</b>	<b>2,740</b>	<b>0,02740</b>	<b>560</b>	<b>12.</b>	<b>9,53</b>	<b>5.</b>
12.	<i>Ochlerotatus rusticus</i>	5232	2,685	0,02685	662	9.	7,90	9.
13.	<i>Culex territans</i>	3144	1,614	0,01614	633	11.	4,97	19.
14.	<i>Ochlerotatus caspius</i>	2673	1,372	0,01372	420	16.	6,36	14.
15.	<i>Culiseta morsitans</i>	2164	1,111	0,01111	542	13.	3,99	25.
16.	<i>Ochlerotatus geniculatus</i>	1796	0,922	0,00922	245	19.	7,33	10.
17.	<i>Ochlerotatus excrucians</i>	1718	0,882	0,00882	469	15.	3,66	27.
18.	<i>Ochlerotatus flavescens</i>	1530	0,785	0,00785	290	18.	5,28	16.
19.	<i>Ochlerotatus refiki</i>	1476	0,758	0,00758	117	23.	12,62	3.
<b>20.</b>	<b><i>Coquillettidia richiardii</i></b>	<b>1440</b>	<b>0,739</b>	<b>0,00739</b>	<b>204</b>	<b>20.</b>	<b>7,06</b>	<b>13.</b>
21.	<i>Anopheles messeae</i>	1004	0,515	0,00515	351	17.	2,86	35.
22.	<i>Uranotaenia unguiculata</i>	833	0,428	0,00428	171	21.	4,87	20.
23.	<i>Anopheles plumbeus</i>	510	0,262	0,00262	148	22.	3,45	30.
24.	<i>Aedes rossicus</i>	168	0,086	0,00086	61	27.	2,75	37.
25.	<i>Culex hortensis</i>	166	0,085	0,00085	71	24.	2,34	39.
26.	<i>Anopheles algeriensis</i>	130	0,067	0,00067	71	25.	1,83	43.
27.	<i>Ochlerotatus punctor</i>	125	0,064	0,00064	31	28.	4,03	22.
28.	<i>Anopheles hyrcanus</i>	114	0,059	0,00059	62	26.	1,84	42.
29.	<i>Anopheles atroparvus</i>	58	0,030	0,00030	8	34.	7,25	12.
30.	<i>Ochlerotatus communis</i>	56	0,029	0,00029	21	29.	2,67	38.
31.	<i>Ochlerotatus dorsalis</i>	48	0,025	0,00025	17	31.	2,82	36.
32.	<i>Culex mimeticus</i>	41	0,021	0,00021	8	35.	5,13	18.
33.	<i>Ochlerotatus leucomelas</i>	36	0,018	0,00018	12	32.	3,00	32.
34.	<i>Culex martinii</i>	31	0,016	0,00016	20	30.	1,55	45.
35.	<i>Culiseta longiareolata</i>	20	0,010	0,00010	5	36.	4,00	23.
36.	<i>Ochlerotatus nigrinus</i>	16	0,008	0,00008	10	33.	1,60	31.
37.	<i>Orthopodomyia pulchripalpis</i>	16	0,008	0,00008	5	37.	3,20	44.
38.	<i>Culex torrentium</i>	14	0,007	0,00007	4	39.	3,50	28.
39.	<i>Culiseta subochrea</i>	14	0,007	0,00007	4	40.	3,50	29.
40.	<i>Culiseta fumipennis</i>	13	0,007	0,00007	3	42.	4,33	21.

41.	<i>Culiseta alaskaensis</i>	12	0,006	0,00006	4	41.	3,00	24.
42.	<i>Culiseta ochroptera</i>	12	0,006	0,00006	3	43.	4,00	33.
43.	<i>Culex theileri</i>	10	0,005	0,00005	5	38.	2,00	40.
44.	<i>Ochlerotatus pulchritarsis</i>	9	0,005	0,00005	3	44.	3,00	34.
45.	<i>Culiseta glaphyroptera</i>	6	0,003	0,00003	3	45.	2,00	41.

Table 2. Basic phenology of the Hungarian mosquito species (species per season are shorted by frequency values; based on 8968 samples and data of 194.825 specimens)

Tabela 2. Główna fenologia węgierskich gatunków komarów (gatunki na sezon w skrócie przez wartości częstotliwości, na podstawie analizy 8968 zespolów danych obejmujących 194,825 okazów)

Spring	Summer	Autumn	Winter
<i>Aedes vexans</i>	<i>Culex pipiens</i>	<i>Culex pipiens</i>	<i>Ochlerotatus rusticus</i>
<i>Ochlerotatus cantans</i>	<i>Aedes vexans</i>	<i>Culiseta annulata</i>	<i>Ochlerotatus cataphylla</i>
<i>Ochlerotatus cataphylla</i>	<i>Culiseta annulata</i>	<i>Aedes vexans</i>	<i>Anopheles claviger</i>
<i>Culex pipiens</i>	<i>Anopheles maculipennis</i>	<i>Anopheles maculipennis</i>	<i>Ochlerotatus cantans</i>
<i>Ochlerotatus sticticus</i>	<i>Culex modestus</i>	<i>Culex modestus</i>	<i>Culiseta morsitans</i>
<i>Ochlerotatus annulipes</i>	<i>Ochlerotatus sticticus</i>	<i>Aedes cinereus</i>	<i>Ochlerotatus annulipes</i>
<i>Ochlerotatus rusticus</i>	<i>Aedes cinereus</i>	<i>Anopheles claviger</i>	<i>Ochlerotatus excrucians</i>
<i>Culiseta annulata</i>	<i>Culex territans</i>	<i>Culex territans</i>	<i>Culiseta annulata</i>
<i>Anopheles claviger</i>	<i>Ochlerotatus geniculatus</i>	<i>Ochlerotatus sticticus</i>	<i>Ochlerotatus flavescens</i>
<i>Aedes cinereus</i>	<i>Ochlerotatus caspius</i>	<i>Culiseta morsitans</i>	
<i>Anopheles maculipennis</i>	<i>Anopheles claviger</i>	<i>Ochlerotatus rusticus</i>	
<i>Ochlerotatus excrucians</i>	<i>Anopheles messeae</i>	<i>Ochlerotatus geniculatus</i>	
<i>Culiseta morsitans</i>	<i>Uranotaenia unguiculata</i>	<i>Anopheles messeae</i>	
<i>Ochlerotatus caspius</i>	<i>Coquillettidia richiardii</i>	<i>Uranotaenia unguiculata</i>	
<i>Ochlerotatus refiki</i>	<i>Anopheles plumbeus</i>	<i>Coquillettidia richiardii</i>	
<i>Ochlerotatus flavescens</i>	<i>Ochlerotatus flavescens</i>	<i>Ochlerotatus caspius</i>	
<i>Coquillettidia richiardii</i>	<i>Ochlerotatus cataphylla</i>	<i>Anopheles plumbeus</i>	
<i>Ochlerotatus geniculatus</i>	<i>Ochlerotatus annulipes</i>	<i>Ochlerotatus cataphylla</i>	
<i>Culex territans</i>			
<i>Anopheles messeae</i>			
<i>Culex modestus</i>			
<i>Anopheles plumbeus</i>			

(1) the drying reed-sedge marshes, (2) the permanent reed-sedge marshes, (3) the mesophytic grasslands with characteristic seasonal inundance, (4) the small opened water surfaces and the border zones of large water surfaces and (5) the tree vegetation with closed canopy as a background pattern determines the pattern of the mosquito communities with individual structural and dynamic characteristics. Borders of the background pattern coincide with the borders of the mosquito community pattern and therefore the mapping of this background pattern – as special vegetation mapping – means the mapping of the mosquito breeding sites. The scale of this background pattern is far rougher than the categorizing scale of vegetation types (plant association) used in the plant coenology.

These results produced the basis for our new GIS-based mapping method of mosquito breeding sites using these background patterns.

The supposed method for the GIS-based mapping of mosquito breeding sites is on the base of background pattern

**Supply of base maps and images.** Along with the field work there are many types of base maps, aerial photos and satellite images which can be used for the breeding site mapping of mosquitoes. Among the topographic maps the 1:10 000 scales is recommendable with 0,846 m/pixel resolution when digitised. Within this the aerial and satellite images are much more useful than the topographic maps. These have considerable differences in their basic and enhanced uses. The aerial photos and satellite images which are not produced for special tasks in the breeding site of mapping mosquitoes in wooded areas have very limited potential in use, but in most cases they are only good for determining the patch

borders or points with help from GPS equipment. The best images can be made in early spring (before frondescence, in February or in mid-March) with well planned thought (on flooding zones of rivers it is advisable to make minimum two series of aerial photos: one in the leafless period and one in the flooded period). In the case of special flight as well as in the use of other aimed photos the resolution of orthophotos must be a minimum of 0,4 m/pixel.

In the breeding site mapping the RGB aerial photos, infrared aerial photos, multi-spectral satellite images, multi-spectral and hyper-spectral aerial photos and laser scanner records are applicable. Among these solutions, there is less potential in RGB aerial photos (because of their few channels), hyper-spectral images (oversensitivity), and laser scanner records (due to their limitations in scanning time). The research of their use can be rewarding.

According to our experiences the multi-spectral aerial and satellite images (e.g. IKONOS) taken in ideal times (before the frondescence or after defoliation, if it is possible in a flooded station) or the infrared aerial photographs taken for the special task have the best results. To determine the patches and patch borders and for locating the patches identified during the sample collecting on the field these give the best and most precise background. In the supplying we recommend the TIFF format and for the field work PDA and ECW mosaics.

**Point data collecting and point mapping of the breeding sites.** The field work is carried out with the use of the same digital maps and images that will be used later in the elaboration of the data (by use of GIS-PDA instrument). In this phase the local qualitative and quantitative circumstances are taken into consideration in the data collecting. Along with this work the efforts for making the most disperse distribution of the samples in space and time is a must, which results in the most representative information cluster regarding the biotic and abiotic factors. At every sampling site the followings must be recorded: (1) geographic co-ordinates (the production of point-layer suggested already in the field work phase); (2) water temperature; (3) water depth of the spot; (4) type of water body (continuous, temporary, or casual); (5) typological class of the water body at the breeding site; (6) coverage value of the pondweed vegetation; (7) surface coverage of the breeding water (1–5 scale values, estimated); (8) shading of the breeding water (1–5 scale values, estimated); (9) plant association of the breeding site or the characteristic plant species; (10) larval density (number of larvae/litre), (11) quantitative and qualitative conditions of the larval community (number of species/individuals) [additional optional collectible

data types can be seen in the „Methods” chapter]. It is important to take documented photos of the sampling site. The collected data are then stored on sampling data sheets (digitally; on these sheets every recorded data and the document photos must also be represented) in tables.

**Patch mapping.** This process started in the field with sampling, with the elaboration continuing later in which every breeding site received a patch with an individual identification code. The elements of the point map (the sampling points) correspond to the elements of the breeding site patch map (breeding site patches) (the identification codes of the sampling points are recorded in the attributing table of the polygonal map). In some cases, the adjacent similar patches get the same identification code and the characterising sample is joined too.

The primary data table must be filled with deducted values and data from categorisations with an empirical background. In every patch minimum the following categorisations must be made:

(1) the importance of the breeding sites in spring, summer, autumn and winter; (2) the importance of the breeding sites from the viewpoint of treatment on the base of species composition; (3) the most characteristic surface area of the breeding site (e.g. a: <10 m<sup>2</sup>, b: 10–50 m<sup>2</sup>, c: 50–200 m<sup>2</sup>, d: 200–800 m<sup>2</sup>, e: >800 m<sup>2</sup>); (4) the type of surface changes at the breeding site [supposed categories: a: stationary (rigid) breeding site border, continuous water coverage; b: the border – according to the size of the breeding site – may alter in small scale, in both directions; c: the border of the breeding site – according to the size – can alter considerably, the water coverage is generally regular (with annual seasonality), the change of the surface is characteristically slow (~linear character), rarely rhapsodical; d: the borders of the breeding site – according to size – often alter and at a considerable scale, beyond the regularity of the water coverage (the annual fluctuation and seasonality of the ground water) often characterised by occasional changes, the changes are fast (~exponential character); e: the border of the breeding site is not linked to vegetation borders but to smaller or larger geomorphological formations. The water coverage is occasional, the change of the size is fast (~exponential character)]

**Joining data.** The primer attribute table of the digital map is shown in Table 3. By the transformation of sample tables a secondary table has been produced which will be linked to the primary attribute table (Table 4). To do this we used the „Join” function of the ArcMap software, which will allow a fully directional function in the use of the program as the table would be the physical part of the primary table.

The table that contains all the recorded data has the same columns and has a plus text-type field for the geographic name of the breeding site. This table is linked to the attribute table with the „Relate” method through the same M1 field of the primary table and the JOIN field of this one. With this method it is possible to connect more rows of this table to one polygon which is the reason for the use of this different linking method. The complete table

of all the recorded data has more rows in the case of repeated samplings therefore the „one-to-one” linking – the „Join” – is not good but the „Relate” one is better.

The Office Word files of the data collecting sheets got unified nomenclature which fits with the M1 field of the primary attribute table. Where more samples are recorded, all of the data sheets are copied together into the one named the M1 field.

Table 3. The primer attribute table of the digital map is produced with the following columns:

Tabela 3. Główna tabela numerycznej mapy oparta na następujących kolumnach:

Field	Function	Type	Length	Form
FID	The software ID for the polygons	Object ID	4	
Shape	Software generated field, shows the polygonal nature of the map element	Polygon		
AREA	Area of the polygons in square metres	Double	16	Number
M1	Serial number of the primary sample, the field used for the joining	Double	16	Number
M2-M12	Serial number of the following samples (in case of repeated sampling)	Double	16	Number
EV 1	Importance of the breeding site in spring	Double	16	Number
EV 2	Importance of the breeding site in summer	Double	16	Number
EV 3	Importance of the breeding site in autumn	Double	16	Number
EV 4	Importance of the breeding site in winter	Double	16	Number
SIZE-CH	The type of surface changes at the breeding site	Double	16	Number
SPECIES	Importance of the species composition from the viewpoint of the biological mosquito control	Double	16	Number
Hyperlink	The relative path pointing to the linked data sheet	Text	15	Text
Centr X	Central X co-ordinate of the patch in HNG [any kind of projection or grid can be used, the HNG is the Hungarian system]	Long	6	Number
Centr Y	Central Y co-ordinate of the patch in HNG	Long	6	Number

Table 4. The columns of the joined table (with optional records in the sampling; “\*”: are arbitrary, names of our project are given)

Tabela 4. Kolumny połączonej tabeli

Field	Function	Type	Length	Form
OID	Automatic ID of the software to the polygons	Long	4	Number
BLT N*	Serial number of the first sampling, the joining field (to the M1 field in the attribute table)	Long	6	Number
INNO KOD*	The code of the samples – from the field notes	Text	9	Code
DATE	Date	Date	8	
MONTH	Month	Long	7	Number
SEASON	Season	Double	10	Number
SETTLEMENT	Settlement (administrational name)	Text	15	Text
HEIGHT M	Height above sea level, m	Long	7	Number
WBODY TYPE	Type of water body	Long	9	Number
WDEPTH AV	Average depth of water	Long	9	Number
W TRANSP	Transparency of water, 5 step scale	Long	7	Number
WATER CH	Type of surface alterations at the breeding site, 5 step scale	Double	12	Number
TREATM	Supposed treatment type, 5 categories	Text	7	Text
CHAR 01	Character	Long	6	Number
PH	pH	Short	4	Number
TEMP C	Temperature	Long	7	Number
PWEED VEG	Pondweed 0/1	Double	11	Number
COVERAGE	Coverage, 5 step scale	Long	7	Number
SHADING	Shading, 5 step scale	Long	6	Number
HAB C	Representing habitat types, according to the NHCS (Fekete et al. 1997)	Text	15	Text
HAB C 1-5	Habitat types in order of importance, according to the NHCS (Fekete et al. 1997)	Text	9	Text
CHT I	I. combined habitat type	Text	9	Text
CHT II	II. combined habitat type	Text	9	Text
CHT III	III. combined habitat type	Text	9	Text
HAB C SU	Surrounding habitats of the breeding site, according to the NHCS (Fekete et al. 1997)	Text	9	Text
H C SU 1-6	Surrounding habitats of the breeding site, one after	Text	9	Text

	one, according to the NHCS (Fekete et al. 1997)			
VEG HYDATO	Hydatophyta vegetation, name of association or species composition	Text	200	Text
VEG HELOPH	Helophyta vegetation, name of association or species composition	Text	254	Text
COLL LARVA	Collected larvae (species/number)	Text	120	Text
LARVA	Larvae	Text	5	Text
PER SPECIES	Number of larvae according to species	Text	7–10	Text

**Visualisation.** The production of the thematic maps for printing and exporting of these maps into graphic files are carried out with the ArcMap software. For every map type a „Template” file is produced which contains the legend and the system of the map sheets. All map sheets are individually exported into JPEG files what makes the visualisation of the maps easy for everyone to read (even without GIS software).

The GIS has a fully functional inquiry capability, and all of the data can be filtered optionally with the actual data being accessed and sorted through any interest (see figs. 1–5). The best data for rearranging are the categories with fix classes (number or text also) therefore the deducted fields have exceptional importance (importance in treatment, combined habitat categories) but for almost all of the data is able to construct useful filter which covers the actual question.

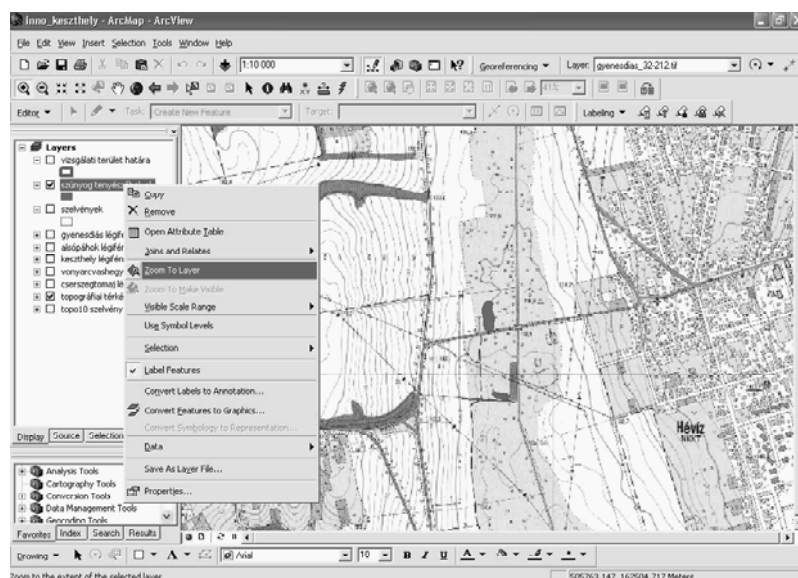


Fig. 1. Map view of the ArcMap and the main functions

Rys. 1. Widok mapy w ArcMap i główne funkcje

The menu and the upper task bar are similar to the conventional Windows softwares and in the second task bar can be found the buttons of the map handling. (4 buttons of the zooming; zooming to the selected element; pan; overview; previous and next view; 3 buttons for selection; selection of map elements; information; filtering; searching of XY co-ordinates; measurements, hyperlink tool). Right clicking on the map layer activates the functions for the handling of the layer. The most important are used for opening the attribute table, handling the joined tables and zooming to the layer (3<sup>rd</sup>-5<sup>th</sup> from top).

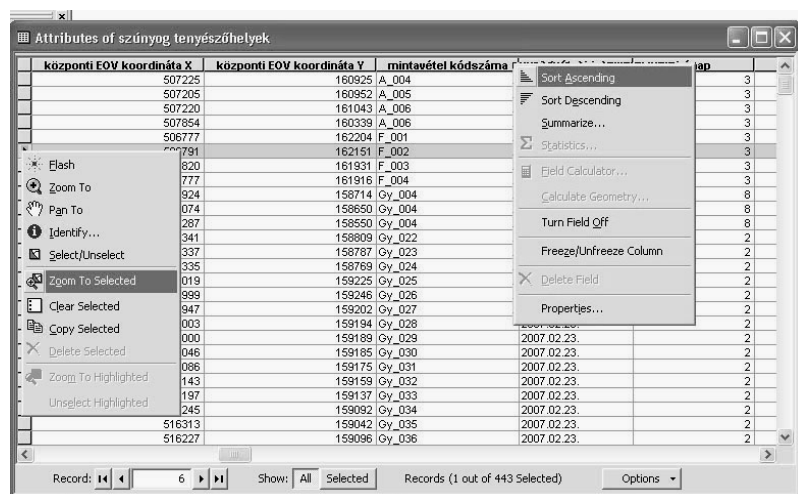


Fig. 2. Attribute table and its handling

Rys. 2. Tabela i jej obróbka

By clicking on the head of the columns we can activate the tools ordering the data and calculations moreover handling the columns. The most simple but very useful function is the ranging of the data. With the use of the „Field Calculator” function it is easy to produce deducted data.

By clicking on the beginning of the rows we can select them and with right click the actual menu can be activated. Very useful is the zooming to the selected element which means we will see in the map view the selected map element or elements at the best zoom ratio (the same function in the active layer can be activated in the map view.)





## DISCUSSION

The presenting method was tested successfully in other areas out of the scope of this research. The results show that the method is effective with the multifunctional mapping of the mosquito breeding sites. The great advantage of the exact vectorised maps produced on the background patterns and using the capabilities of the GIS successfully are that the actualisation can be carried out fast and with less field work than the base mapping. After the basic researches are carried out according to the above methods, such as with use of aerial photographs – taken in advisable seasons (after about three years) for the task – or good quality and well classifiable multi-spectral satellite images, the actualisation of the vectorial map files can be made in characteristically shorter times than the basic researches needs. The practical importance of our results is that the exact geographically patch maps of the mosquito breeding sites make it possible for the detailed planning of the BTI treatments and minimization of the environmental side effects.

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