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Evaluation of habitat features influencing turtle abundance in the Donau-Auen

In Austria the European pond terrapin is considered a critically endangered species and its only autochthonous population can be found in the Lower Austrian part of the Donau-Auen National Park.
In order to develop measures of protection the thesis analyzed the specific needs of this species in the Donau-Auen National Park.

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KOSTBARE NATUR FÜR GENERATIONEN

Evaluation of habitat features influencing turtle abundance in the Donau-Auen National Park

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by

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Abstract

The European pond terrapin is a widely distributed species, which inhabits various habitats. However, in Austria its only autochthonous population can be found in the Lower Austrian part of the Donau-Auen National Park (Grillitsch, Cabela 2001) and it is considered a critically endangered species (Gollmann 2007). In order to develop measures of protection for the European pond terrapin the thesis analyzed the specific needs of this species in the Donau-Auen National Park. The study showed that a high amount of dead wood and a high diversity of macrophytes are essential habitat features for a high abundance of the European pond terrapin. Moreover, the amount of available nutrition seems to be a decisive factor. The used method and the indication of a homing behavior over a longer section of water than the catching area of the fish trap (more than 50 meters) may imply that the findings mainly concern only the feeding grounds of the European pond terrapin. Nevertheless, since nutrition seems to be an important factor, the feeding grounds are an essential area for the European pond terrapin and thus, a representative study area. Therefore, the abundance of dead wood and the diversity of macrophytes as well as the availability of nutrition should be monitored and secured. For re-introduction programs in other areas these habitat features should be considered and, if needed, dead wood should be artificially introduced in the waters.

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List of Abbreviations

CL	carapax length
CW	crapax width
D	Side of the Danube of the dike
E	Water 3 *(Eckartsau)*
e. g.	for example
etc.	et cetera
GIS	geographical information system
HW	head width
i. e.	it est (synonym for that is)
I/3	individuals per 3 minutes (individuals per unit effort)
L	Side of the land of the dike
NP	National Park
O	Water 2 *(Orth)*
pers. com.	personal commentary
PL	plastron length
PW	plastron width
sp.	species (it means that it is a defined species which can however not be identified)
std. dev.	standard deviation
U	Water 1 *(Uferhaus)*
W	Water 4 *(Witzelsdorf)*

1. Introduction

The European pond terrapin (*Emys orbicularis)* is a fresh water turtle, which has a wide distribution range. It occurs in the North African region of the Maghreb to the Iberian peninsula, in South as well as Middle Europe to Asia Minor and the Aral Sea (Fritz 1998; Fritz et al. 2001). With this geographic range it has the largest distribution area of all freshwater turtles living in Europe. Nevertheless, the species is endangered in almost all of its range (Ficetola et al. 2004). There are several reasons for its rareness, for example centuries of usage for food (Gemel 2001; Fritz et al. 2001; Devaux 2000). Although today the catching of turtles is forbidden the populations are still decreasing. One main reason for this is the habitat loss (inter alia Meeske, Poggenburg 2014; Meeske, Mühlenberg 2004; Fritz 2000). Therefore, to protect the species, knowledge about its habitat[1] requirements is needed so that the needed habitat features can be ensured. The importance of habitat protection and knowledge of species needs has already been acknowledged by scientists and was outlined in various articles (inter alia Cadi et al. 2008; Rössler 2000b; Cadi et al. 2004).

To analyze the needs of the European pond terrapin an area with an intact environment and a big population size is recommendable. An area of interest in this regard, is the Donau-Auen National Park (NP). Since habitat destruction occurs inter alia through river regulations which reduces the natural dynamic of a river (Schindler, Reckendorfer 2006), an area with a nearly intact floodplain environment and low human impact can be seen as favourable for the European pond terrapin. Maybe this is one reason, that the only known autochthonous population in Austria is located in the Lower Austrian part of the Donau-Auen National Park and parts of the March (Grillitsch, Cabela 2001). However, also here possible threats occur by sedimentation of waters and possible accumulation of toxics in waters caused by intensive agriculture around the Donau-Auen National Park which could have long time impacts on the population of the European pond terrapin (Broggi, Grillitsch 2012; Schindler 2012; Schindler, Reckendorfer 2006). Moreover, the development of the habitat could be contrary to the needs of the European pond terrapin.

[1] Habitat is by definition a “type of place where an animal normally lives or, more specifically, the collection of resources and conditions necessary for its occupancy” (Garshelis 2000). However, in this thesis habitat refers to a “set of specific environmental features” (Garshelis 2000) that a species views as suitable.

Despite those threats, the population is currently estimated at around 1,000-1,500 individuals (pers. com. Maria Schindler), which seems sufficient to analyze the needs of this endangered species. There are already protection measures taken, in order to support this important population within the Donau-Auen National Park. Within the protection program “Europäische Sumpfschildkröte” which was initiated in 1997 the clutches of the European pond terrapin are protected, education about the species is done (Figure 1) and data is collected (Schindler 2008).

Figure 1 European pond terrapins on the Schlossinsel in the National Park Centrum, where they are presented to the public in order to inform people about this rare species.

However, despite this relative big population size and the efforts of protection, the European pond terrapin is listed in the Roten Liste Österreichs as “critically endangered” (Gollmann 2007). Therefore, knowledge about its specific needs should be generated in order to develop suitable protection programs for this endangered species.

1.1. State of knowledge and research gap

As outlined above *Emys orbicularis* is a species which is widely distributed and can live in a wide range of different habitat structures (Fritz et al. 2001). For example, the terrapin normally living in fresh water lives on Corsica also in brackish water (Rogner 2009). There are different factors which are considered to be relevant for the habitat of the European pond terrapin as places for sunbathes, aquatic vegetation or muddy ground (Rogner 2009; Lebboroni, Chelazzi 1991). There are already studies about relevant habitat features which are favourable to the European pond terrapin existing (e. g. Cadi et al. 2008; Ficetola et al. 2004).

Also in the Donau-Auen National Park studies about the habitat features that might be relevant for the European pond terrapin were done. Rössler (2000b) did a survey about the habitat of *Emys orbicularis* in the Donau-Auen National Park and about the influence of specific features on the age distribution by describing the habitat of two waters and doing sight as well as trap surveys of terrapins (Rössler 2000b). However, only two waters (i. e. one separated by the dike) were studied and just few habitat features described (vegetation, dead wood and vegetation on shoreline). Schindler, Reckendorfer (2006) also did a survey about the influence of specific habitat features (i. e. maximum water depth, connectivity to the river dynamics and solar radiation) on the abundance of the European pond terrapin (Schindler, Reckendorfer 2006). However, the influence of water temperature and availability of nutrition on the abundance was, for example, not studied (Schindler 2012). Moreover, the data of the abundances was based on sight surveys which can lead to an underestimation (Kotenko 2000).

In conclusion, there are studies about the influence of habitat features in the Donau-Auen National Park existing. However, since the studies analyzed just few features and the methods used for the estimation of abundances were mostly sight based, there is still a lack of well-founded knowledge about the specific features a habitat has to fulfil in the Donau-Auen National Park in order to be suitable for the local European pond terrapin population.

1.2. Goal and objectives

Therefore, the goal of this thesis is to evaluate habitat features of waters that are thought to be European pond terrapin friendly and to analyze their influence on the abundance. This is done, in order to determine the needed habitat features of *Emys orbicularis* in the Donau-Auen National Park. This knowledge will then help to protect the habitat features, which are essential for the suitability of the habitat for this endangered species.

In order to reach these goals the following question has to be answered: Are there habitat features that have an influence on the abundance of *Emys orbicularis* and thus, are essential for the suitability of the habitat for the European pond terrapin in the Donau-Auen National Park?

2. Methods

To answer the question, a field study was conducted in the Donau-Auen National Park, where the European pond terrapin was caught and habitat features mapped.

2.1. Study area

The Donau-Auen National Park is located between the two capital cities Vienna and Bratislava. The Danube is accompanied by floodplain forests from Vienna to the confluence of the March, which is the border river to Slovakia, on a distance from about 38 kilometres (Schindler 2008; Manzano 2000). This area is a refuge for a lot of rare species of flora and fauna, like e. g. the kingfisher, the beaver and the European pond terrapin. Therefore, the main part of this area – around 9,300 hectares – was declared a National Park in 1996. Of this area around 20% are aquatic habitats that are, despite the Danube itself, no regularly flowing waters (Schindler 2008; Manzano 2000). Especially at the north side of the Danube the floodplain forest is characterised by stagnant side and old channels of the Danube. These waters are the main habitat of the European pond terrapin in Austria (Rössler 2000b; Schindler, Reckendorfer 2006; Schindler 2008) (Figure 2). One reason for this is the requirement of high temperatures of this species in this latitude (Grillitsch, Cabela 2001).

Figure 2 A typical habitat of the European pond terrapin in the Donau-Auen National Park – the old channel close to Witzelsdorf (Water 4).

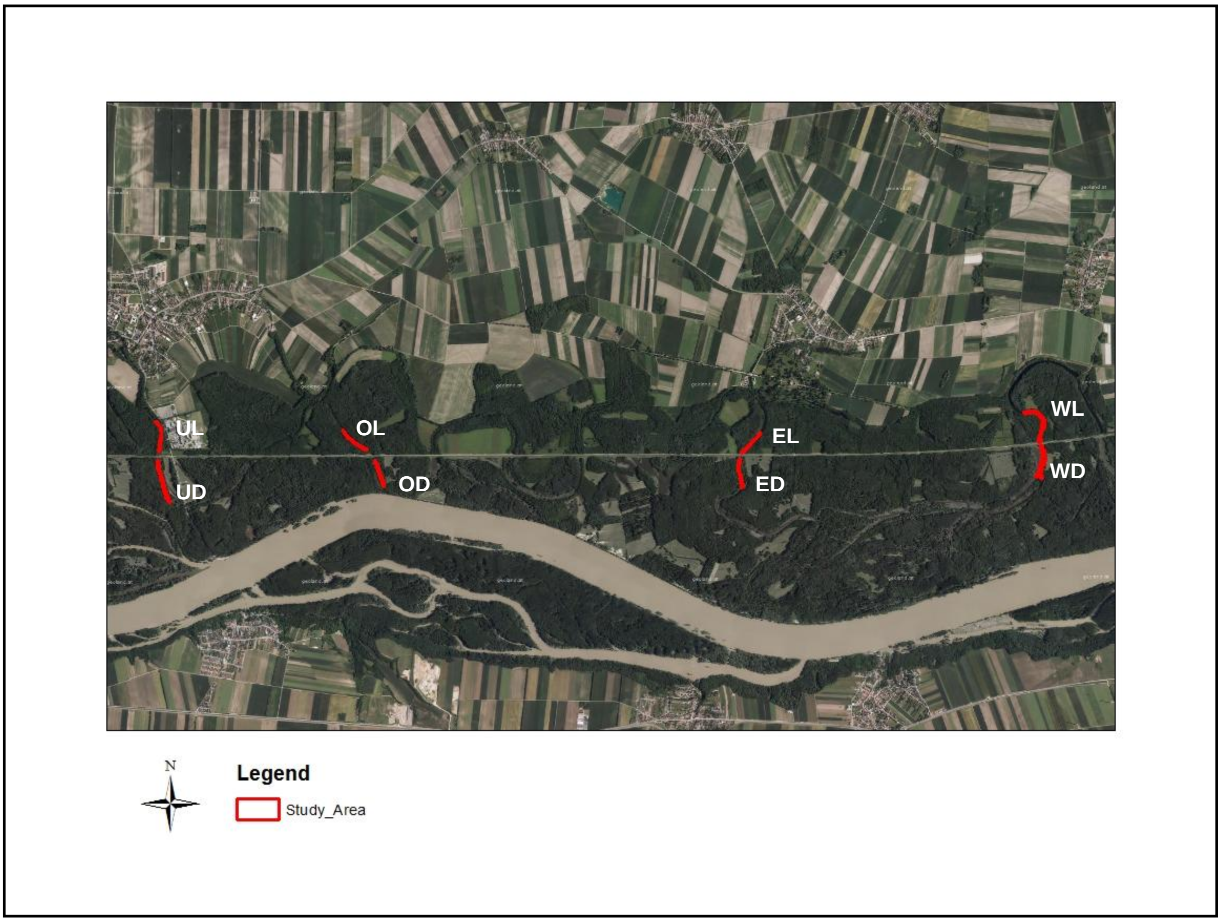

Figure 3 The studied waters in the Donau-Auen National Park (Datenquelle: basemap.at).

The studied waters are located in the Lower Austrian part of the Donau-Auen National Park since here the autochthonous population is located (Grillitsch, Cabela 2001). They are old channels of the Danube which are not or only during a high flood connected to the Danube. Four waters close to the dike Marchfeldschutzdamm in the Donau-Auen National Park were chosen and the first 300 meters on the north and the south side of the dike studied. In the following, these waters are called Water 1 (Uferhaus), Water 2 (Orth), Water 3 (Eckartsau) and Water 4 (Witzelsdorf) since there are no common names for the waters they were numbered and named after the closest village or street. Moreover, these waters are separated in the two studied parts: south of the dike (side of the Danube = D) and north of the dike (side of the land = L) (Table 1). Their position is illustrated in Figure 3. In the following, a "water" will refer to a separated part of the water studied (D or L), so that there are eight separated waters.

Table 1 Naming of the studied waters and there abbreviations.

Name of Water	Side of dike	Abbreviation
Water 1 (Uferhaus)	Side of the Danube	UD
Water 1 (Uferhaus)	Side of the land	UL
Water 2 (Orth)	Side of the Danube	OD
Water 2 (Orth)	Side of the land	OL
Water 3 (Eckartsau)	Side of the Danube	ED
Water 3 (Eckartsau)	Side of the land	EL
Water 4 (Witzelsdorf)	Side of the Danube	WD
Water 4 (Witzelsdorf)	Side of the land	WL

The selection of waters was done based on four criteria:

1. Waters which are located in the Lower Austrian part of the Donau-Auen National Park,
2. Waters were the European pond terrapin occurs (was based on the perception of Maria Schindler[2]),
3. Waters which contained in August to October 2016 on both sides of the dike (D and L) water
4. and waters were no fishermen are fishing.

[2] Maria Schindler is the head of the protection program "Europäische Sumpfschildkröte" in the Donau-Auen National Park and thus, has a good perception about the occurrence of turtles in the different waters.

These requirements were met by eight waters (Figure 3).

2.2. Method for determining abundances of the European pond terrapin

In these waters the habitat features needed to be mapped and abundances determined. As mentioned in Garshelis (2000) the density in an habitat of a particular species can be seen as an indicator for the suitability of the habitat for this species (Garshelis 2000). Therefore, the abundance in specific habitat sectors (i. e. the density) can be an important tool to evaluate the suitability of different habitat features. Thus, the European pond terrapin needed to be caught in order to calculate the densities.

2.2.1. Method of catching of the European pond terrapin

In the eight waters fish traps with a fence to lead were positioned (Figure 4). This was done for each of the waters on the side of the Danube and on the side of the land from the dike with 12 fish traps[3] (each 50 meters on both sides) (Figure 6). So for each side of the dike 300 meters of the water were analyzed. This approach was based on the methods outlined in Schindler (2012) and chosen due to the fact that different methods of observation (sight studies) can lead to different results and thus, to wrong estimated abundances (Kotenko 2000). Therefore, a mark-recapture analysis with help of fish traps was chosen.

[3] In the first water EL 16 fish traps were positioned. However, due to a too high time effort including a high stress factor for the turtles the number of fish traps was reduced to 12. To have comparable results the turtles caught with the last four fish traps in EL were not included in the data used for this thesis.

Figure 4 A used fish trap with the fence to lead (can be seen in the right high corner). The pole is used to fix the end of the trap in order to enable the turtle to breath (Figure 5).

For a mark-recapture analysis with help of the Lincoln-Petersen-Index two catching events have to be done shortly after each other so that a closed population can be assumed[4] (Donnelly, Guyer 1994). Therefore, the fish traps were positioned on the first day. On the second day they were checked in the morning and on the third day they were checked again and then removed. They were checked in the morning and positioned during the day since the European pond terrapin is searching in the evening and during the night for food at the shoreline (Mosimann 2002a in Schindler 2012) and thus, gets caught in the evening with a high probability. Moreover, the European pond terrapins may avoid any obstacles (i.e. fence to lead) during their search for food by swimming in deeper water (Schindler 2012) and therefore, they may swim in the direction of the trap and get caught.

[4] There are five assumptions which have to be fulfilled for a mark-recapture analysis if the Lincoln-Petersen-Index shall be used. One is the mentioned closed population (no birth, death, immigration or emigration) (Donnelly, Guyer 1994). This is fulfilled by the shortly after each other done catches. For the other four assumptions see Appendix I.

Figure 5 A caught turtle in a fish trap which uses the fixed end of the trap to breath.

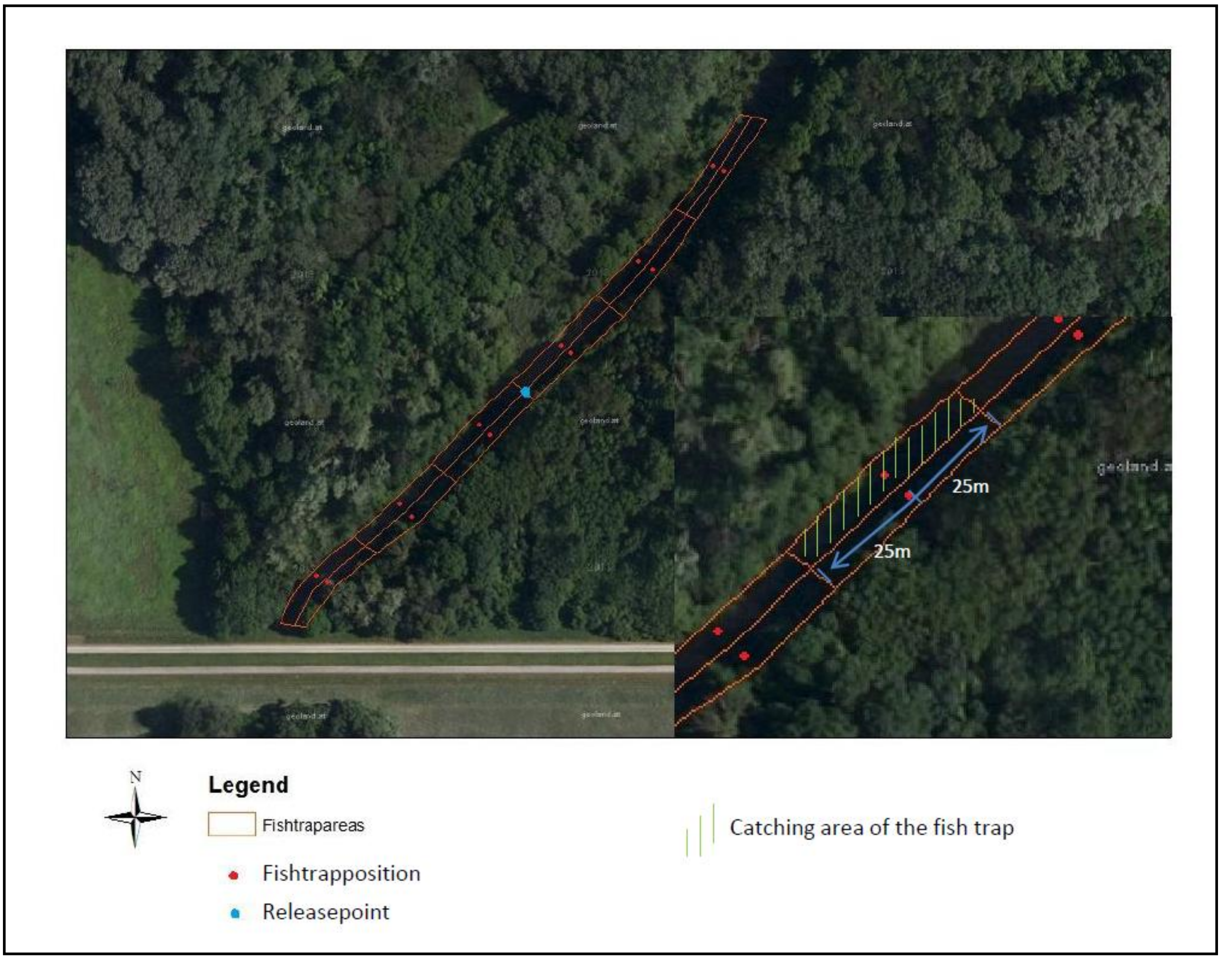

Figure 6 Illustration of the positioning of the traps, their catchment area and release point (Datenquelle: basemap.at).

The catching was done from end of August until the end of September since in this time there is the activity period (March-October) of the European pond terrapin in Austria (Rössler 2000b) and they are not disturbed during oviposition (May-July in Austria) and mating (April-May in Austria) (Rössler 1998).

The caught terrapins were measured[5], sex and age determined, weighted and pictures taken[6]. Moreover, they were marked by marginal notching (after Stubbs et al. 1984; Rössler 1998). This method is commonly used in the Donau-Auen National Park. The determination of the sex was done by sexual characteristics (i. e. colour of iris, concavity of plastron and the position of the opening of the cloaca) as outlined in Fritz et al. (2001). The age was determined by recorded age parameters (morphology) (Appendix II) and an age determination table developed after Schneeweiss (2004) (Appendix III). Moreover, the number of the fish trap was noted in order to enable an allocation of a specific European pond terrapin to a specific position.[7][8] After the collection of all data, the turtles were released in the middle of the study area (Figure 6 and Figure 7) in order to enable a natural distribution of the turtles in the water after catching.

Figure 7 European pond terrapin after its release in the water WL.

[5] The carapax length (CL), the plastron length (PL), the crapax width (CW), the plastron width (PW) and the height as well as the head width (HW) were measured with a caliper. Therefore, always the straight line was measured.
[6] Furthermore, DNA-samples were taken. However, the results of the analysis could not be included in this thesis.
[7] The fish trap position was marked with help of a GPS devise, so the location of the turtle could be recorded.
[8] For the data sheet including the marking code and the age parameters see Appendix II.

2.2.2. Method for calculation of abundances of turtles

After catching the turtles, the abundances needed to be calculated. For the evaluation of the suitability of the habitat features in this study mainly the abundances (i. e. densities) in the different catching areas of the fish traps are used. However, no densities in common sense were calculated since the wideness of the water changes strongly with different water heights. Therefore, the measured area of the water body would be just a snapshot. However, since the used catching method is based on the assumption that the turtles of the whole section of the water (catching area of the fish trap see Figure 6) are caught with the fish traps which are positioned just at the edge of the water, the length of the water section is used as density measure.

Therefore, for the calculation of the abundance of the catching area of each trap (50 meter, one side), the total number of the caught turtles in this fish trap was seen as minimum abundance (i. e. turtles per 50 meter shoreline, one side) since no recaptures were done and the population cannot be seen as closed.

However, for three of the analyzed habitat features (i. e. temperature of the water, pH of the water and nutrition (macro-zoobenthos)) the abundances of the whole water section (300 meter, both sides) were needed. For this calculation of the abundances (i. e. turtles per 300 meter shoreline, both sides) the Lincoln-Petersen-Index was used (Donnelly, Guyer 1994):

$$\mathrm{N(x)} = \frac{r * n}{m} \quad (1)$$

N = population size in the water section

r = total number of turtles caught at the first day

n = total number of turtles caught at the second day

m = total number of recaptures at the second day

In the cases with a low recapture rate (≤ 10) Bailey`s modification was used (Donnelly, Guyer 1994):

$$N(v) = \frac{r * (n+1)}{(m+1)} \quad (2)$$

The standard error of *N* (v) was calculated after Bailey`s formula (Donnelly, Guyer 1994):

$$SE = \left[\frac{r^2 * (n+1) * (n-m)}{(m+1)^2 * (m+2)}\right]^{1/2} \quad (3)$$

In two cases no recaptures were caught, there the total number of all caught turtles was the minimum abundance of the water (300 meter long, both sides) and no standard error could be calculated. Also for the two waters with more than 10 recaptures the formula 3 could not be used to calculate the standard error.

2.3. Method for choosing and estimating habitat features

After calculating the abundances, the habitat features that are considered to be European pond terrapin friendly needed to be chosen.

2.3.1. Choosing of habitat features

The European pond terrapin needs a habitat which meets all its needs (i. e. nutrition, reproduction (places for oviposition), thermoregulation (sunbathes), hibernation and protection (hiding places)) (Rössler 1998). Therefore, when looking for relevant habitat features one has to search for the features which can meet this requirements, which may be convenient and those which are adverse to its needs, i. e. disturbances. The habitat features that may be relevant for a European pond terrapin friendly habitat were identified by literature research and discussions with Maria Schindler. The habitat features found are illustrated in Table 2.

Table 2 Identified habitat features which seem to be relevant for the suitability of the water for the European pond terrapin.

Habitat feature	Literature mentioned in	Why is it important
Degree of softness of the ground	(Dall'Antonia et al. 2001; Rössler 2000b; Kotenko 2004; Thienpont et al. 2004)	Hibernate in the mud of the ground of the water
Degree of vegetation of the shoreline	(Rogner 2009; Grillitsch, Cabela 2001; Lebboroni, Chelazzi 1991)	Can be inter alia used as a possibility to hide
Abundance of dead wood	(Mosimann 2002b; Meeske, Poggenburg 2014; Capula et al. 1994; Ficetola et al. 2004; Rössler 1998, 2000b)	Used for basking, preferred in contrast to other possible places for sunbathing
Steepness of the shoreline above water	(Andreas 2000 and Meeske 2000 in Ficetola et al. 2004)	Better access to terrestrial habitats

Depth at the middle of the water	(Zuffi 2000; Schindler, Reckendorfer 2006; Rogner 2009)	Prefer shallow waters since they are inter alia warmer
Steepness of the shoreline below water	Not directly mentioned in the literature, indirectly in (Mosimann 2002a in Schindler 2012)	Just indirectly, since turtles seem to search for food in shallow areas which speaks for a flat shoreline
Abundance of macrophytes	(Cadi et al. 2004; Ayres et al. 2010; Ottonello et al. 2005; Ficetola, Bernardi 2006; Arvy, Servan 1998; Broggi, Grillitsch 2012; Rössler 2000b; Kotenko 2004; Thienpont et al. 2004)	As food source direct and indirect by harbouring inter alia insect larvae and snails
Diversity of macrophytes	(Ficetola, Bernardi 2006; Ottonello et al. 2005; Ayres et al. 2010; Cadi et al. 2004; Rössler 2000b)	As food source direct and indirect by harbouring inter alia insect larvae and snails
Distance to nesting place	(Servan 2000; Mitrus 2006; Rogner 2009)	Needs in the surroundings a suitable nesting place
External disturbances	(Gemel 2001; Servan 2000; Rössler 2000a)	Disturbances by inter alia walkers which results in stress for the turtles
Temperature of the water	(Rogner 2009; Rössler 2000b; Grillitsch, Cabela 2001)	Prefer warm waters
pH of the water	No literature found	Could have a preference towards a specific pH value
Nutrition (macro-zoobenthos)	(Gemel 2001; Servan 2000; Rogner 2009)	Needs a sufficient amount of macrozoobenthos

2.3.2. Estimation of habitat features

The chosen habitat features have to be mapped. They were recorded with the parameters and study areas illustrated in Figure 8 and Figure 9. Each parameter was recorded with different methods and with help of five classes (Table 3).

The mapping of the macrophytes was mainly done by Aaron Griesbacher. I only supported him. In a five meter radius around the fish traps the vegetation of macrophytes was recorded with its frequency distribution. Additionally to this mapping, an overall species list of the waters was conducted. Furthermore, it has to be noted that there exists a variety of definitions of macrophytes since there cannot be a clear distinction between “terrestial” and “aquatic” plants (Wiegleb 1991). However, in this thesis macrophytes are defined as plants that can be seen without a microscope and which are situated in the study area’s water or close to the water (after Wiegleb 1991; Baart 2005). Plants that grow in the shore area and are connected to the water (helophytes) are not macrophytes in the narrower sense. Nevertheless, for the thesis the structure in and outside of the water is an important factor which may influence the abundance of the European pond terrapin. Thus, helophytes with a strong influence on the structure of the water (e.g. *Phragmites australis*) were mapped as well. Moreover, plants that grow to a similar amount in the water and at land (amphiphytes) were included as well, even if they were in the study area just present at the shore area. And of course plants that always have a connection to water (hydrophytes) were recorded (Wiegleb 1991).

Table 3 Methods used for recording the identified habitat features and the used classes.

Habitat feature	Method	Classes		
Degree of softness of the ground	A paddle was several times put into the ground and so the depth of the soft layer of the ground was measured in a 5 meter radius around the fish trap position	1	very hard	< 0.5 cm
		2	hard	0.5-2 cm
		3	middle hard	2.1-5 cm
		4	soft	5.1-10 cm
		5	very soft	> 10 cm
Degree of vegetation of the shoreline	The ratio coverage of the vegetation of the shoreline was estimated at a ten meter long and 5 meter wide strip of the shoreline at the position of the fish trap	1	no vegetation	<5%
		2	little vegetation	5-25%
		3	middle vegetation	26-50%
		4	a lot vegetation	51-75%
		5	very much vegetation	76-100%
Abundance of dead wood	An estimate of quantities was done, the number of dead wood was counted whereby the wood needed to be in the water and wider than 10 cm so that turtles can use it for sunbathes, to include the proportion of the wood it was counted double if it was wider than 20 cm or longer than 5 meters, from each fish trap a in both directions 25 meter long and to the middle of the water wide strip was studied	1	no dead wood	0
		2	few dead wood	1-5
		3	Middle amount of dead wood	6-10
		4	a lot dead wood	11-15
		5	very much dead wood	>15
Steepness of the shoreline above water	The gradient of the shoreline above water was estimated at a ten meter long and 5 meter wide strip of the shoreline at the position of the fish trap	1	really flat shoreline	< 10°
		2	flat shoreline	10-20°
		3	middle flat shoreline	21-30°
		4	steep shoreline	31-40°
		5	really steep shoreline	>40°
Depth at the middle of the water	The depth was measured at the middle of the water between each fish trap pair	1	really shallow water	0-30 cm
		2	shallow water	31-60 cm
		3	middle deep water	61-90cm
		4	deep water	91-120 cm
		5	really deep water	>120 cm

Steepness of the shoreline below water	The depth was measured at a distance from 0.5 m and 1 m from the shore at the position of each trap, than the depth of 1 m was subtracted by the depth of 0.5 m	1	really flat shoreline	0-2 cm
		2	flat shoreline	3-5 cm
		3	middle flat shoreline	6-8 cm
		4	steep shoreline	9-11 cm
		5	really steep shoreline	>11 cm
Abundance of macrophytes	The cover ratio of the macrophytes was estimated in a 5 meter radius around the fish trap position. If the water was narrow and homogenous it was mapped for opposite fish traps as one point.	1	very low abundance	0-20 %
		2	low abundance	21-40 %
		3	middle high abundance	41-60 %
		4	high abundance	61-80 %
		5	very high abundance	81-100 %
Diversity of macrophytes	The number of macrophyte species respectively genus or families (if a determination of the species was not possible) was counted in a 5 meter radius around the fish trap position. If the water was narrow and homogenous it was mapped for opposite fish traps as one point.	1	very low diversity	0-3
		2	low diversity	4-6
		3	middle high diversity	7-9
		4	high diversity	10-12
		5	very high diversity	>12
Distance to nesting place	The European pond terrapin lays its eggs in the Donau-Auen National Park mainly on the dike (pers. com. Maria Schindler), therefore, the distance from each trap to the dike was calculated with help of a geographical information system (GIS)	1	very short distance	0-50 m
		2	short distance	50-100 m
		3	middle long distance	100-150 m
		4	long distance	150-200 m
		5	very long distance	>200 m
External disturbances	External disturbances are mainly trough human activities (loud walkers, walkers with dogs etc.), therefore, the distance from each trap to the closest path was calculated with help of GIS	1	very high disturbance	0-50 m
		2	high disturbance	50-100 m
		3	middle high disturbance	100-150 m
		4	low disturbance	150-200 m
		5	very low disturbance	>200 m
Temperature of the water	With help of 22 data loggers and Hoboware the temperatures in the eight waters were measured and illustrated, the data loggers were positioned on the east side of the water at 50 m, 100 m and 150 m from the dike, and in a depth of 30 cm, if the water was deep enough, otherwise it was measured close to the bottom, in two waters just two data logger could be positioned due to the limited number, they were put in waters which seemed to be evenly structured, however the measured temperature is just a snapshot of the autumns temperatures of the water and can be seen only as a relative measure	1	cold water	<12 °C
		2	middle warm water	12-12.5 °C
		3	warm water	12.5-13 °C
		4	very warm water	13-13.5 °C
		5	hot water	>13.5 °C
pH of the water	A empty 0.5 l bottle was put ca. 30 cm underwater and opened and then closed again, the water was analysed of its pH value with help of test strips	1	neutral	<7,2
		2	little alcaline	7.2-7.6
		3	middle alcaline	7.6-8
		4	alcaline	8
		5	very alcaline	>8

Nutrition (macro-zoobenthos)	Three minutes long the macro-zoobenthos was caught with help of a long-handed landing net at three different points in the waters (always east side, 25 m, 125 m and 225 m from the dike), however, this can not show the abundance of the macrozoobenthos but a relative value to compare the waters	1	very few nutrition	<1 Individuals / 3 minutes (I/3)
		2	few nutrition	1-5 I/3
		3	middle amount of nutrition	6-10 I/3
		4	a lot nutrition	11-15 I/3
		5	very much nutrition	>15 I/3

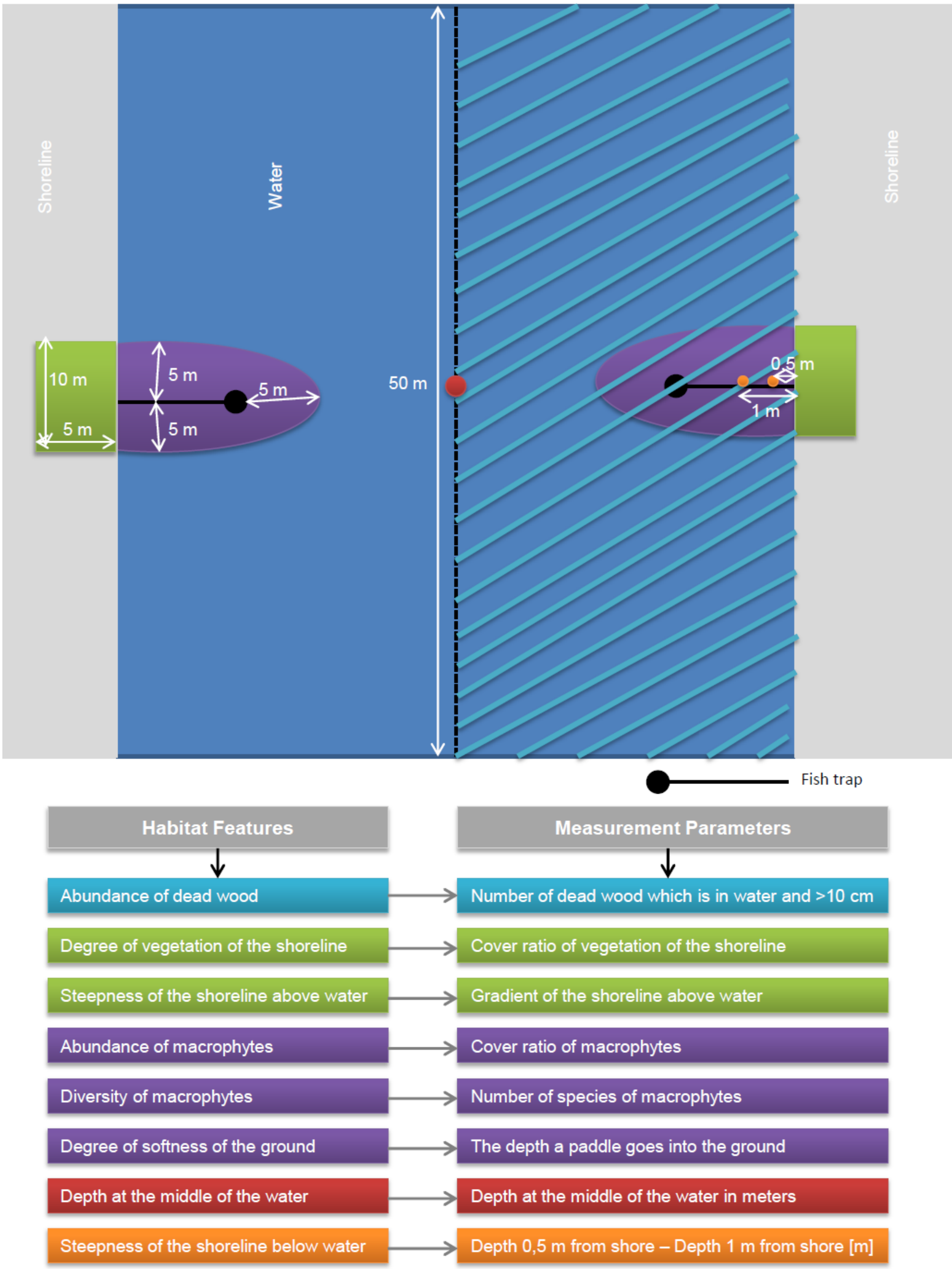

Figure 8 Study area and parameters of habitat features (1).

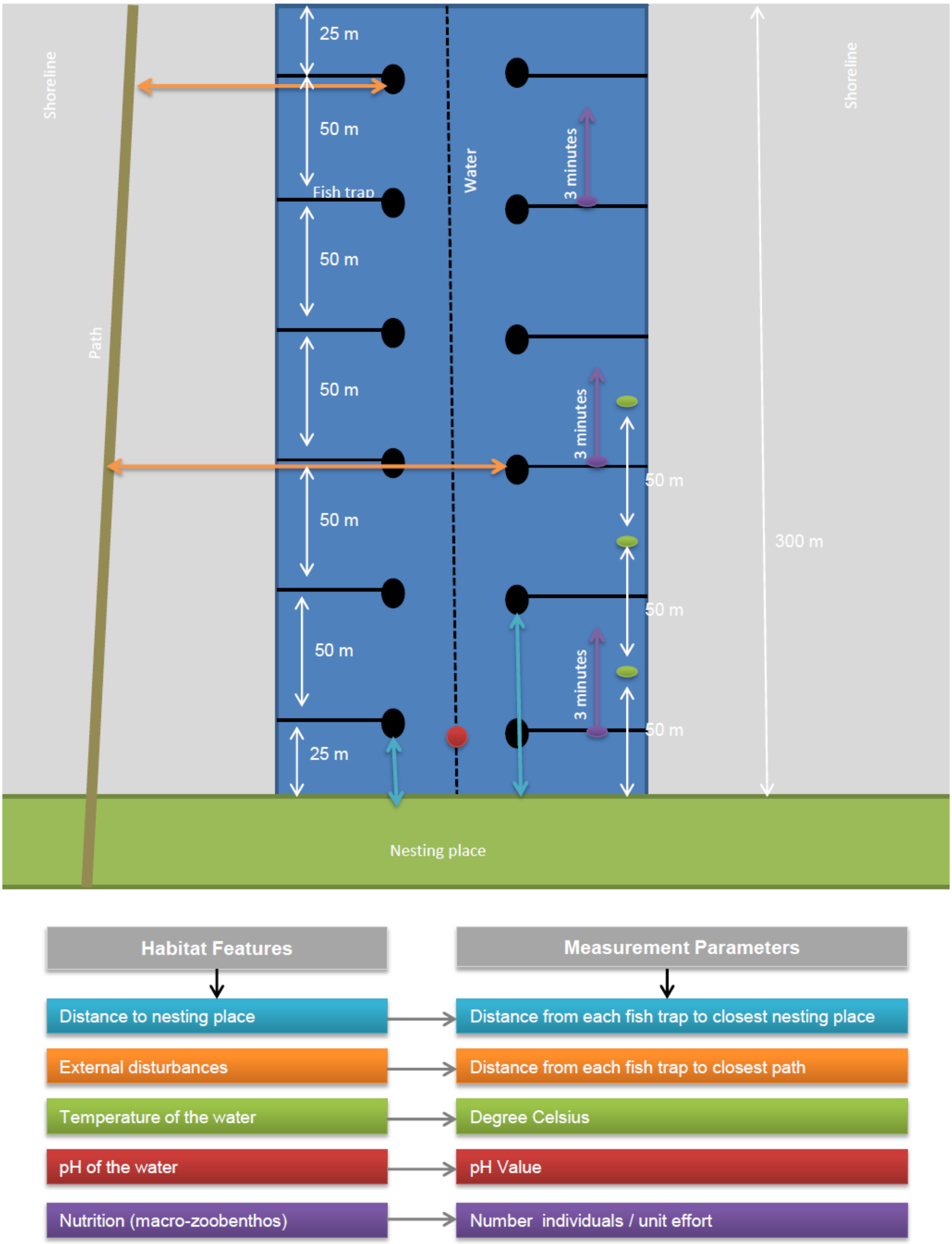

Figure 9 Study area and parameters of habitat features (2).

2.4. Method for evaluating of habitat features influencing abundances of turtles

After mapping the habitat features and determining the abundances, both parameters needed to be correlated. The statistics were created with the program Statistica 13.2. First, it was checked with help of the Shapiro-Wilk test, whether the abundance is normally distributed. Since it was not normally distributed a non-parametric test, the Kruskal-Wallis test, was used to test significance of differences between the different categories of a habitat feature. Moreover, box plots were created and described. The visualization of the differences of the habitat features (i. e. heterogeneity of the water) and abundances was done with help of the programme ArcGis 10.4.

3. Description of the habitat features of the studied waters

After describing the used methods, an impression of the habitat and its features in the different studied waters is given to be able to evaluate its suitability for the European pond terrapin.

The waters are for the most parts on both sides surrounded by floodplain forest, which casts shadows on some parts of the water. Moreover, they are all stagnant waters and have a similar high entering groundwater volume. They show similar geochemical values and are based on the water measurements classified as not very nutritious (pers. com. Prof. Dr. Thomas Hein). However, the studied waters have different habitat features that will be outlined below. It should be noted that this descriptions are for the whole water and are the results of the average of the observations made in the single sections (fish trap areas) of the water (for them see Appendix V). Thus, they do not represent the heterogeneity of the waters. To do so, the variation in the different habitat features was illustrated for each of the water in ArcGIS including the abundances (see Appendix VI).

3.1. Water UD

In the study area of UD 13 species of macrophytes were found: sedges (*Carex sp*.), rigid hornwort (*Ceratophyllum demersum*), Canadian Waterweed (*Elodea canadensis*), frogbit (*Hydrocharis morsus ranae*), common duckweed (*Lemna minor),* star duckweed *(Lemna trisulca),* twopenny thot *(Lysimachia nummularia),* whorl-leaf watermilfoil *(Myriophyllum verticillatum),* watercress *(Nasturtium officinale),* yellow water-lily *(Nuphar lutea),* water knotweed *(Polygonum amphibium),* common duckmeat (*Spirodela polyrhiza)* and grasses (*Poaceae).* These results show a low diversity of macrophytes, which have a very low cover ratio in the water.

UD has a middle thick layer of digested sludge. Therefore, the ground of the water is middle hard. The shoreline is steep below and above water and covered by no vegetation. However, there is a middle amount of dead wood in the water. It is a deep water (91-120 cm in the middle), has a pH of 7.6-8 and provides a relative high amount of nutrition. The average of all temperatures measured is 13.530 °C and thus, the water is, compared to the other waters, a hot water.

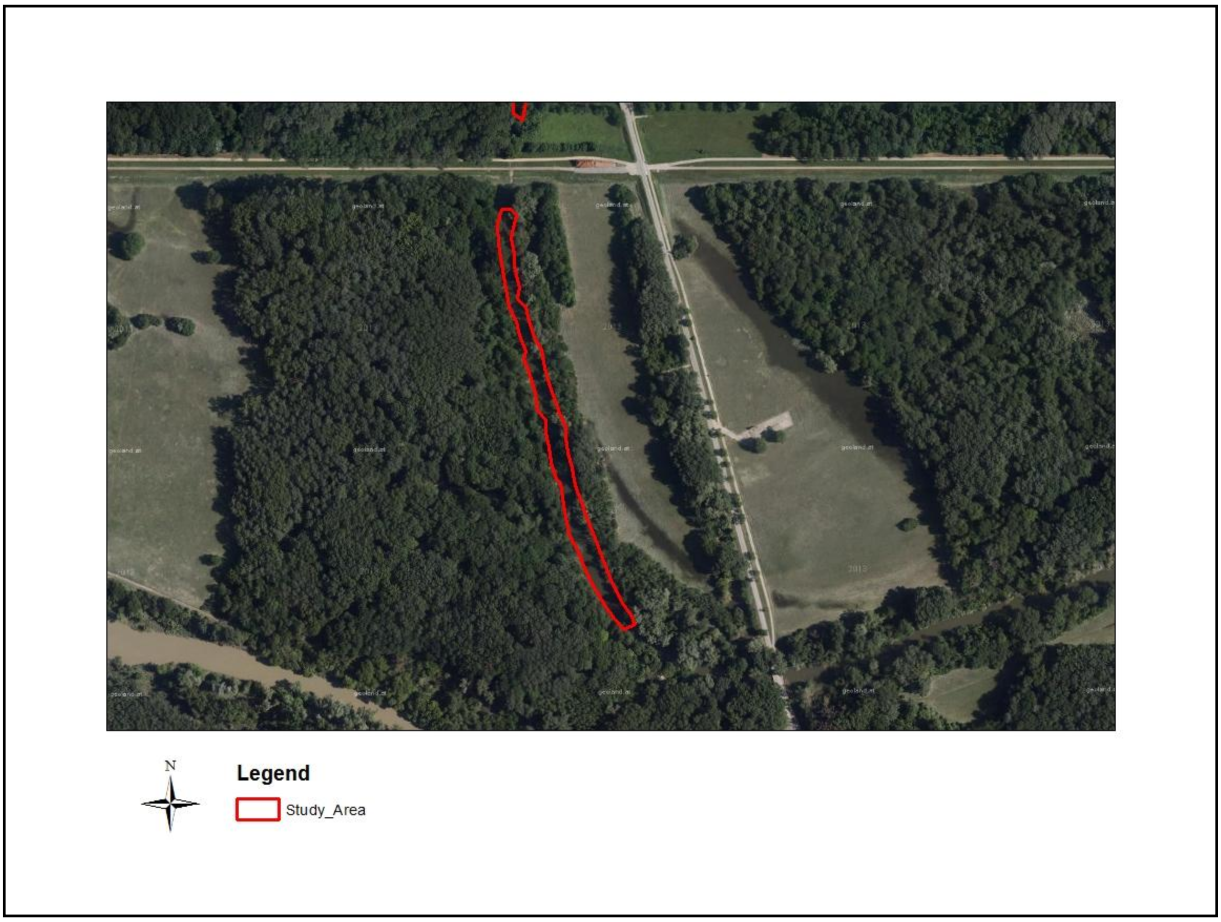

Figure 10 Study area and surrounding habitat of the water UD (Datenquelle: basemap.at).

Figure 11 The habitat of the water UD.

The distance to the next potential nesting place is long and the external disturbances are very high. For the structure of the surrounding areas see Figure 10 and for a typical impression of the habitat see Figure 11.

3.2. Water UL

Also, in UL 13 species of macrophytes were found. However, they vary from the species recorded in UD. Sedges (*Carex sp.*), rigid hornwort (*Ceratophyllum demersum*), frogbit (*Hydrocharis morsus-ranae*), yellow iris (*Iris pseudacorus*), common duckweed (*Lemna minor*), star duckweed (*Lemna trisulca*), twopenny thot (*Lysimachia nummularia*), whorl-leaf watermilfoil (*Myriophyllum verticillatum*), watercress (*Nasturtium officinale*), common reed (*Phragmites australis*), Water-pepper (*Polygonum hydropiper*), common duckmeat (*Spirodela polyrhiza*) and aquatic bladderwort (*Utricularia australis*) were found in UL. This results in a middle high diversity and a high abundance of macrophytes as can be seen in Figure 13.

The amount of disturbance is very high, which can be seen in Figure 12, due to the road that is close to the water. Moreover, the distance to a nesting place is long. However, the ground of the water is very soft. There is a little coverage ratio of vegetation on the shoreline. The shoreline is flat above and steep below water. UL is a relatively shallow water with a middle amount of dead wood.

The average of all temperatures measured is 12.296 °C. Therefore, UL is relative to the other waters a middle warm water with a pH of 8 and a lot of nutrition.

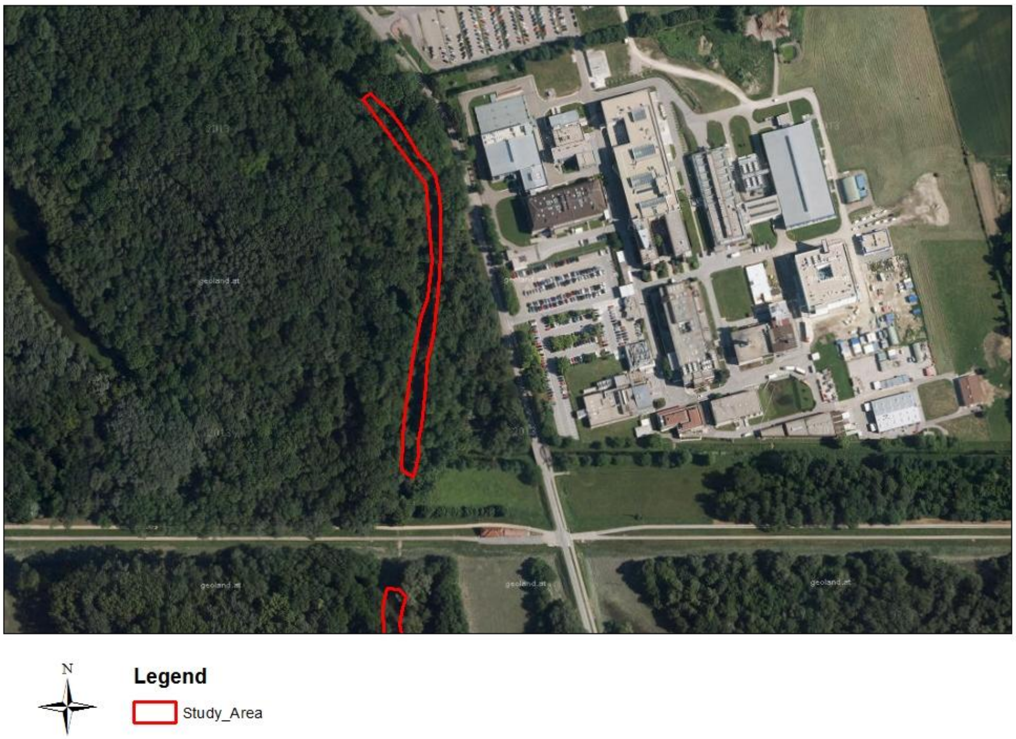

Figure 12 Study area and surrounding habitat of the water UL (Datenquelle: basemap.at).

Figure 13 The habitat of the water UL.

3.3. Water OD

14 different species macrophytes were found in OD: European water-plantain (*Alisma plantago aquatic*), sedges (*Carex sp*.), rigid hornwort (*Ceratophyllum demersum*), charophyte green algae (*Chara sp*.), western waterweed (*Elodea nutalli*), yellow iris (*Iris pseudacorus*), common duckweed (*Lemna minor*), water mint (*Mentha aquatica*), brittle waternymph (*Najas minor*), common reed (*Phragmites australis*), grasses (*Poaceae),* knotweed (*Polygonum mite*), curled pondweed (*Potamogeton crispus*) and common duckmeat (*Spirodela polyrhiza*). The diversity of macrophytes was thus middle and the abundance high.

OD is a water with a middle hard ground, a very high coverage of vegetation on the shoreline and a middle flat shoreline above as well as below water. There is nearly no dead wood for sunbathing of the turtles available. It is a relative shallow water (31-60 cm in the middle) and it is, compared to the other studied waters, a very warm water since the average of all temperatures measured is 13.076 °C. The water has a pH of 7.6-8 and a high amount of available nutrition. The disturbances by humans are very high and the distance to the next nesting place is long.

An image of the surrounding habitat of OD can be seen in Figure 14 and of a typical habitat in Figure 15.

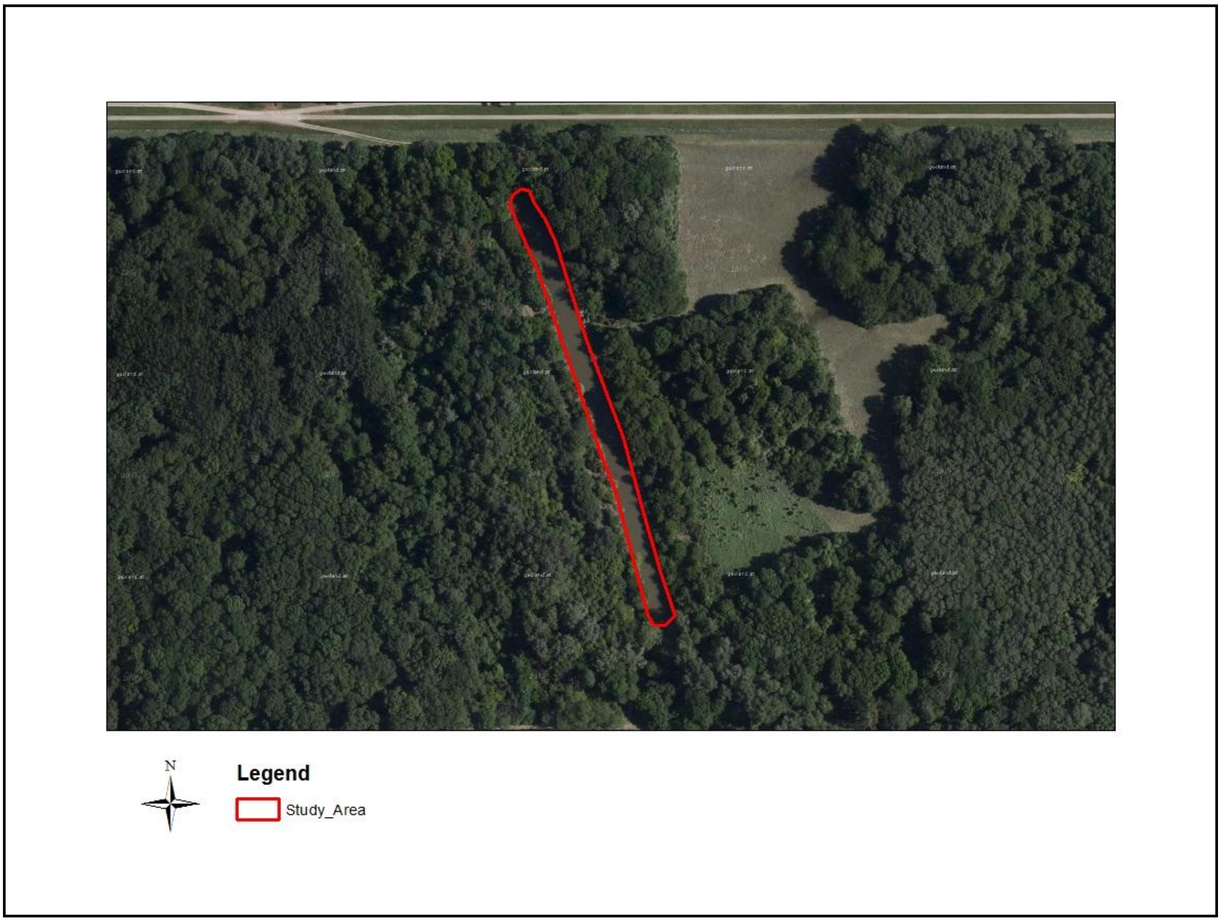

Figure 14 Study area and surrounding habitat of the water OD (Datenquelle: basemap.at).

Figure 15 The habitat of the water OD.

3.4. Water OL

With 10 species of macrophytes OL has the lowest diversity in aquatic plants. Rigid hornwort (*Ceratophyllum demersum*), water moss (*Fontinalis*), frogbit (*Hydrocharis morsus-ranae*), common duckweed (*Lemna minor*), star duckweed (*Lemna trisulca*), Starry stonewort (*Nitellopsis obtusa*), yellow water-lily (*Nuphar lutea*), floating crystalwort (*Riccia fluitans*), arrowhead (*Sagittaria sagittata*) and common duckmeat (*Spirodela polyrhiza*) were found. The abundance of macrophytes is also low.

The ground of OL is middle hard and the abundance of dead wood low. The shoreline has no vegetation and is above as well as below water steep. Furthermore, it is a relatively deep water with a pH of 8, a very high amount of nutrition and it is middle warm. The average of all temperatures measured is 12.303 °C. The external disturbances are at OL middle high and the distance to the next nesting place is middle long.

For the surrounding habitat types of the water see Figure 16 and for a typical image of the habitat see Figure 17.

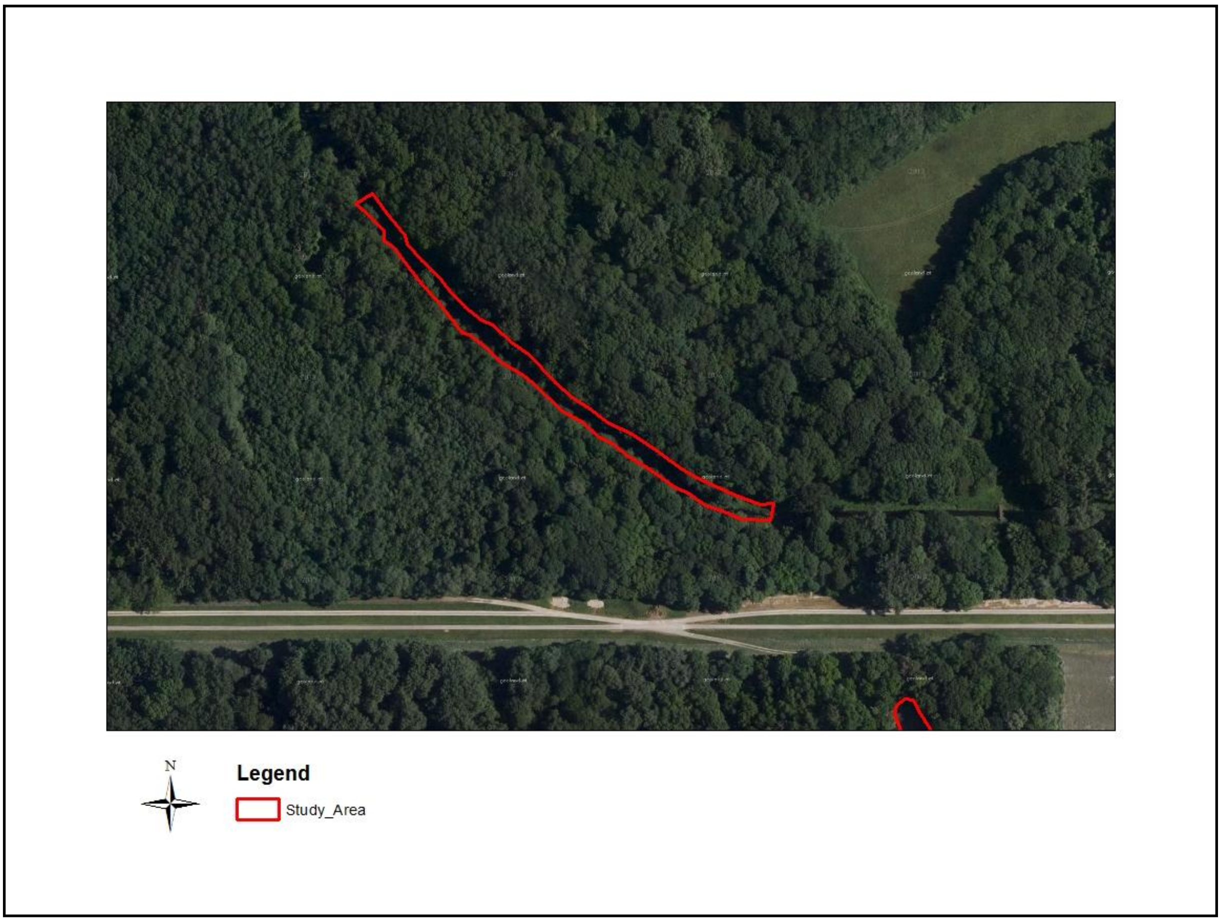

Figure 16 Study area and surrounding habitat of the water OL (Datenquelle: basemap.at).

Figure 17 The habitat of the water OL.

3.5. Water ED

ED has a wide range in macrophyte species. The 21 species found were: European water-plantain (*Alisma plantago aquatica*), sedges (*Carex sp*.), rigid hornwort (*Ceratophyllum demersum*), charophyte green algae (*Chara sp*.), water moss (*Fontinalis*), grass (*Poaceae*), common mare's tail (*Hippuris vulgaris*), frogbit (*Hydrocharis morsus-ranae*), yellow iris (*Iris pseudacorus*), common duckweed (*Lemna minor*), star duckweed (*Lemna trisulca*), whorl-leaf watermilfoil (*Myriophyllum verticillatum*), yellow water-lily (*Nuphar lutea*), knotweed (*Polygonum mite*), shining pondweed (*Potamogeton lucens*), water crowfoot (*Ranunculus circinatus*), celery-leaved buttercup (*Ranunculus sceleratus*), floating crystalwort (*Riccia fluitans*), arrowhead (*Sagittaria sagittifolia*), European bur-reed (*Sparganium emersum*) and common duckmeat (*Spirodela polyrhiza*). Therefore, ED has a high diversity and a high abundance in macrophytes.

With a soft ground, a lot of vegetation on the shoreline and a lot of dead wood ED can be characterised. The shoreline is above water flat and below middle flat. Moreover, the water is shallow, has a pH of 8 and a middle amount of nutrition. It is a warm water since the average of all temperatures measured is 12.979 °C. The external disturbances are low and the distance to the next nesting place is long.

The area around the water is shown in Figure 18 and a typical picture of the habitat of ED can be seen in Figure 19.

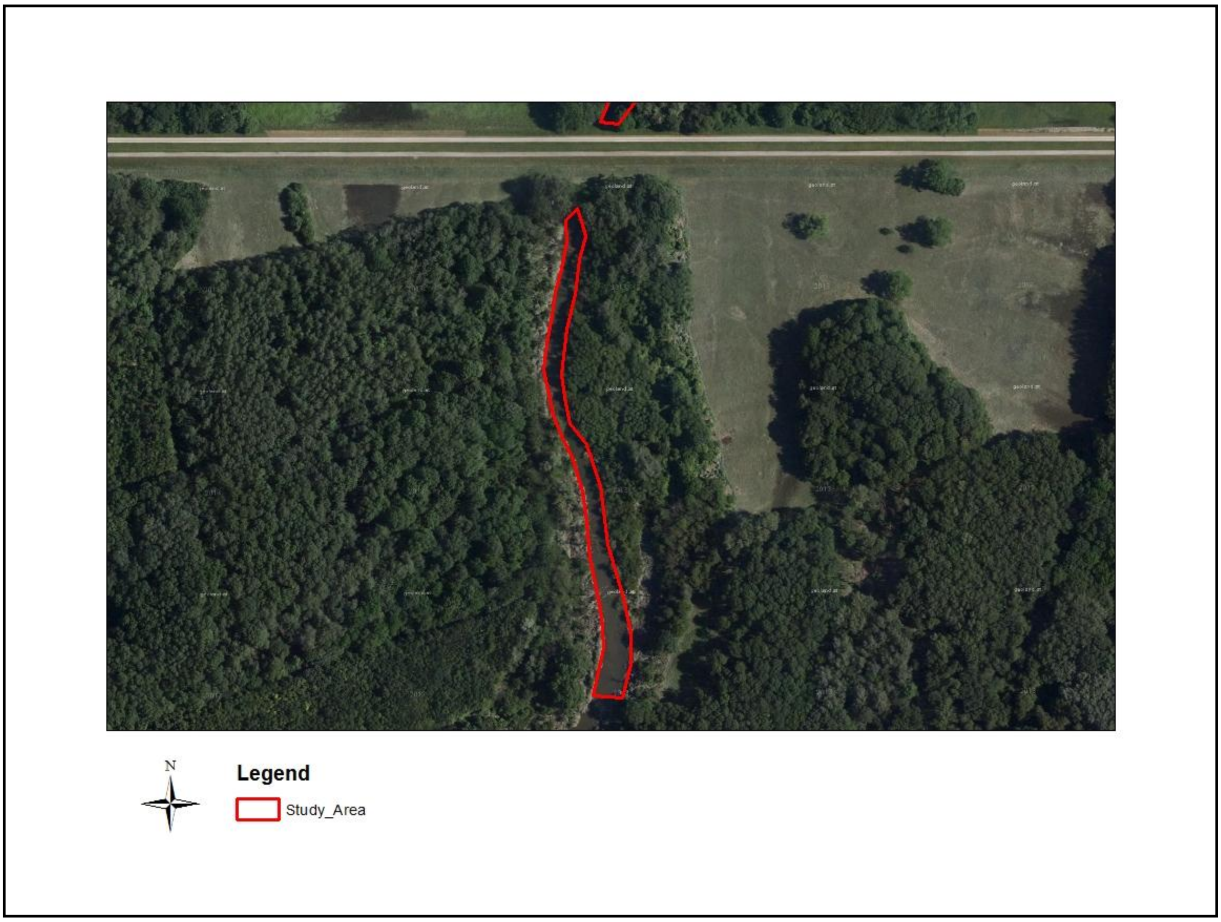

Figure 18 Study area and surrounding habitat of the water ED (Datenquelle: basemap.at).

Figure 19 The habitat of the water ED.

3.6. Water EL

21 species were found in EL: European water-plantain (*Alisma plantago-aquatica*), sedges (*Carex sp*.), rigid hornwort (*Ceratophyllum demersum*), charophyte green algae (*Chara sp*.), grass (*Poaceae*), frogbit (*Hydrocharis morsus-ranae*), yellow iris (*Iris pseudacorus*), common duckweed (*Lemna minor*), twopenny thot (*Lysimachia nummularia*), purple loosestrife (*Lythrum salicaria*), whorl-leaf watermilfoil (*Myriphyllum verticillatum*), spiny water nymph (*Najas marina*), brittle waternymph (*Najas minor*), watercress (*Nasturtium officinale*), common reed (*Phragmites australis*), knotweed (*Polyongum mite*), shining pondweed (*Potamogeton lucens*), arrowhead (*Sagittaria sagittata*), lakeshore bulrush (*Schoenoplectus lacustris*), European bur-reed (*Sparganium emersum*), water soldier (*Stratiotes alloides*) and common bladderwort (*Utricularia vulgaris*). Therefore, the diversity and abundance of macrophytes was high.

EL has a middle hard ground, a middle amount of vegetation coverage on the shoreline and a small amount of dead wood. The shoreline is steep below and above water. With a depth between 91-120 cm, it is a deep water. Moreover, the pH of the water is 7.2-7.6 and the temperature is warm since the average of all temperatures measured is 12.641 °C. The turtles have a lot of nutrition available in the water. The external disturbances are middle high and the distance to the next nesting place is middle long.

The habitat around the water is shown in Figure 20 and a typical picture of the habitat in Figure 21.

Figure 20 Study area and surrounding habitat of the water EL (Datenquelle: basemap.at).

Figure 21 The habitat of the water EL.

3.7. Water WD

In WD 17 species were found: lanceleaf water plantain (*Alisma lanceolata*), sedges (*Carex sp*.), rigid hornwort (*Ceratophyllum demersum*), common mare's tail (*Hippuris vulgaris*), lakeshore bulrush (*Schoenoplectus lacustris*), common duckweed (*Lemna minor*), star duckweed (*Lemna trisulca*), twopenny thot (*Lysimachia nummularia*), Eurasian watermilfoil (*Myriophyllum spicatum*), whorl-leaf watermilfoil (*Myriophyllum verticillatum*), spiny water nymph (*Najas marina*), watercress (*Nasturtium officinale*), common reed (*Phragmites australis*), water knotweed (*Polygonum amphibium*), knotweed (*Polygonum mite*), perfoliate pondweed (*Potamogeton perfoliatus*) and common duckmeat (*Spirodela polyrhiza*). It has a low diversity of macrophytes with a middle high abundance.

With a soft ground, a lot of vegetation on the shoreline, a middle amount of dead wood and a flat shoreline above and below water WD can be characterized. The shallow water has a pH of 7.6-8 with the average of all temperatures measured of 13.718 °C since it is compared to the other waters a relatively hot water. Moreover, it has a middle amount of nutrition. The external disturbances are middle high and the distance to the next nesting place is long.

The surrounding habitat of the water is shown in Figure 22 but it should be noted that this satellite image was taken during a high water level. Normally, the flooded area is not as wide. An image of a habitat type of the water WD is given in Figure 23.

Figure 22 Study area and surrounding habitat of the water WD (Datenquelle: basemap.at).

Figure 23 The habitat of the water WD.

3.8. Water WL

WL is the water with the highest diversity of macrophytes. 23 macrophyte species were found: European water-plantain (*Alisma plantago-aquatica*), lesser water-parsnip (*Berula erecta*), sedges (*Carex sp*.), rigid hornwort (*Ceratophyllum demersum*), common mare's tail (*Hippuris vulgaris*), frogbit (*Hydrocharis morsus-ranae*), yellow iris (*Iris pseudacorus*), common duckweed (*Lemna minor*), star duckweed (*Lemna trisulca*), twopenny thot (*Lysimachia nummularia*), water mint (*Mentha aquatica*), whorl-leaf watermilfoil (*Myriophyllum verticillatum*), spiny water nymph (*Najas marina*), Starry stonewort (*Nitellopsis optusa*), yellow water-lily (*Nuphar lutea*), reed canary grass (*Phalaris arundinacea*), perfoliate pondweed (*Potamogeton perfoliatus*), arrowhead (*Sagittaria sagittifolia*), lakeshore bulrush (*Schoenoplectus lacustris*), great water-parsnip (*Sium latifolia*), European bur-reed (*Sparganium emersum*), simplestem bur-reed (*Sparganium erectum*) and marsh woundwort (*Stachys palustris*). However, the average of all studied sections of the water for the diversity of macrophytes is low as well as the abundance.

WL has a relative hard ground, little vegetation on the shoreline and a small amount of dead wood. The shoreline is steep above and middle flat below water. It is a substantially deep water with a pH of 8 and very few nutrition. Moreover, it is a relatively hot water since the average of all temperatures measured is 13.993 °C. The external disturbances are high and the distance to the nesting place is long.

The surroundings of the study area are shown in Figure 25 and an image of a typical habitat of WL can be seen in Figure 26. Moreover, one of the few old turtles caught was found here (see Figure 24).

Figure 24 A turtle caught in WL on 22.09.2016 which is older than 50 years and has a broad head width.

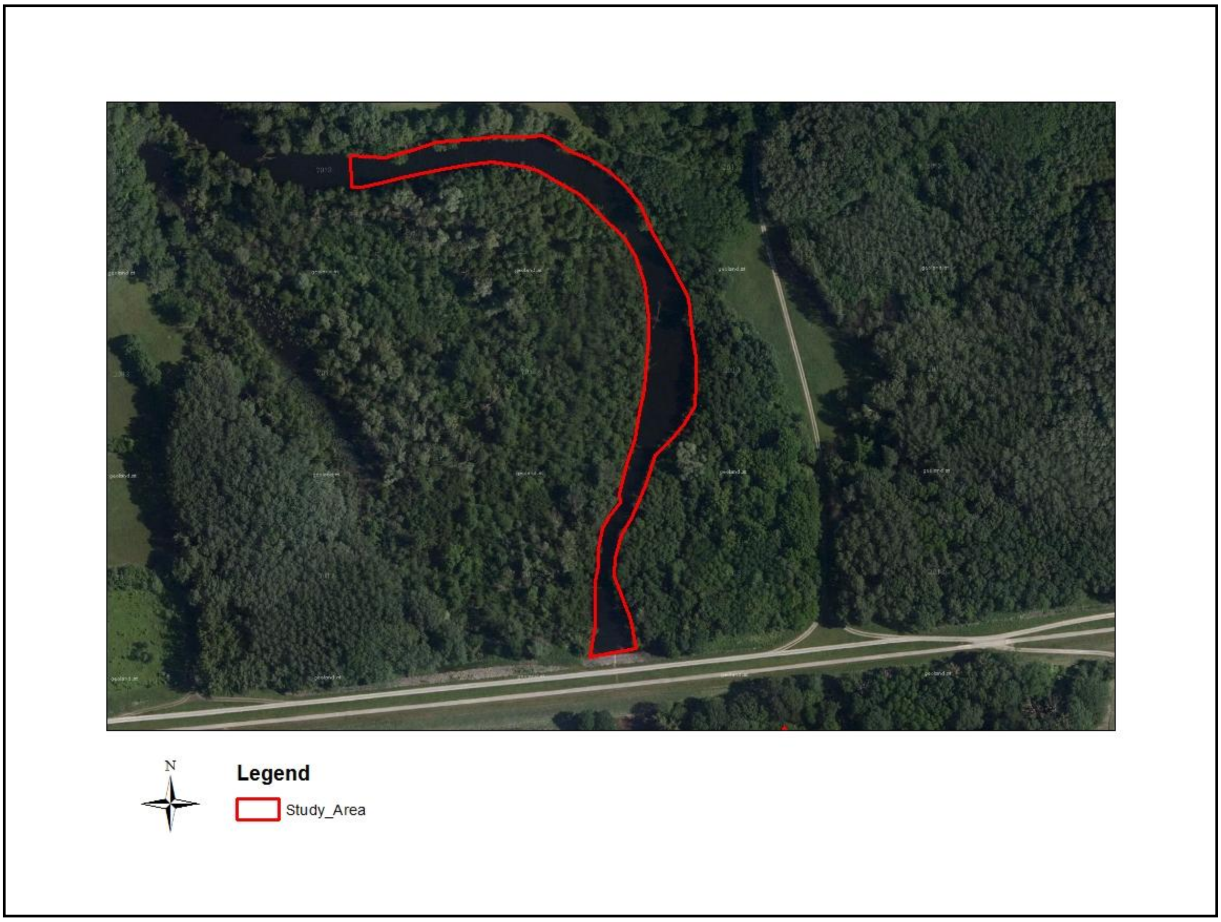

Figure 25 Study area and surrounding habitat of the water WL (Datenquelle: basemap.at).

Figure 26 The habitat of the water WL.

4. Results and discussion

After describing the habitat the abundances will be determined in order to correlate the abundances with the habitat features.

4.1. Abundances of single waters

The abundances of the single water sections (300 meters, both sides) are calculated first. During the study 246 catches occurred with 31 recaptures. Therefore, 215 individuals were caught. All turtles caught were *Emys orbicularis* and no other species was found.[9] The calculated abundances of the different study areas are shown in Table 4. There it can be seen that the most turtles seem to be in ED, the lowest number in OL. The abundances of the different fish trap areas (50m, one side) are listed in Appendix V.

Table 4 Calculated population sizes (N) in the study areas and the standard error of N.

Study area	Population size of study area (N)	Standard error of N
WD	32	
WL	7	
ED	126	
EL	114	52.03
OD	22.5	
OL	1	0
UD	70	13.29
UL	15	3.87

4.2. Influence of the habitat features on the abundance

After describing the habitat features and calculating the abundances, they will be correlated with each other. To do so, the abundance of the catching areas of the fish traps needs to be analyzed first. The Shapiro-Wilk test ($W=0.58$; $p<0.001$) and Figure 27 show that the abundances of the European pond terrapin in the studied fish trap areas are not normally distributed. Therefore, non-parametric tests are used for the analysis.

[9] So no *Trachemys scripta elegans* was caught or seen. This is a good sign, since the red-eared slider is no native species in the Donau-Auen National Park and is seen in some literature as a competition to the European pond terrapin (Cadi, Joly 2004; Arvy, Servan 1998).

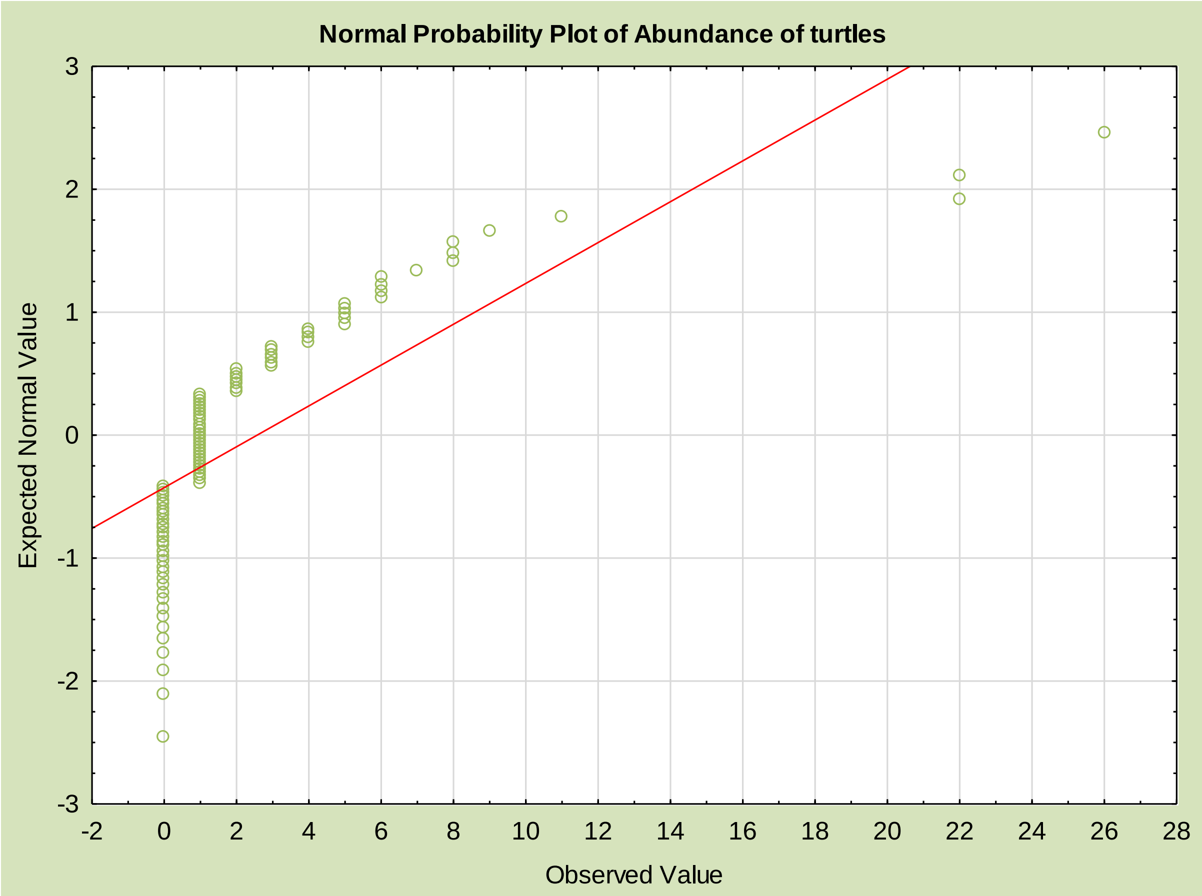

Figure 27 The normal probability plot of the abundance of turtles shows that the abundance is not normally distributed.

The influence of the habitat features on the abundance of the European pond terrapin will be described in the following and thus, it will be analyzed which habitat features are essential for the suitability of the habitat of the European pond terrapin. This will be done mainly descriptively with help of box plots. Before the box plots can be analysed, it should be noted that the outliers and extremes are labelled by the abbreviation of the water and the number of the fish trap (e. g. ED16 for Eckartsau side of the Danube fish trap number 16). This labelling allows for providing the exact position of the outliers and extremes.

4.2.1. Degree of softness of the ground

Soft ground seems to be favoured by the European pond terrapin since in this category of the habitat feature “degree of softness of the ground” are the highest abundances of turtles found (including outliers and extremes) (see Figure 28). Furthermore, in the category “middle hard” ground are high abundances and a high extreme. The categories “hard” and “very soft” ground have low abundances. The category “very hard” ground was not found in the study areas. Therefore, it seems that *Emys orbicularis* prefers soft or middle hard ground. However, the Kruskal-Wallis-test shows that there is no significant difference in abundances for all categories ($H(3) = 4.2703$; $p = 0.2337$).

The Reasons for this tendency to prefer soft ground is probably based on the fact that the European pond terrapin hibernates[10] mainly under water buried in the mud of the ground of the water (Cadi et al. 2008; Dall'Antonia et al. 2001; Rössler 2000b; Thienpont et al. 2004). However, Novotný et al. (2004) observed that the turtles stay on the bottom and not buried in mud during hibernation (Novotný et al. 2004). Nevertheless, observations were made that they stay predominantly in waters with a soft ground (Kotenko 2004).

All in all, the results are not significant and thus, this habitat feature seems to have no high influence on the abundance of turtles in the Donau-Auen National Park even though catching was done shortly before hibernation.

[10] There is a discussion if the European pond terrapin truly hibernates since it has occasional activities in the winter (for more information see e. g. Dall'Antonia et al. 2001).

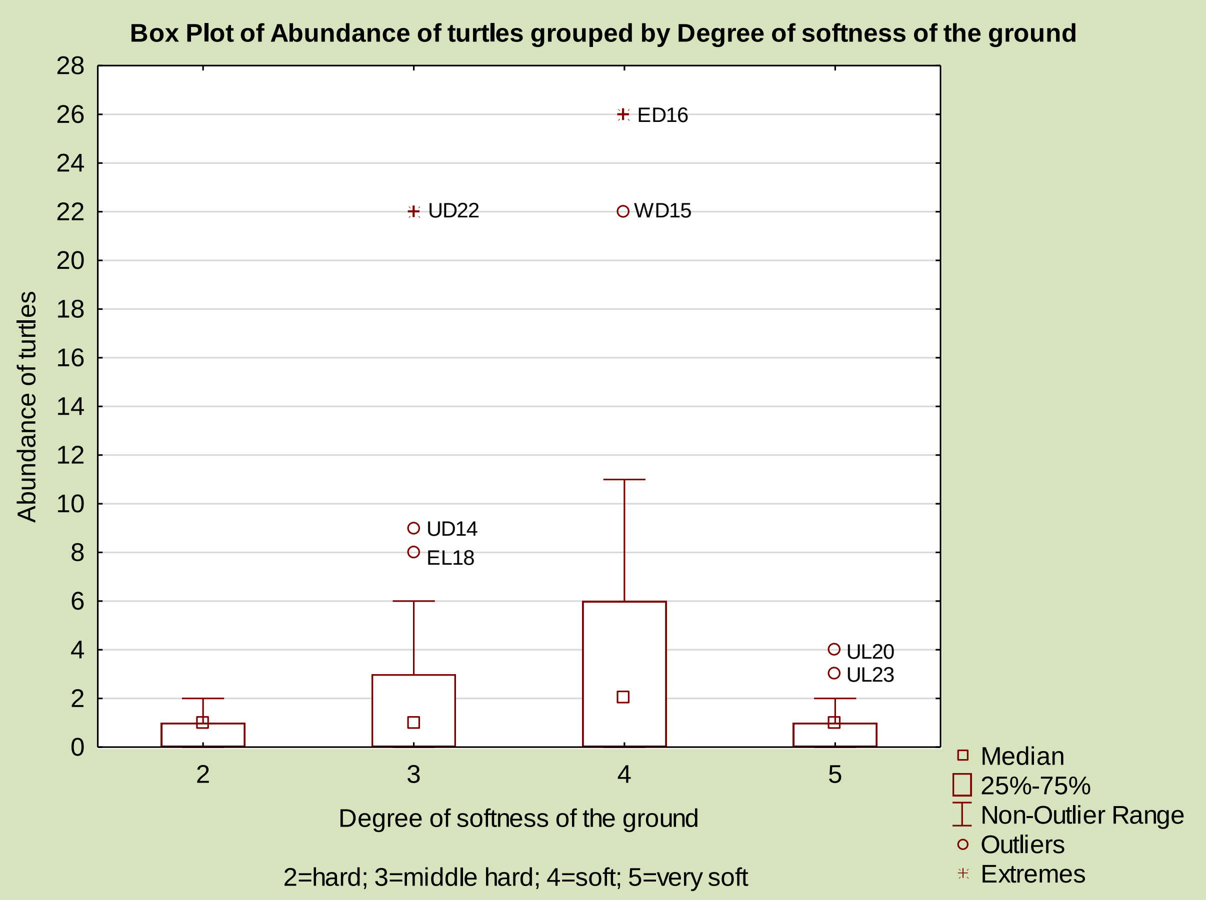

Figure 28 Box plot of abundance of turtles grouped by degree of softness of the ground.

4.2.2. Degree of vegetation of the shoreline

The habitat feature "Degree of vegetation of the shoreline" shows no clear tendency towards a preference of the turtles. There are disparities between the different categories in the box plot (Figure 29) recognizable (i. e. highest amount in the category "middle vegetation") but those disparities are reduced by the outliers and extremes. Therefore, no clear preference of the European pond terrapin towards a specific degree of vegetation on the shoreline seems to exist in the Donau-Auen National Park. This finding is supported by the Kruskal-Wallis-test, which showed no significant difference in the tendency of the abundance in the different categories (H (4) = 5.6670; p = 0.2254).

However, other studies suggest a high importance of the vegetation on the shoreline since it provides shelter (e. g Lebboroni, Chelazzi 1991). Moreover, Rössler (1998) mentioned that during mating season shorelines with a low amount of vegetation (males can be seen by women during sunbathing) and outside this season shorelines with a high amount of vegetation (provide protection) are preferred by the European pond terrapin (Rössler 1998). Thus, in this study a clear preference for a high amount of vegetation on the shoreline would be expected (outside mating season). However, Rogner (2009) stated that the European pond terrapin prefers a middle amount of vegetation on the shoreline since it provides hiding possibilities but at the same time does not cast too much shadow for basking (Rogner 2009). An explanation for the current study not showing an importance of the habitat feature "vegetation of the shoreline" could be that in the studied waters were generally high amounts of dead wood that can also function for sunbathing possibilities, provide shelter and function as source for food items (Meeske 2000 in Ficetola et al. 2004).

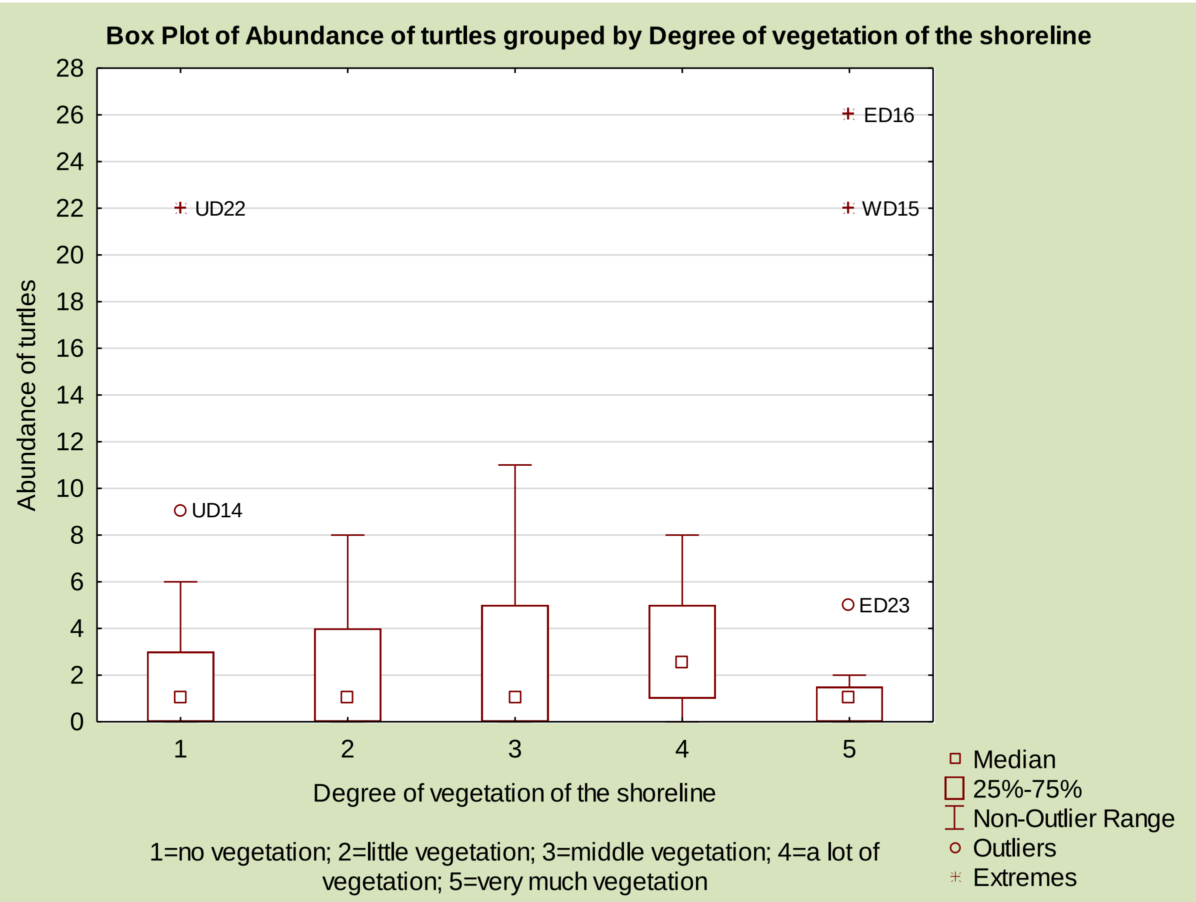

Figure 29 Box plot of abundance of turtles grouped by degree of vegetation of the shoreline.

4.2.3. Abundance of dead wood

Consequently, Figure 30 shows a tendency toward a preference of turtles for a high amount of dead wood. The fish trap WD15, normally an outlier or extreme, is included in the box of the category “very much dead wood” what indicates a high abundance in this type of habitat feature. However, it should be noted that in this category “very much dead wood” only three measurements were taken. Nevertheless, the Kruskal-Wallis-test shows a significant difference between the abundance in the categories (H (4) = 13.6516; p = 0.0085). But it does not show between which categories, just that there is a significant difference between two or more of the categories. In the graph it can be seen that we have a higher abundance in the category “middle amount of dead wood” than in “a lot of dead wood”. However, with all these information it seems to be reasonable to conclude that the European pond terrapin prefers habitats with a high amount of dead wood and needs at least a middle amount of dead wood to be abundant.

These results are supported by several studies which found out that the European pond terrapin prefers dead wood for basking rather than the shoreline (inter alia Meeske, Poggenburg 2014; Mosimann 2002b). The same tendency was found by Rössler (1998, 2000b). However, they also found differences in the usage of dead wood between adults and juveniles. Adults use the shoreline more often for basking than juveniles and juveniles use the vegetation and dead wood more often than adults (Rössler 1998, 2000b). The importance of dead wood for the European pond terrapin is also mentioned in Ficetola et al. (2004). Capula et al. (1994) studied whether *Emys orbicularis* prefers the shoreline or small islands in a canal for sunbathing. They found a clear tendency in usage for the small islands (Capula et al. 1994). Since dead wood functions as small islands in the water this can also be seen as an indication for the preference for dead wood. Reasons for this could be that they are more secure on the islands than in the water and/or that the islands are often longer exposed to the sun than the shoreline and thus, allow for a longer sunbathing period (Capula et al. 1994). These findings are supported by the observations made during this study. The European pond terrapin was almost exclusively using dead wood for basking (own observations).

Beside basking possibilities dead wood also provides shelter and functions as a source for nutrition (Meeske 2000 in Ficetola et al. 2004) which also indicates the importance of a high amount of dead wood in the waters for the European pond terrapin. Furthermore, it explains why the abundance of *Emys orbicularis* seems to be significantly influenced by this habitat feature.

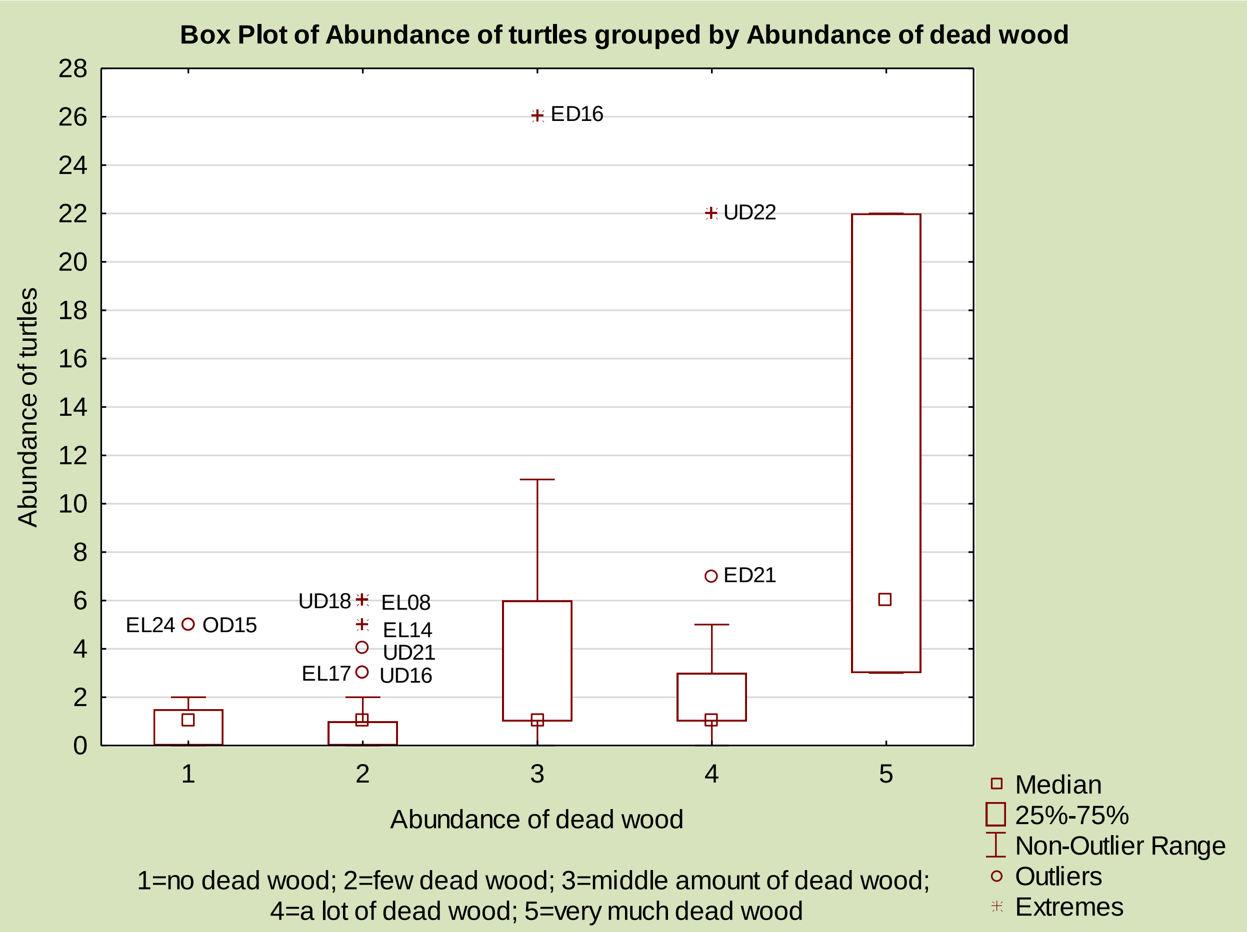

Figure 30 Box plot of abundance of turtles grouped by abundance of dead wood.

4.2.4. Steepness of the shoreline above water

The influence of "steepness of the shoreline above water" on the abundance of turtles is illustrated in Figure 31. There seems to be a slightly higher abundance in "really flat shorelines" than in steep shorelines. The lowest abundance is found in "really steep shorelines". Between the other categories (flat, middle flat and steep shoreline) no significant differences was detectable. The extremes are found in these three categories. This weakens the tendency towards a higher abundance in really flat shorelines. However, the effect of the habitat feature "steepness of the shoreline above water" on the abundance seems to be small. This is supported by the high p-value of the Kruskal-Wallis-test (H (4) = 1.7975; p = 0.7729), which indicates no significant tendency towards a specific shoreline's flatness.

Similarly, the steepness of the shoreline above water is just mentioned once in the literature, which indicates a low importance of this habitat feature with regard to the abundance. In the study it is stated that a flat shoreline enables the turtle to better access terrestrial habitat (Andreas 2000 and Meeske 2000 in Ficetola et al. 2004) which could be an explanation for the findings that a flat shoreline tends to support a slightly higher abundance compared to steep ones. Moreover, a flat shoreline could be better for basking than a steep one. However, since dead wood is mainly used for sunbathing by the European pond terrapin this should have no significant impact.

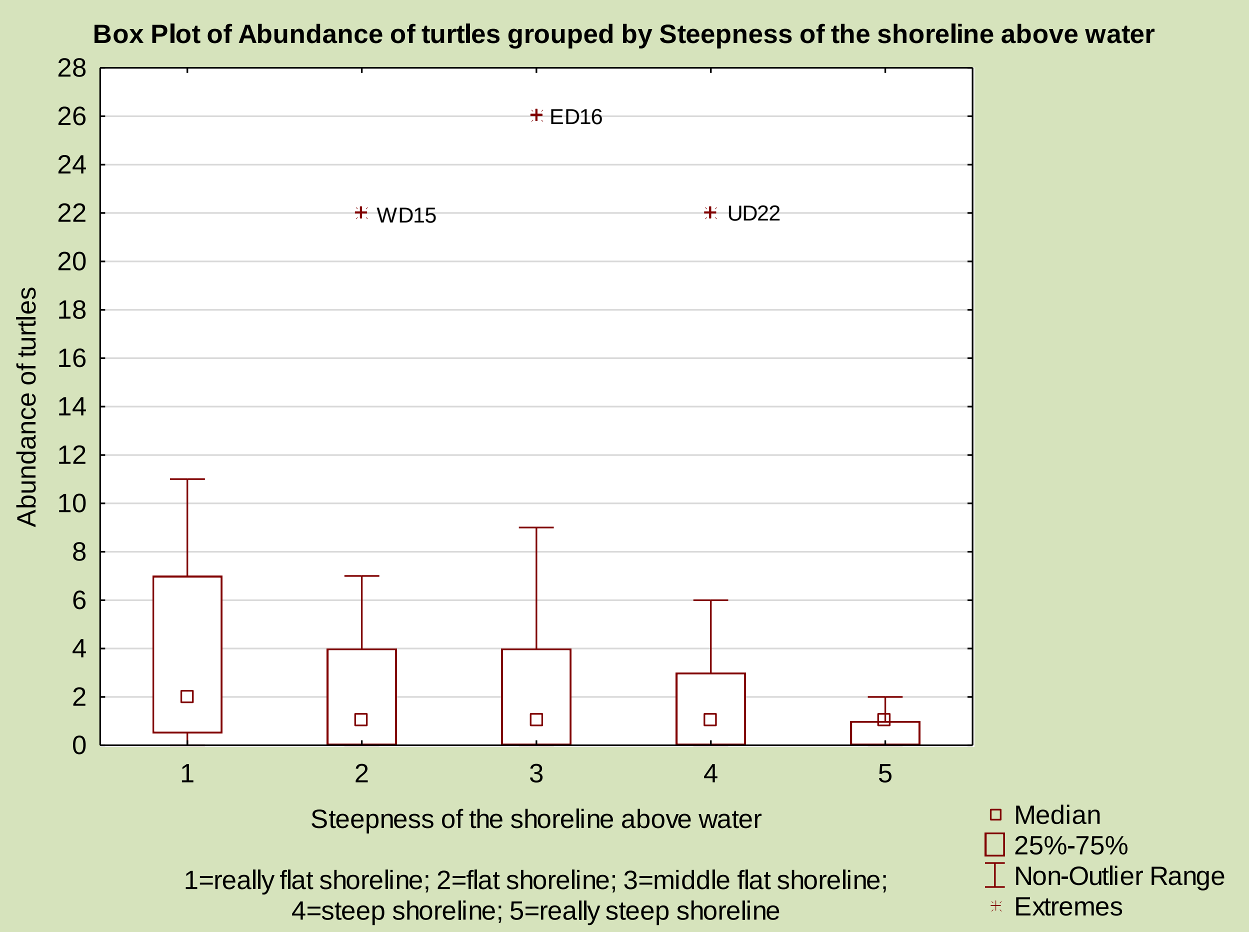

Figure 31 Box plot of abundance of turtles grouped by steepness of the shoreline above water.

4.2.5. Steepness of the shoreline below water

Also, for the habitat feature "steepness of the shoreline below water" no clear tendency can be seen (Figure 32). The highest abundances seem to be in "steep shorelines", also the highest extreme (ED16) is found here. In the category "really flat shoreline" the smallest abundances are seen, but the extreme WD15 with a high abundance is also found here. Moreover, the Kruskal-Wallis-test shows no significant tendency towards a specific steepness of the shoreline below water of turtles, the p-value is even very high (H (4) = 0.7523; p = 0.9447).

One would have expected a tendency towards a flat shoreline below water since turtles search food in shallow and flat water at the shoreline (Mosimann 2002a in Schindler 2012). However, maybe even the "really steep shoreline" in the studied areas was flat enough for searching for food since the highest disparity between the depths at the measure points is 27 cm and the class "really steep shoreline" only covers depths' disparities higher than 11 cm. Nevertheless, the steepness of the shoreline below water seem to have no strong impact on the abundance. This is also supported by the fact that this habitat feature has not been mentioned in the literature directly and only once indirectly (Mosimann 2002a in Schindler 2012).

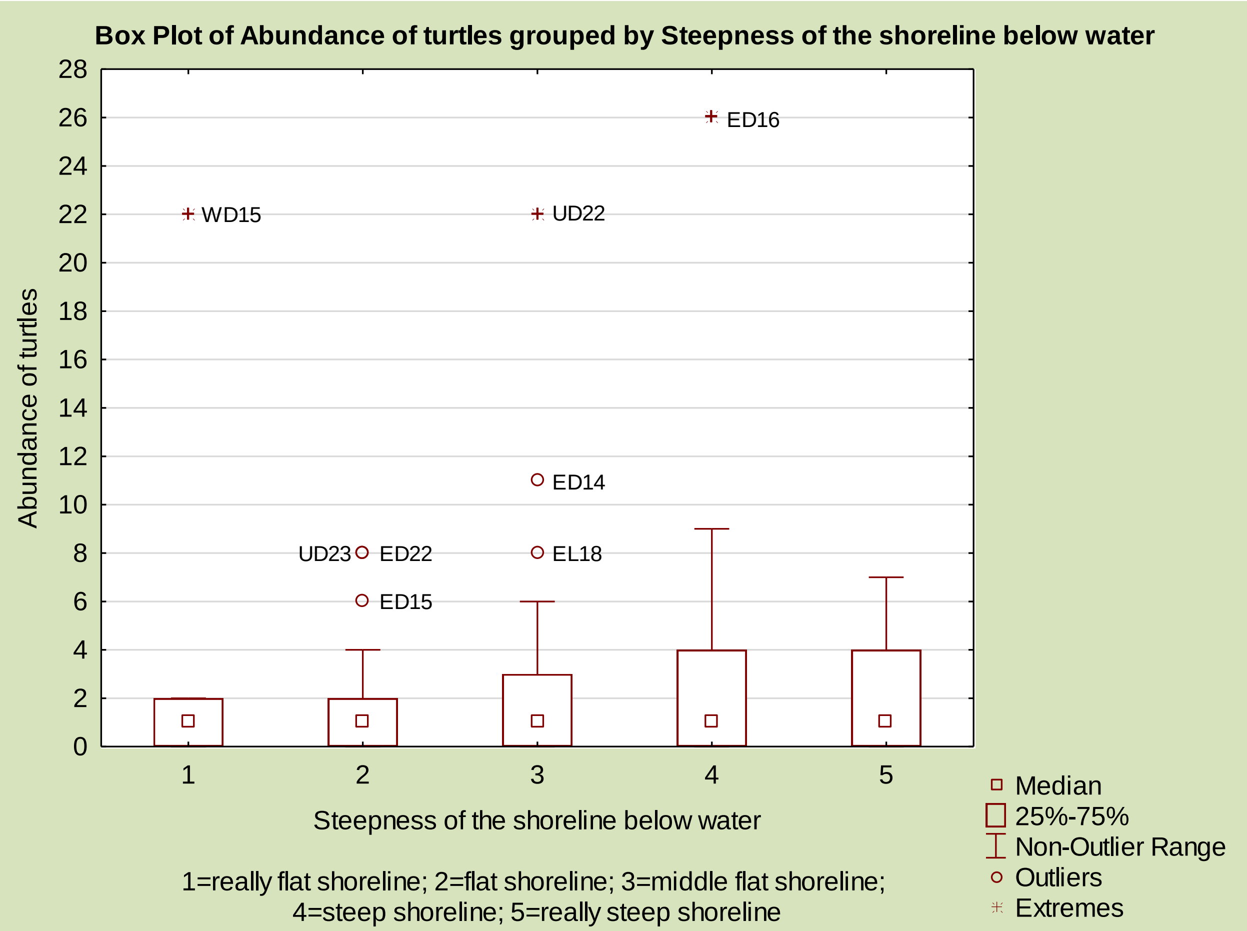

Figure 32 Box plot of abundance of turtles grouped by steepness of the shoreline below water.

4.2.6. Depth at the middle of the water

In Figure 33 the influence of the “depth at the middle of the water” on the abundances of the European pond terrapin is illustrated. The lowest abundances seem to be in “really deep water” and the highest in “really shallow water”. However, the extremes are found in the other categories (“shallow water”, “middle deep water” and “deep water”). This indicates no clear tendency towards a category. This finding is also supported by the Kruskal-Wallis-test, which shows no significant differences in abundances between the categories ($H(4) = 2.8264$; $p = 0.5873$). However, “really deep water”, which means water deeper than 1.20 m, seems to cause small abundances of turtles.

These findings are supported by several studies that state that the European pond terrapin prefers shallow waters (Meeske, Poggenburg 2014; Rogner 2009; Schneeweiss, Fritz 2000; Zuffi 2000) mainly due to the fact that they are warmer (Rogner 2009; Schindler, Reckendorfer 2006). However, these results were found during the activity period of the turtle and do not need to represent the preferences during the hibernation period during which they may prefer deeper waters (Schindler, Reckendorfer 2006). It should be noted that the water depth was measured not during catching but afterwards and that the water level had dropped down from catching to measuring. Therefore, the measured depths cannot be seen absolute but since measuring was conducted in a short timeframe they are comparable (relative values).

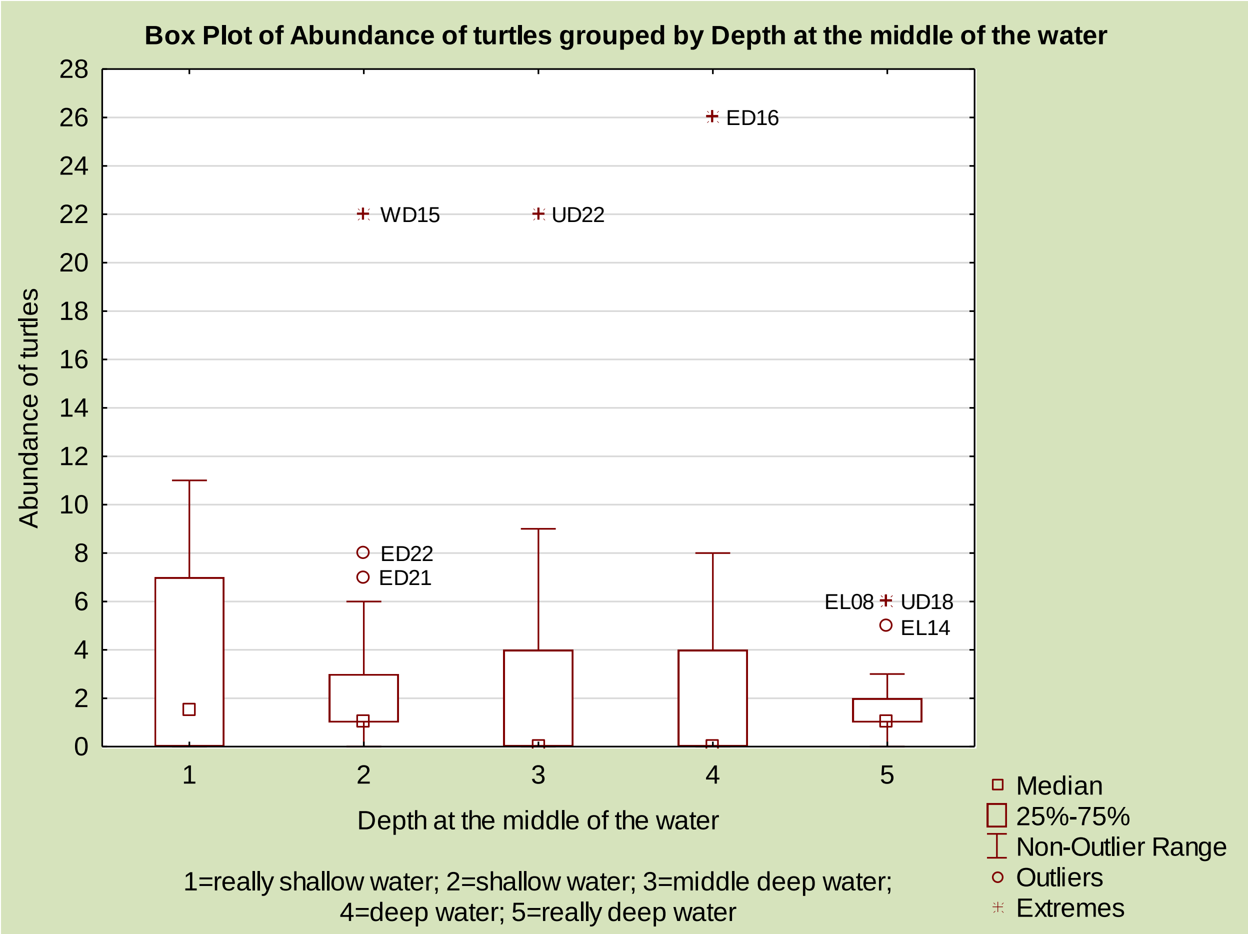

Figure 33 Box plot of abundance of turtles grouped by depth at the middle of the water.

4.2.7. Distance to nesting place

In Figure 34 it can be seen that the lowest abundances of the European pond terrapin are found in the closest areas ("very short distance") to the nesting place. The other categories seem to have no clear difference in abundances considering the extremes and outliers. This finding is supported by the Kruskal-Wallis-test (H (4) = 0.9775; p = 0.9132), which shows no significant tendency towards a distance to the nesting place of the turtles. Therefore, the distance to the nesting place seems to have low to no impact on the abundance of the European pond terrapin.

Reasons for this could be that in this study only a low proportion of the caught turtles were females. Moreover, the nesting places were in all waters reachable in less than hundred meters if the turtles swam to the end of the water (which was observed in Slovakia inter alia in Novotný et al. 2004). Since the catching was done after egg laying season just the reachability and not the closeness to the nesting site could be relevant. This concurs with other findings where the most distances to the nesting place from the next water were less than 150 meters (Mitrus 2006). The category “very short distance” describes mainly the first 50 meters of the water from the dike. The low abundance in this category could be due to the closeness to the dike since on the dike is relatively high traffic of bikers, walkers and some authorized cars that may disturb the turtles.

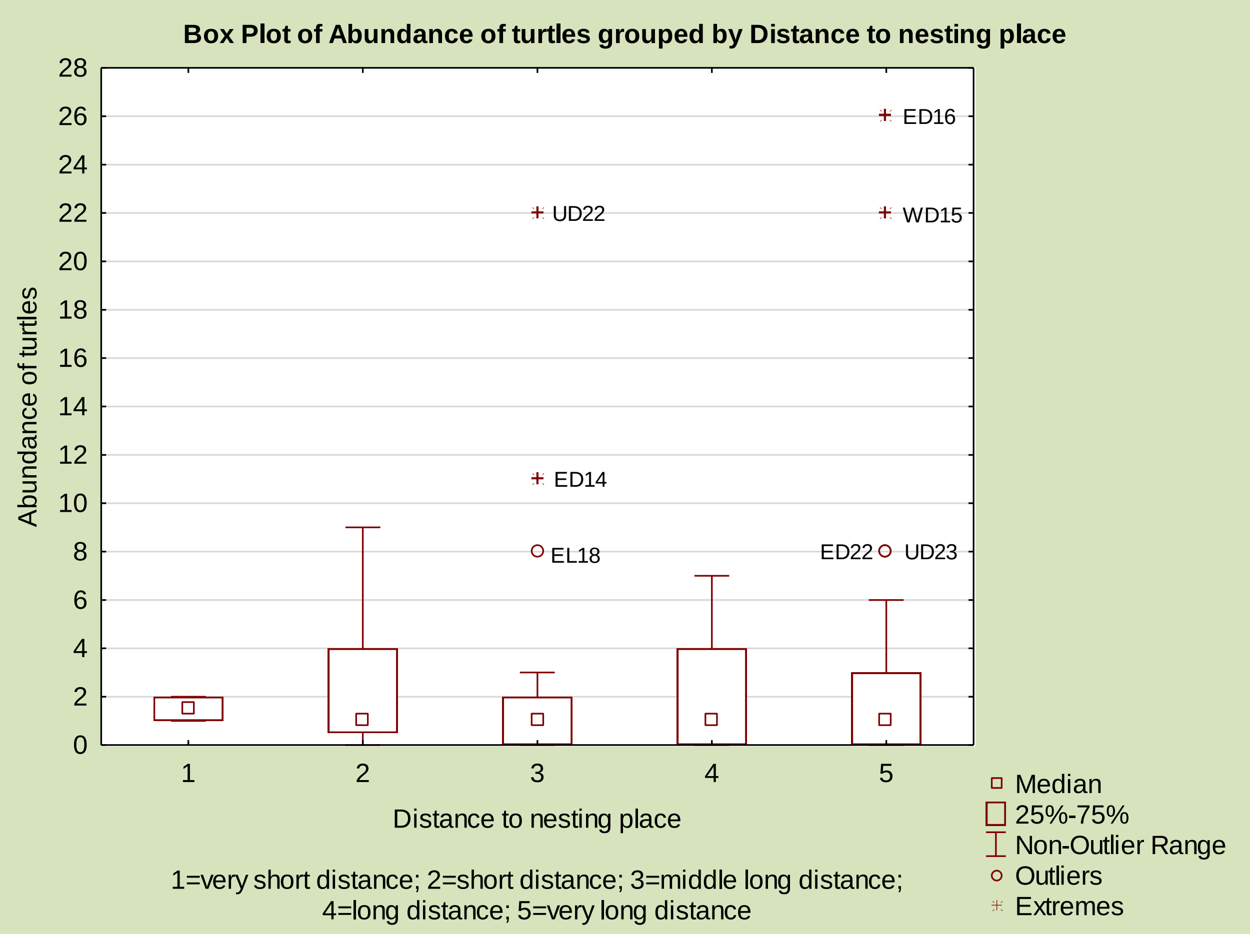

Figure 34 Box plot of abundance of turtles grouped by distance to nesting place.

4.2.8. External disturbances

The highest amount of turtles seems to be found in areas with a very low disturbance (including extreme ED16) and the lowest in an area with a very high disturbance (Figure 35). However, the differences are small and the Kruskal-Wallis-test shows that they are not significant ($H(4) = 3.1281$; $p = 0.5366$).

The tendency of the European pond terrapin towards a low disturbance is supported by several authors (Rössler 2000a; Gemel 2001; Servan 2000). However, the tendency is not significant. This could be due to the fact that just the distance to the next way was measured and not the intensity of traffic. Moreover, turtles are not as stressed by disturbances in the water as during land movement; e. g. during oviposition (Rössler 2000c).

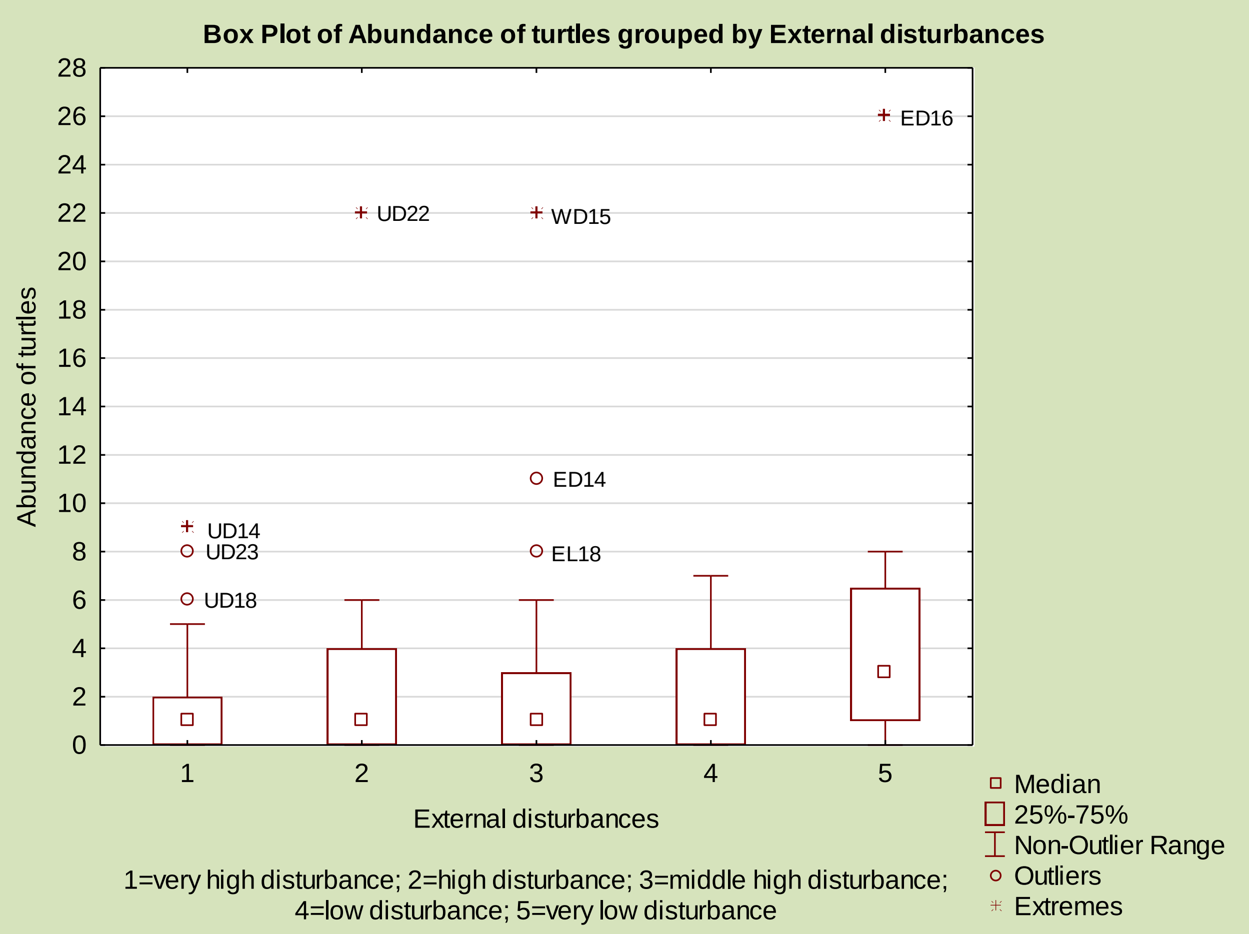

Figure 35 Box plot of abundance of turtles grouped by external disturbances.

4.2.9. Abundance of macrophytes

No clear tendency towards a specific category can be seen by the habitat feature "abundance of macrophytes" (Figure 36). However, the highest abundances are found in the category "very low abundance" but the highest extreme is seen in "very high abundances". Therefore, no clear tendency can be seen except for both extremes (categories "very low abundance" and "very high abundance") having a higher amount of abundances than the middle categories. Nevertheless, these differences are not significant. This is shown by the Kruskal-Wallis-test (H (4) = 9.0439; p = 0.06).

In contrast, several other studies found a preference of the European pond terrapin towards a high amount of macrophytes (e. g. Kotenko 2004; Meeske, Poggenburg 2014; Cadi et al. 2008; Lebboroni, Chelazzi 1991). They even tend to catch food mainly in areas where macrophytes are abundant (Arvy, Servan 1998), which would increase the probability of being caught by the used method. Moreover, Thienpont et al. (2004) showed a preference of *Emys orbicularis* towards a dense macrophyte cover during time of hibernation since it protects against freezing (Thienpont et al. 2004). Therefore, this study is contrary to general findings. This could be due to the fact that the studied waters have a high amount of dead wood. The dead wood may similar to the macrophytes provide structure and thus, sufficient food and hiding spots are available. This should be further investigated.

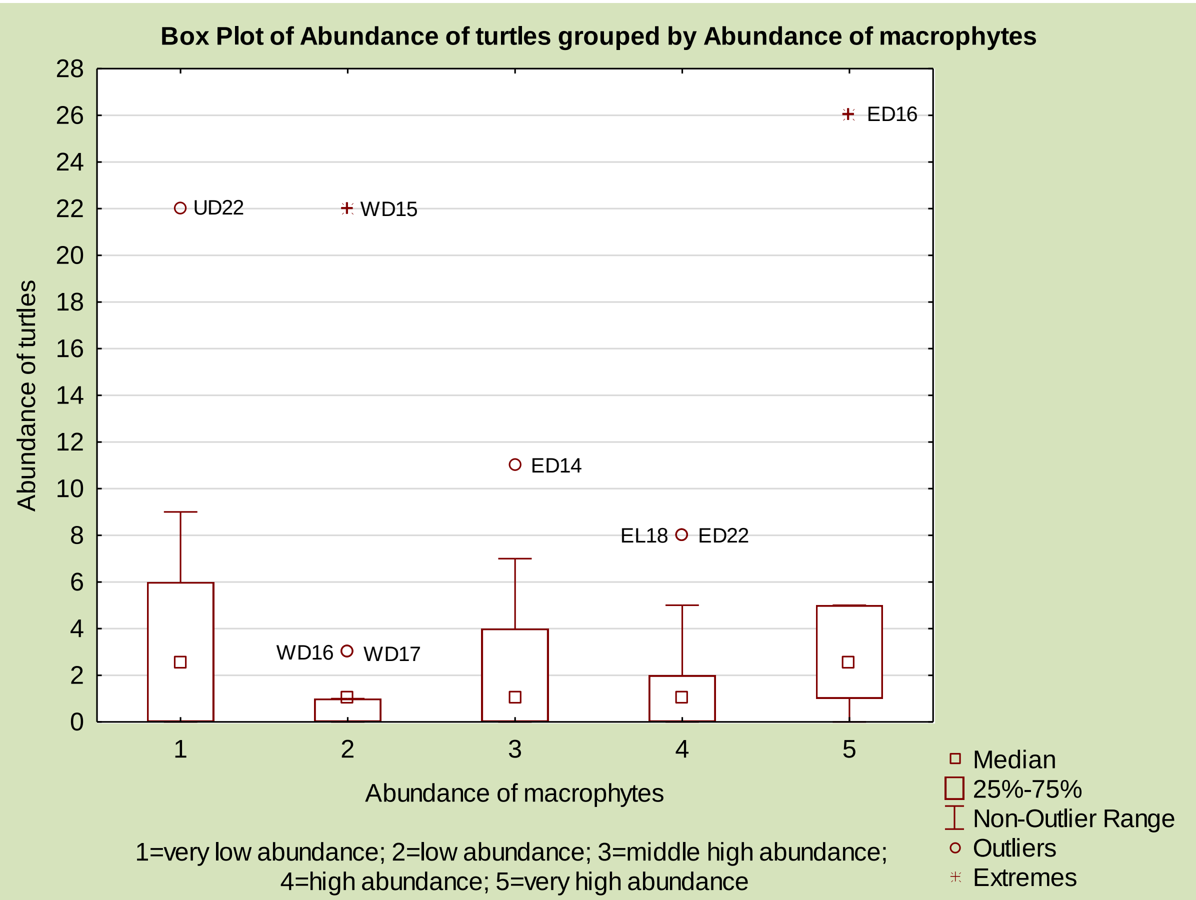

Figure 36 Box plot of abundance of turtles grouped by abundance of macrophytes.

4.2.10. Diversity of macrophytes

In Figure 37 the influence of the diversity of macrophytes on the abundance of the European pond terrapin is illustrated. There seems to be an increase in abundances in cases of an increase in diversity of macrophytes. Just the extremes UD22 and WD15, which are in the category "low diversity", do not fit in this scheme. However, the Kruskal-Wallis-test shows a significant difference between the categories (H (4) = 18.6087; p = 0.0009). The categories between which the difference is significant cannot be identified. Nevertheless, between two or more categories the difference is significant and thus, the abundance of turtles is affected by the habitat feature "diversity of macrophytes". Therefore, a high diversity of macrophytes supports a high abundance of the European pond terrapin.

Reasons for this could be that a high structural variety in a water, which is given by a high diversity of macrophytes, could increase the nutrition (prey) availability for turtles (Cadi et al. 2004; Cadi et al. 2008). This effect could be even intensified by the fact that the turtles, in this study, were caught during their search for food (due to the catching method used in this thesis). Moreover, the European pond terrapin is not only carnivorous but also eats plant material (Ayres et al. 2010; Çiçek, Ayaz 2011; Ficetola, Bernardi 2006; Ottonello et al. 2005). Ayres et al. (2010) found out that the European pond terrapin in Spain eats high amounts of *Nymphaea alba* (Ayres et al. 2010), but this plant was not present in the studied waters in the Donau-Auen National Park. One study suggested that the turtles eat *Myriophyllum* (Lebboroni, Chelazzi 1991) which is present in six of the studied waters; only in OD (abundance of turtles: 12) and OL (abundance of turtles: 1) it is absent. However, Çiçek, Ayaz (2011) discovered that *Emys orbicularis* eats a variety of mainly aquatic forms of plants (Çiçek, Ayaz 2011). Furthermore, when there is a high diversity of macrophytes the probability of eatable plants for *Emys orbicularis* increases too. Therefore, an increase in plant diversity seems to increase the availability of nutrition and thus, the abundance of turtles.

Another aspect is that a high diversity of macrophytes can also lead to a higher amount of possibilities for hiding, which can increase the suitability of a water for turtles as outlined in Rössler (2000b) and Lebboroni, Chelazzi (1991).

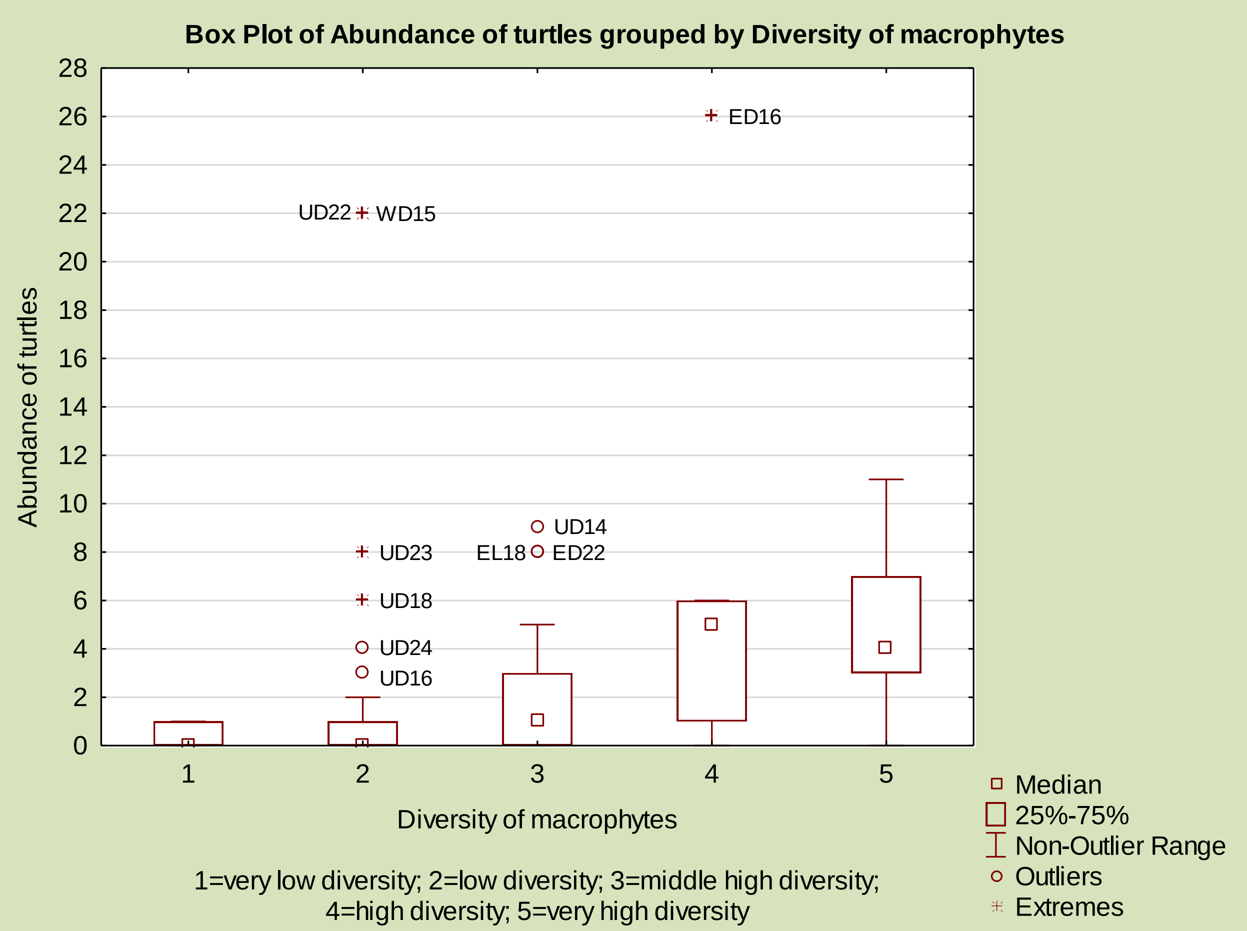

Figure 37 Box plot of abundance of turtles grouped by diversity of macrophytes.

4.2.11. Temperature of the waters

The following three habitat features were measured for the whole water (300 meters) and were thus in each section of the water equal. Therefore, the following graphs deal with the calculated abundance of the total water and not with the abundances of the single sections (catching areas of the fish traps), thus the measured values do not represent the heterogeneity in the different sections of this habitat feature.

In Figure 38 it can be seen that the highest abundances of the European pond terrapin are found in “warm waters”; the second most in “hot waters”. In “middle warm waters” just a low number of turtles are found. No studied water was in the category “cold waters”. This indicates that turtles prefer “warm waters”. However, the Kruskal-Wallis-test shows no significant differences of abundances between the categories (H (3) = 5.1389; p = 0.1619).

The preference of warm waters is also found in other studies (Rogner 2009; Rössler 2000b). However, it is interesting that the turtles have the highest abundance in the middle temperature range and not in the warmest. This may be due to the low sample number (n = 8). Moreover, it should be noted that the measured temperatures can only be evaluated relatively since they cover just a 6 day period in begin of October. Thus, they serve only as a basis to compare the different waters. For a more detailed result in all 8 waters the temperatures over a whole year should be measured with help of data loggers.

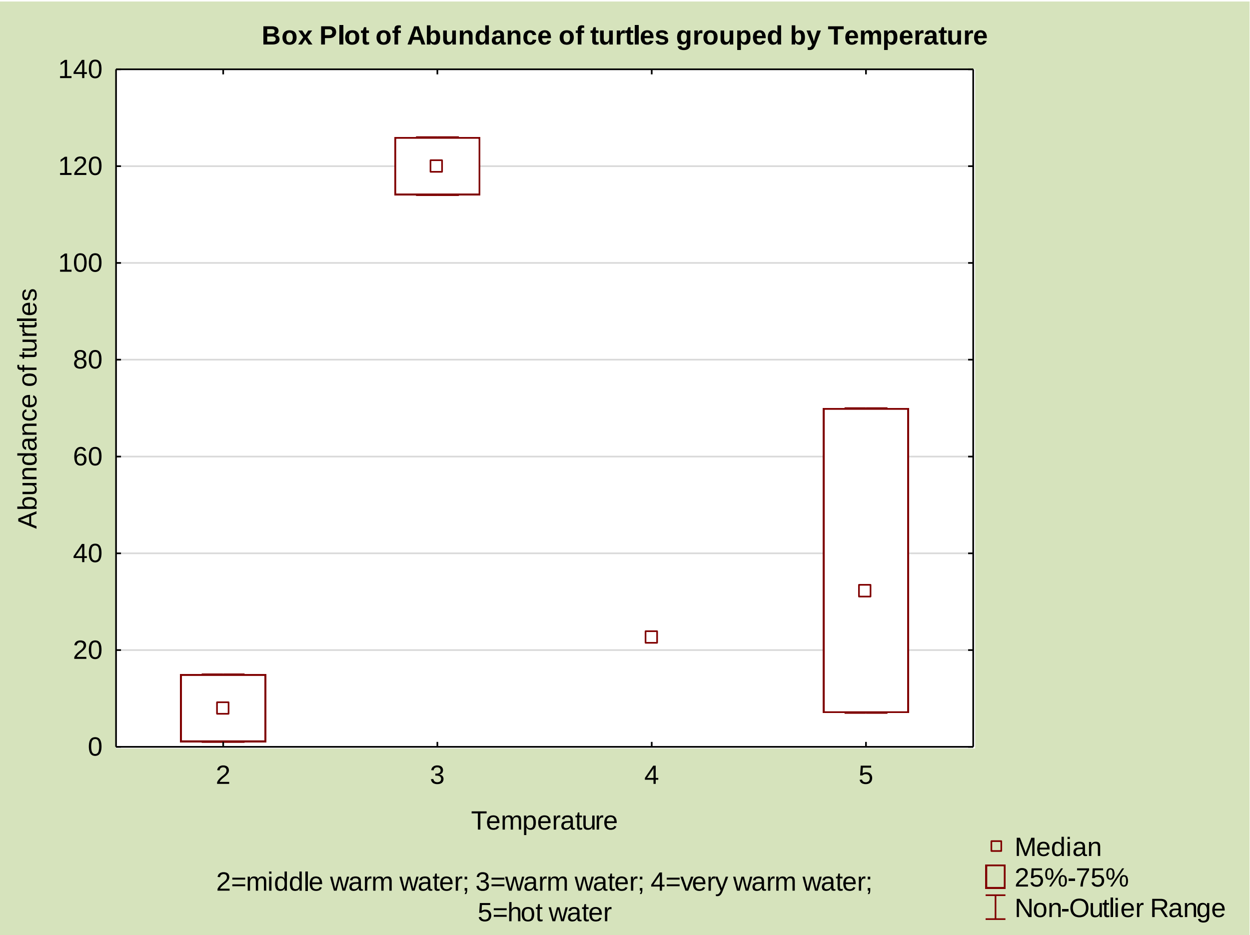

Figure 38 Box plot of abundance of turtles grouped by temperature.

4.2.12. pH–value of the water

The most waters have a pH of 8 (4 waters). However, the range of found pH-values was from 7.2 to 8. A clear tendency of high abundances towards a specific pH cannot be seen in Figure 39. The lowest and the highest abundances is found in “alkaline” water (pH = 8). Also the Kruskal-Wallis-test does not show a significant tendency ($H(2) = 1.8333$; $p = 0.3999$).

There seems to be no clear tendency towards a specific pH value of the water. Moreover, the author has no knowledge of studies analyzing the impact of the pH on the abundance of turtles. Therefore, there seems to be no relevant impact of the pH value of the water on the abundance of the European pond terrapin.

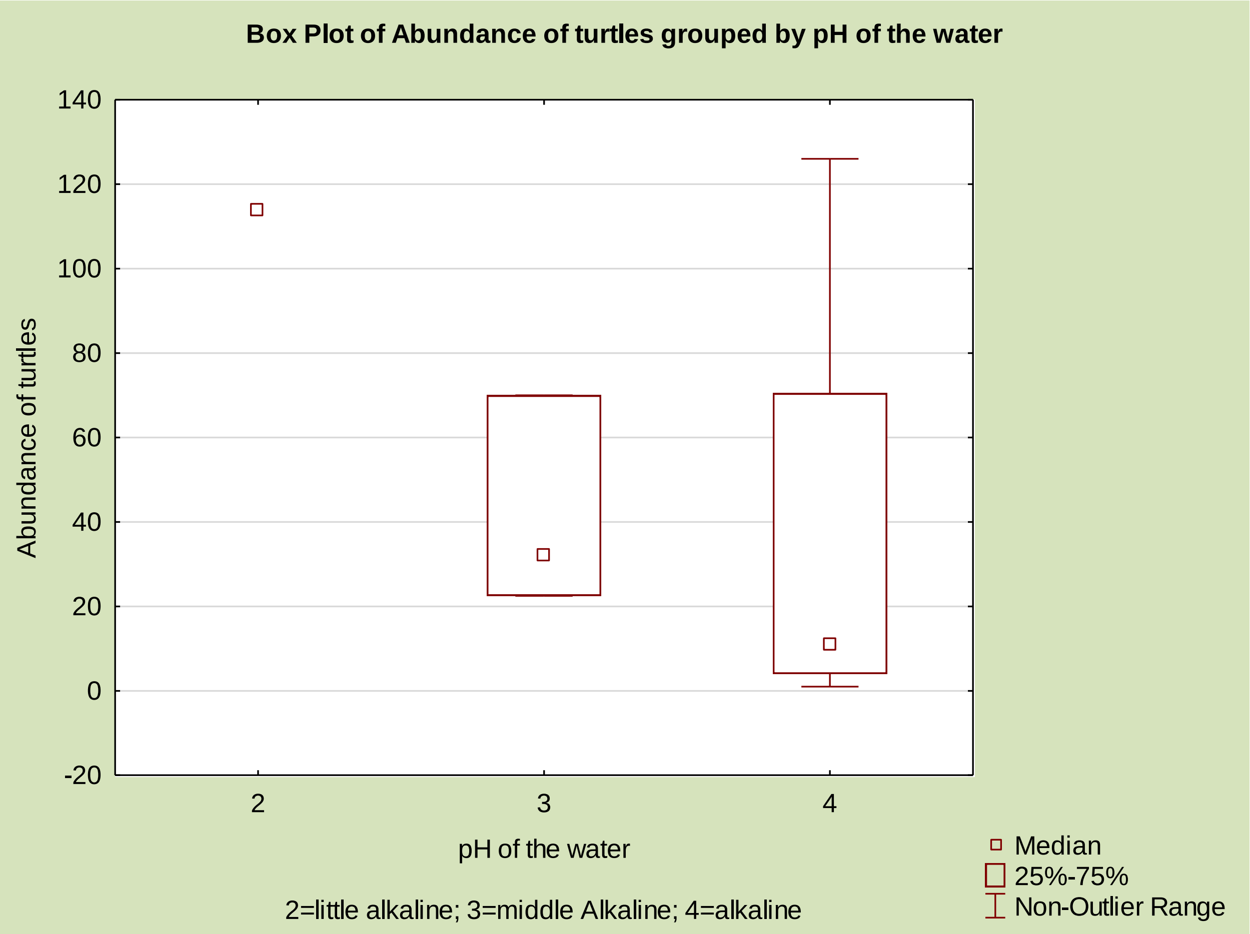

Figure 39 Box plot of abundance of turtles grouped by pH of the water.

4.2.13. Nutrition (macrozoobenthos)

The highest abundances are found in waters with a “middle amount of nutrition”. The abundances decrease with an increase in available nutrition. However, the lowest median of abundance is found in waters with “very few nutrition”. No studied water had the category “few nutrition”. All these tendencies are, however, not significant

(Kruskal-Wallis-test: H (3) = 2.8056; p = 0.4226). Nevertheless, it seems that a middle amount of nutrition is needed in a water to support a larger number of turtles.

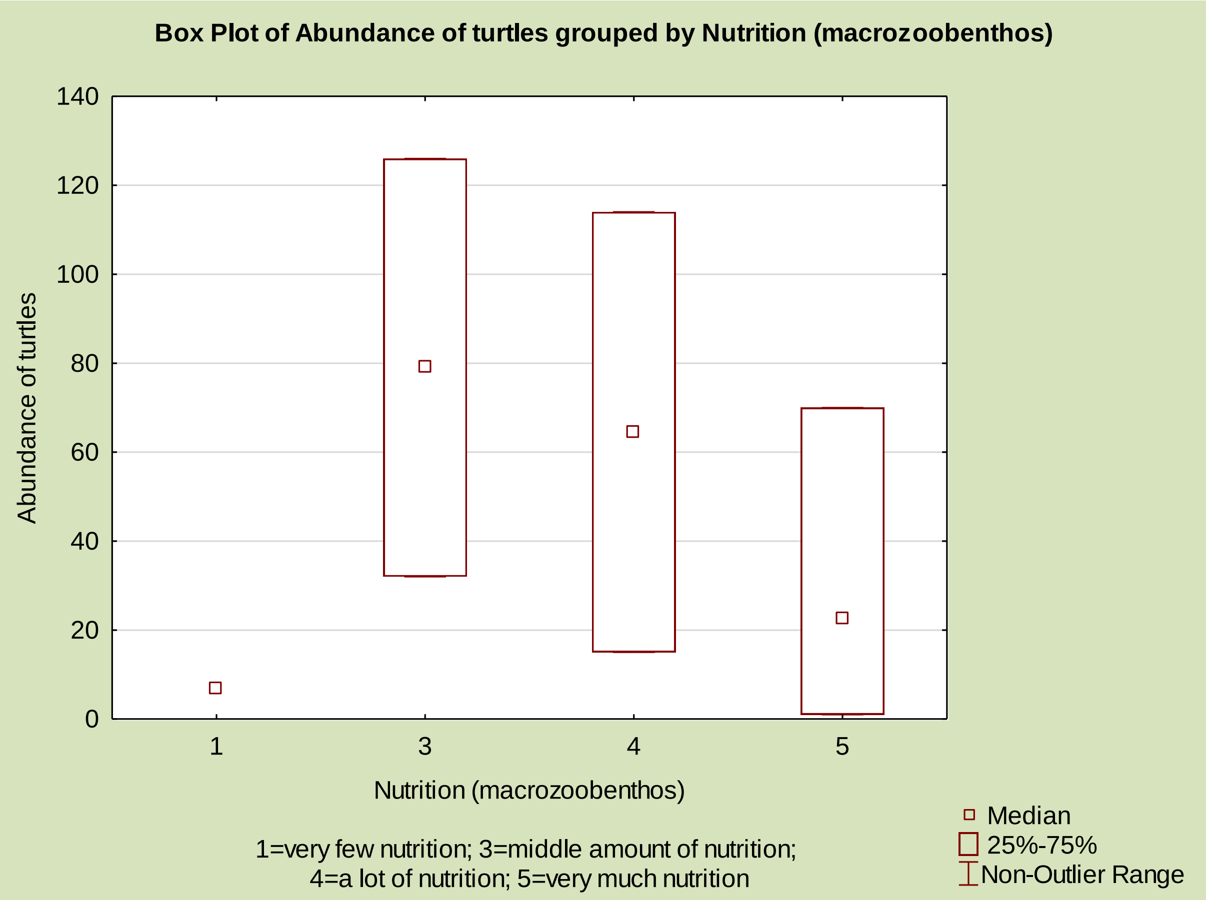

Figure 40 Box plot of abundance of turtles grouped by nutrition (macrozoobenthos).

Reasons for this low impact of the habitat feature “nutrition (macrozoobenthos)” could be the used method for determining the amount of nutrition. Although the used method was adapted to the method applied in Ficetola et al. (2004), it can only show the relative differences between the waters and not the abundances itself. Moreover, the European pond terrapin is not merely carnivorous (as outlined above) and thus, the macrozoobenthos does not cover its whole nutrition range. However, the European pond terrapin feeds mainly on the macrozoobenthos (Schindler, Reckendorfer 2006).

Another reason could be that in all studied waters a sufficient amount of nutrition to support a high number of turtles is available which would reduce the impact of the feature. This is supported by Gemel (2001) who said that in the waters of the Donau-Auen National Park sufficient food items for the European pond terrapin are available

(Gemel 2001). However, the development of the mean carapax length indicates that there is a higher competition about food, which would indicate that the habitat feature "Nutrition (macrozoobenthos)" is a limiting and important factor. To explain, the mean carapax length (CL) of females was 15.89 cm (std. dev. = 1.87 cm), of males 14.32 cm (std. dev. = 1.33 cm) and of juveniles 9.15 cm (std. dev. = 2.03 cm).[11] There were no differences between the waters regarding the CL compared to age. Thus, in all waters they seemed to be equally fed.

However, in contrast to the findings of Rössler (1998) the females were relative small (CL: 17.2 cm compared to 15.89 cm). Reasons for this could also be the low catching number of females. However, the mean carapax length of males was also smaller in this study than in Rössler (CL: 15.4 cm (Rössler 1998) compared to 14.32 cm). This could be due to less nutrition in the last years, a higher competition over available resources due to an increasing density of turtles in the last years or due to a higher proportion of young turtles caught for which the sex could be identified compared to the catchings of Rössler (1998). Also, a combination of several factors is possible. Therefore, even if the tendency towards a specific amount of nutrition influencing the abundance of the European pond terrapin is not significant, it could be an important habitat feature. And if the development of smaller mean CL is continuing, it could be the limiting factor in the future. However, to verify this further studies are needed.

5. Possible limitations of results

The above finding could be limited by a number of issues which will be discussed next.

5.1. Extremes

The outliers and extremes do not always represent the found trends. The three main extremes and their main characteristics are listed in Table 5. There it can be seen that the amount of dead wood is in all three sections at least middle high, but the diversity of macrophytes is in two sections low. Why the abundances are despite this so high cannot conclusively be said. It could depend on a specific combination of habitat features. One aspect could also be a particularly high amount of nutrition in this section since the turtles were caught during their search for food. One would

[11] For more measurements and growth curves see Appendix VIII.

therefore expect a high diversity of macrophytes, which is in two sections not given. The macrophyte species present in the water sections of the three main extremes are listed in Table 6. Noteworthy is that in all three sections the species *Ceratophyllum demersum* and *lemna minor* are present. Especially, *Ceratophyllum demersum* could provide a water with structure and thus, influence the abundance of nutrition for the European pond terrapin in the water. However, if this macrophyte has an influence on the abundance of the turtle and if it is even a part of the nutrition of the European pond terrapin has to be studied; particularly, since it is present in all studied waters.

Table 5 Characteristics of the extremes UD22, ED16 and WD15.

ID	Abundance of turtles	Distance[12]	Side	Amount of dead wood	Diversity of macrophytes
UD22	22	75	west	a lot	low
ED16	26	275	east	middle	high
WD15	22	225	west	very much	low

All extremes are on the side of the Danube. Interesting is that in general the abundances of the whole water (300 m) are on the side of the Danube higher than on the side of the land. One reason for this could be that these waters are sometimes directly connected to the Danube. Contrary to this, the European pond terrapin is considered to prefer stagnant waters (with a high temperature) which are not connected (Schindler, Reckendorfer 2006). Another reason could be that in the waters of the side of the Danube a higher amount of dead wood and a higher diversity of macrophytes is present compared to the waters of the side of the land. This tendency could, however, not be found in this study.

[12] The distance from the beginning of the water at the side of the dike to the fish trap.

Table 6 Macrophytes present in the extremes UD22, ED16 and WD15.

UD22	ED16	WD15
Elodea canadensis		
Ceratophyllum demersum	Ceratophyllum demersum	Ceratophyllum demersum
	Hydrocharis morsus-ranae	
	Iris pseudacorus	
Lemna minor	Lemna minor	Lemna minor
	Lemna trisulca	
	Polygonum mite	
	Ranunculus circinatus	
	Sagittaria sagittifolia	
	Sparganium emersum	
Spirodela polyrhiza	Spirodela polyrhiza	
		Phragmites australis
		Lysimachia nummularia
		Myriophyllum spicatum
		Carex sp.

5.2. Heterogeneity and connectivity

Even though only two habitat features show a significant impact on the abundance of the European pond terrapin, also the other habitat features could be important since the turtles may need a specific combination or heterogeneity in the water. For example, the waters need to be suitable for inter alia hibernation and mating and both lead to different requirements for the water.

Moreover, the European pond terrapin needs a connection of different habitat types (e. g. water to live and places for oviposition). In general, the connectivity of different habitats is important for species in terms of inter alia genetic diversity (inter alia Howes et al. 2009). Ficetola et al. (2004) showed for example the relevance of woodlands around the waters since they enable the European pond terrapin to migrate between different habitat types and thus, lead to a higher connectivity (Ficetola et al. 2004). In the study area all waters are surrounded by forests thus the parameter was not analyzed.

5.3. Further habitat features

Also, further habitat features that were not studied in this thesis could be relevant. Other studies suggested the importance of inter alia chemical pollution, connectivity to the main stream and solar radiation (Ficetola et al. 2004; Schindler, Reckendorfer 2006). The European pond terrapin seems to be resistant against a high organic pollution of the water at least in the short run (Devaux 2000; Ficetola et al. 2004). In this study the phosphate concentrations in the waters were between 0 mg/l and 0.05 mg/l, the nitrate concentration was between 0 mg/l and 10 mg/l and the chloride concentration between 0 mg/l and 0.8 mg/l. According to Prof. Dr. Thomas Hein these findings indicate that there is no pollution by nutrients and chloride in the waters (pers. com. Prof. Dr. Thomas Hein). Schindler, Reckendorfer (2006) showed that turtles in Austria prefer stagnant waters which is probably connected to a declination in water temperature in waters with a high current. Moreover, waters with less solar radiation seem to be preferred. This may be due to less disturbances by humans (humans prefer sunny ways), less dead wood in sunny waters due to few trees on the shoreline or less solar radiation being found in waters which are not as wide and often have a low depth which lead to higher water temperatures despite the high shadowing (Schindler, Reckendorfer 2006). In this study these factors were not analyzed due to the limited scope of this thesis and problems with data acquisition.

5.4. Assumptions behind Lincoln-Petersen-Index

A further limitation of the results would be a violation of the assumptions behind the Lincoln-Petersen-Index (for the assumptions see Appendix I). All but one seem to be fulfilled. Whether the assumption that “the initial sample taken is representative of the entire population (i.e., not biased by age or sex)” (Donnelly, Guyer 1994) is violated, is discussed below. The focus is on the sex ratio since the age distribution seems to be representative (see Figure 41).

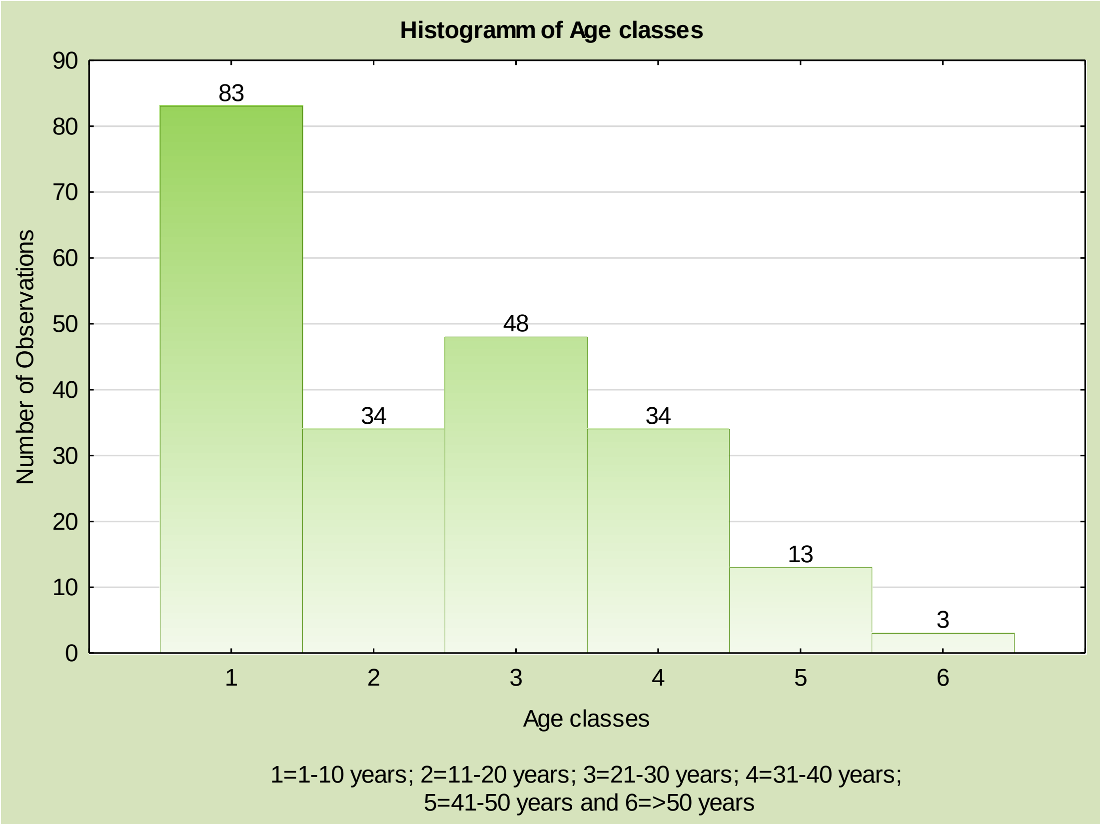

Figure 41 Histogram of the age classes of all studied waters.

With 102 males, 31 females and 82 juveniles[13] there was a high proportion of males and juveniles[14]. Therefore, the sex ratio of all turtles was male-biased (males/females = 3.29). If it is representative for the population is analyzed in the following.

This high proportion of males was not found in other studies, some studies were even female biased (see Table 7). Moreover, during the protection program „Europäische Sumpfschildkröte" a high number of females were marked in the Donau-Auen National Park before this study (48 males, 250 females and 44 were the sex was not identified)[15] (pers. com. Maria Schindler). However, just 6 already marked females were caught during this study and in one case it was not clear if it was marked before. Therefore, combined with the fact that *Emys orbicularis* seems to have a survivorship in adults of nearly 1.0 (Mitrus, Zemanek 2004), the population

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[13] Juveniles were turtles between 1 and around 15 years were the sex could not be determined due to the young age. However, it has to be mentioned that for some turtles younger than 15 years it was possible to identify sex.
[14] The proportion of juveniles is discussed in chapter 4.4.
[15] However, here it has to be mentioned that the females were mostly marked during oviposition and not during mark-recapture studies.

of the European pond terrapin in the National Park does not seem to be as male biased as this study suggests which speaks for a violation of the assumption.

Table 7 Sex ratios of this and other studies.

Study	male : female	Country
This study (2016)	3.29 : 1	Austria, Donau-Auen NP
Auer, Taskavak (2004)	1.4 : 1	Turkey
Ayaz et al. (2008)	1.3 : 1	Turkey
Schindler (2012)	1.3 : 1	Austria; Donau-Auen NP
Mosimann (2002b)	2 : 3	Switzerland
Ayaz, Çiçek (2011)	1 : 1.4	Turkey
Bayrakci, Ayaz (2014)	1 : 1.11	Turkey

Reasons for these male biased results could be that females are more cautious in their behavior. An indication for this could be a lower recapture probability of females. The percentage of males recaptured in this study was 18.62%, of females 3.23% and of juveniles 13.41%. Therefore, there seems to exist a lower recapture probability of females which indicates a more cautious behavior of females.

However, whether this can describe this low catching number of females alone is questionable. Particularly, in light of the fact that with the identical catching method a less male biased result was generated (Schindler 2012). Mosimann (2002b) used similar catching methods and caught more females than males. Interesting is that before oviposition more adult males and after oviposition more adult females were caught (Mosimann 2002b). This is in contrast to the findings of this study, since the catching was done after oviposition.

Another reason for this male biased result could be that males are more active than females during the time of the catching event (end of August until end of September) and would thus have a higher probability of being caught. This observation was made by Auer, Taskavak (2004) in Turkey, who caught turtles with different methods from June until begin of October. Furthermore, Gariboldi, Zuffi (1994) observed a lower activity of females than males in late summer. But if this is the case in this study cannot be said. In addition, it should be noted that the results from Auer, Taskavak (2004) were not as male biased as the current study.

Nearly the same male biased results were found in a study about freshwater turtles in Florida (USA) (*Pseudemys floridana*: 80% males; *Trachemys scripta*: 73% males; *Sternotherus odoratus*: 65% males) (Aresco 2005). The reason for this high proportion of males was here seen in the high number of road kills of females during their search for a nesting place on a close highway (Aresco 2005). Possible effects of road mortality on the demographic structure in the European pond terrapin in small northern populations was also discussed (Trakimas, Sidaravičius 2008). However, since the Donau-Auen National Park has only a low number of small roads, no small population size and just in some areas of the national park the females have to travel over official roads during their search for a nesting place it seems not likely that this is the reason for the male biased results in this study.

However, a plausible reason could be that females could stop earlier to eat and were thus not caught by this catching method since the assumption behind it is that they search for food in the night in shallow waters (as outlined in Chapter 2.2.1.).

Moreover, females could avoid waters with a high male population outside mating season to have more peace. Therefore, they could be in other parts of the waters that were not studied. Similar behaviour was suggested for wood turtles (*Clemmys insculpta*) (Kaufmann 1992).

Another reason could be that females inhabit other habitats than males. However, in the literature no indication for this was found. Also the habitat used by the caught females shows no differences in the tendencies towards a specific characteristic of the habitat features compared to males, except that they seem to avoid shallow water more than males (see Appendix VII).

The sex ratios of the single waters show that they are in all waters highly male biased (Table 8). Especially OD has a relative high abundance of males compared to females. However, this could be due to the low number of total catches in this water. ED is the lowest male biased water. In general it can be seen that the catches of females are distributed over the waters and no clear tendency towards a specific water can be seen. This speaks against a preference of females for a specific water and thus, against a preference of a different habitat than males.

Table 8 Abundances of females, males and juveniles as well as sex ratios of the single waters.

Water ID	Abundance females	Abundance males	Abundance juveniles	Sex ratio (males:females)
WL	1	4	2	4 : 1
WD	4	18	10	4.5 : 1
ED	10	23	38	2.3 : 1
EL	5	16	13	3.2 : 1
UL	1	4	7	4 : 1
OD	1	6	5	6 : 1
UD	9	30	7	3.33 : 1
OL	0	1	0	1 : 0
Total	31	102	82	3.29 : 1

In conclusion, it cannot be conclusively said which of the discussed reasons are valid. However, it seems to be a combination of several aspects. Therefore, the preciseness of the calculated abundances in the single waters depends on the reason for this high proportion of males. If the females were not caught due to being in other parts of waters, which were not studied, the abundances could be estimated quite precise. But if they were not caught by the used method although they were present in the study area, it could lead to an underestimation of the abundances. Therefore, the preciseness of the calculations cannot be conclusively established. However, the relations between the abundances in the waters and between the water sections and thus their influence on the habitat features should be representative.

5.5. Preference of specific habitat features by juveniles

A further limitation could be that juveniles prefer a different habitat from adults. To investigate this, it has to be analyzed if the proportion of juveniles in the single waters is influenced by the habitat or the protection program. The percentage of juveniles on the total number of catches is 38.14 %. If this is a higher proportion than in Rössler (1998) cannot be conclusively said since this data is missing in Rössler (1998). However, the proportion is relative high compared to other studies (Ayaz et al. 2008; Ayaz, Çiçek 2011) with the exception of one study (55 %) (Auer, Taskavak 2004). The current study has an age distribution in all waters with a relatively high proportion of young turtles (1-10 years) (see Figure 42 and Appendix IV). The percentages of the young turtles on the total number of catches in the single waters are shown in Table 9.

Table 9 Percentages of young turtles on the catches in the single waters.

Water	UD	UL	OD	OL	ED	EL	WD	WL
% of young turtles	13.04	58.33	41.67	0	47.89	44.12	43.75	28.57

Figure 42 A one year old turtle (JT34) caught on the 04.09.2016 in OD.

They show different proportions of young turtles in the studied waters. This could be due to the protection of the nests or the habitat features. At the nest sites close to the water Uferhaus only few nest protection measure were taken (2007-2012) and in Orth no protection measures at all. In contrast, at Eckartsau and Witzelsdorf a high effort of nest protection was done since 2007 (pers. com. Maria Schindler). However, no clear tendency towards a high percentage in the waters, where nesting protection measures were taken, can be seen. The percentages in UL, OD and WL are in contrast to the hypothesis that the percentage of young turtles is higher in waters with an intensive nesting protection. Yet, the results could be not representative for the waters due to the low catching numbers (12-7 turtles total). Moreover, the effect of this hypothesis could be reduced by the probably lower density of nests in the areas of Uferhaus and Orth compared to Eckartsau and Witzelsdorf, which may lead to a lower predation rate. Furthermore, there were observations of juveniles changing between waters in other studies (Meeske, Mühlenberg 2004). However, if they are able to travel the long distances between the waters is questionable.

The influence of the habitat features on the abundance on juveniles revealed, however, differences compared to males and females. Juveniles seem to prefer a higher amount of vegetation on the shoreline and water areas with low disturbances. Moreover, they are more in shallow waters than adults and are not as abundant in areas with a low abundance of macrophytes. Furthermore, they have a stronger tendency towards a very high diversity of macrophytes than males and females (see Appendix VII). Therefore, an influence of the habitat features on the abundance of young turtles seems plausible. Also, other studies stated a difference between the preferred habitat features between young turtles and adults. The findings of this study that young European pond terrapins prefer shallower water and a higher abundance of macrophytes than adults is supported by a number of other studies (Rössler 2000b; Cadi et al. 2008; Schindler, Reckendorfer 2006).

Nevertheless, the variations between the waters could be influenced by both factors but it seems more influenced by habitat features. This relatively high proportion of young turtles on the catches is an indication for a healthy population, which successfully reproduces, and speaks against a high male biased population. Moreover, the results show that there are differences in the habitat requirements between young turtles and adults. This has to be considered when developing a suitable protection program for the European pond terrapin. However, since the young turtles also prefer a high amount of dead wood and a high diversity of macrophytes the differences are not as crucial.

5.6. General suitability of the habitat for the European pond terrapin

A main limitation of the results would be, if the current status of the habitat were not generally suitable for the European pond terrapin. To check this, the population size and its development will be presented and discussed next.

The total length of the waters that are possible turtle habitats (not connected to the Danube by middle water and on the north side of the Danube)[16] in the lower Austrian part of the Donau-Auen National Park is 62,756 meters. The densities and population sizes of the minimum, maximum and mean are represented in Table 10.

Table 10 Densities and population sizes of the European pond terrapin in the Donau-Auen National Park.

	Minimum	Mean	Maximum
Density (turtle per 1 meter shoreline, both sides)	0.003	0.161	0.42
Population size in the Donau-Auen NP	209	10,132	26,358

These values show a wide range in which the true population size could lie. The minimum of 209 individuals seems to be too low. Since the sum of all calculated abundances of the studied waters is 387 individuals and these waters were just a small part of all waters in the National Park. Therefore, this can be seen as the minimum of the population size in the lower Austrian part of the Donau-Auen National Park. Moreover, in 1989 the population was estimated at over 100 individuals (Lutschinger 1989), in 1998 a population size around 270 individuals was expected (Rössler 1998) and before this study the population size was estimated at 1,000-1,500 individuals (pers. com. Maria Schindler). So, in the recent years there seems to be an increase in the population that may be the result of the protection of the nests by the protection program "Europäische Sumpfschildkröte" in the National Park. This is supported by the high proportion of young turtles. However, this increase could also be due to more verified data about the population size and not a true increase on individuals. Considering these aspects and the fact that not in all waters such a low density as 1 turtle per 300 meters shoreline (both sides) is found, it seems reasonable to estimate the population higher than the minimum.

The maximum seems to be at 26,358 individuals too high since not in all potential waters suitable for the European pond terrapin is such a high abundance as 126 turtles per 300 meters shoreline (both sides). Moreover, the studied waters were waters in which *Emys orbicularis* was expected and thus probably waters with relative high abundances. Furthermore, there seems to be a tendency that in the water sections close to the dike there is a higher abundances than in water sections

[16] For detailed information and the used method for the calculation of the population size see Appendix VIIII.

with a high distance from the dike (Schindler, Reckendorfer 2006). However, this tendency was not found in the first 300 meters of the studied waters in this study. These aspects seem to lead to an overestimation of the population size if the maximum is used.

Also, the mean population size seems considering these aspects as an overestimation. This is supported by the fact that some of the waters which were seen as potential suitable waters for the European pond terrapin are not permanent with water and thus, not as suitable as the studied waters. But there is also an indication for a underestimation since in WD and WL were relative low densities and this could be due to the already cold weather during catching (inactivity) and / or a stop of feeding by the turtles before hibernation or a high number of females which were not caught. In general, the low number of females could lead to an underestimation of the number of individuals if they were present in the studied waters but not caught due to their cautiousness or other reasons.

Nevertheless, the factors for an overestimation seem to outweigh those for an underestimation. Therefore, a population size between the minimum and mean seems plausible. An estimated population size of 387-10,132 can be assumed. Considering all aspects, a population size within the middle of this range seems plausible. However, to narrow this further down further investigations need to be conducted (e. g. to study the suitability of the not studied water sections and/or include just waters were the presence of the European pond terrapin is known).

Generally, there seems to be an increase in the population size in the last years which could be due to the protection of the nests by the protection program “Europäische Sumpfschildkröte” and/ or a development in the habitat which is more suitable for the European pond terrapin (e. g. increase in dead wood through the reintroduction of the beaver and the increase in its population size) (Rössler 2000b). However, the current status of the habitat is generally suitable for the European pond terrapin. Therefore, the Donau-Auen National Park is an applicable area to analyze the needs of *Emys orbicularis* regarding the habitat.

5.7. Homing behavior

Another important question is whether the fish trap areas represent the homing area of the European pond terrapin and thus, the turtles are loyal to a specific fish trap area. This would indicate that the results are applicable for the whole living area of the turtle and not just for the feeding grounds.

Several studies suggest that the European pond terrapin is loyal to a specific part of a water (homing behavior) which is in some studies only 50 meters long (Cadi et al. 2004; Cadi et al. 2008; Lebboroni, Chelazzi 1991, 2000) and thus, support the assumption behind the thesis that the European pond terrapin has a homing behavior and the caught turtles are loyal to the fish trap area.

However, the findings of this study contradict this assumption, as will be outlined below.

After catching and taking measurements the turtles were released in the middle of the water section as illustrated in Figure 6. Consequently, a movement of the turtles towards the fish trap where they were caught first would be expected. For all recaptures it was analyzed if this was the case by looking at the positions of the fish traps of the first and the second catching.

From 31 recaptures 51.61 % were towards the direction of the first trap if one considers the north south direction (as 573 in Figure 43 contrary 548).[17] If one looks at the direction west east 45.16 % of all movements were towards the same shoreline side (as 573 in Figure 43 contrary 548). This indicates no homing behavior; the movements seem to be random. However, the directions of the movements of the European pond terrapin were not randomly distributed as it can be seen in Table 11. There, a clear tendency towards the north direction can be seen. The mean distance the turtles swam was 52.42 m. However, since the turtles were released in the middle of the study area the maximum recognizable distance was 125 meters (n = 4). Therefore, it has to be considered that turtles with a higher traveled distance were not caught again.

[17] Two of the analyzed movements were towards the direction of the first fish trap but the turtle already passed the trap (see Figure 43 turtle 554). Therefore, these two movements were considered as movements away from the first fish trap.

Table 11 Directions of the movements of the European pond terrapin.

Direction	Northwest	northeast	southwest	southeast
N	13	12	3	3
% of all recaptures	41.93	38.71	9.68	9.68

There seems to be no significant differences in the movements of males and juveniles just the distance seems longer for males (males = 59.32 m; juveniles = 43.18 m). Since only one female was recaptures no assumption can be made for females.

There were no travels of turtles between the different waters observed as in other studies (inter alia Cadi et al. 2004; Cadi et al. 2008). However, this could be due to the short timeframe between the capture events in the different waters.

In conclusion, the findings do not indicate a homing behavior of the European pond terrapin in the Donau-Auen National Park as found in other areas by various studies. However, it could be that the home range is larger than the estimated 50 meters (around the fish trap). Therefore, there could be a homing behavior if one employs a larger scale. For a more verified result telemetry studies should be conducted. With help of these studies also the strong tendency towards north could be verified or refuted and reasons identified. However, this indicates that the assumption behind this thesis that the turtles have a small homing behavior is wrong and thus, the results have to be seen critically. They only show the preferences for the feeding grounds of the European pond terrapin. However, as discovered in this thesis the nutrition seems to be an important factor. Hence, the feeding grounds are an essential area for the European pond terrapin and thus, a representative study area.

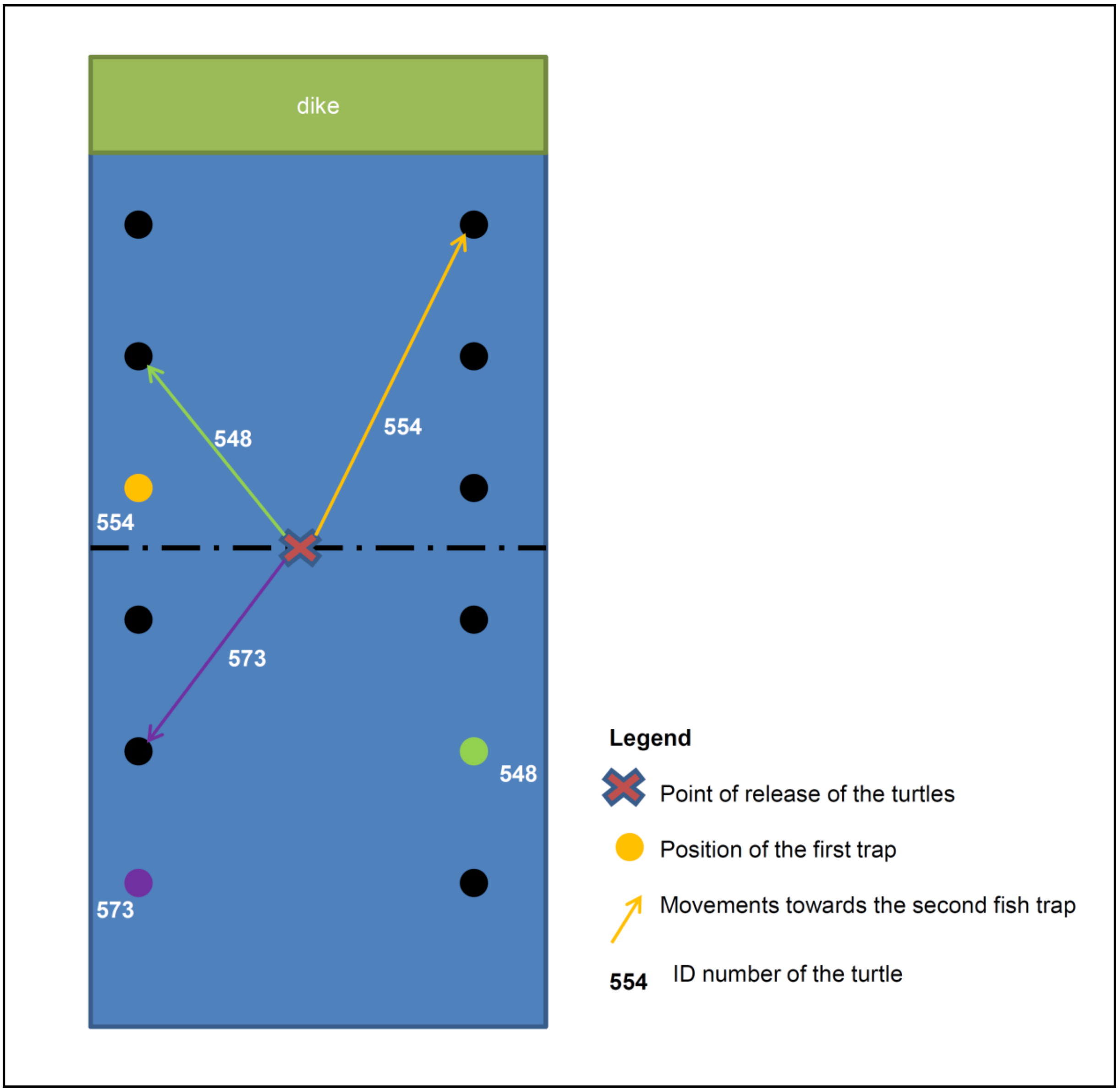

Figure 43 Illustration of the movements of three turtles in UD.

5.8. Time and local limitations

For all results found it should be noted that they reflect only short time window before hibernation and do not include the whole annual cycle even though it was tried to include factors of the whole cycle (e. g. hibernation by "Degree of softness of the ground"). Nevertheless, for more verified results further telemetry and observations during other periods of the year are required.

Moreover, the results may only be valid for the local population since they may represent adaptations to specific conditions in the studied waters and not generalizable needs for the species European pond terrapin. For example, a study about hawksbill sea turtles (*Eretmochelys imbricata*) showed that they have different needs regarding nesting habitats in various areas (Liles et al. 2015).

6. Consequences for protection measures

Two of the analyzed habitat features are found to have a significant effect on the abundance of the turtles:

- An increase in the diversity of macrophytes seems to lead to an increase in the abundance of the European pond terrapin.
- A higher amount of dead wood seems to result in a higher abundance of *Emys orbicularis*.

This indicates that for the suitability of the habitat for the European pond terrapin in the Donau-Auen National Park a high diversity of macrophytes and a high amount of dead wood is essential. Moreover, the amount of nutrition seems, despite the non-significant results, to be an important factor. Therefore, it has to be ensured that the diversity of macrophytes and the high amount of dead wood is sustained in the waters of the Donau-Auen National Park. Moreover, the amount of nutrition should be monitored.

The protection of the habitat features can be ensured by habitat protection measures like those taken in the Donau-Auen National Park which are in line with the idea of a national park (ecosystem protection and recreation): the protection of habitat with the least possible interventions (i. e. no economical use, no to few fishery and nearly no interference in nature), but at the same time enabling the visitors recreation (i. e. allowed to walk on paths) (Rössler 2000a; Dudley 2008). However, those may not always suffice to sustain a population if it has unknown threats which are not easily recognized in cases of a long-lived species as impacts are not seen directly (Browne, Hecnar 2007). Therefore, the two habitat features should be monitored and a long-term survey should be conducted over the next decades in order to see if interventions may be needed. In 10 years a study employing the same catching method in the same waters should be done in order to gain knowledge about the development of the population. Due to the relatively high proportion of juveniles the population seems to successfully reproduce and a positive development can be expected. Nevertheless, threats as sedimentation of the water or toxics by nearby agriculture could lead to a contrary development. Moreover, the amount of nutrition could be a limiting factor for the population size and could lead to a spreading of the European pond terrapin in waters outside the national park. Therefore, the development of the mean carapax lenght should be monitored as well. Thereby, it is also important to consider the age of the turtles caught compared to the age distribution of this study.

For re-introduction programs in other regions the two habitat features “diversity of macrophytes” and “abundance of dead wood” should be considered during the search for a re-introduction area as well as the availability of nutrition. However, also other studied features could be relevant for the European pond terrapin and should be kept in mind.

Further findings of this thesis showed that the waters on the side of the Danube have a higher abundance of *Emys orbicularis* than the waters on the land side. Therefore, these waters should be prioritized for protection measures (especially with regard to reconnection programs to the Danube[18]). Moreover, the reason for this tendency should be studied in order to develop suitable protection measures.

One main issue that was identified during this study is the high male-biased result. It has to be checked if these results are based on a truly male-biased population or if they are caused by the above-discussed reasons (e. g. cautiousness of females).

7. Conclusion

The goal of this thesis was to identify habitat features that are essential for the suitability of the habitat for the European pond terrapin in the Donau-Auen National Park in order to find suitable protection measures.

To reach this goal, a capture-recapture study was conducted and habitat features, which were identified as relevant for the European pond terrapin by literature research, were mapped. Finally, both factors, the abundances and habitat features, were correlated.

[18] A higher current could decrease the suitability of the habitat for the European pond terrapin.

The results showed that only two of the analyzed habitat features have a significant influence on the abundance of the turtles. An increase in the diversity of macrophytes seems to lead to an increase in the abundance of the European pond terrapin. Similarly, a higher amount of dead wood seems to result in a higher abundance of *Emys orbicularis*. This indicates that for the suitability of the habitat for the European pond terrapin in the Donau-Auen National Park a high diversity of macrophytes as well as a high amount of dead wood is essential. Moreover, the amount of nutrition seems, despite the non-significant results, to be an important factor. This was indicated by the development over the last years towards a smaller mean carapax length.

However, the found male-biased sex ratio could have led to an underestimation of the abundances of females, but the relative values should be comparable and thus, the results should be representative. However, the found homing behavior of the European pond terrapin could limit the results of the study. The study showed a wider homing area than the catching area (50 meters) and thus, the results represent just the preferences of habitat features in the feeding grounds of the European pond terrapin. Nevertheless, due to the high importance of the available amount of nutrition the feeding grounds seem to be the crucial living area of the turtles and thus, a representative study area.

Therefore, to protect this rare species a high amount of dead wood and a high diversity of macrophytes should be ensured. For this, a long-term monitoring of these two habitat features should be conducted, to see if interventions in the habitat of the European pond terrapin in the Donau-Auen National Park are needed. Moreover, the availability of nutrition should be monitored. For re-introduction programs in other areas a high amount of dead wood, a high diversity of macrophytes and a sufficient availability of nutrition should be present, although the dead wood could be artificially introduced.

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10. Appendix

Appendix I Assumptions behind the Lincoln-Petersen-Index

The five assumptions behind the mark-recapture method with the Lincoln-Petersen-Index are: “[…] (1) the initial sample taken is representative of the entire population (i.e., not biased by age or sex); (2) all animals taken in the initial sample are marked, and the marks are permanent and recorded correctly; (3) the marked animals are released and become distributed randomly in the population; and (4) marking does not affect the probability of recapture or survival (i.e., marked and unmarked animals have equal catchability).” (Donnelly, Guyer 1994) As well as (5) the population has to be closed (Donnelly, Guyer 1994).

In this study, the assumptions 2), 3) and 4) as well as 5) seem to be met; however, the sex distribution seems to be not representative for the entire population (see Chapter 5.4.).

Appendix II Data sheet for caught turtles

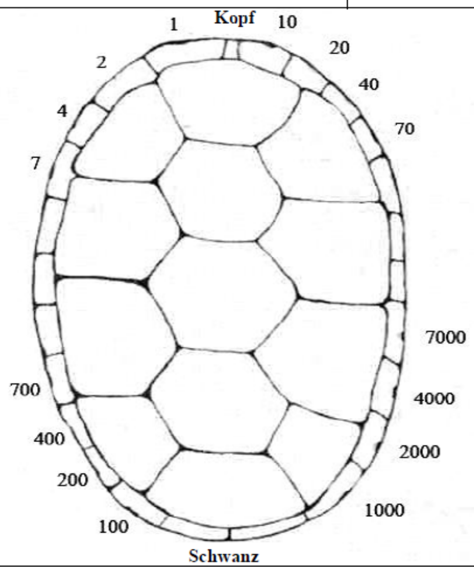
Datum: ……………………… Bearbeiter: ……………………………….

Uhrzeit: …………………….. ……………………………….

Reusennr.	

Angaben zum Standort			
Gewässer	Dammseite		Abstand zum Damm
	L	D	

Angaben zur Schildkröte				
Codierungsnummer (Kerben in Zeichnung eintragen und nebenstehende Zahlen addieren)		Vorher Markiert		Wiederfang
		Ja	Nein	



Größenangaben

CL:

CW:

PL:

PW:

Höhe:

Kopfbreite:

Gewicht:

Geschlecht	weiblich	männlich	JT
Panzeranomalien			
Verletzungen			

Geschätztes Alter:	(Klassen: 1-10; 11-20; 21-30; 31-40; 41-50; >50)

presence of plastral hinge: not distinct distinct

width of plastral hinge: narrow widened broad

carapax growth rings (n):

plastral growth rings (n):

% of surface with visible growth rings

on carapax:

on plastron:

Smoothness of carpax: none middle strong

Smoothness of plastron: none middle strong

erosion of carpax: none middle strong

erosion of plastron: none middle strong

Bemerkungen:

Fotos: IMG____

Figure 44 The data sheet for captured turtles.

Appendix III Age determination table

Age classes	plastral hinge		Growth rings		% of surface with visible growth rings		Smoothness of		Erosion of	
	presence	width	carapax	plastron	carapax	plastron	carapax	plastron	carapax	plastron
1-10	not distinct	narrow	<11	<11	100	100	none	none	none	none
11-20	not distinct	narrow	>11	>11	100	100	none-middle	none - middle	none	none
21-30	not distinct	narrow	>16, or not visible	>16, or not visible	99-60	99-60	middle-strong	middle-strong	none-middle	none-middle
31-40	distinct	narrow	>16, or not visible	>16, or not visible	59-30	59-30	middle-strong	middle-strong	middle	middle
41-50	distinct	widened	>16, or not visible	>16, or not visible	29-0	29-0	strong	strong	middle-strong	middle-strong
>50	distinct	broad	>16, or not visible	>16, or not visible	10-0	10-0	strong	strong	strong	strong

Figure 45 The Age determination table after Schneeweiss (2004).

The age determination is just an estimate and was done with the above shown table and the taken age parameters. However, in reality it was not as clearly distinct as in the table, but with all parameters together an estimate was possible. To mention is that the growth rings (both on carapax and plastron) were never over 10 and mostly between 6 and 7 even if the turtle was older than 20 years.

Appendix IV Histogram of Age classes in the single waters

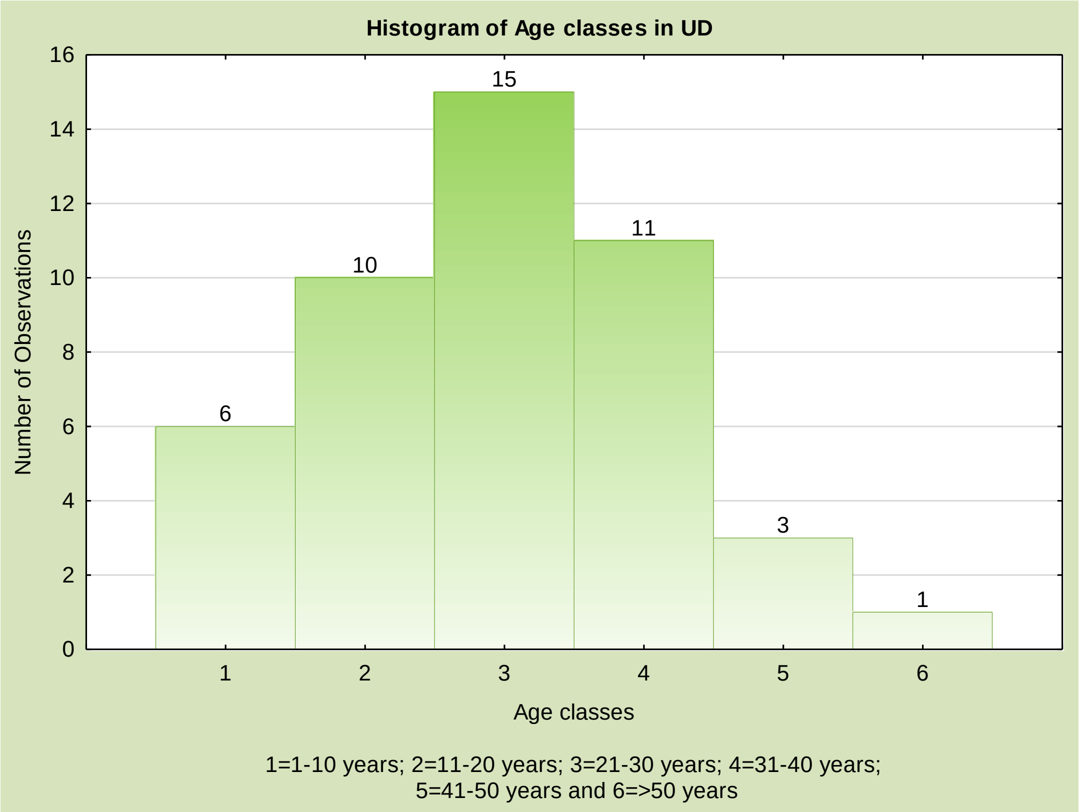


Figure 46 Histogram of age classes in UD.

Figure 47 Histogram of age classes in UL.

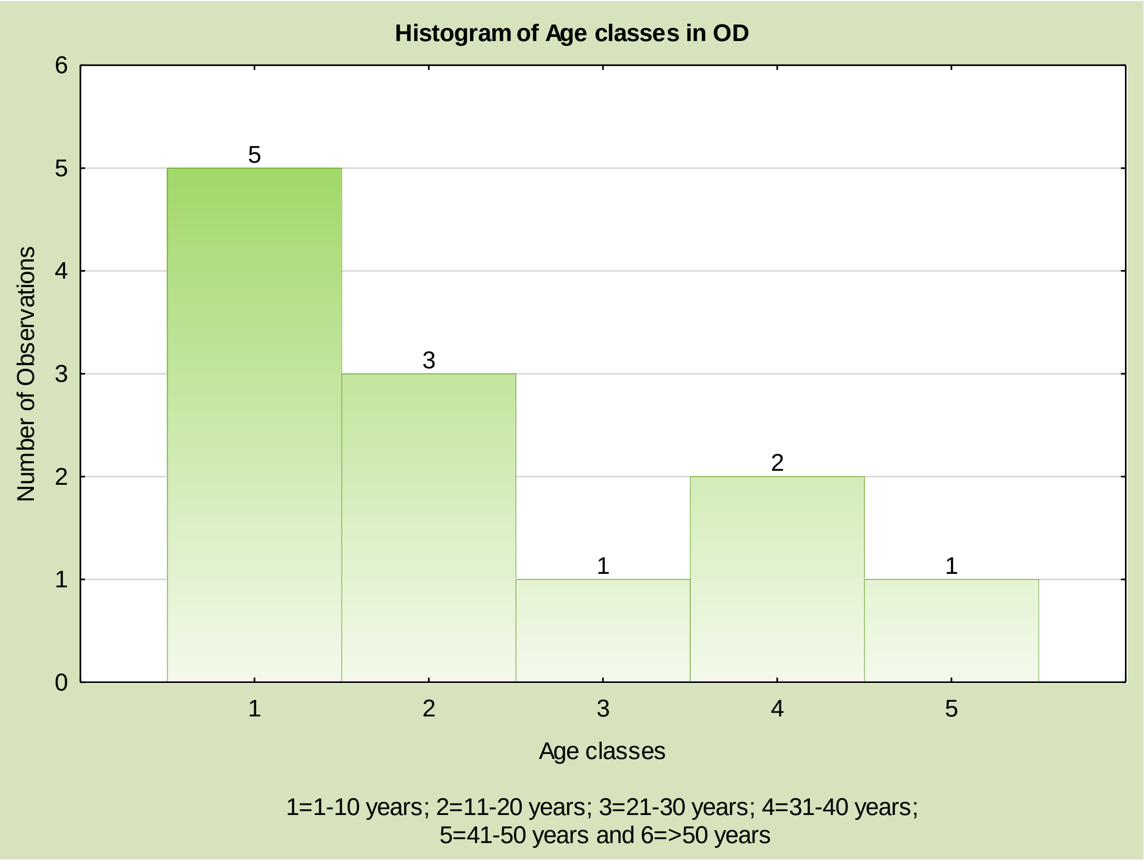


Figure 48 Histogram of age classes in OD.

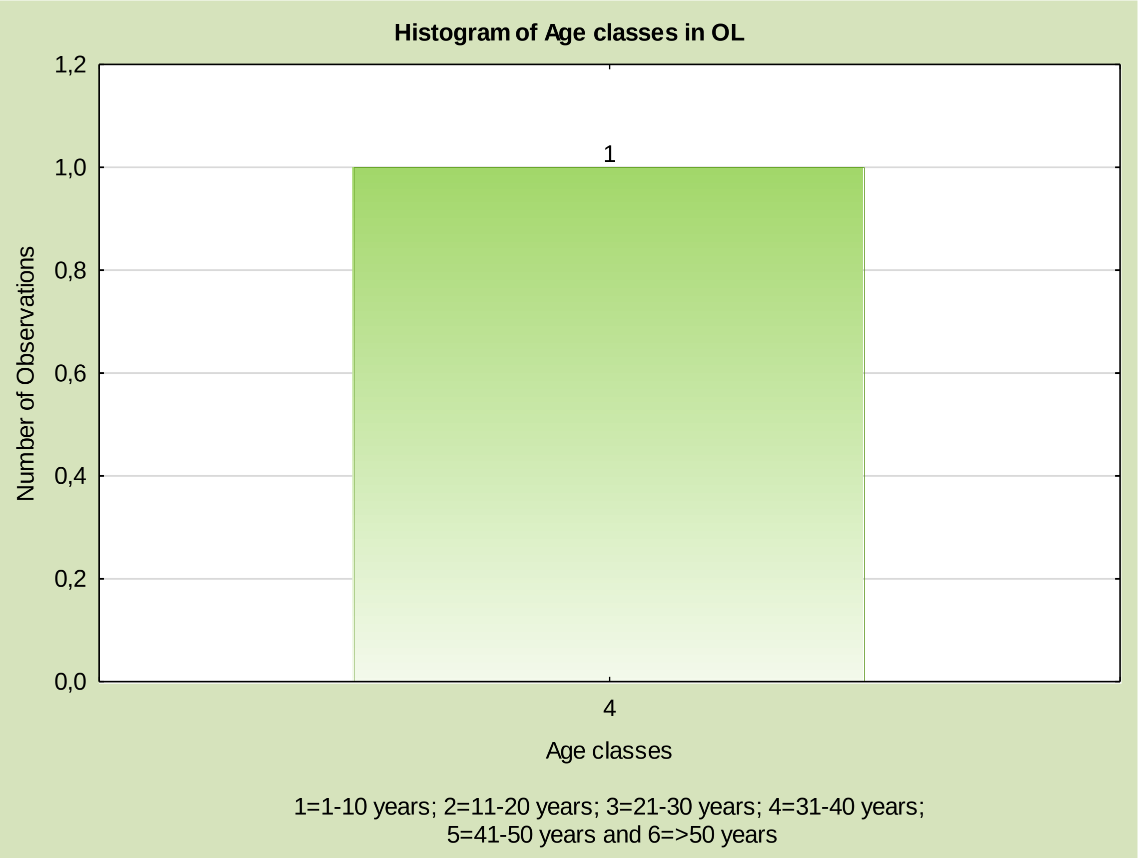


Figure 49 Histogram of age classes in OL.

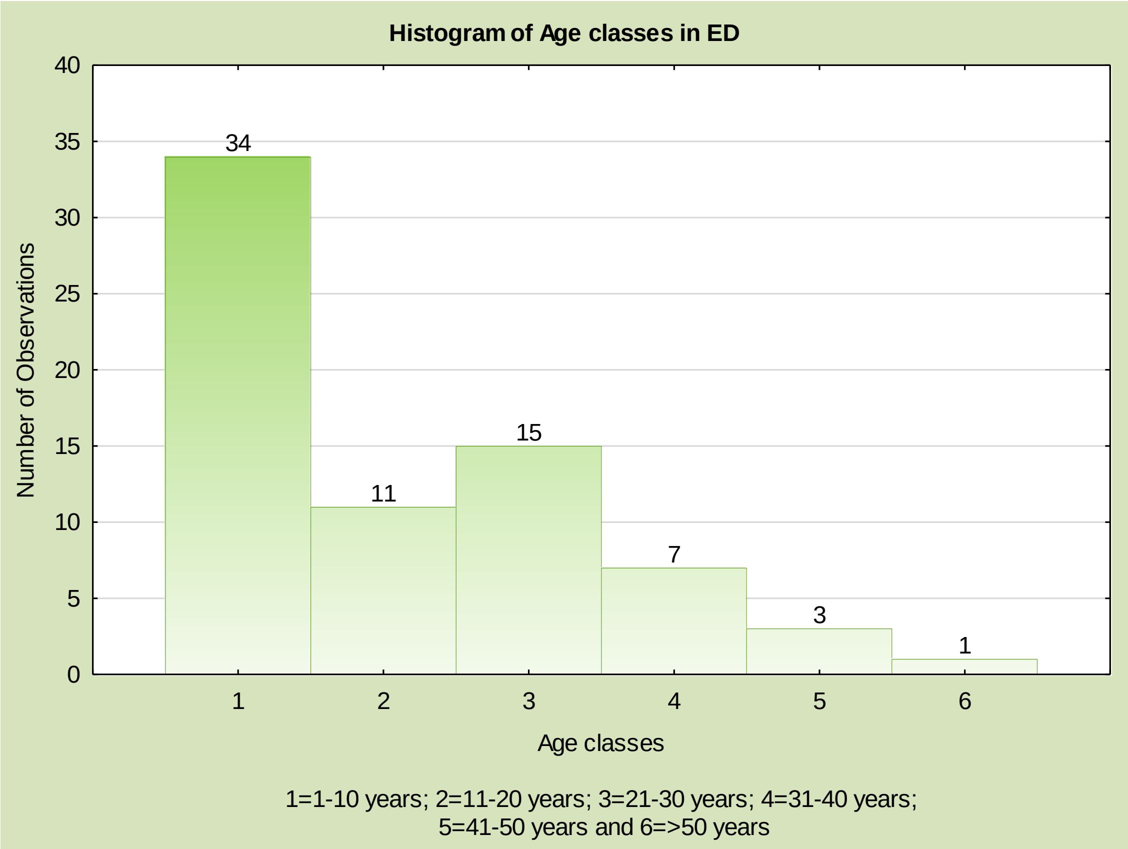


Figure 50 Histogram of age classes in ED.

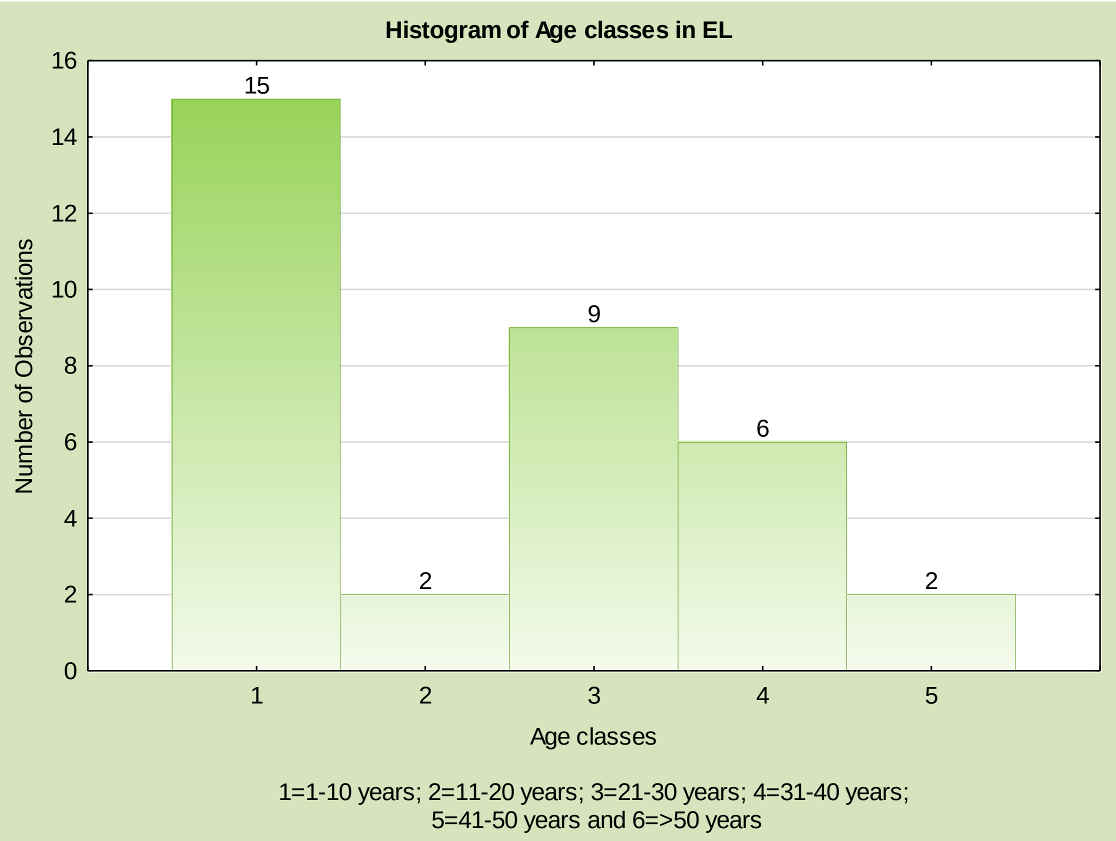


Figure 51 Histogram of age classes in EL.

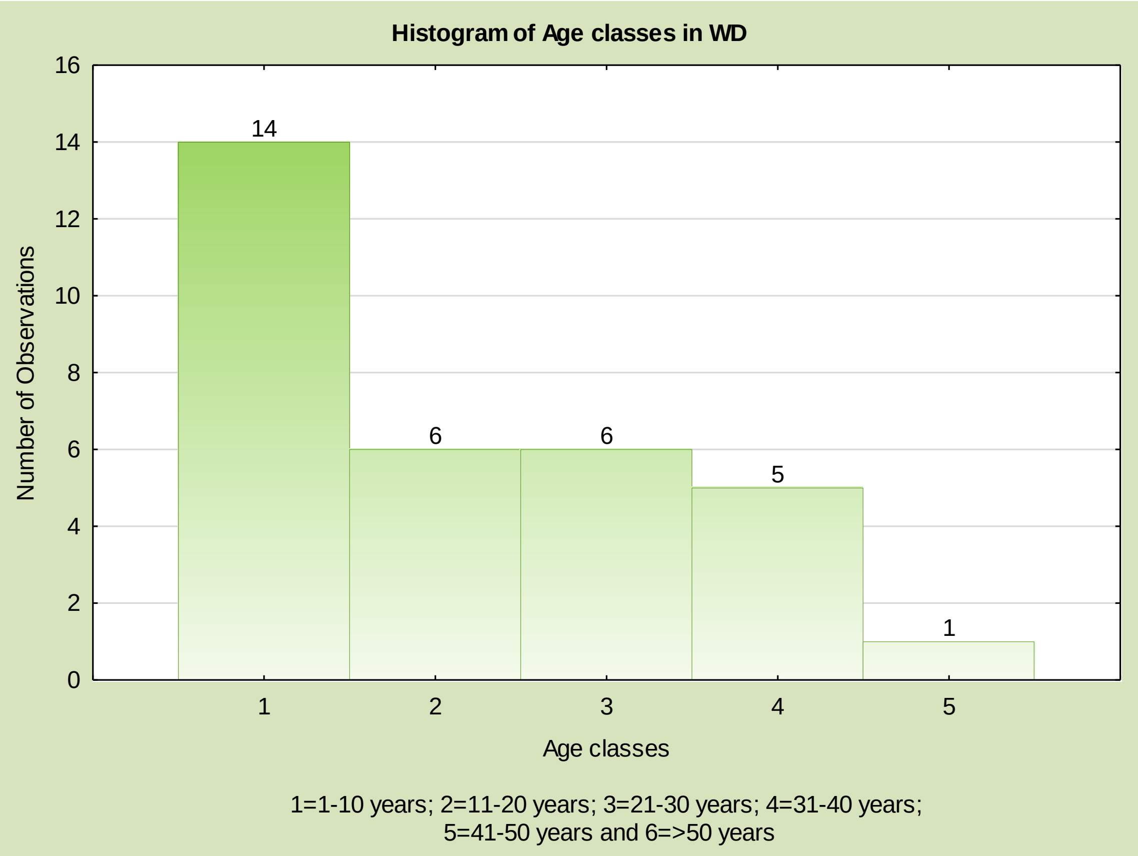


Figure 52 Histogram of age classes in WD.

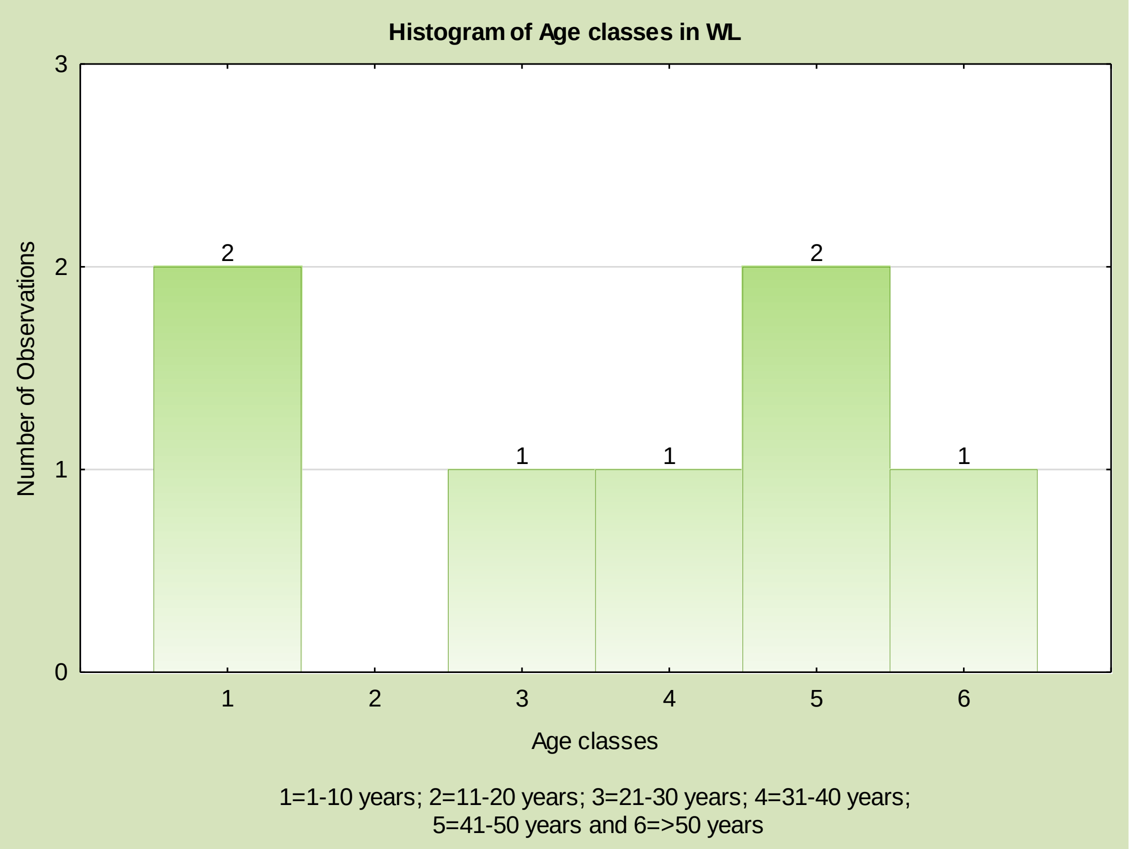


Figure 53 Histogram of age classes in WL.

Appendix V Table of abundances and habitat features

ID	Abundance of females	Abundance of males	Abundance of juveniles	**Abundance of turtles**	Degree_of_softness_of_the_ground	Degree_of_vegetation_of_the_shoreline	Abundance_of_dead_wood	Steepness_of_the_shoreline_above_water	Steepness_of_the_shoreline_below_water	Depth_of_the_middle_at_the_water	Distance_to_nesting_places	External_disturbances	Abundance_of_macrophytes	Diversity_of_macrophytes	Temperature	pH_of_the_water	Nutrition_macrozoobenthos
ED15	2	0	4	**6**	4	4	3	2	2	2	2	2	3	4	3	4	3
ED14	0	5	6	**11**	4	3	3	1	3	1	3	3	3	5	3	4	3
ED21	1	0	6	**7**	4	2	4	2	5	2	4	4	3	5	3	4	3
ED18	0	0	1	**1**	4	3	3	2	3	2	5	5	4	3	3	4	3
ED19	0	1	0	**1**	4	4	4	2	2	2	5	5	3	4	3	4	3

ED16	5	9	12	**26**	4	5	3	3	4	4	5	5	5	4	3	4	3
ED13	0	2	4	**6**	4	2	5	3	3	2	2	2	3	4	3	4	3
ED20	0	0	3	**3**	4	4	4	3	3	1	3	3	3	5	3	4	3
ED24	0	0	4	**4**	4	4	4	3	2	2	4	4	3	5	3	4	3
ED22	0	3	5	**8**	4	4	3	3	2	2	5	5	4	3	3	4	3
ED17	1	3	1	**5**	4	3	4	2	5	2	5	5	3	4	3	4	3
ED23	1	2	2	**5**	4	5	3	3	5	4	5	5	5	4	3	4	3
EL20	0	2	0	**2**	4	4	2	2	2	2	1	1	3	4	3	2	4
EL24	1	3	1	**5**	3	4	1	4	5	4	2	2	5	4	3	2	4
EL16	0	1	1	**2**	2	2	1	5	5	5	2	2	4	4	3	2	4
EL13	0	0	0	**0**	3	1	1	5	5	4	3	3	4	3	3	2	4
EL15	0	0	2	**2**	2	4	1	4	2	5	4	4	5	3	3	2	4
EL14	1	2	2	**5**	3	2	2	4	3	5	5	3	3	4	3	2	4
EL23	0	0	1	**1**	4	4	2	2	5	2	1	1	3	4	3	2	4
EL17	1	1	1	**3**	3	1	2	4	5	4	2	2	5	4	3	2	4
EL19	0	1	0	**1**	3	4	2	4	5	5	3	3	4	4	3	2	4
EL18	1	4	3	**8**	3	3	3	3	3	4	3	3	4	3	3	2	4
EL21	0	1	0	**1**	3	3	3	3	5	5	4	4	5	3	3	2	4
EL08	1	3	2	**6**	3	3	2	3	3	5	5	3	3	4	3	2	4
OD21	1	0	0	**1**	3	5	1	3	3	2	2	1	4	3	4	3	5
OD22	0	1	0	**1**	3	5	1	2	2	2	3	1	3	3	4	3	5
OD19	0	1	0	**1**	3	5	2	3	1	2	4	1	3	2	4	3	5
OD20	0	0	0	**0**	4	5	1	4	5	2	5	1	3	3	4	3	5
OD18	0	0	0	**0**	3	5	1	4	2	2	5	1	5	2	4	3	5
OD23	0	0	0	**0**	4	3	1	4	3	1	5	1	4	2	4	3	5
OD15	0	3	2	**5**	3	4	1	4	5	2	2	1	4	3	4	3	5
OD14	0	2	0	**2**	3	5	1	2	3	2	3	1	3	3	4	3	5
OD24	0	0	1	**1**	3	5	1	3	2	2	4	1	3	2	4	3	5
OD13	0	0	1	**1**	3	5	1	4	1	2	5	1	3	3	4	3	5
OD17	0	0	1	**1**	4	5	1	4	2	2	5	1	5	2	4	3	5
OD16	0	0	0	**0**	3	3	1	4	2	1	5	1	4	2	4	3	5
OL19	0	0	0	**0**	3	2	2	4	3	3	2	2	2	2	2	4	5
OL18	0	1	0	**1**	3	1	2	3	2	3	2	2	2	3	2	4	5
OL23	0	0	0	**0**	3	1	2	4	4	4	3	3	2	2	2	4	5
OL24	0	0	0	**0**	4	1	2	4	5	4	3	3	1	2	2	4	5
OL14	0	0	0	**0**	3	1	2	4	5	4	4	4	3	3	2	4	5
OL15	0	1	0	**1**	3	1	3	4	3	4	5	5	3	3	2	4	5
OL20	0	0	0	**0**	3	1	2	3	5	3	2	2	2	2	2	4	5
OL16	0	0	0	**0**	3	1	2	3	5	3	2	2	2	3	2	4	5
OL17	0	0	0	**0**	3	1	3	4	5	4	3	3	2	2	2	4	5
OL22	0	0	0	**0**	3	1	1	4	3	4	4	3	1	2	2	4	5
OL21	0	0	0	**0**	4	2	2	3	5	4	4	4	3	3	2	4	5
OL13	0	0	0	**0**	3	1	4	3	4	4	5	5	3	3	2	4	5

UD14	1	7	1	**9**	3	1	3	3	4	3	2	1	1	3	5	3	5
UD24	0	3	1	**4**	3	1	3	3	5	3	4	2	1	2	5	3	5
UD21	1	3	0	**4**	3	2	2	4	4	3	5	2	1	3	5	3	5
UD13	0	1	0	**1**	3	2	4	4	4	4	5	1	1	1	5	3	5
UD18	1	5	0	**6**	3	1	2	4	5	5	5	1	1	2	5	3	5
UD20	0	0	0	**0**	3	2	2	3	4	3	5	1	3	2	5	3	5
UD15	0	0	0	**0**	3	1	4	3	1	3	3	1	3	2	5	3	5
UD22	6	12	4	**22**	3	1	4	4	3	3	3	2	1	2	5	3	5
UD23	1	7	0	**8**	4	2	3	3	2	3	5	1	1	2	5	3	5
UD17	0	0	0	**0**	3	1	4	3	3	4	5	1	1	2	5	3	5
UD16	0	2	1	**3**	3	1	2	4	3	5	5	1	1	2	5	3	5
UD19	0	1	0	**1**	3	1	2	4	4	3	5	1	2	2	5	3	5
UL19	0	0	1	**1**	5	1	3	3	2	2	2	1	4	3	2	4	4
UL13	0	1	0	**1**	5	5	1	1	5	2	3	1	4	2	2	4	4
UL20	1	2	1	**4**	5	1	3	2	5	2	4	1	3	3	2	4	4
UL14	0	1	0	**1**	5	2	4	3	5	2	5	1	4	3	2	4	4
UL24	0	0	2	**2**	5	1	3	3	5	2	5	1	4	2	2	4	4
UL16	0	0	1	**1**	5	2	4	3	5	2	5	1	2	3	2	4	4
UL22	0	0	0	**0**	5	1	3	2	2	2	2	1	4	3	2	4	4
UL18	0	0	0	**0**	5	5	3	1	5	2	3	1	4	2	2	4	4
UL21	0	0	1	**1**	5	5	3	3	1	2	5	1	3	3	2	4	4
UL23	0	2	1	**3**	5	1	4	3	5	2	5	1	4	3	2	4	4
UL15	0	0	0	**0**	5	1	3	3	3	2	5	1	4	2	2	4	4
UL17	0	0	1	**1**	5	1	4	2	5	2	5	1	2	3	2	4	4
WD20	0	0	2	**2**	3	5	4	2	1	2	2	2	1	2	5	3	3
WD23	0	0	1	**1**	4	3	3	3	2	2	2	2	3	2	5	3	3
WD21	0	0	0	**0**	4	5	3	3	2	2	3	3	4	3	5	3	3
WD16	1	2	0	**3**	4	4	4	1	3	2	4	3	2	3	5	3	3
WD17	0	3	0	**3**	4	1	5	3	3	2	5	3	2	3	5	3	3
WD14	0	0	0	**0**	3	2	1	2	2	3	5	3	2	1	5	3	3
WD22	0	0	1	**1**	3	5	2	2	2	2	2	2	2	3	5	3	3
WD18	0	0	0	**0**	4	5	1	2	1	2	2	2	3	2	5	3	3
WD13	0	0	0	**0**	4	5	2	2	3	2	3	3	3	1	5	3	3
WD19	0	0	0	**0**	5	4	4	2	3	2	4	4	4	4	5	3	3
WD15	3	13	6	**22**	4	5	5	2	1	2	5	3	2	2	5	3	3
WD24	0	0	0	**0**	4	3	3	3	3	3	5	3	3	2	5	3	3
WL13	0	0	1	**1**	2	2	2	5	5	5	2	2	2	2	5	4	1
WL22	0	1	0	**1**	2	1	3	3	3	5	3	3	3	3	5	4	1
WL17	0	0	0	**0**	2	3	2	3	2	3	4	2	2	3	5	4	1
WL14	0	0	0	**0**	2	3	2	5	5	5	5	1	2	2	5	4	1
WL24	0	1	0	**1**	2	4	2	5	3	5	5	1	2	2	5	4	1
WL15	0	0	1	**1**	2	3	3	5	4	5	5	2	2	1	5	4	1
WL18	0	1	0	**1**	2	2	2	5	3	5	2	2	1	2	5	4	1

WL20	1	1	0	**2**	2	1	3	4	3	5	3	3	3	2	5	4	1
WL23	0	0	0	**0**	4	3	2	4	2	3	4	2	2	5	5	4	1
WL21	0	0	0	**0**	2	2	2	4	2	5	5	2	2	1	5	4	1
WL16	0	0	0	**0**	2	2	1	3	5	5	5	1	4	2	5	4	1
WL19	0	0	0	**0**	2	1	2	3	3	5	5	3	1	2	5	4	1

Appendix VI Heterogeneity of habitat features in the waters

Heterogeneity of the parameters in the water UD:

Figure 54 Heterogeneity of the parameter "Degree of softness of the ground" in UD (Datenquelle: basemap.at).

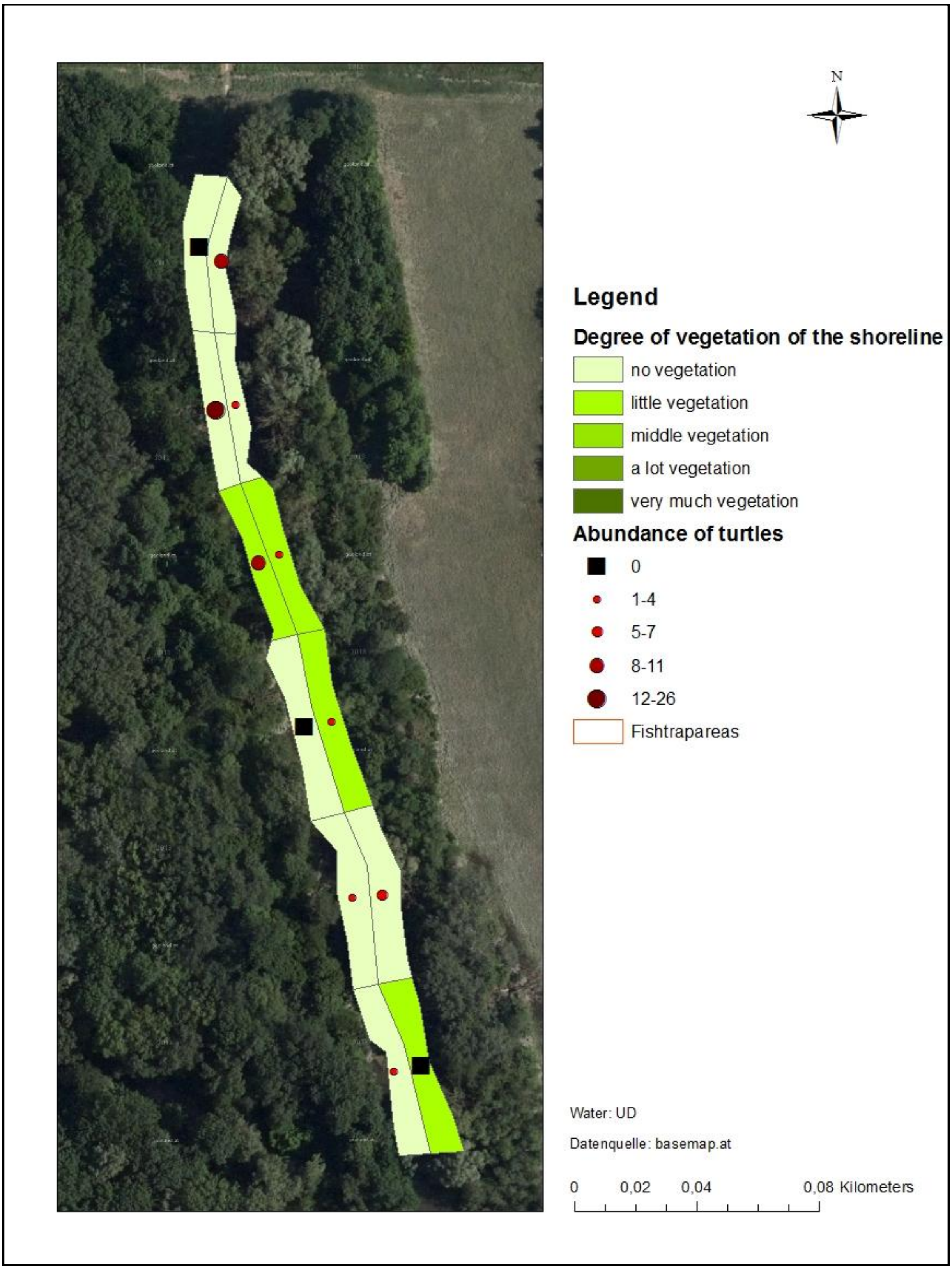


Figure 55 Heterogeneity of the parameter "Degree of vegetation of the shoreline" in UD (Datenquelle: basemap.at).

Figure 56 Heterogeneity of the parameter "Abundance of dead wood" in UD (Datenquelle: basemap.at).

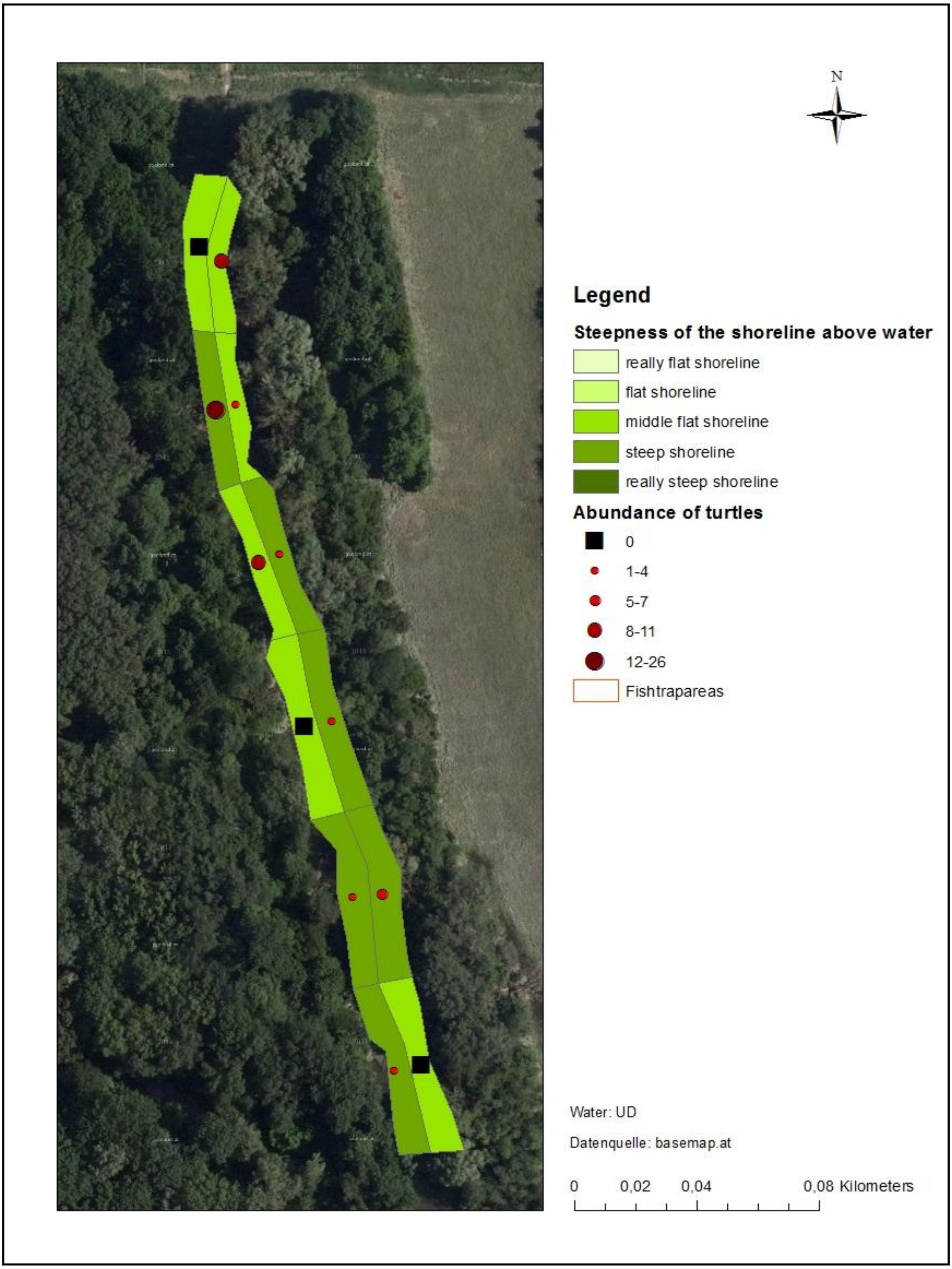


Figure 57 Heterogeneity of the parameter "Steepness of the shoreline above water" in UD (Datenquelle: basemap.at).

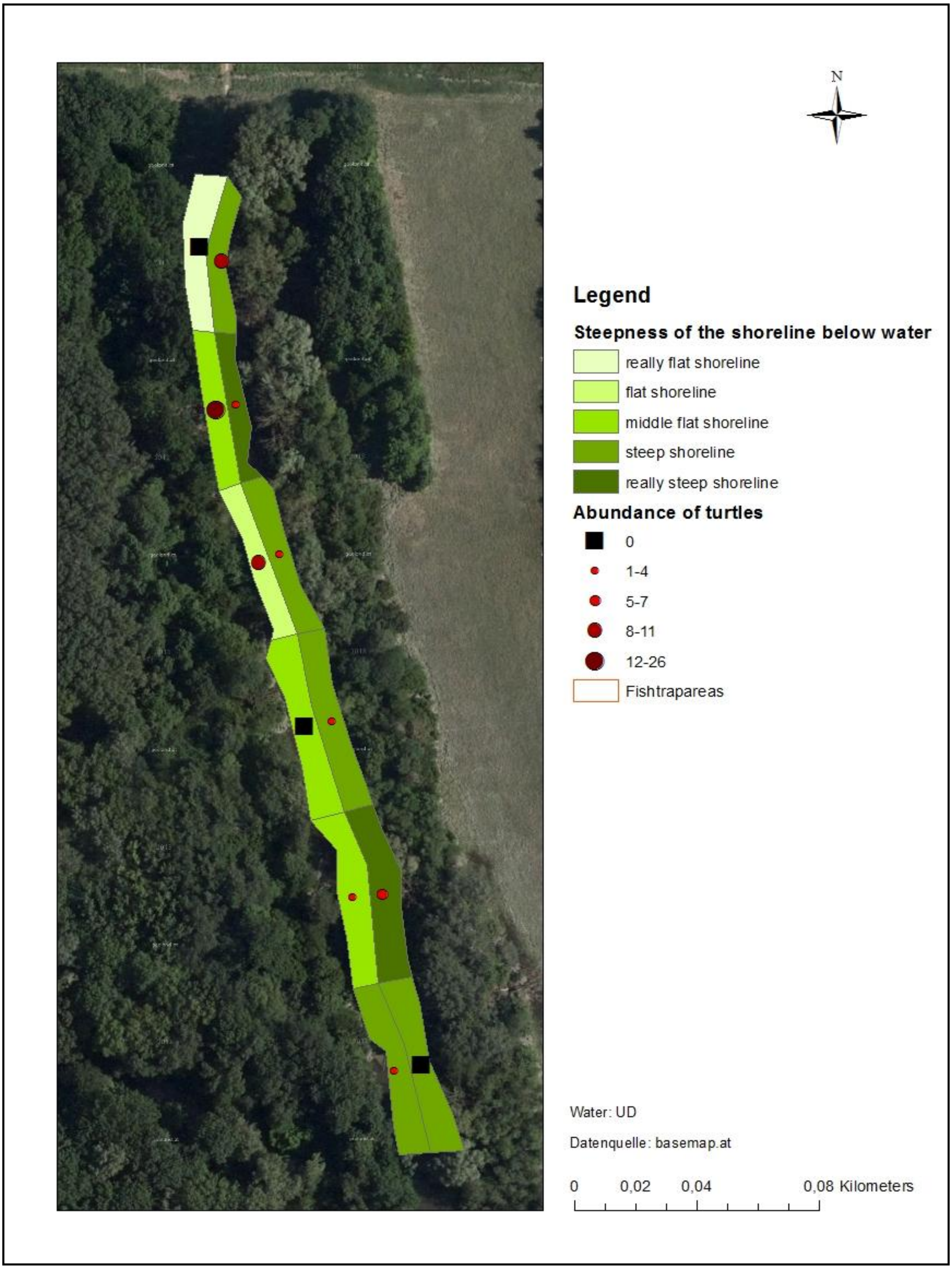


Figure 58 Heterogeneity of the parameter "Steepness of the shoreline below water" in UD (Datenquelle: basemap.at).

Figure 59 Heterogeneity of the parameter "Depth at the middle of the water" in UD (Datenquelle: basemap.at).

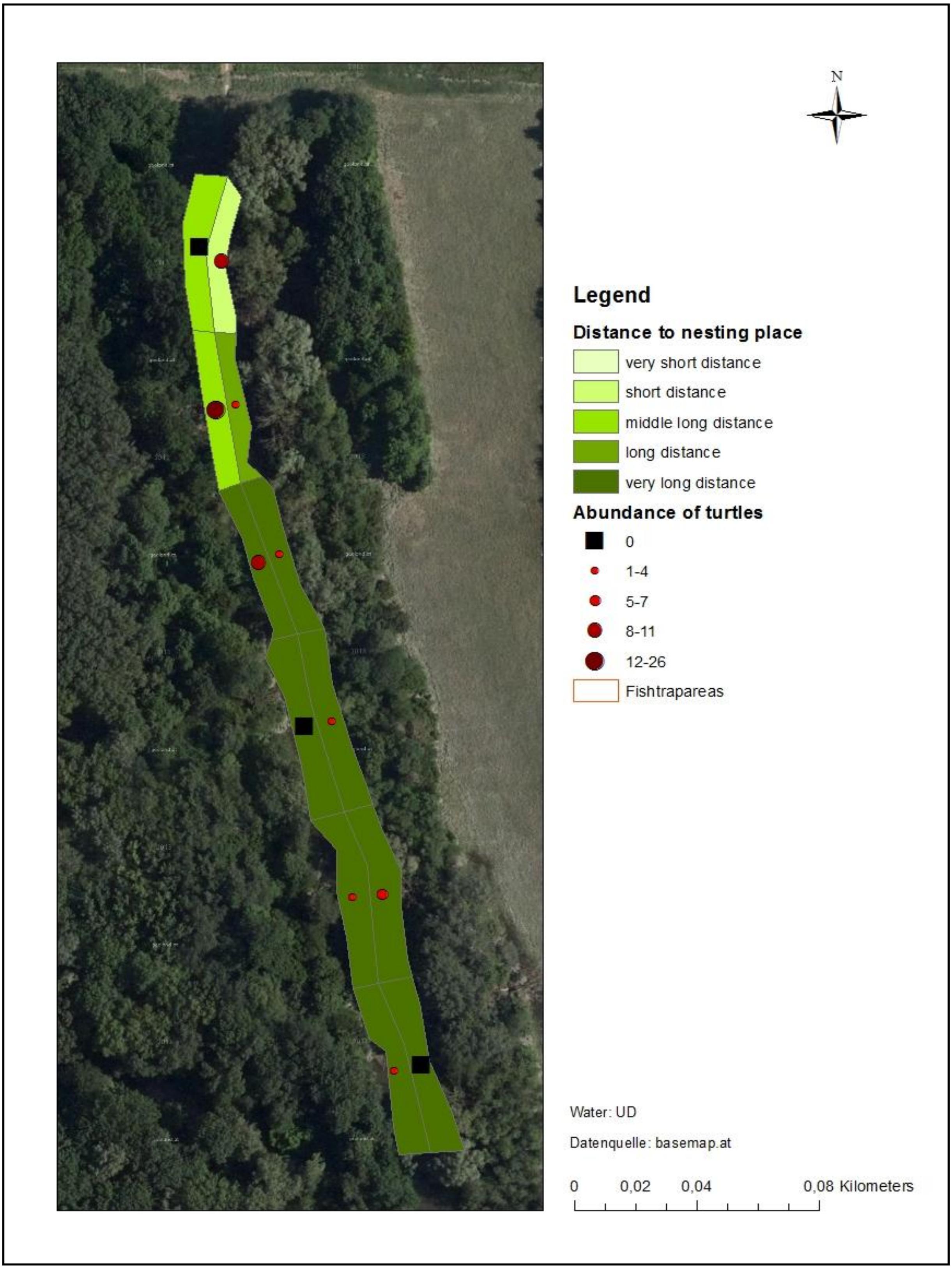


Figure 60 Heterogeneity of the parameter "Distance to nesting place" in UD (Datenquelle: basemap.at).

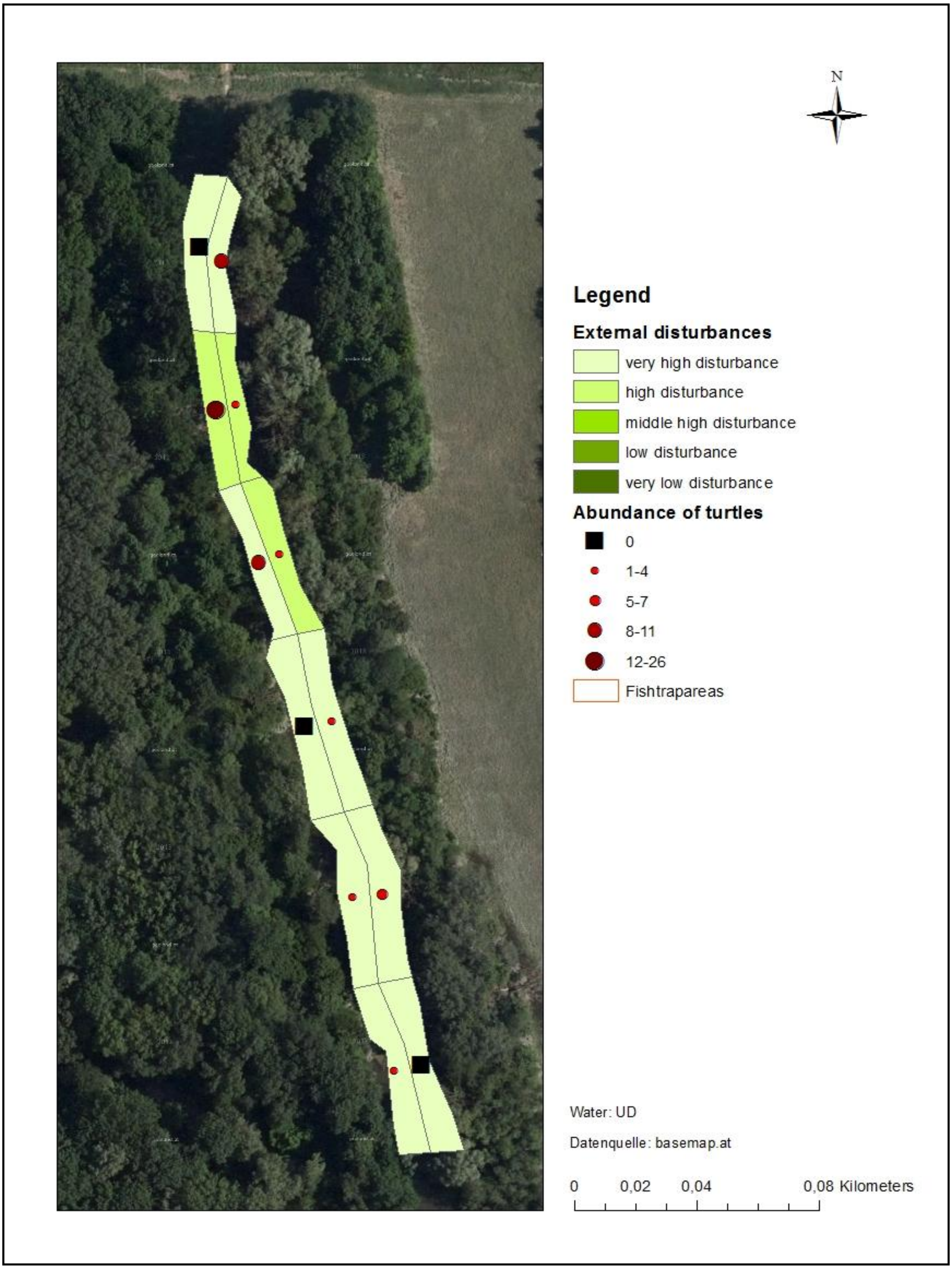


Figure 61 Heterogeneity of the parameter "External disturbances" in UD (Datenquelle: basemap.at).

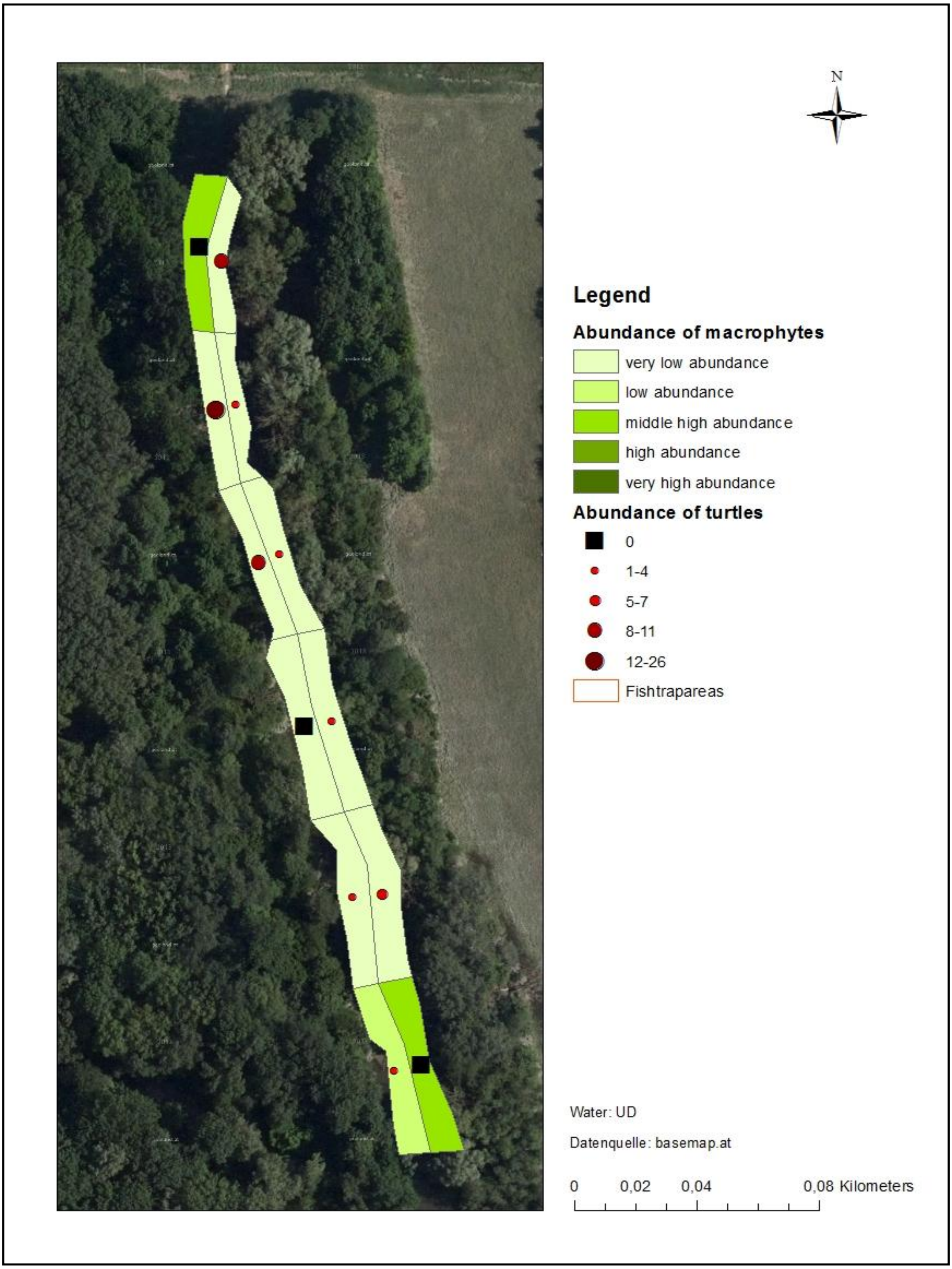


Figure 62 Heterogeneity of the parameter "Abundance of macrophytes" in UD (Datenquelle: basemap.at).

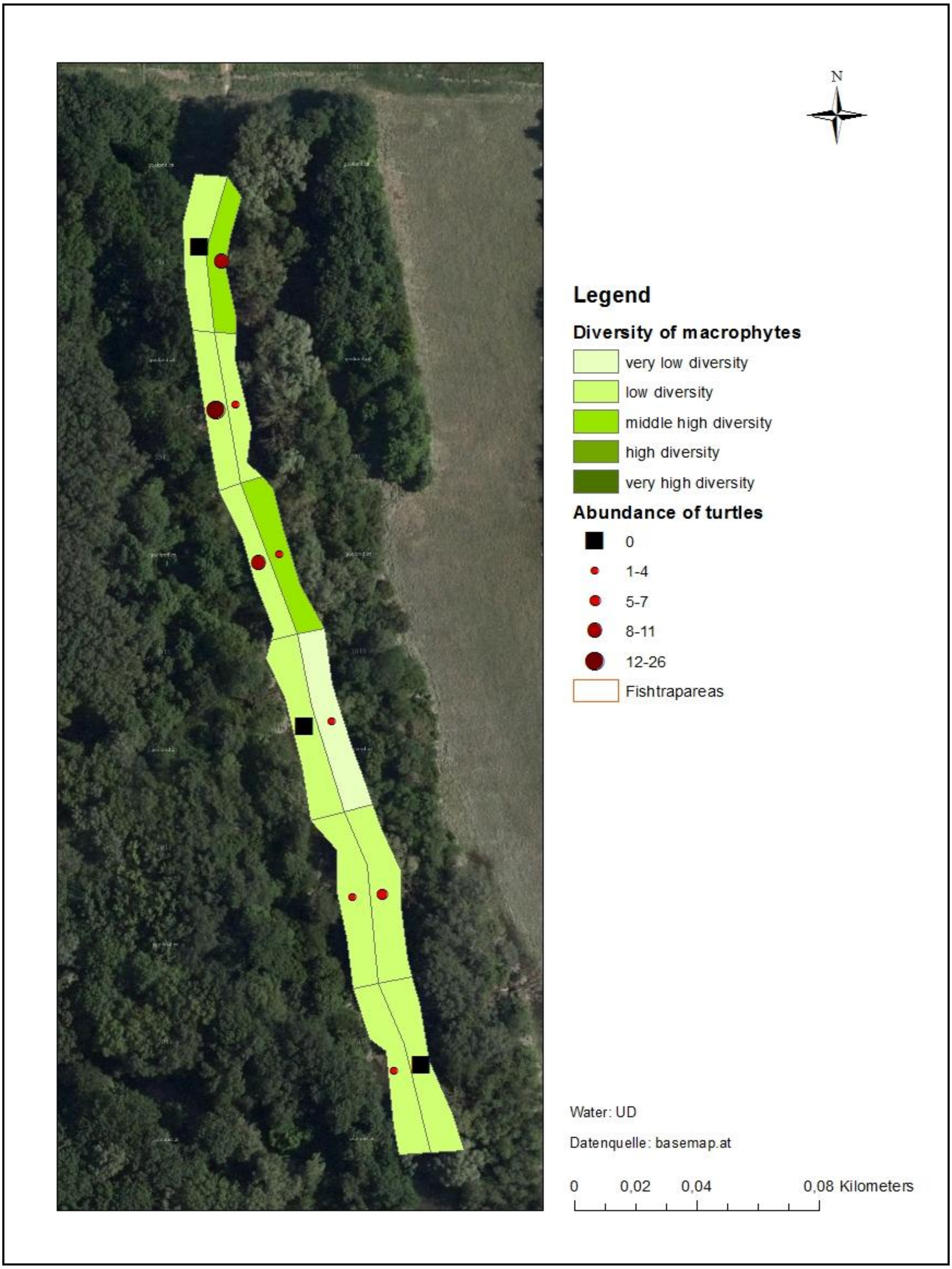


Figure 63 Heterogeneity of the parameter "Diversity of macrophytes" in UD (Datenquelle: basemap.at).

Heterogeneity of the parameters in the water UL:

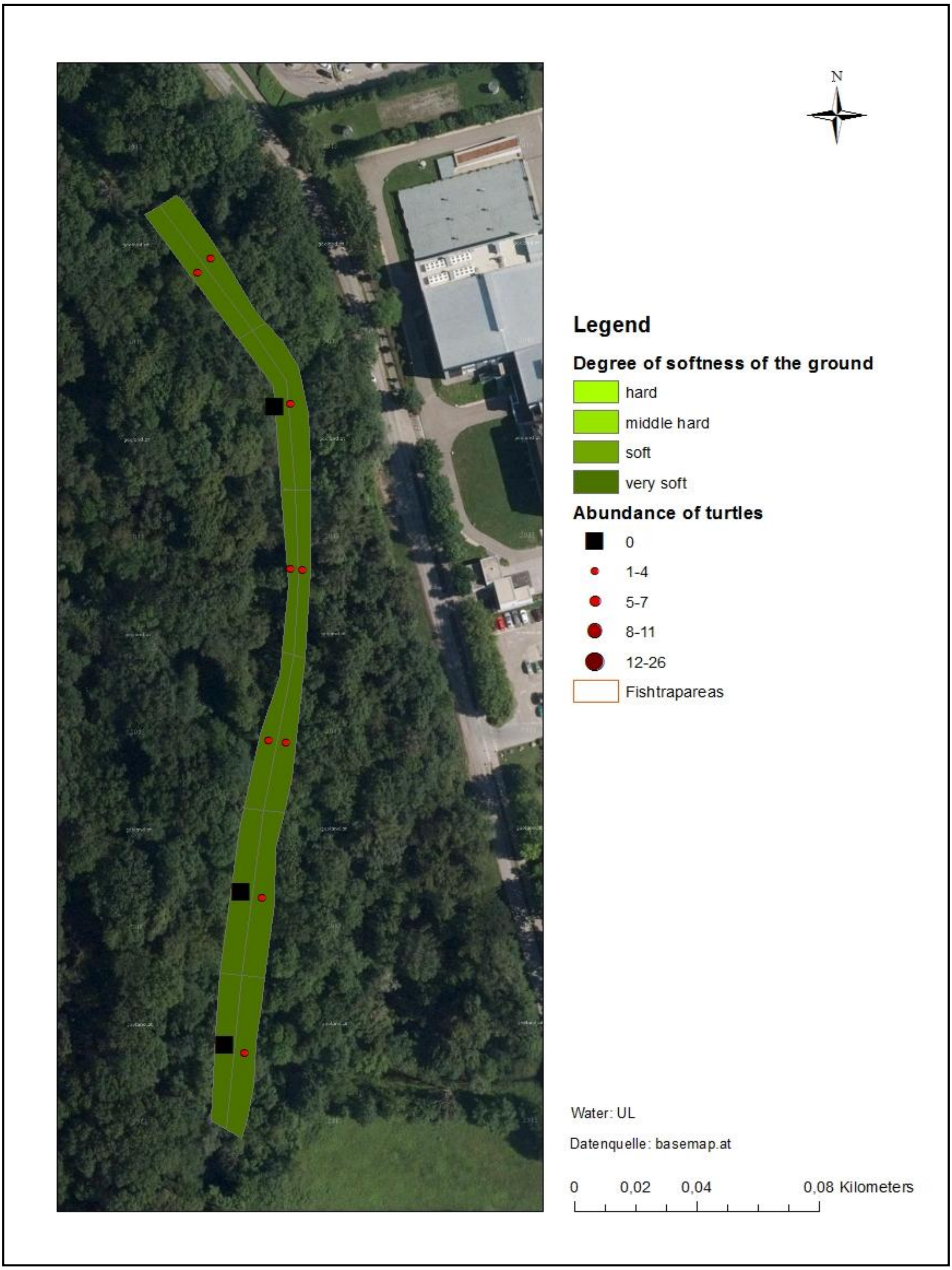


Figure 64 Heterogeneity of the parameter "Degree of softness of the ground" in UL (Datenquelle: basemap.at).

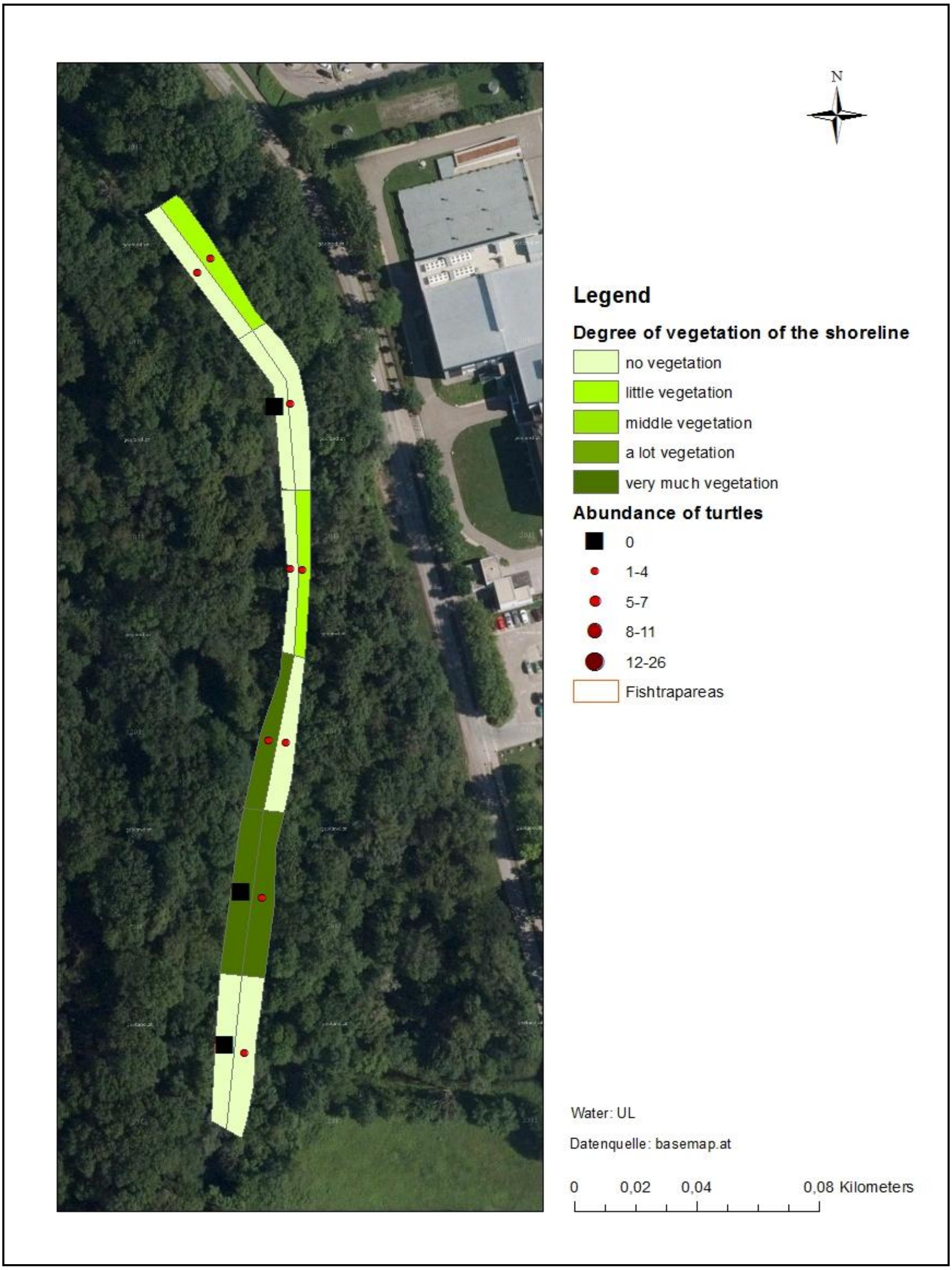


Figure 65 Heterogeneity of the parameter "Degree of vegetation of the shoreline" in UL (Datenquelle: basemap.at).

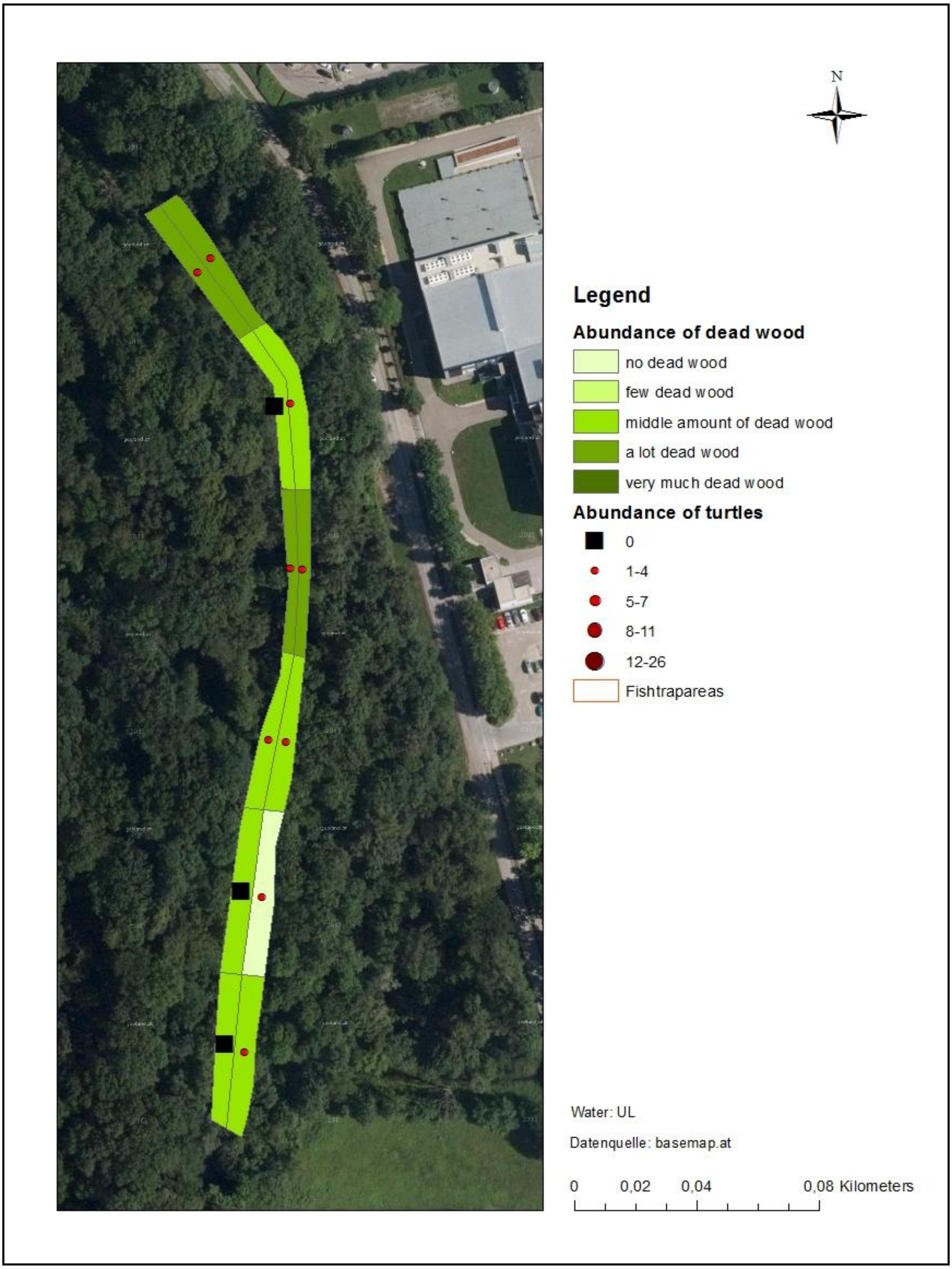


Figure 66 Heterogeneity of the parameter "Abundance of dead wood" in UL (Datenquelle: basemap.at).

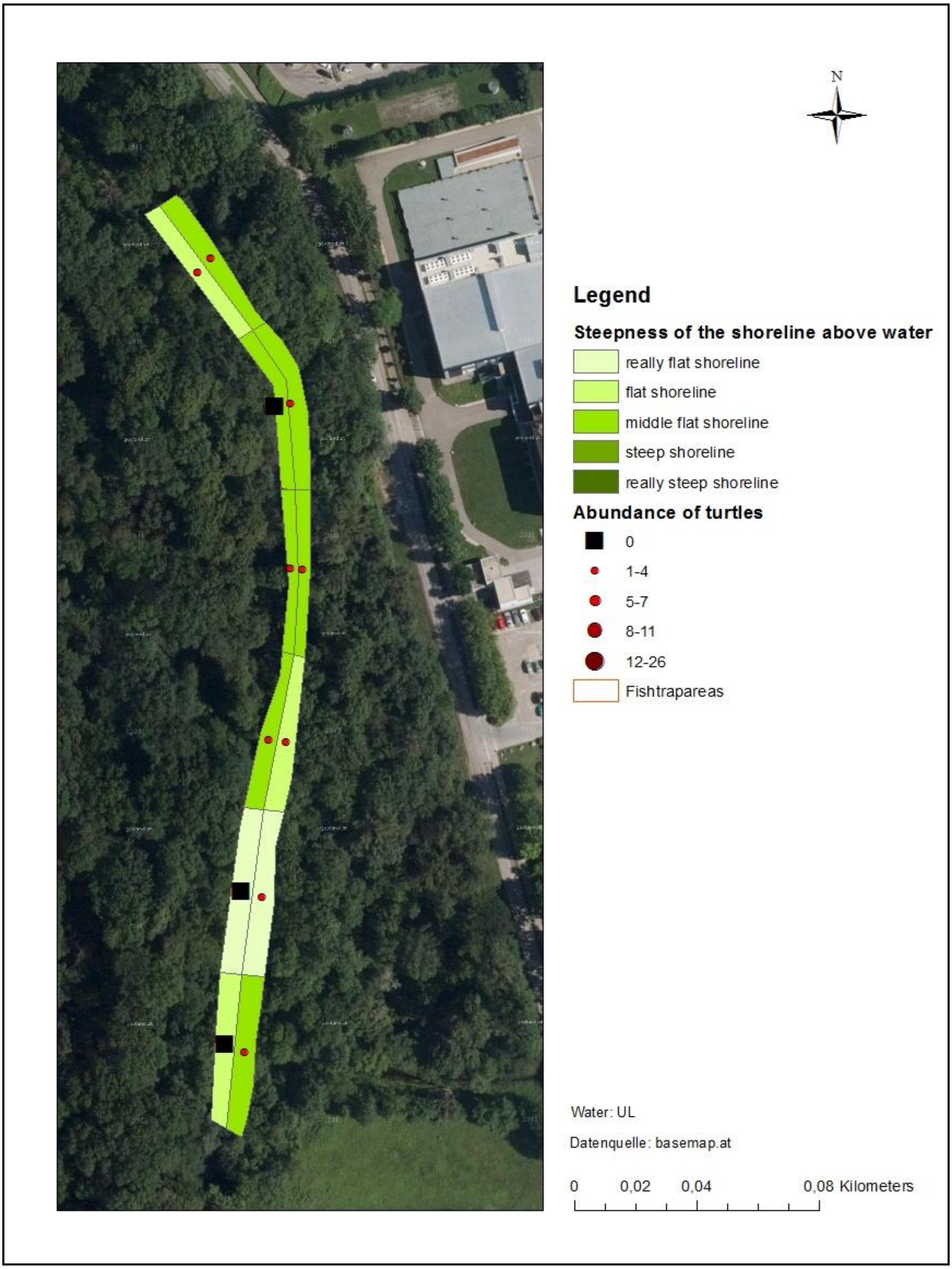


Figure 67 Heterogeneity of the parameter "Steepness of the shoreline above water" in UL (Datenquelle: basemap.at).

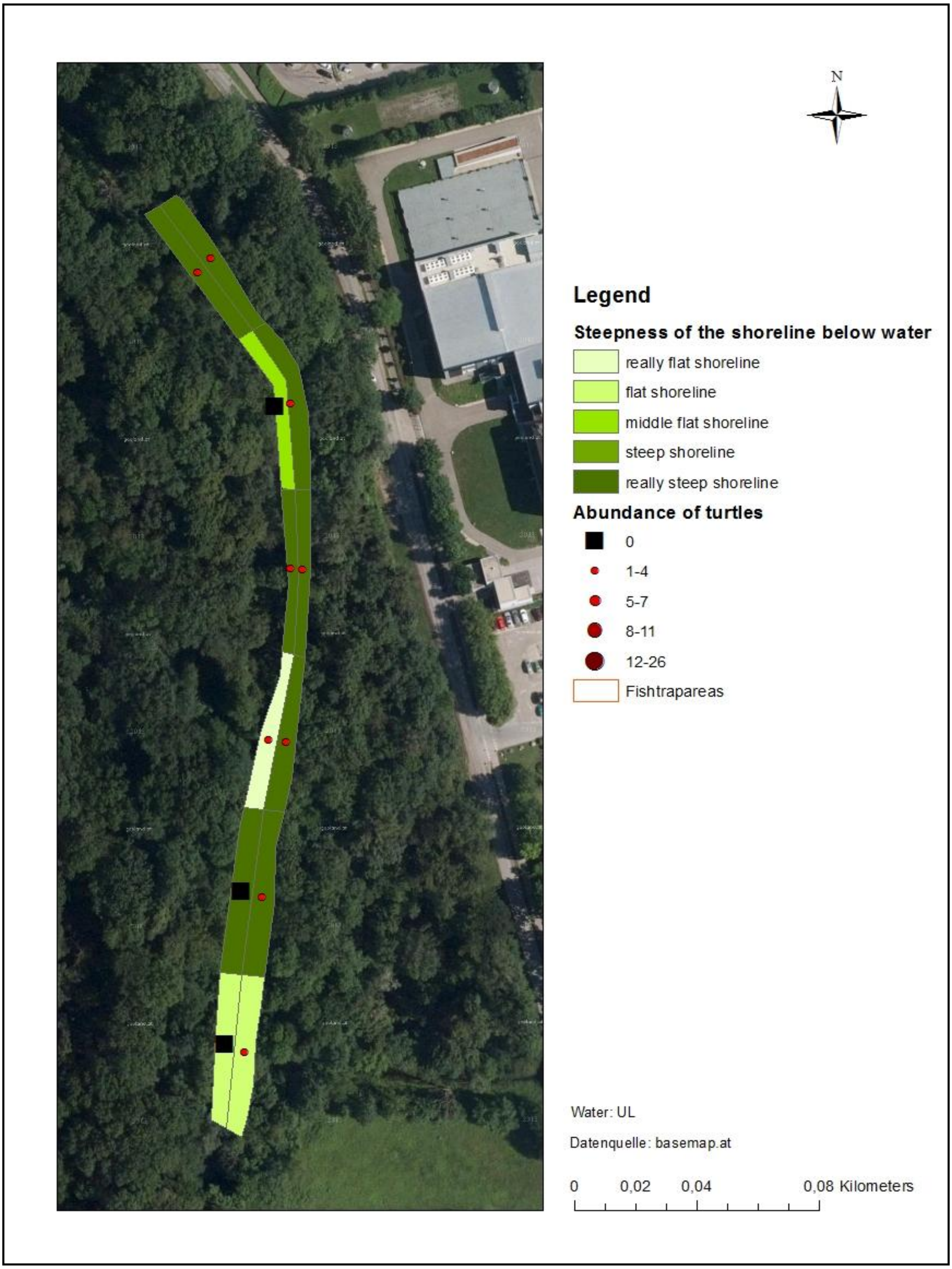


Figure 68 Heterogeneity of the parameter "Steepness of the shoreline below water" in UL (Datenquelle: basemap.at).

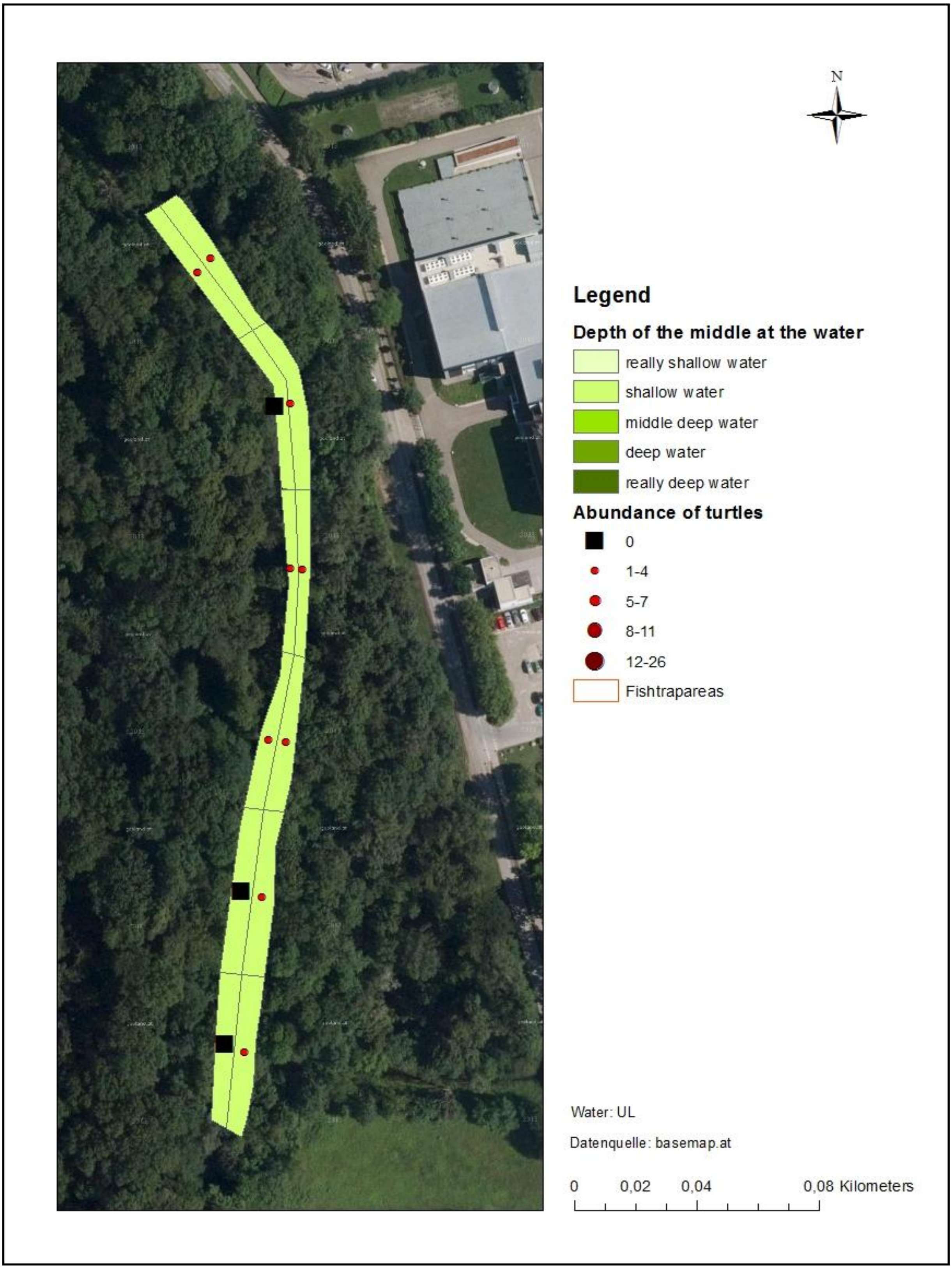


Figure 69 Heterogeneity of the parameter "Depth at the middle of the water" in UL (Datenquelle: basemap.at).

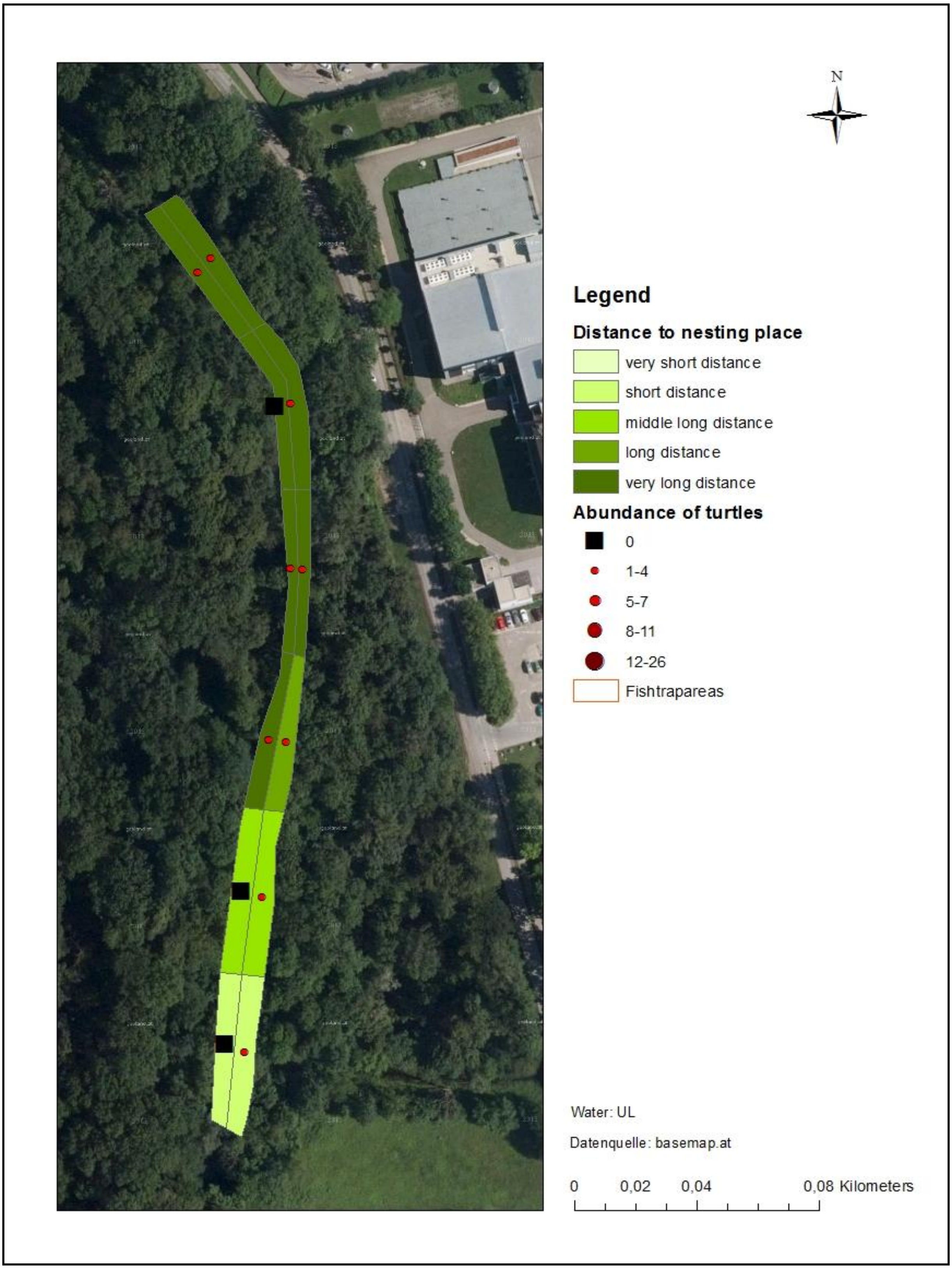


Figure 70 Heterogeneity of the parameter "Distance to nesting place" in UL (Datenquelle: basemap.at).

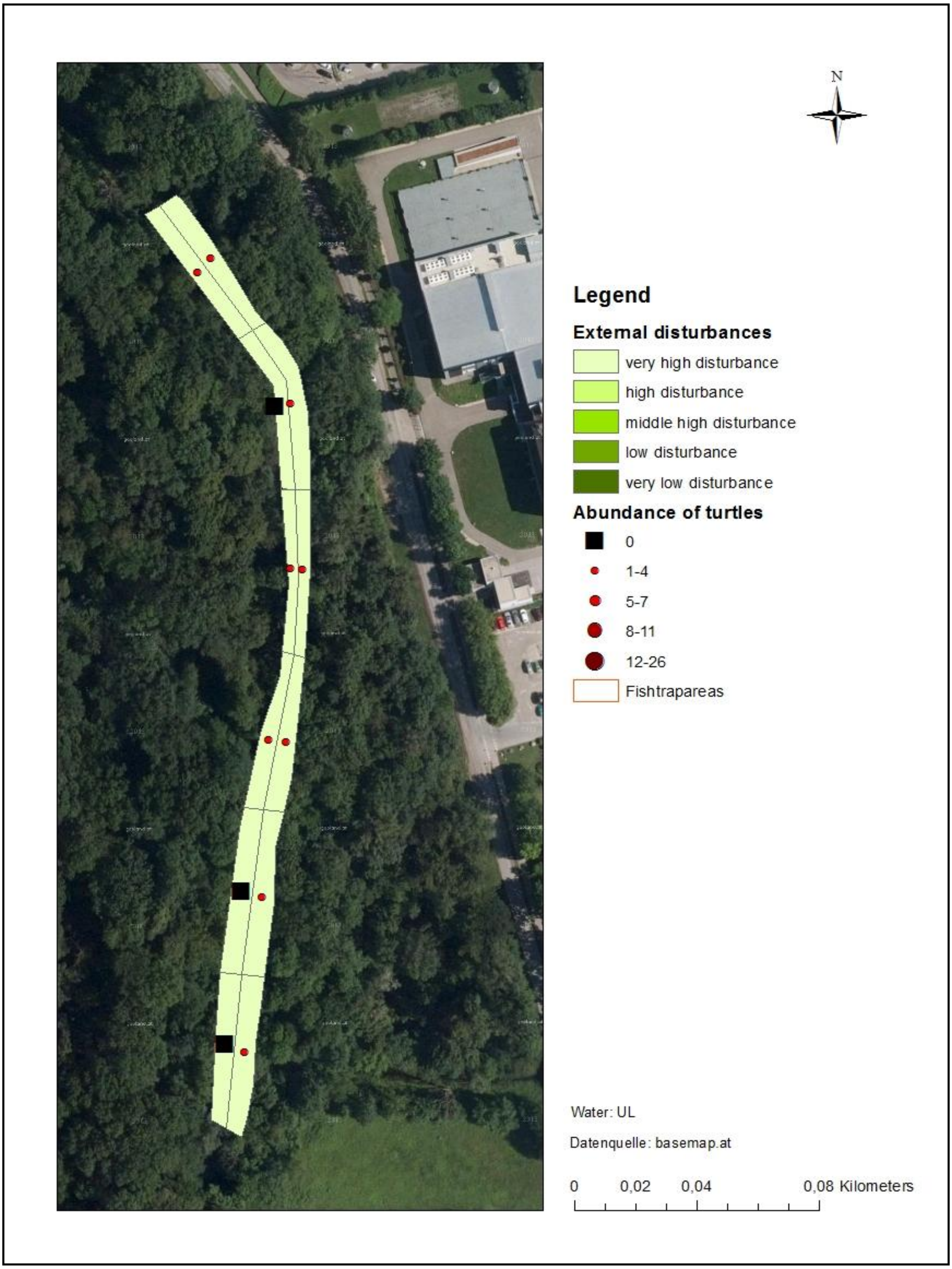


Figure 71 Heterogeneity of the parameter "External disturbances" in UL (Datenquelle: basemap.at).

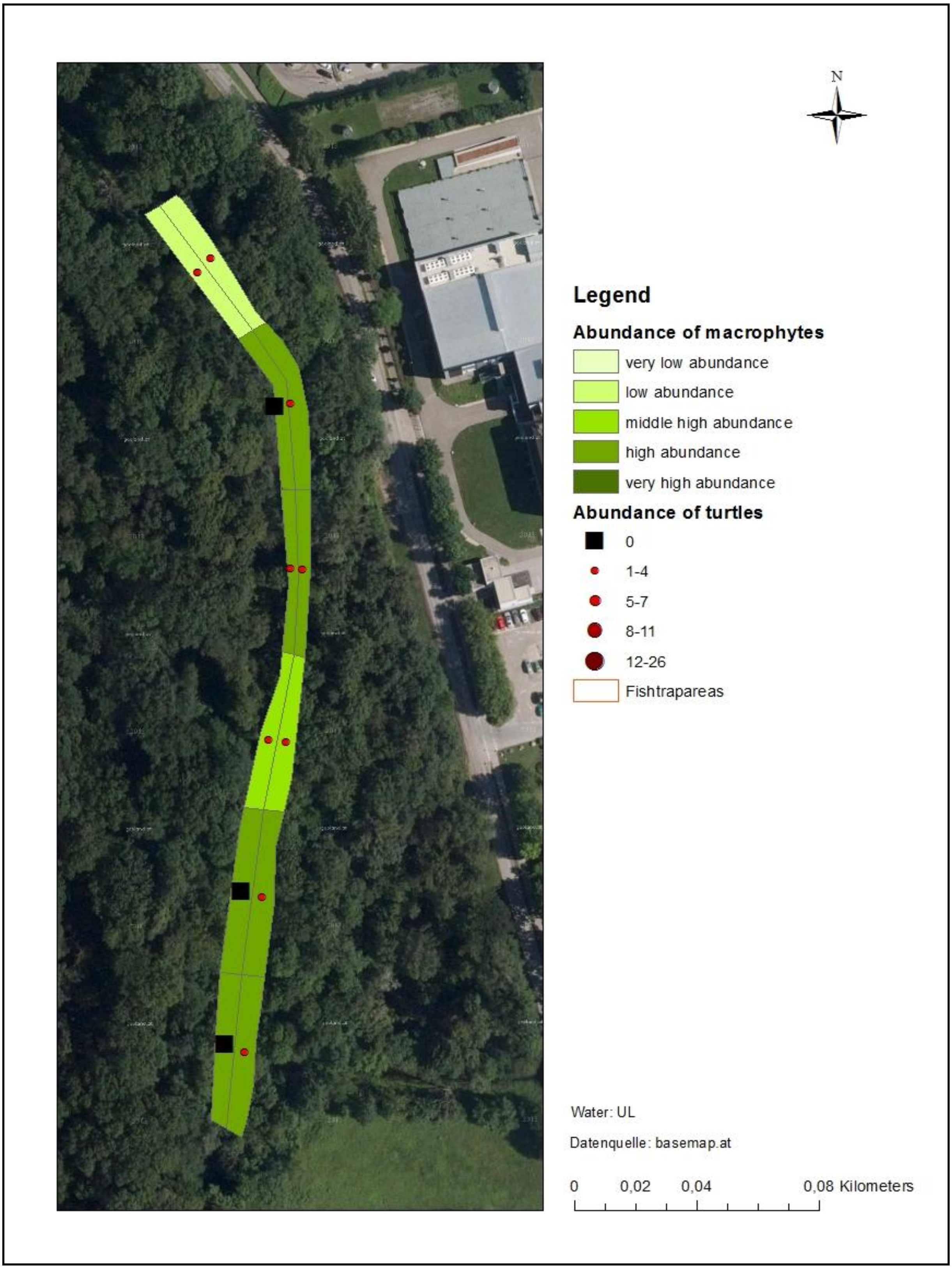


Figure 72 Heterogeneity of the parameter "Abundance of macrophytes" in UL (Datenquelle: basemap.at).

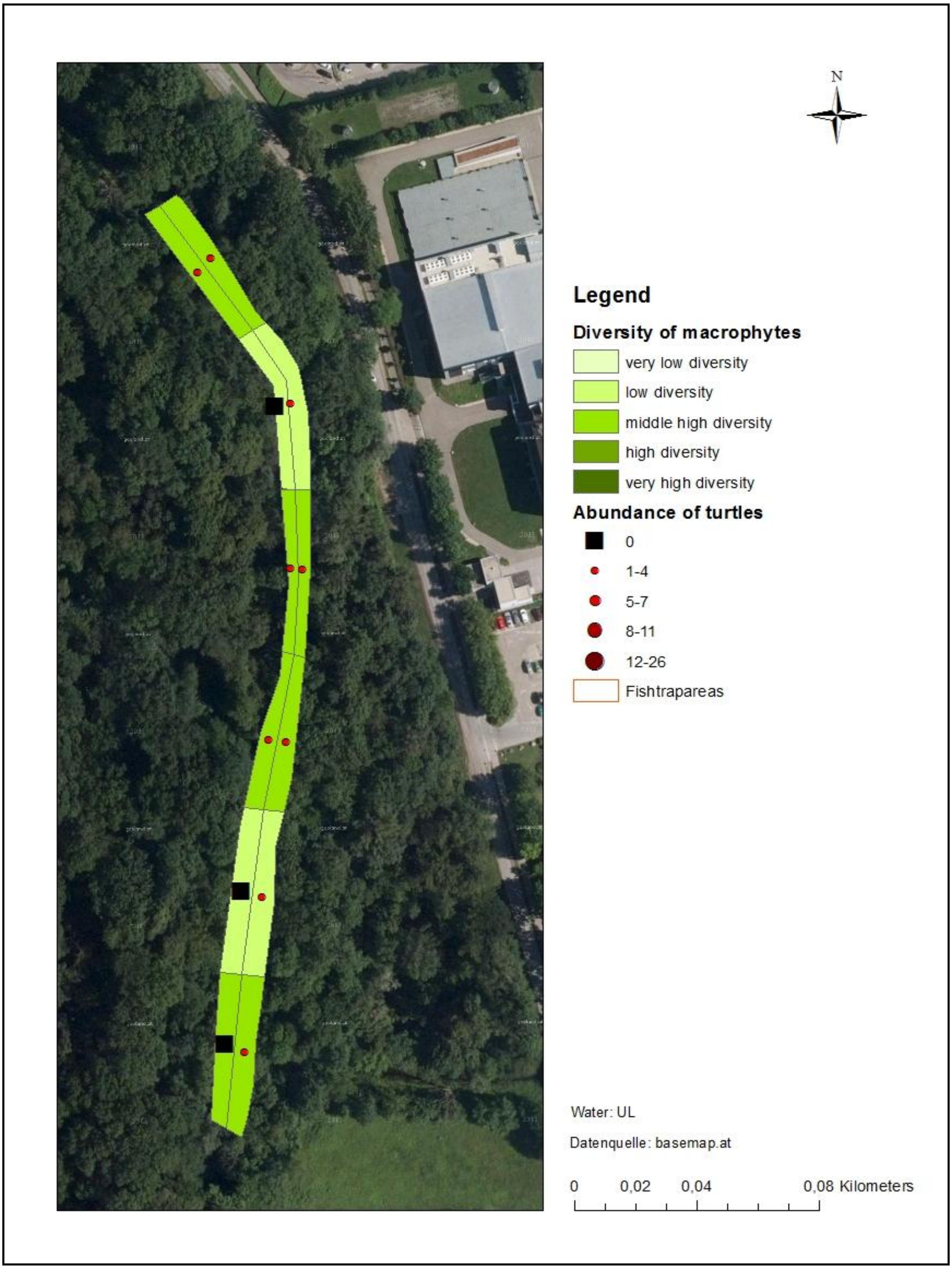


Figure 73 Heterogeneity of the parameter "Diversity of macrophytes" in UL (Datenquelle: basemap.at).

Heterogeneity of the parameters in the water OD:

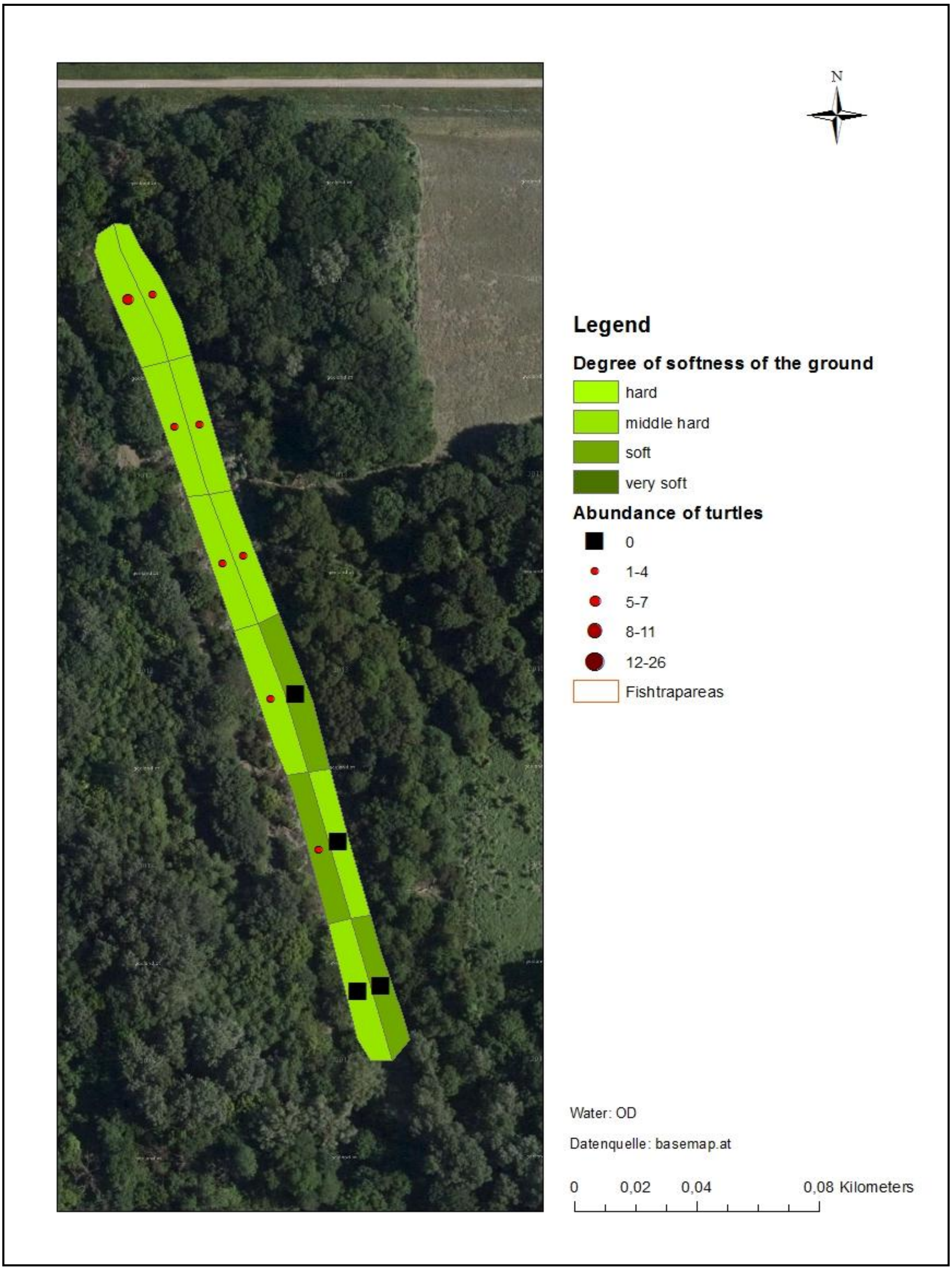


Figure 74 Heterogeneity of the parameter "Degree of softness of the ground" in OD (Datenquelle: basemap.at).

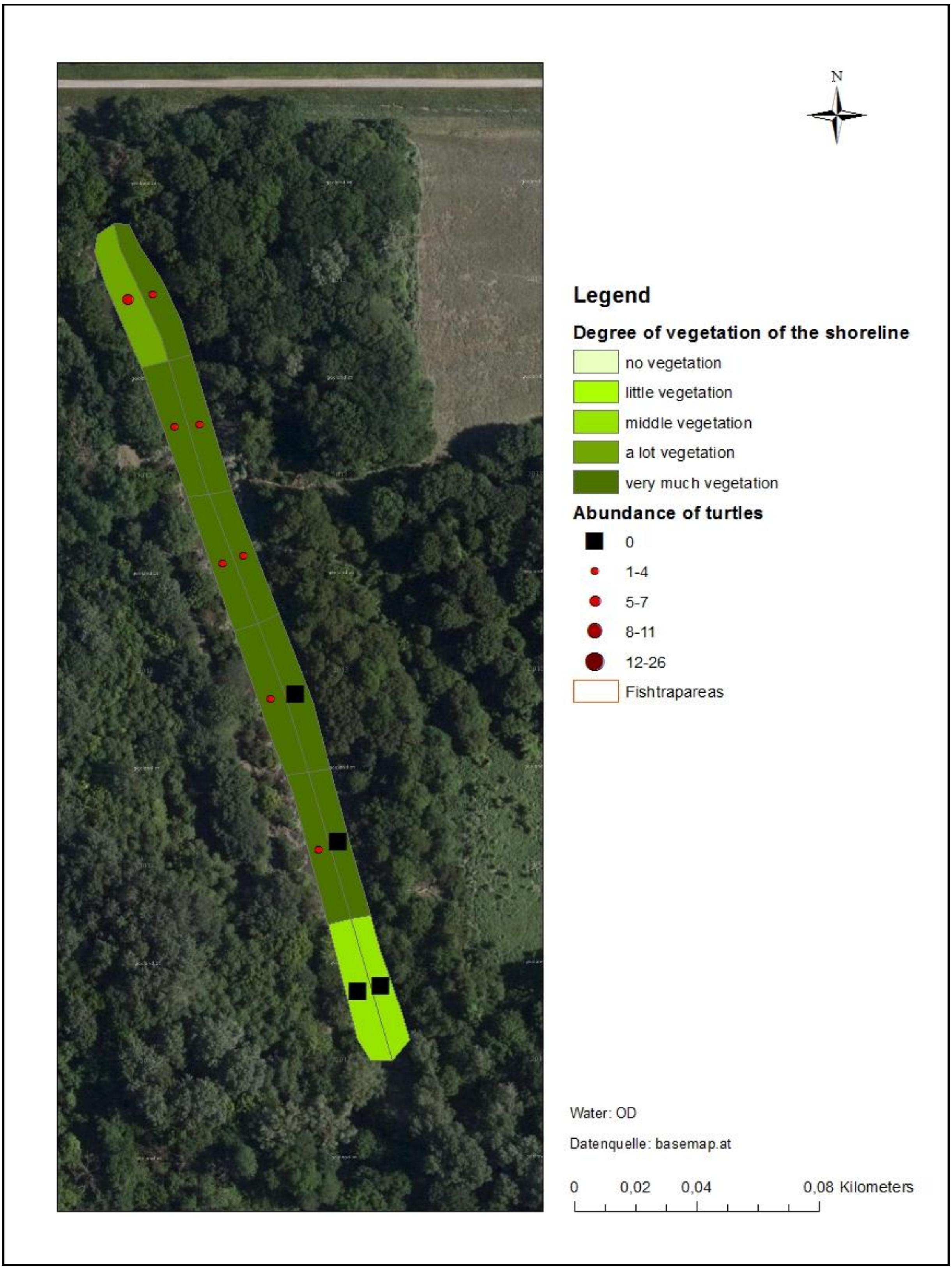


Figure 75 Heterogeneity of the parameter "Degree of vegetation of the shoreline" in OD (Datenquelle: basemap.at).

Figure 76 Heterogeneity of the parameter "Abundance of dead wood" in OD (Datenquelle: basemap.at).

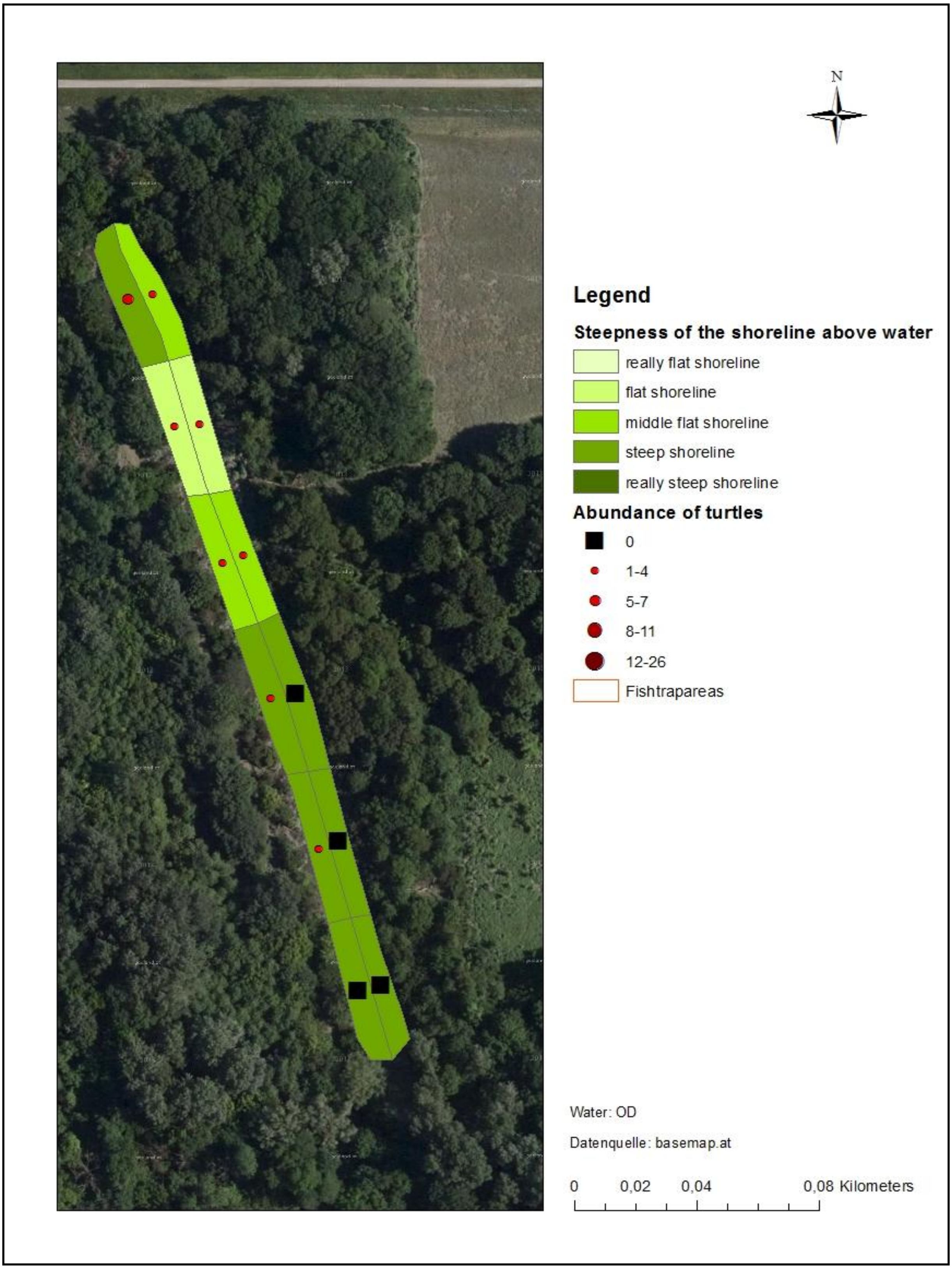


Figure 77 Heterogeneity of the parameter "Steepness of the shoreline above water" in OD (Datenquelle: basemap.at).

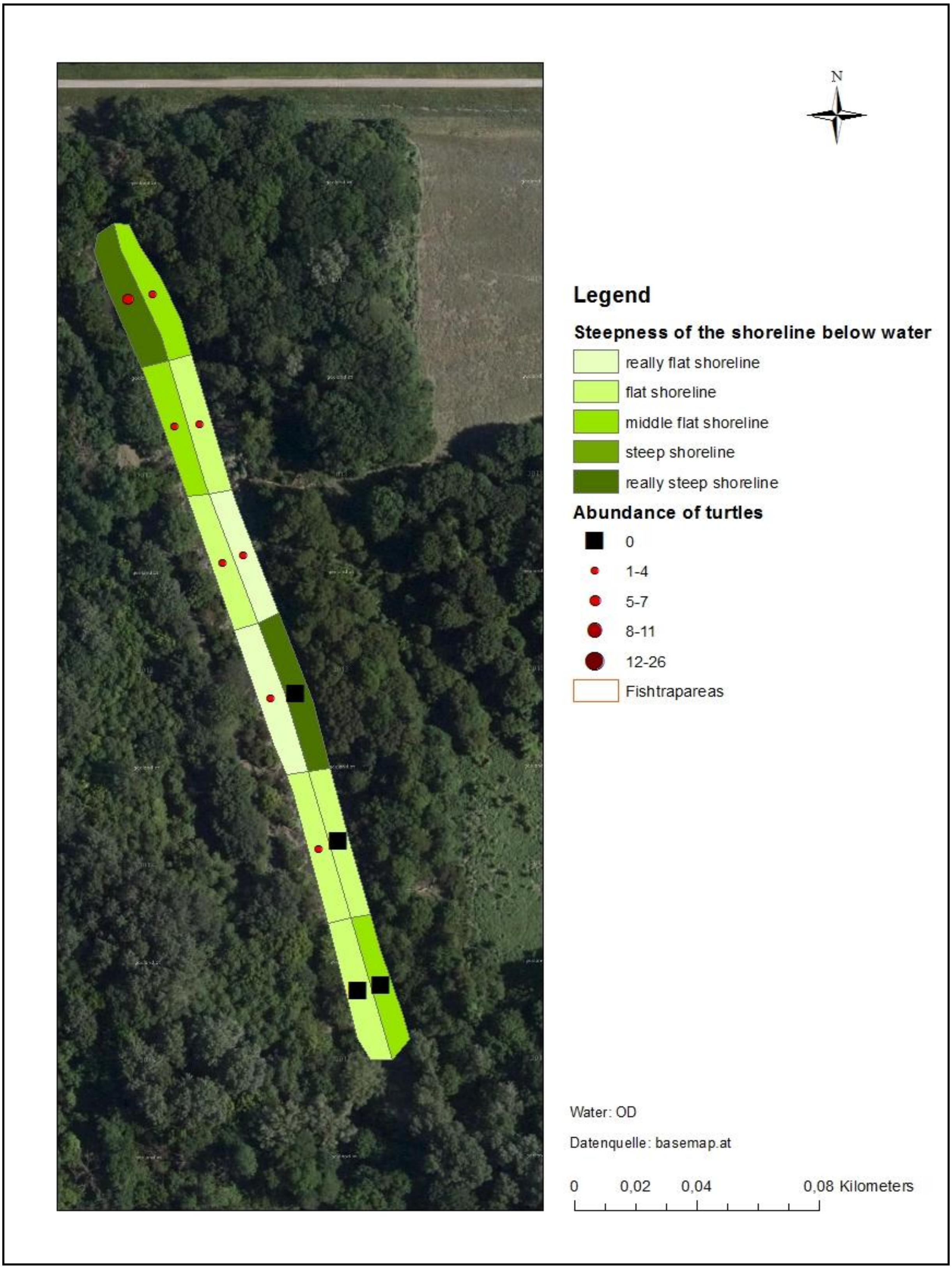


Figure 78 Heterogeneity of the parameter "Steepness of the shoreline below water" in OD (Datenquelle: basemap.at).

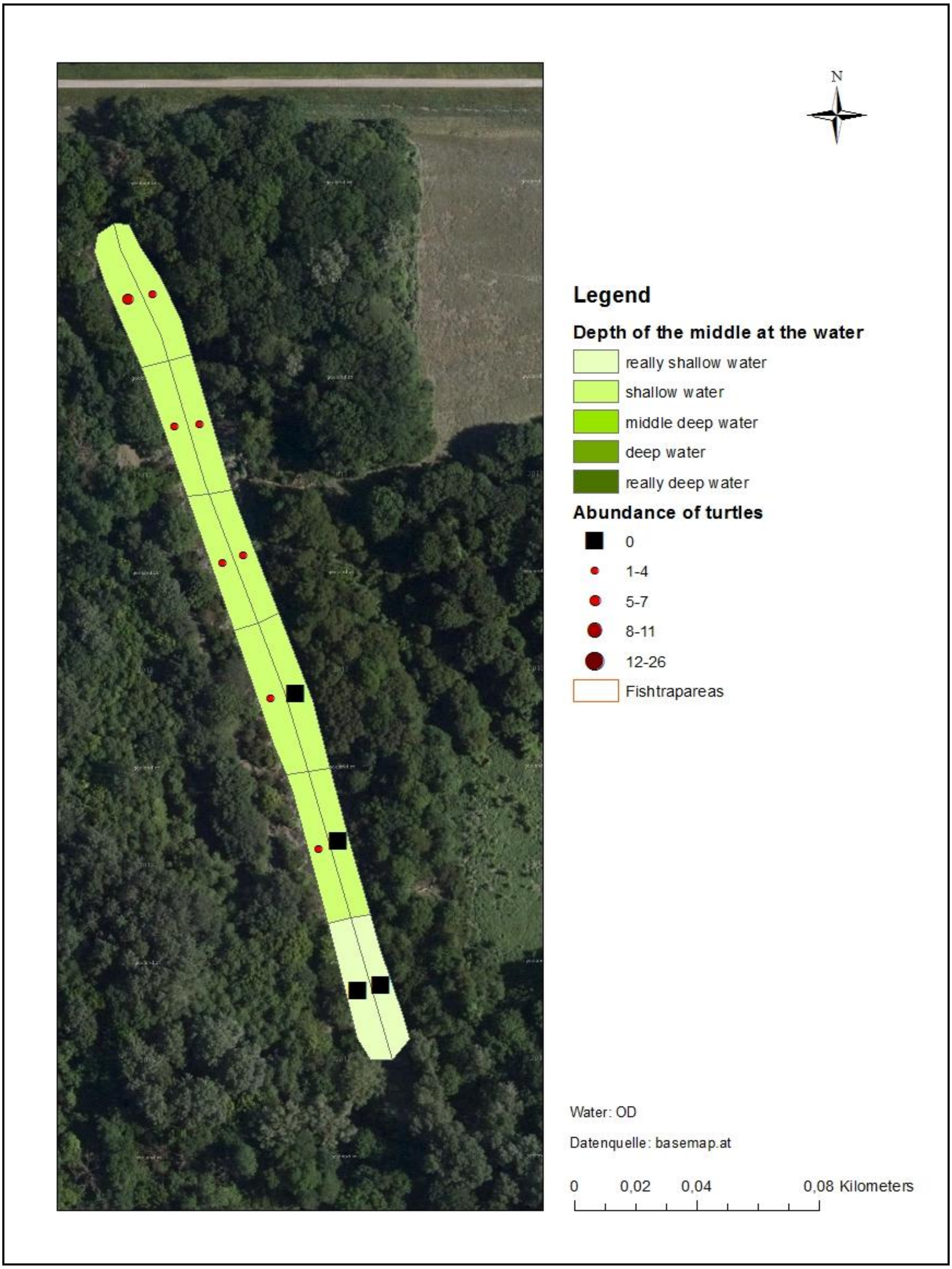


Figure 79 Heterogeneity of the parameter "Depth at the middle of the water" in OD (Datenquelle: basemap.at).

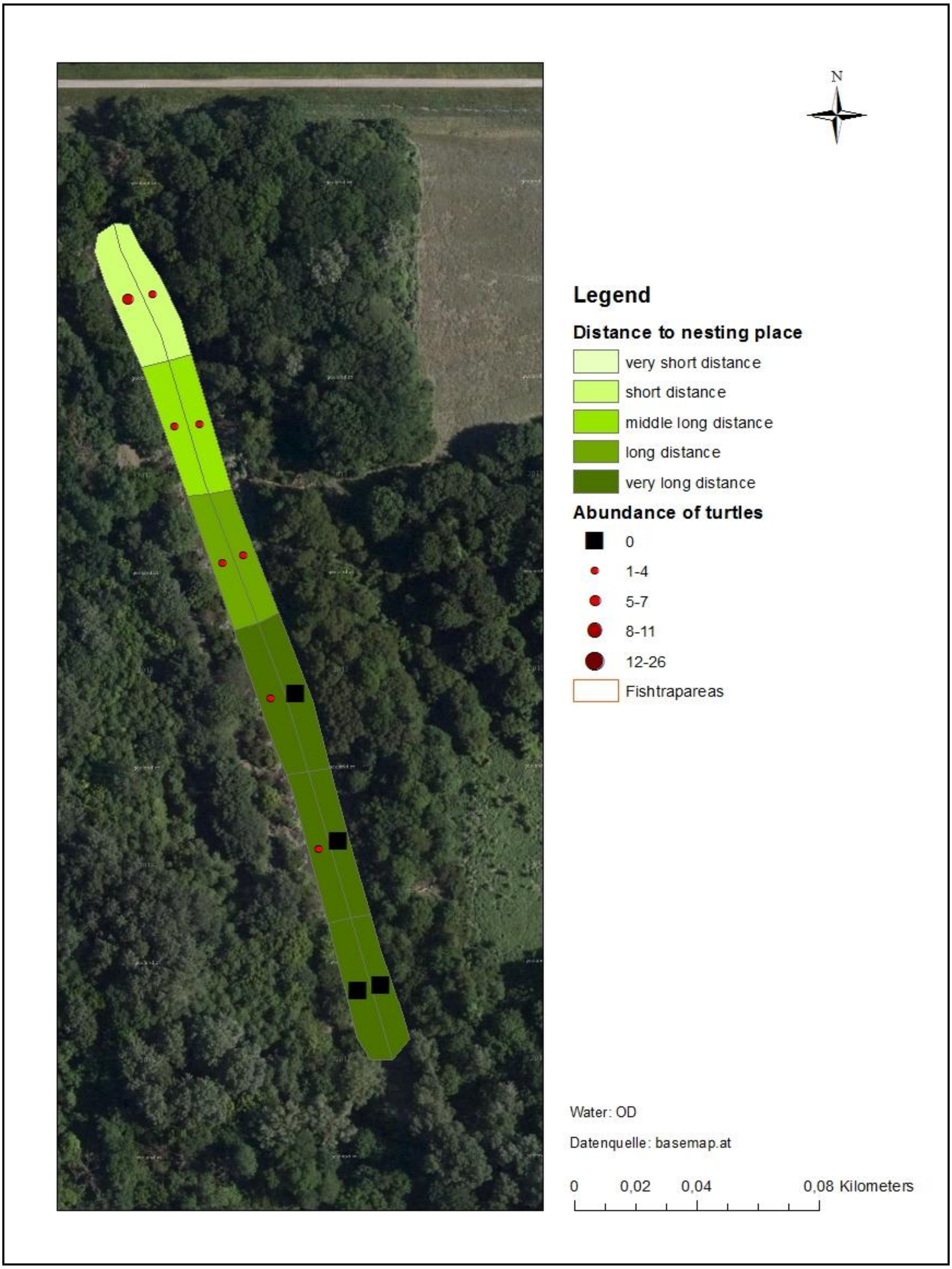


Figure 80 Heterogeneity of the parameter "Distance to nesting place" in OD (Datenquelle: basemap.at).

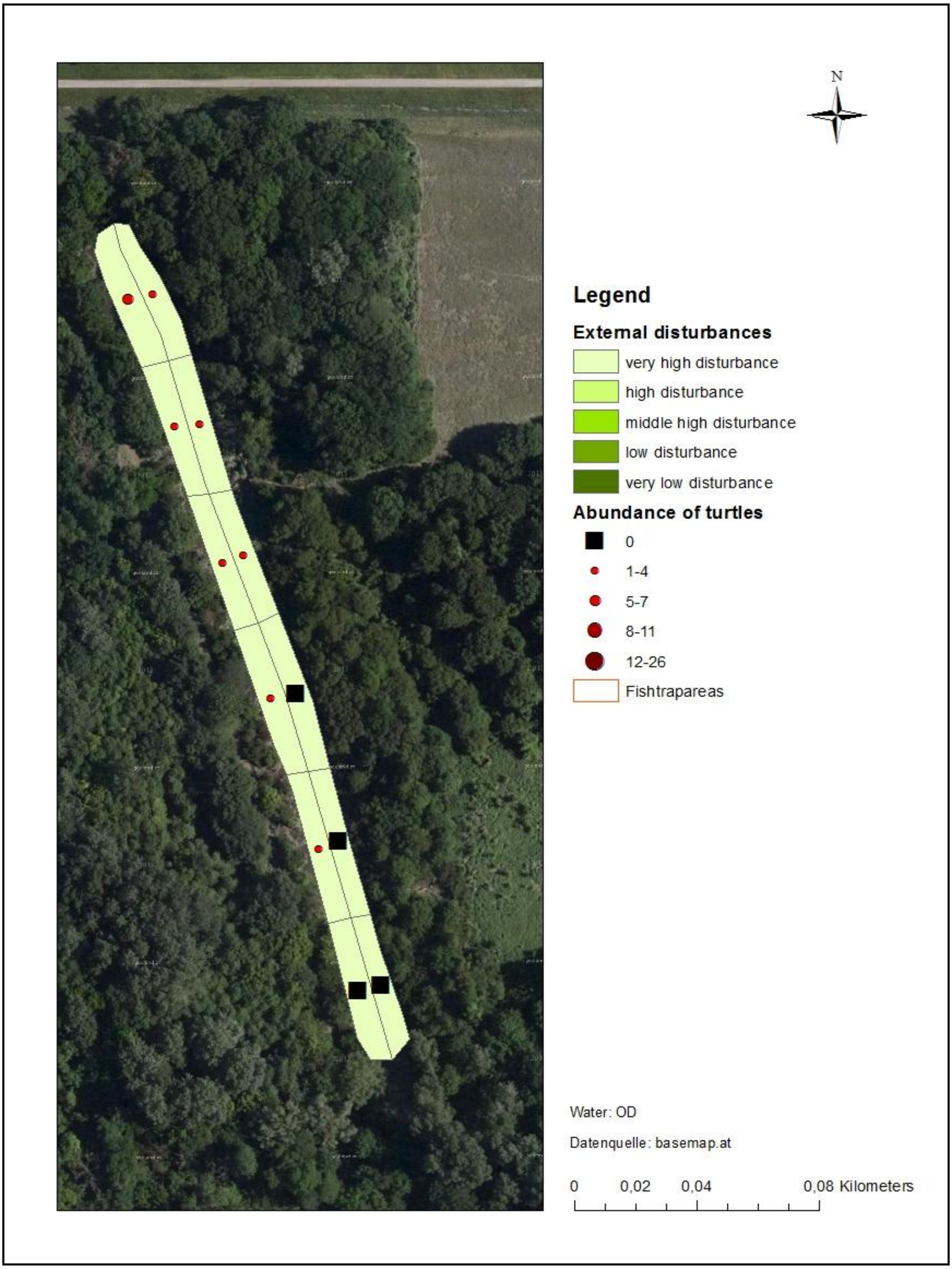


Figure 81 Heterogeneity of the parameter "External disturbances" in OD (Datenquelle: basemap.at).

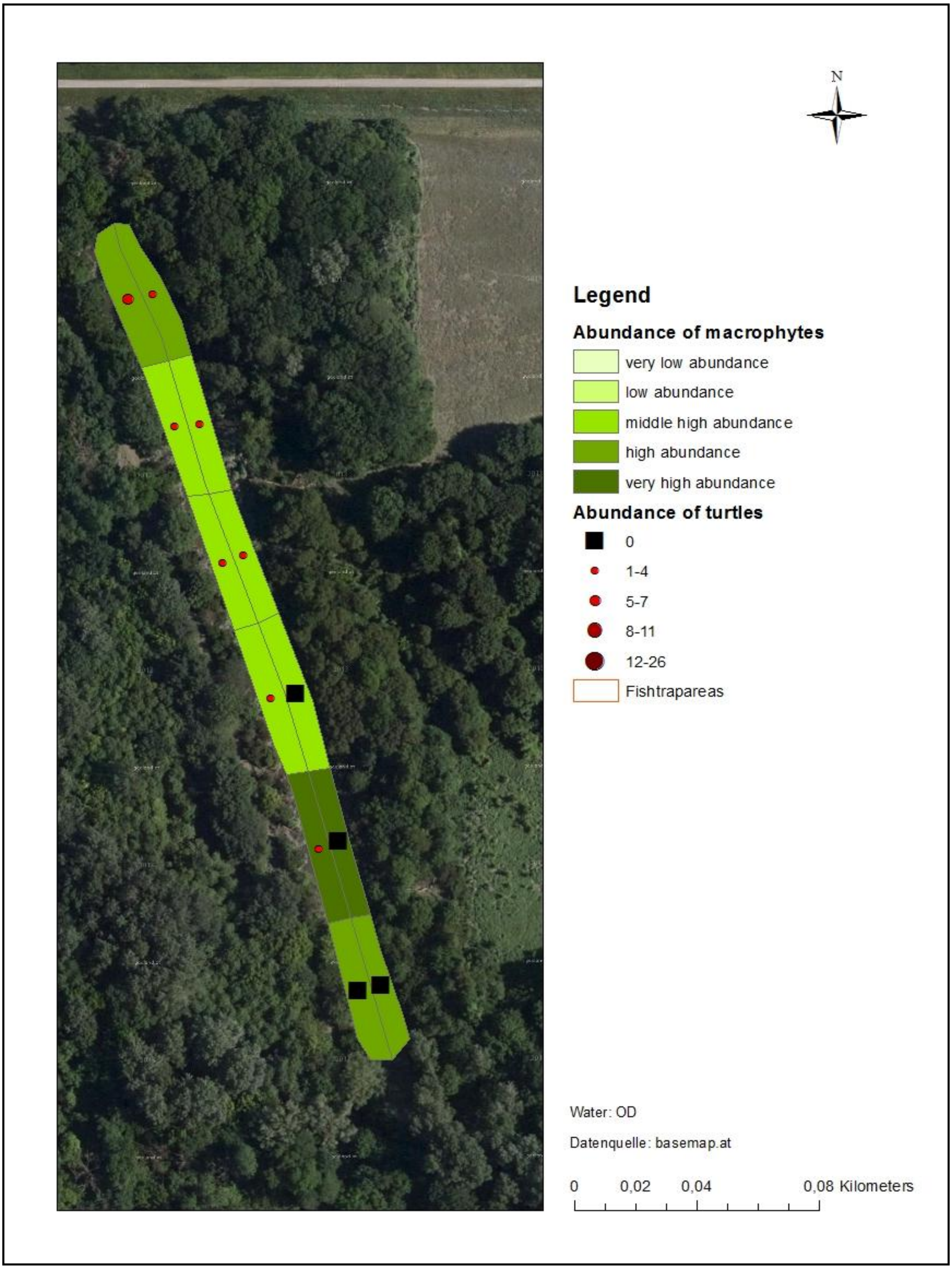


Figure 82 Heterogeneity of the parameter "Abundance of macrophytes" in OD (Datenquelle: basemap.at).

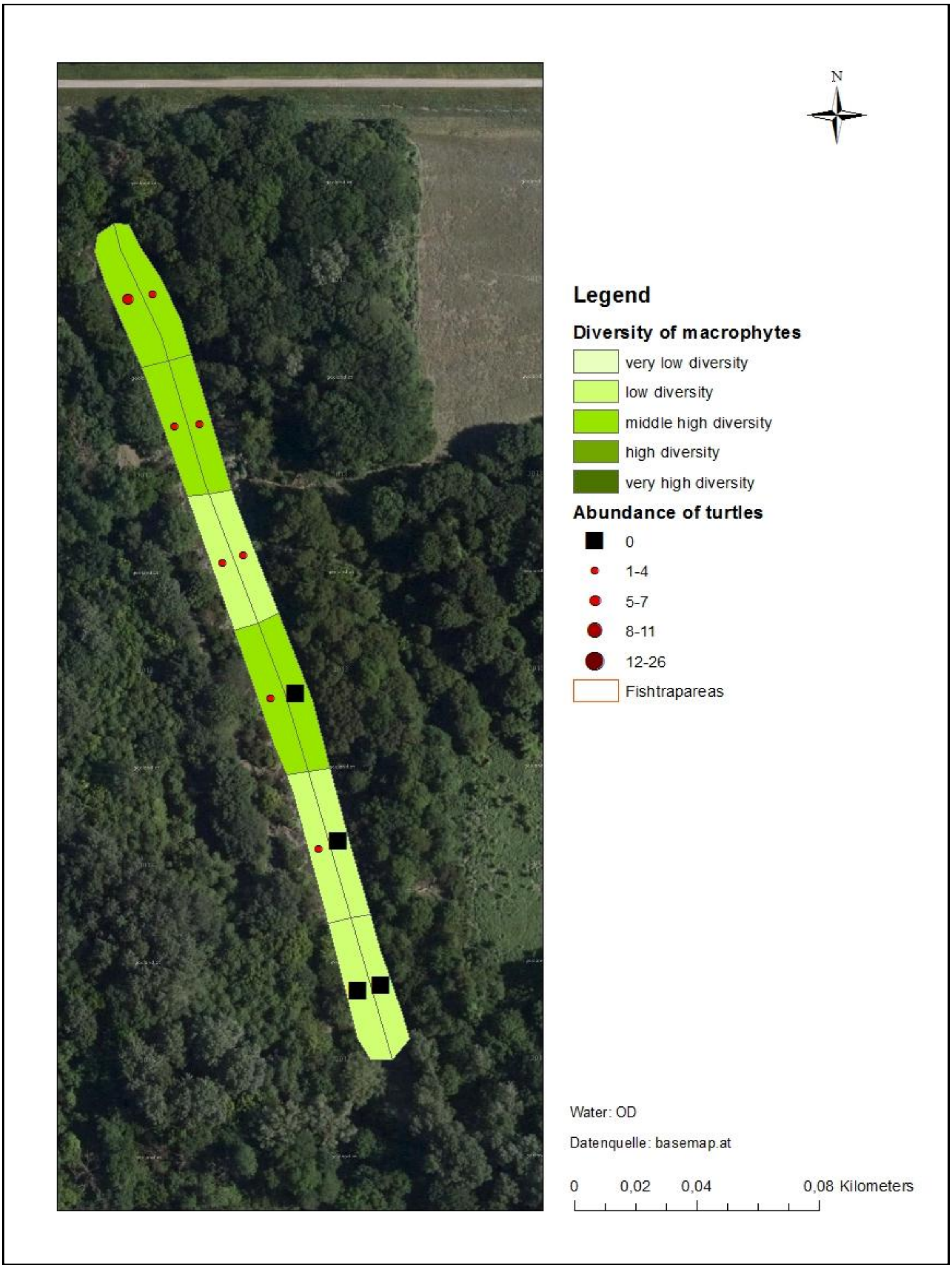


Figure 83 Heterogeneity of the parameter "Diversity of macrophytes" in OD (Datenquelle: basemap.at).

Heterogeneity of the parameters in the water OL:

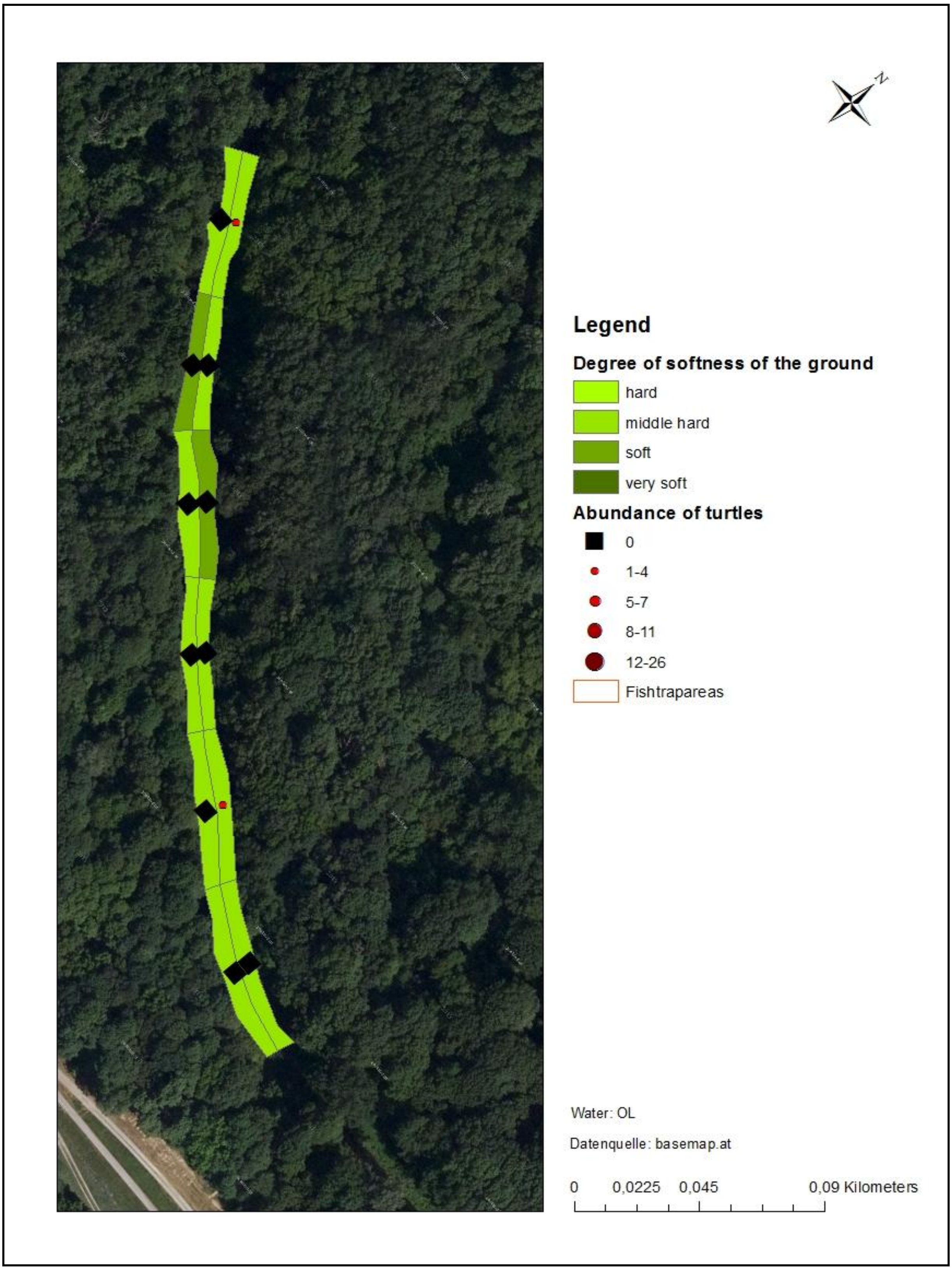


Figure 84 Heterogeneity of the parameter “Degree of softness of the ground” in OL (Datenquelle: basemap.at).

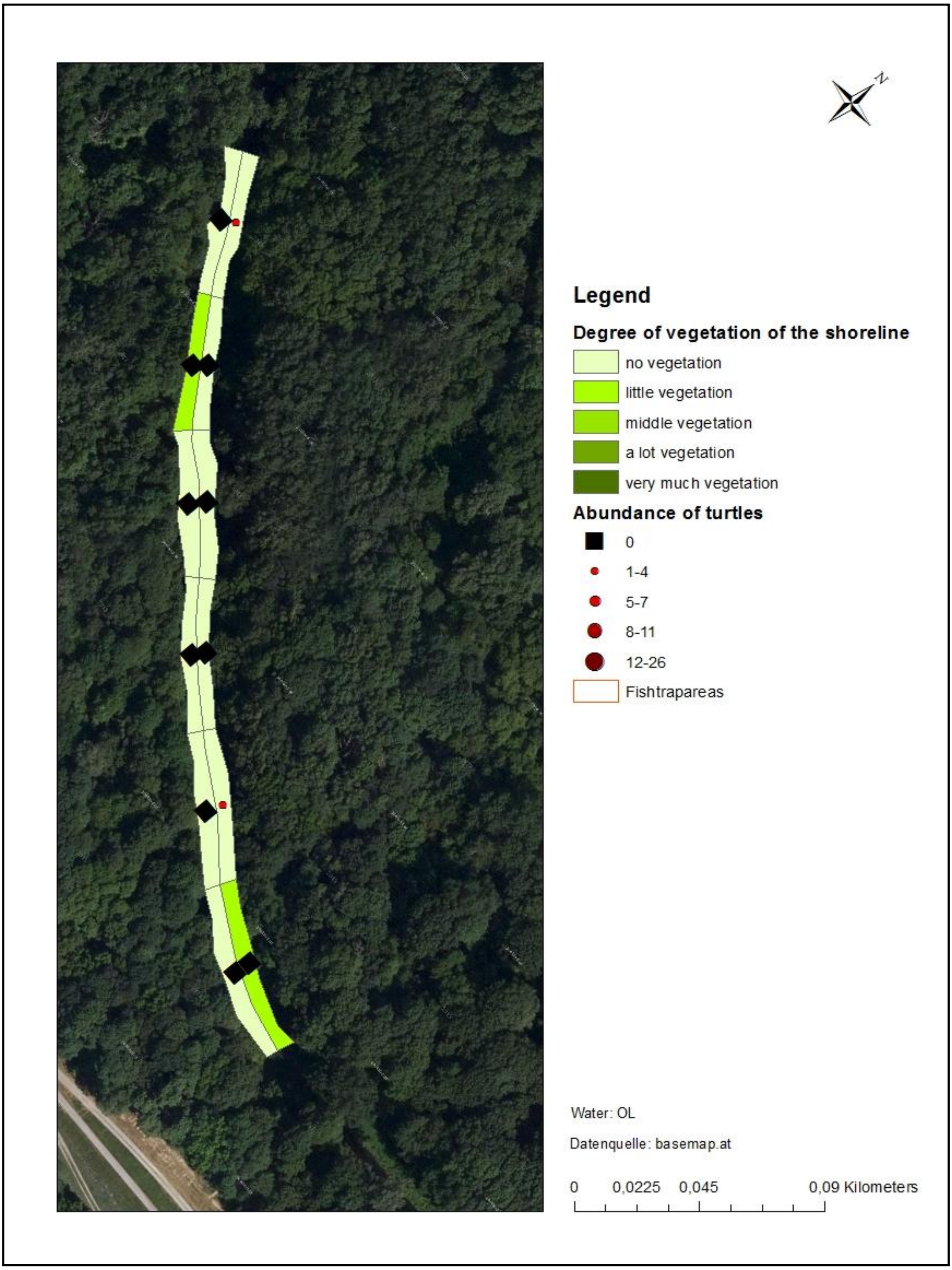


Figure 85 Heterogeneity of the parameter "Degree of vegetation of the shoreline" in OL (Datenquelle: basemap.at).

Figure 86 Heterogeneity of the parameter “Abundance of dead wood” in OL (Datenquelle: basemap.at).

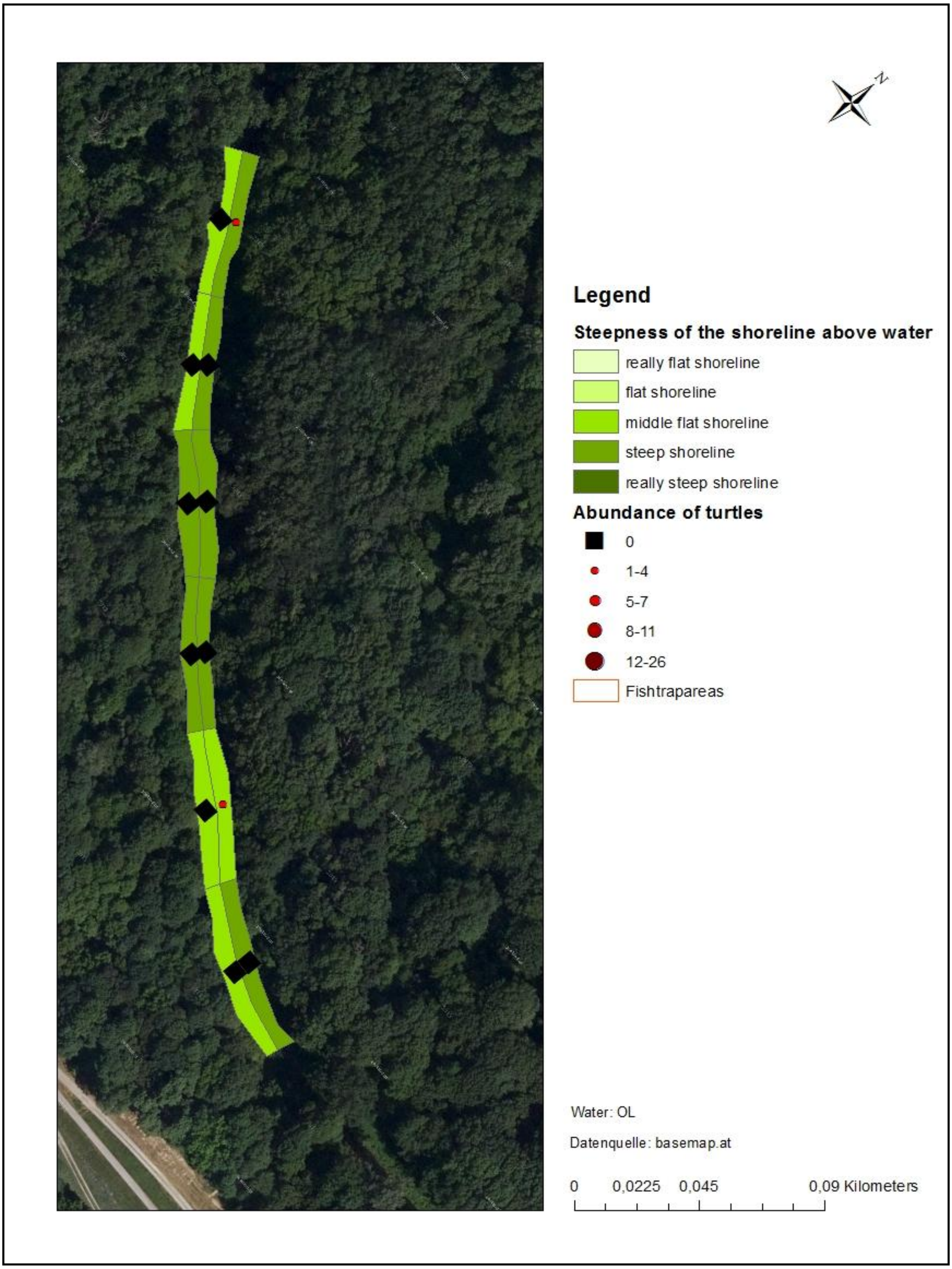


Figure 87 Heterogeneity of the parameter "Steepness of the shoreline above water" in OL (Datenquelle: basemap.at).

Figure 88 Heterogeneity of the parameter "Steepness of the shoreline below water" in OL (Datenquelle: basemap.at).

Figure 89 Heterogeneity of the parameter "Depth at the middle of the water" in OL (Datenquelle: basemap.at).

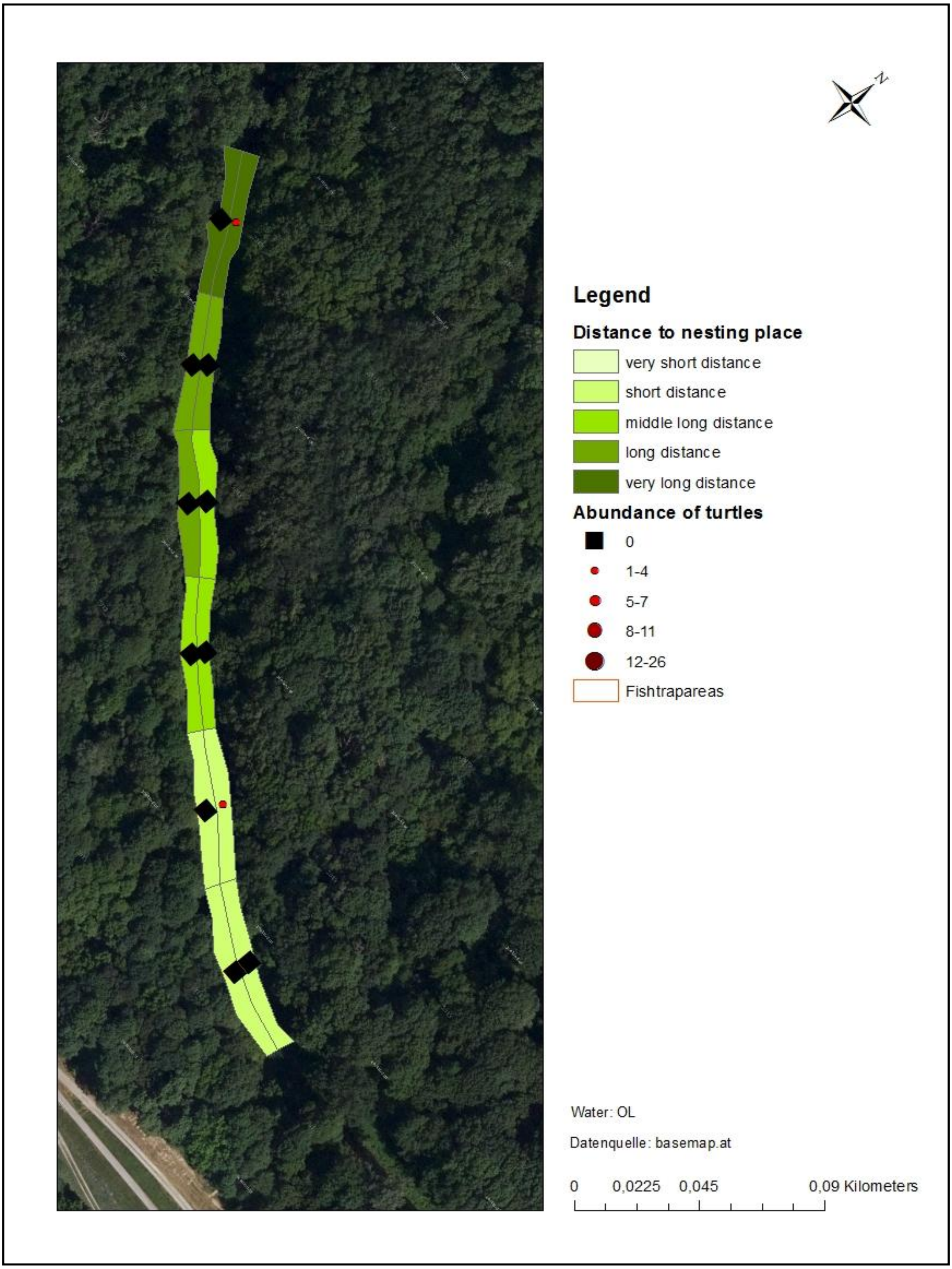


Figure 90 Heterogeneity of the parameter "Distance to nesting place" in OL (Datenquelle: basemap.at).

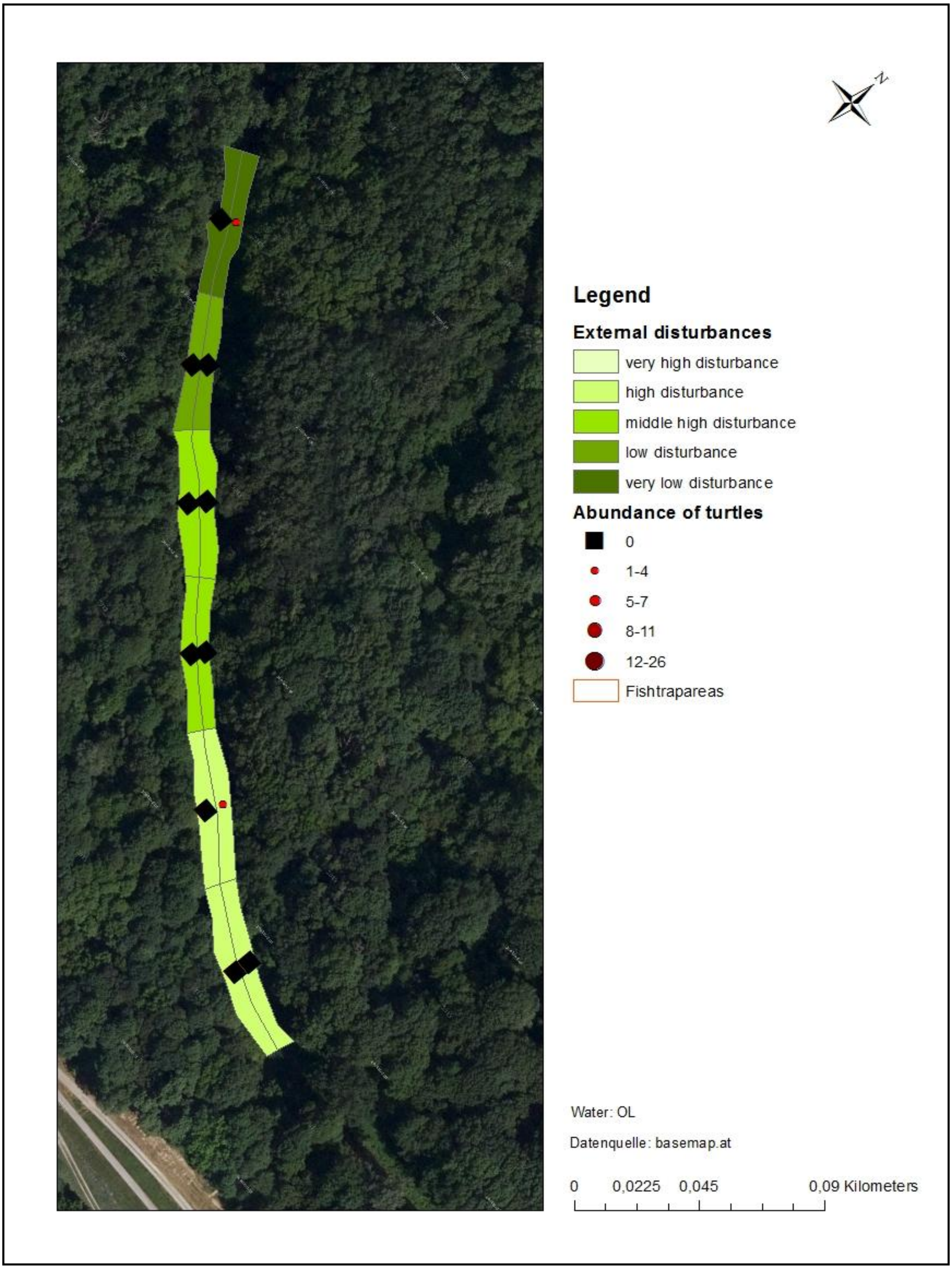


Figure 91 Heterogeneity of the parameter "External disturbances" in OL (Datenquelle: basemap.at).

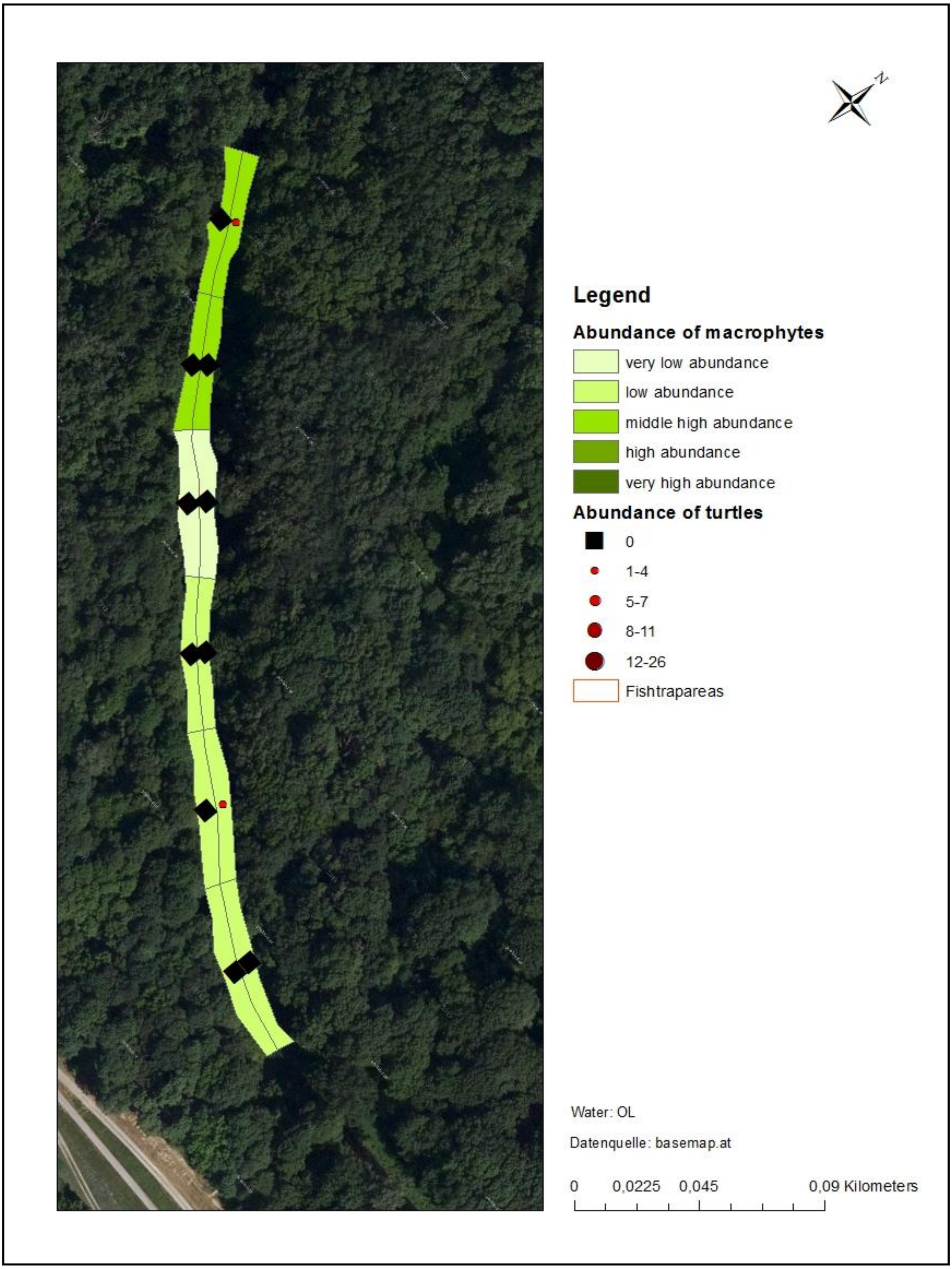


Figure 92 Heterogeneity of the parameter "Abundance of macrophytes" in OL (Datenquelle: basemap.at).

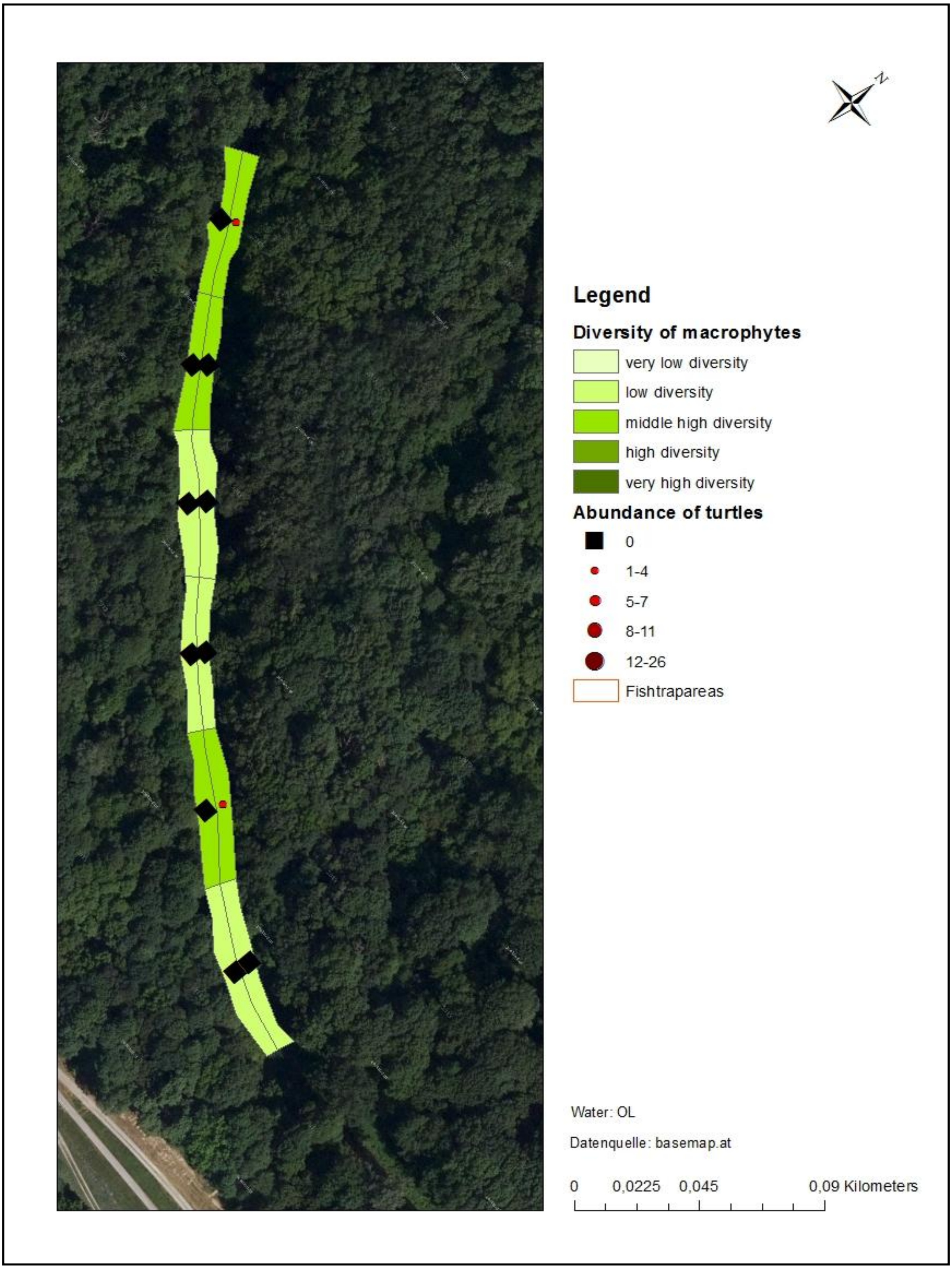


Figure 93 Heterogeneity of the parameter "Diversity of macrophytes" in OL (Datenquelle: basemap.at).

Heterogeneity of the parameters in the water ED:

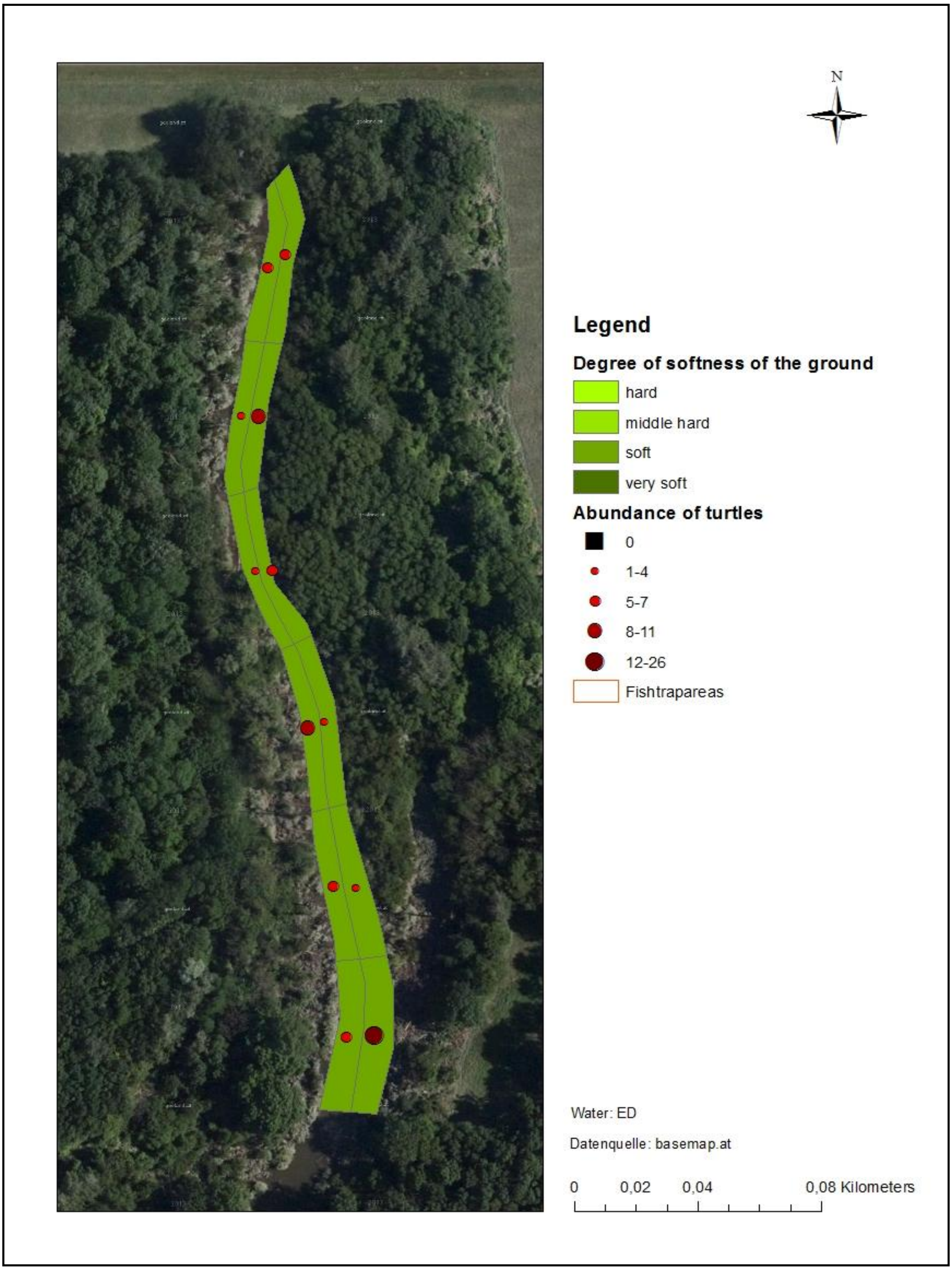


Figure 94 Heterogeneity of the parameter "Degree of softness of the ground" in ED (Datenquelle: basemap.at).

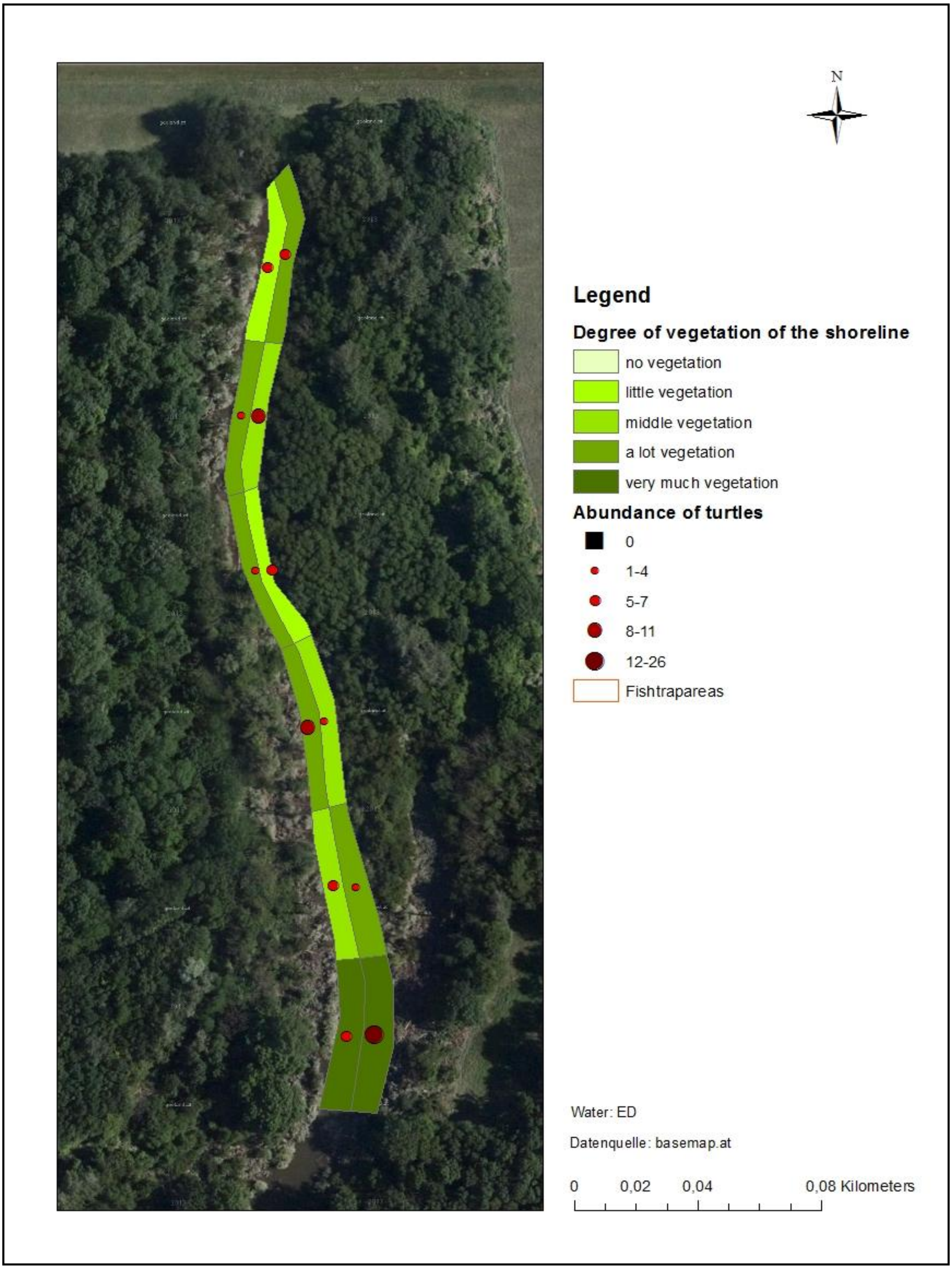


Figure 95 Heterogeneity of the parameter "Degree of vegetation of the shoreline" in ED (Datenquelle: basemap.at).

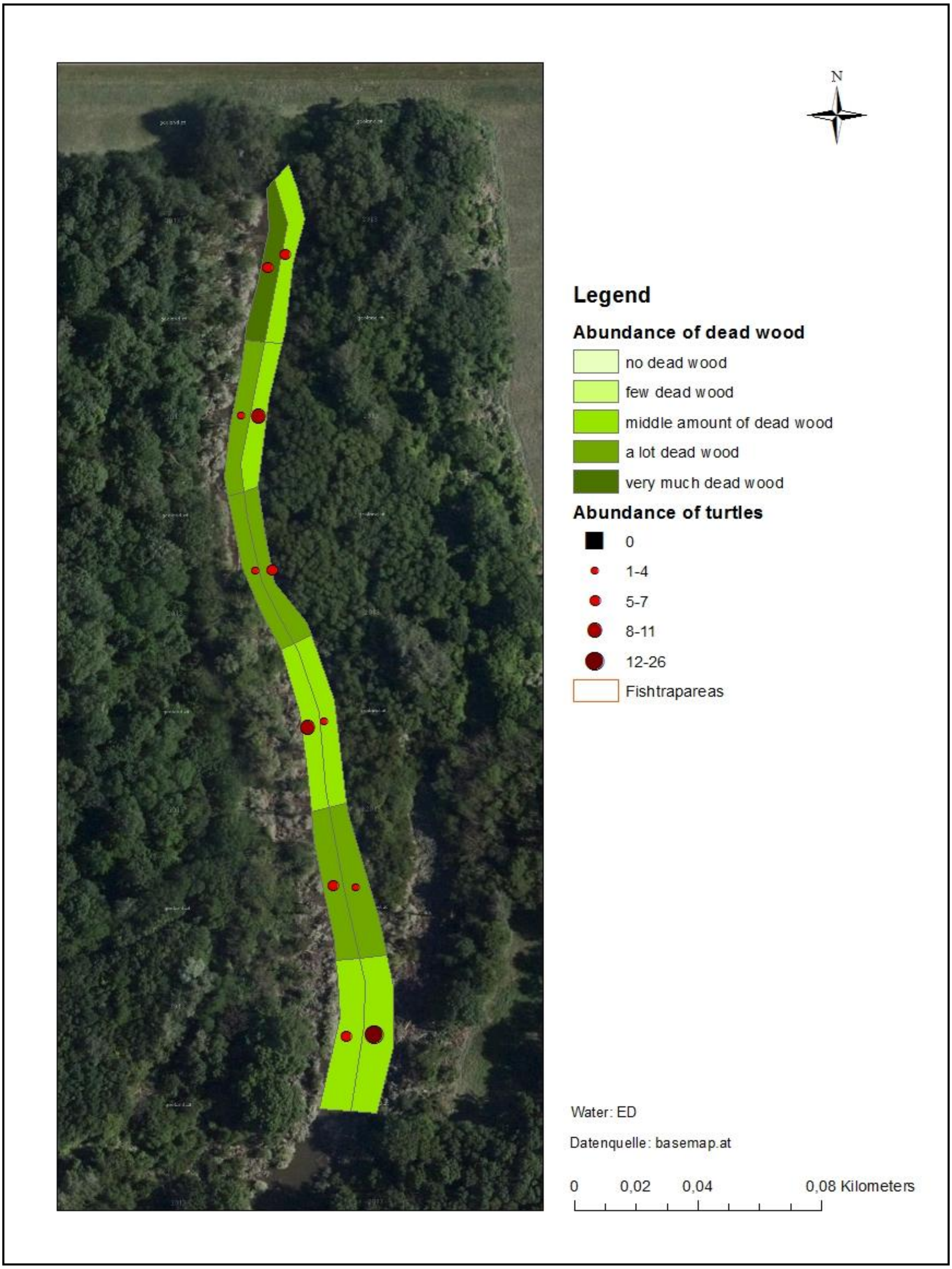


Figure 96 Heterogeneity of the parameter "Abundance of dead wood" in ED (Datenquelle: basemap.at).

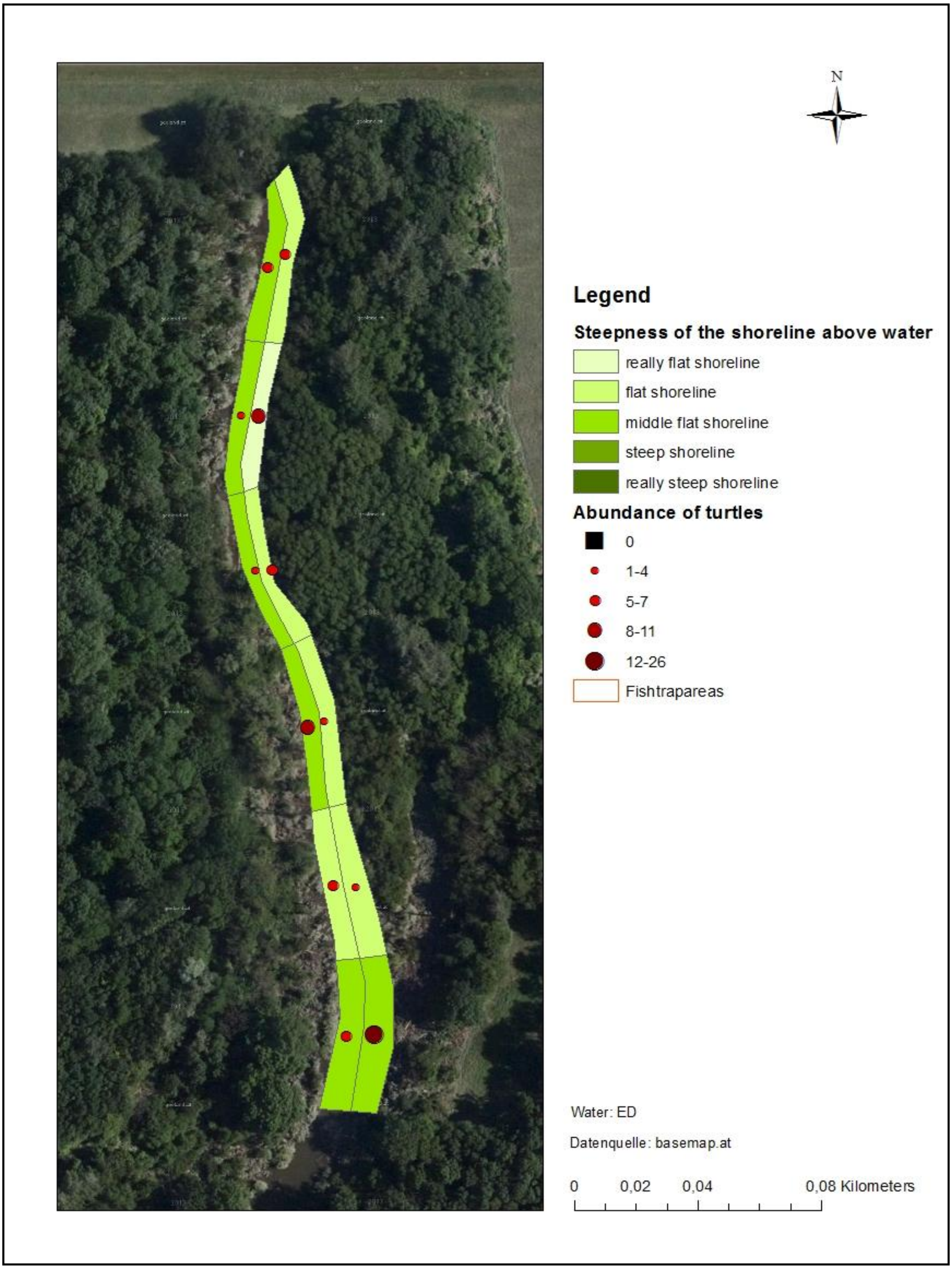


Figure 97 Heterogeneity of the parameter "Steepness of the shoreline above water" in ED (Datenquelle: basemap.at).

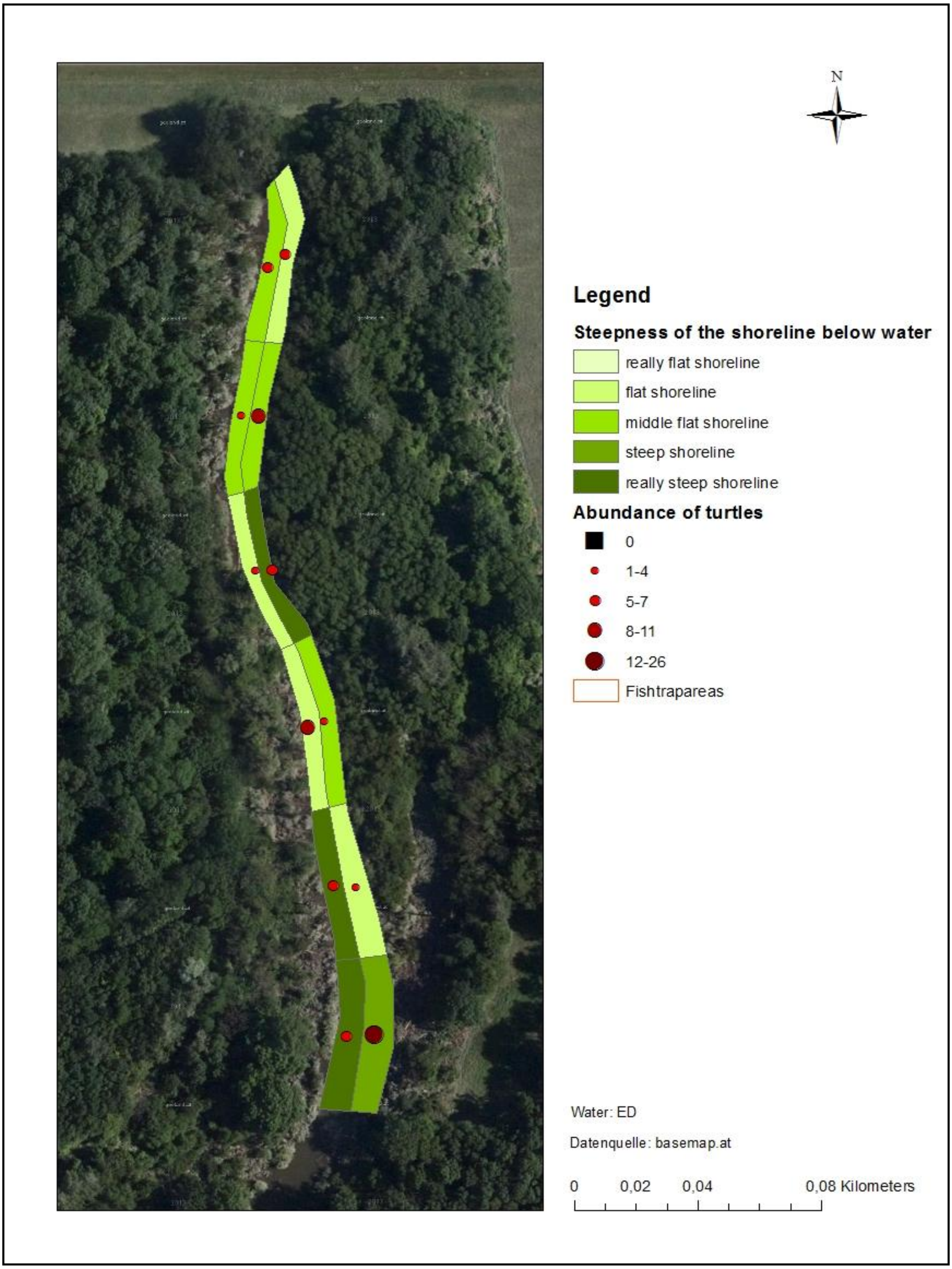


Figure 98 Heterogeneity of the parameter "Steepness of the shoreline below water" in ED (Datenquelle: basemap.at).

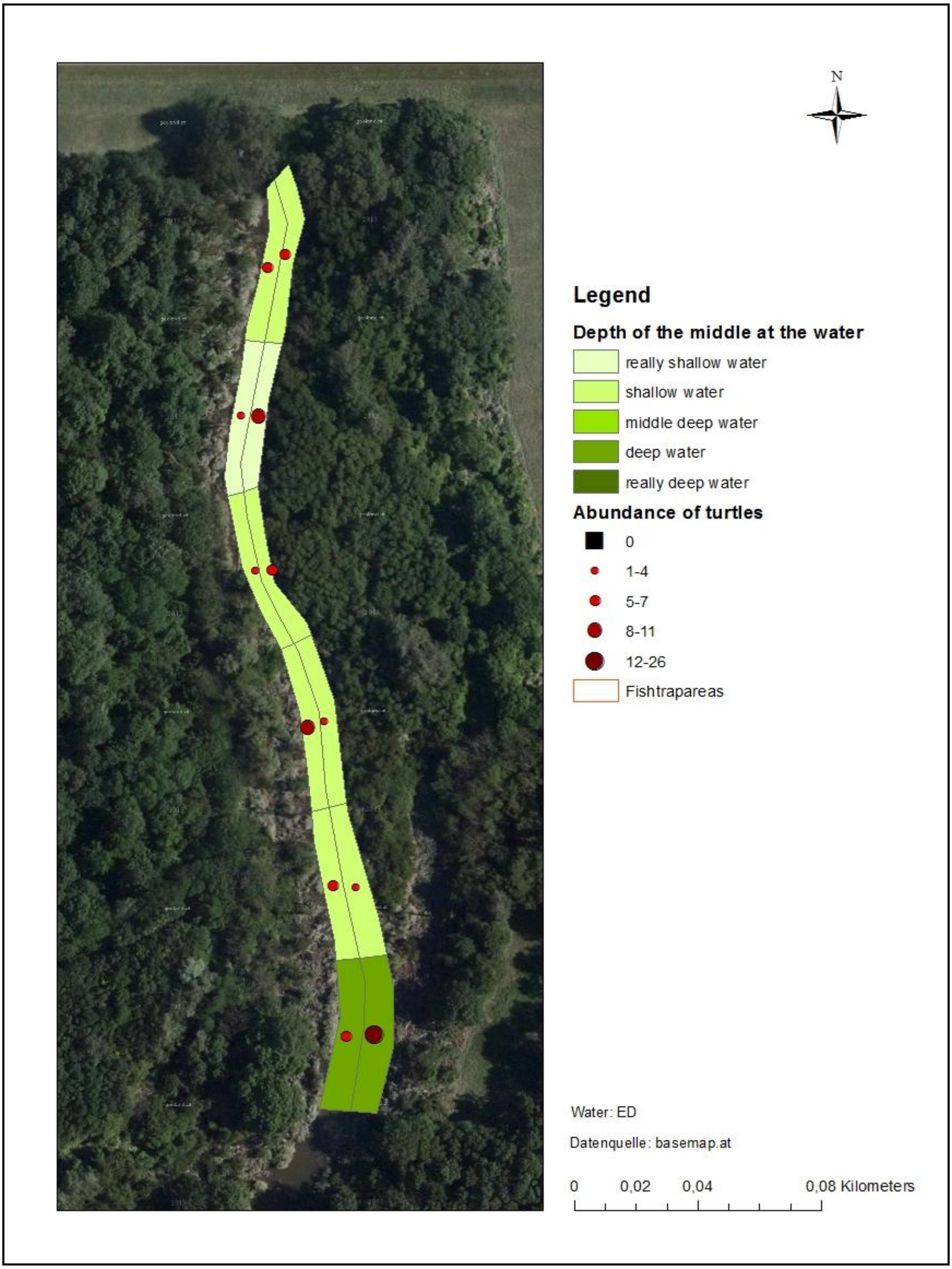


Figure 99 Heterogeneity of the parameter "Depth at the middle of the water" in ED (Datenquelle: basemap.at).

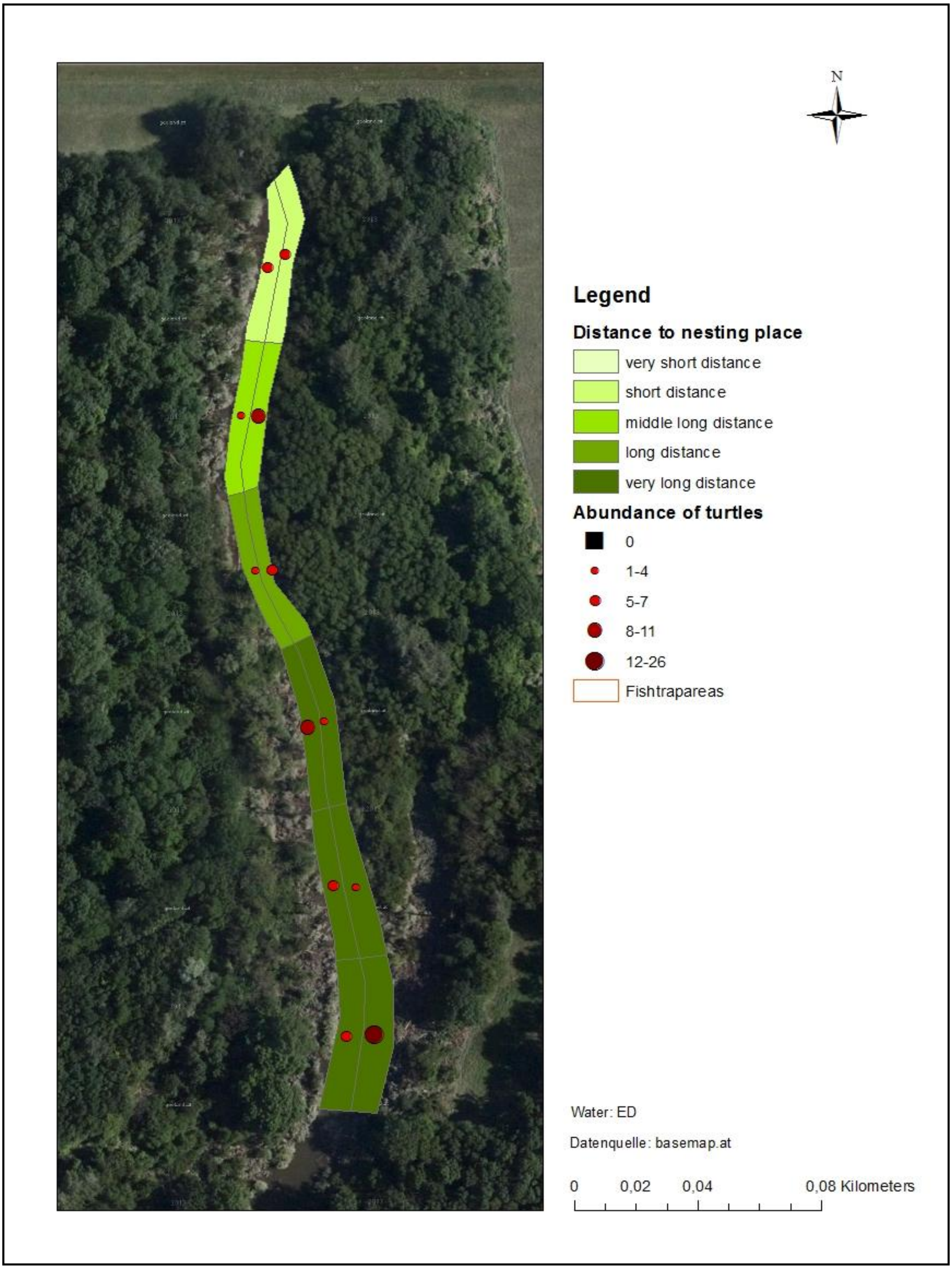


Figure 100 Heterogeneity of the parameter "Distance to nesting place" in ED (Datenquelle: basemap.at).

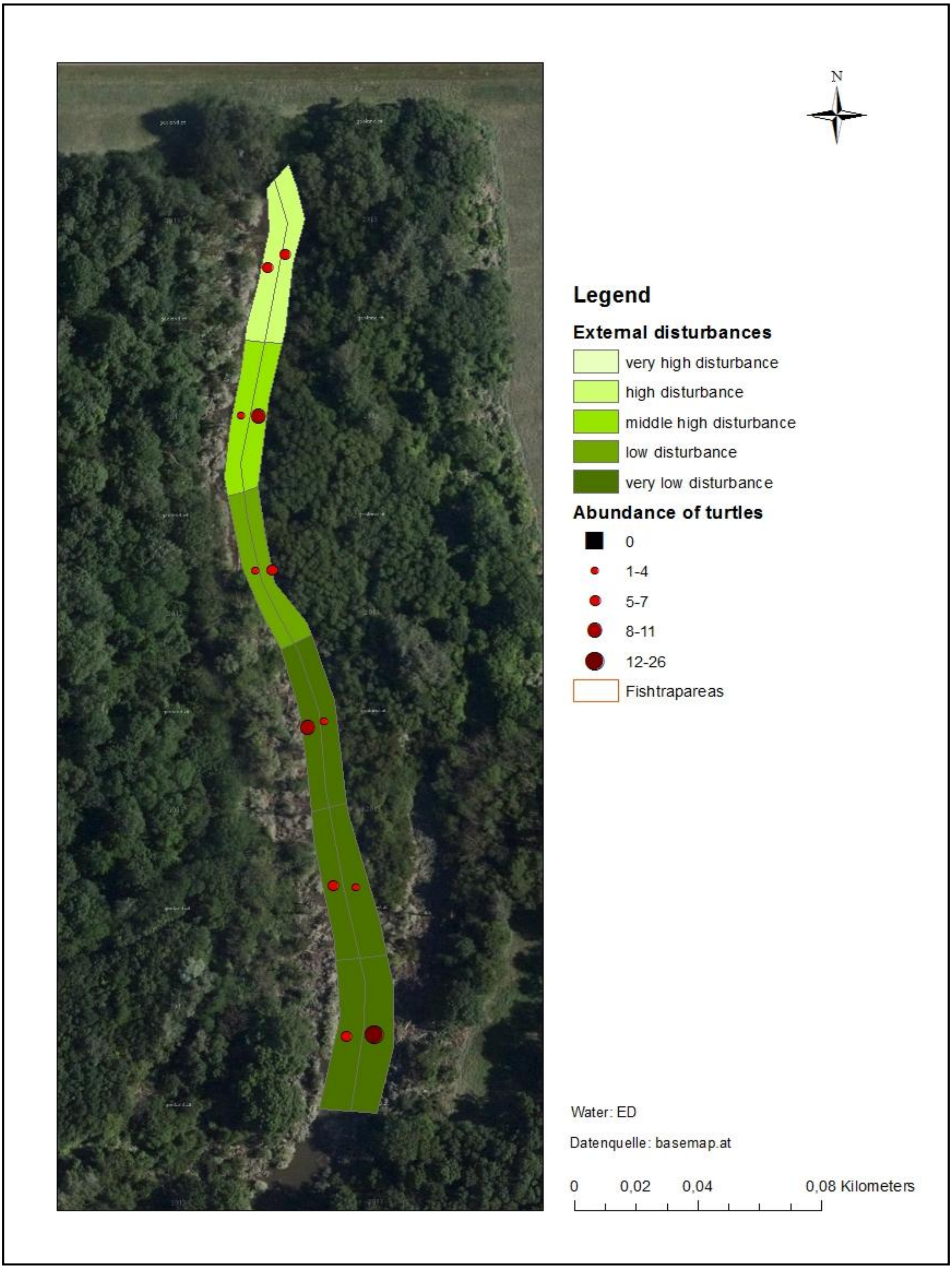


Figure 101 Heterogeneity of the parameter "External disturbances" in ED (Datenquelle: basemap.at).

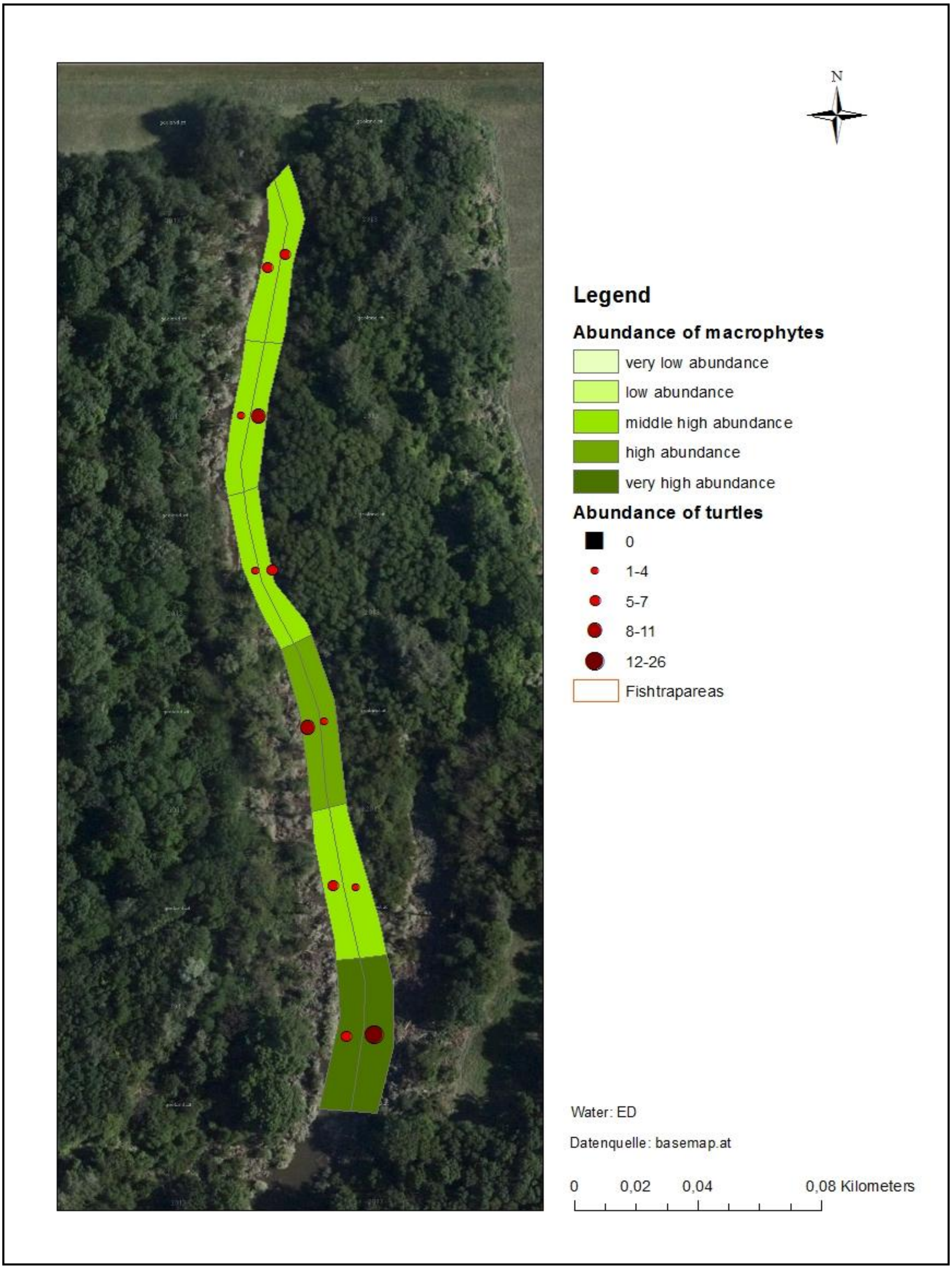


Figure 102 Heterogeneity of the parameter "Abundance of macrophytes" in ED (Datenquelle: basemap.at).

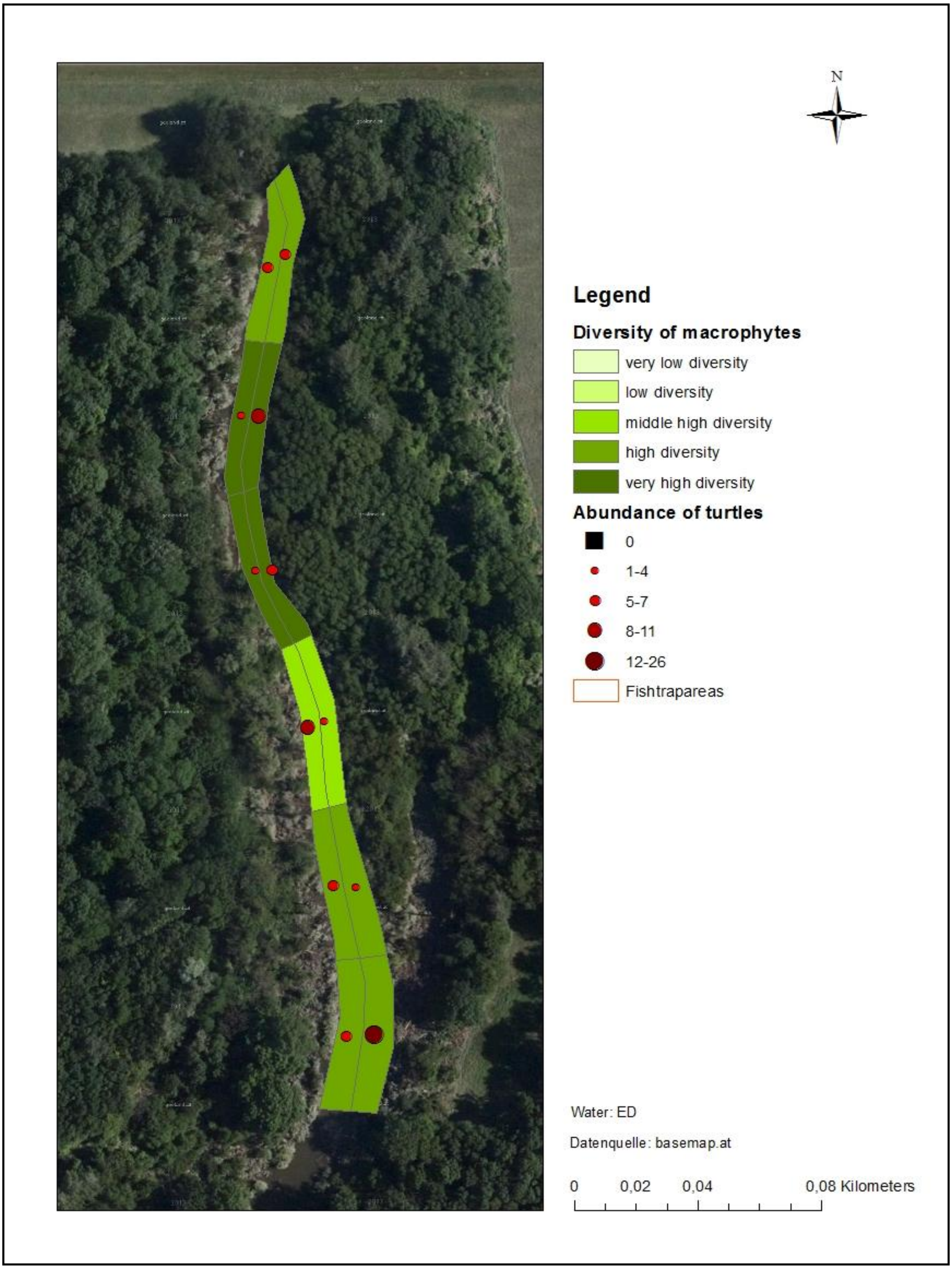


Figure 103 Heterogeneity of the parameter "Diversity of macrophytes" in ED (Datenquelle: basemap.at).

Heterogeneity of the parameters in the water EL:

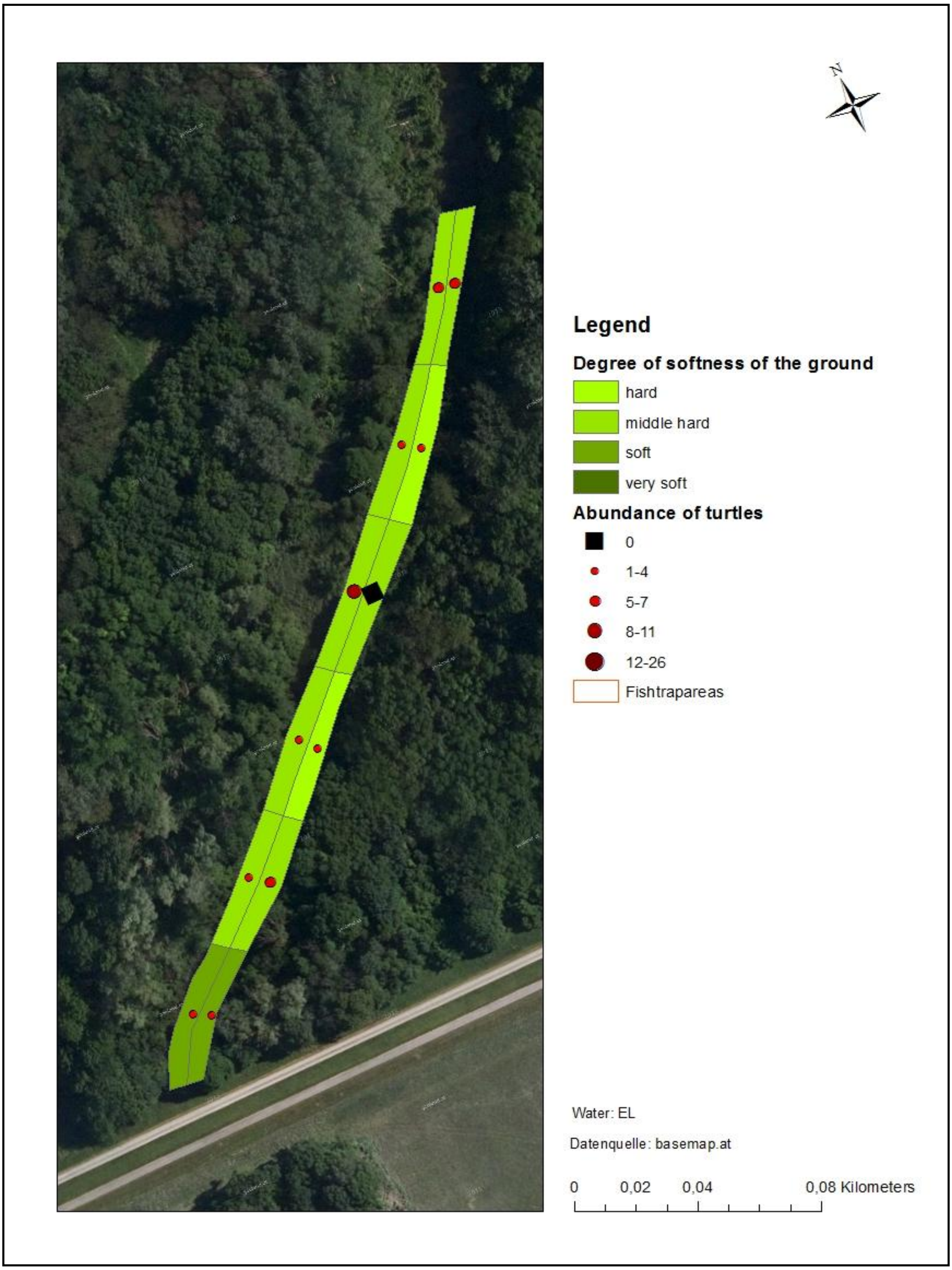


Figure 104 Heterogeneity of the parameter "Degree of softness of the ground" in EL (Datenquelle: basemap.at).

Figure 105 Heterogeneity of the parameter "Degree of vegetation of the shoreline" in EL (Datenquelle: basemap.at).

Figure 106 Heterogeneity of the parameter "Abundance of dead wood" in EL (Datenquelle: basemap.at).

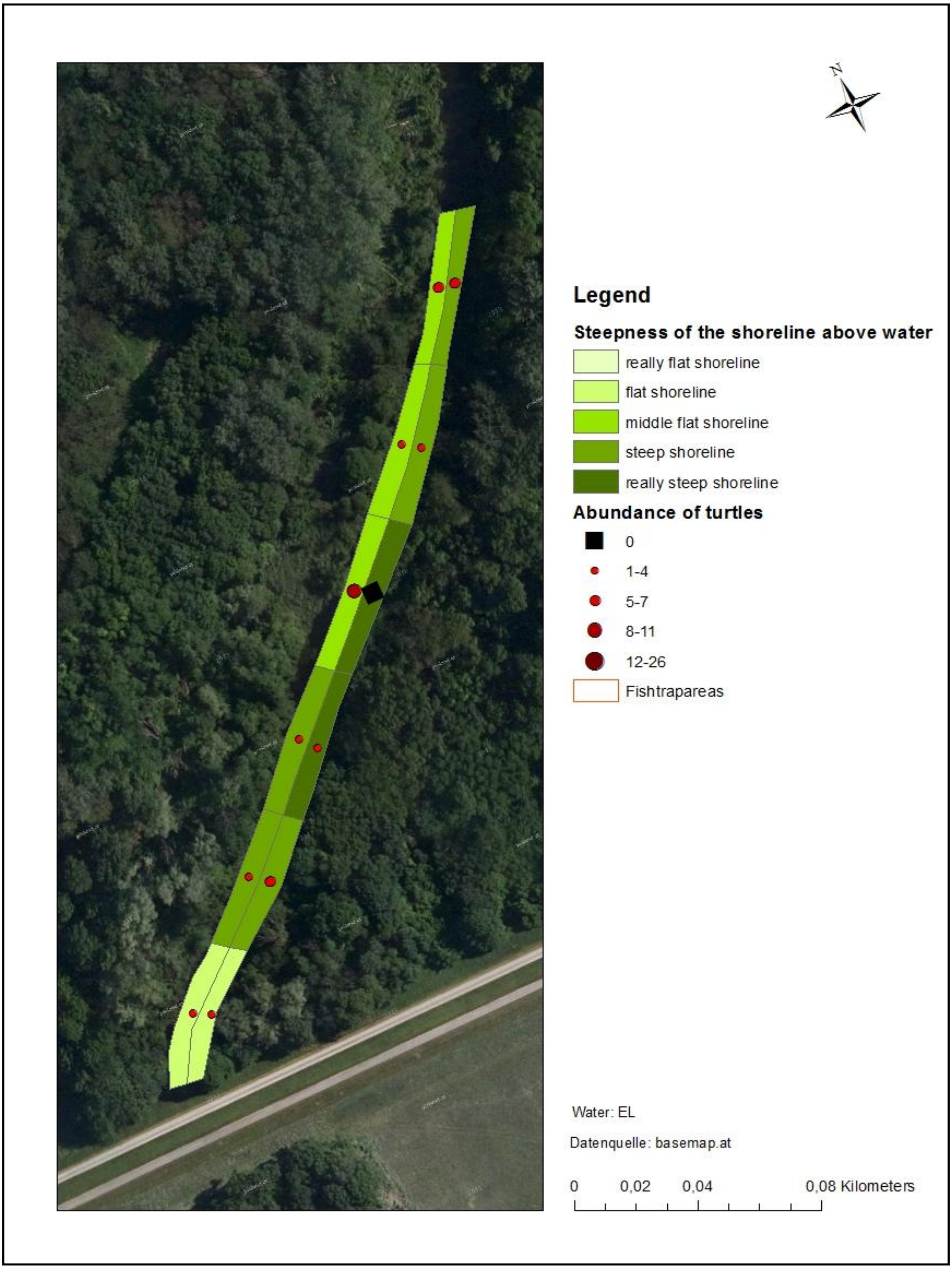


Figure 107 Heterogeneity of the parameter "Steepness of the shoreline above water" in EL (Datenquelle: basemap.at).

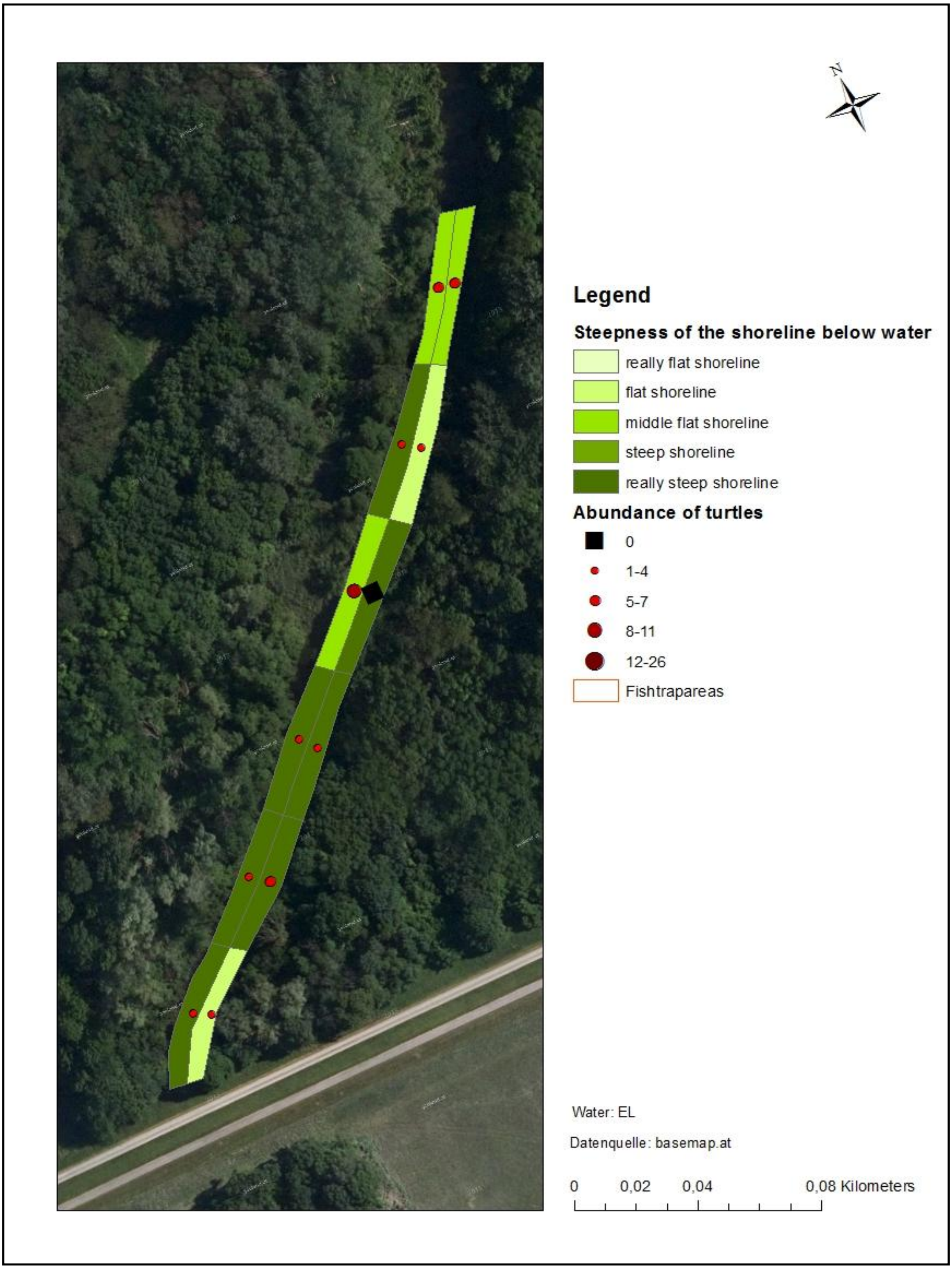


Figure 108 Heterogeneity of the parameter "Steepness of the shoreline below water" in EL (Datenquelle: basemap.at).

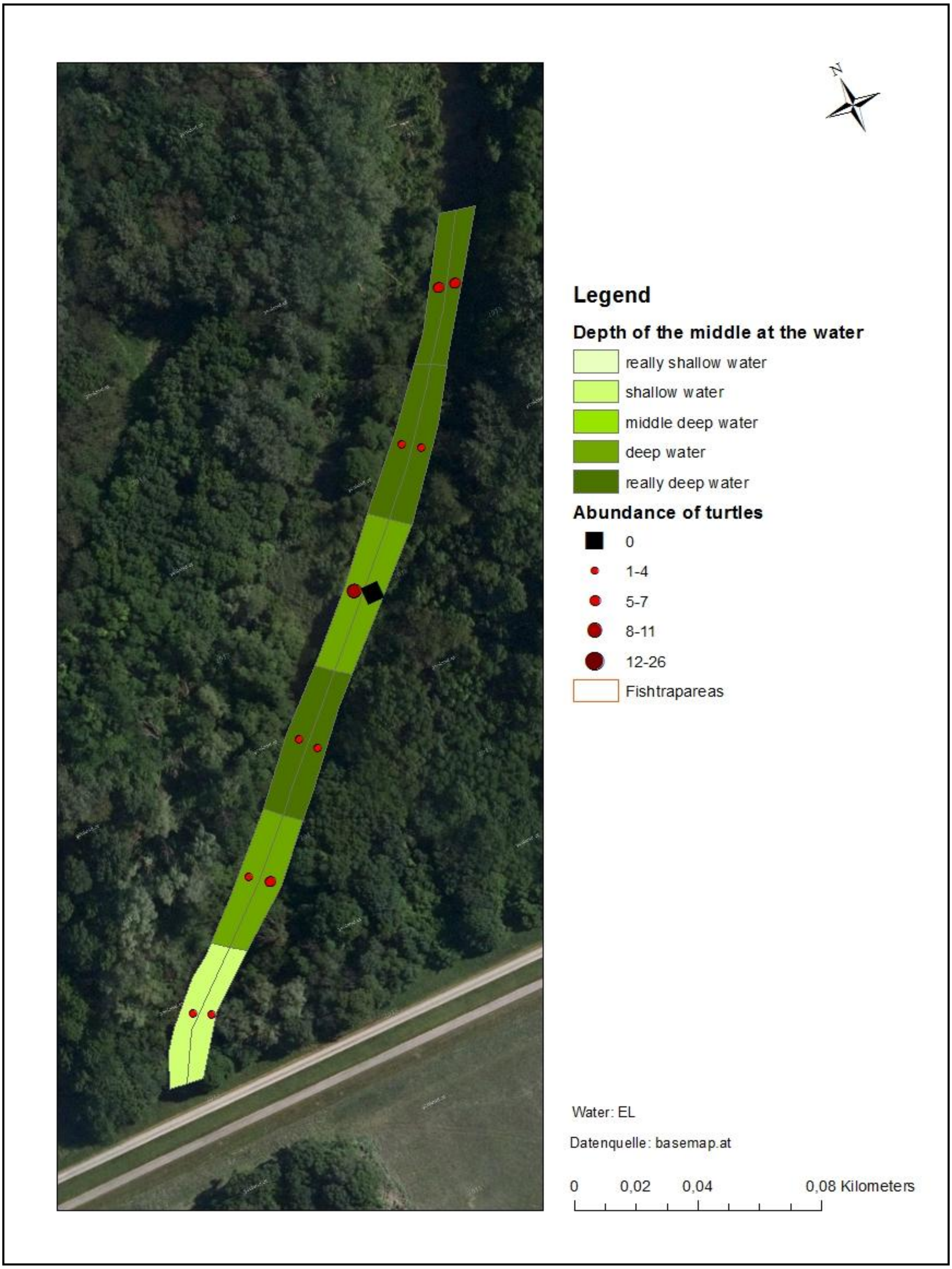


Figure 109 Heterogeneity of the parameter "Depth at the middle of the water" in EL (Datenquelle: basemap.at).

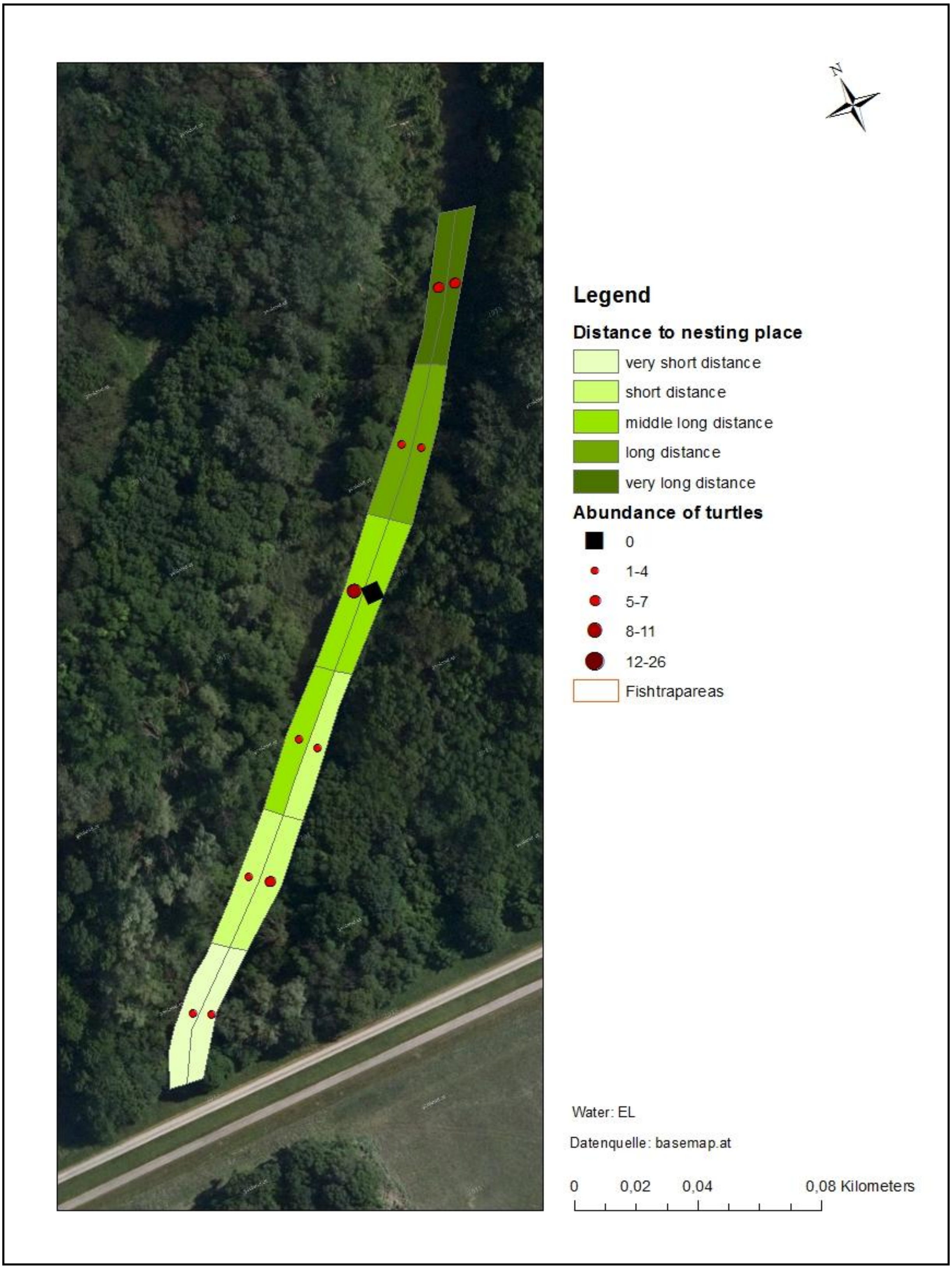


Figure 110 Heterogeneity of the parameter "Distance to nesting place" in EL (Datenquelle: basemap.at).

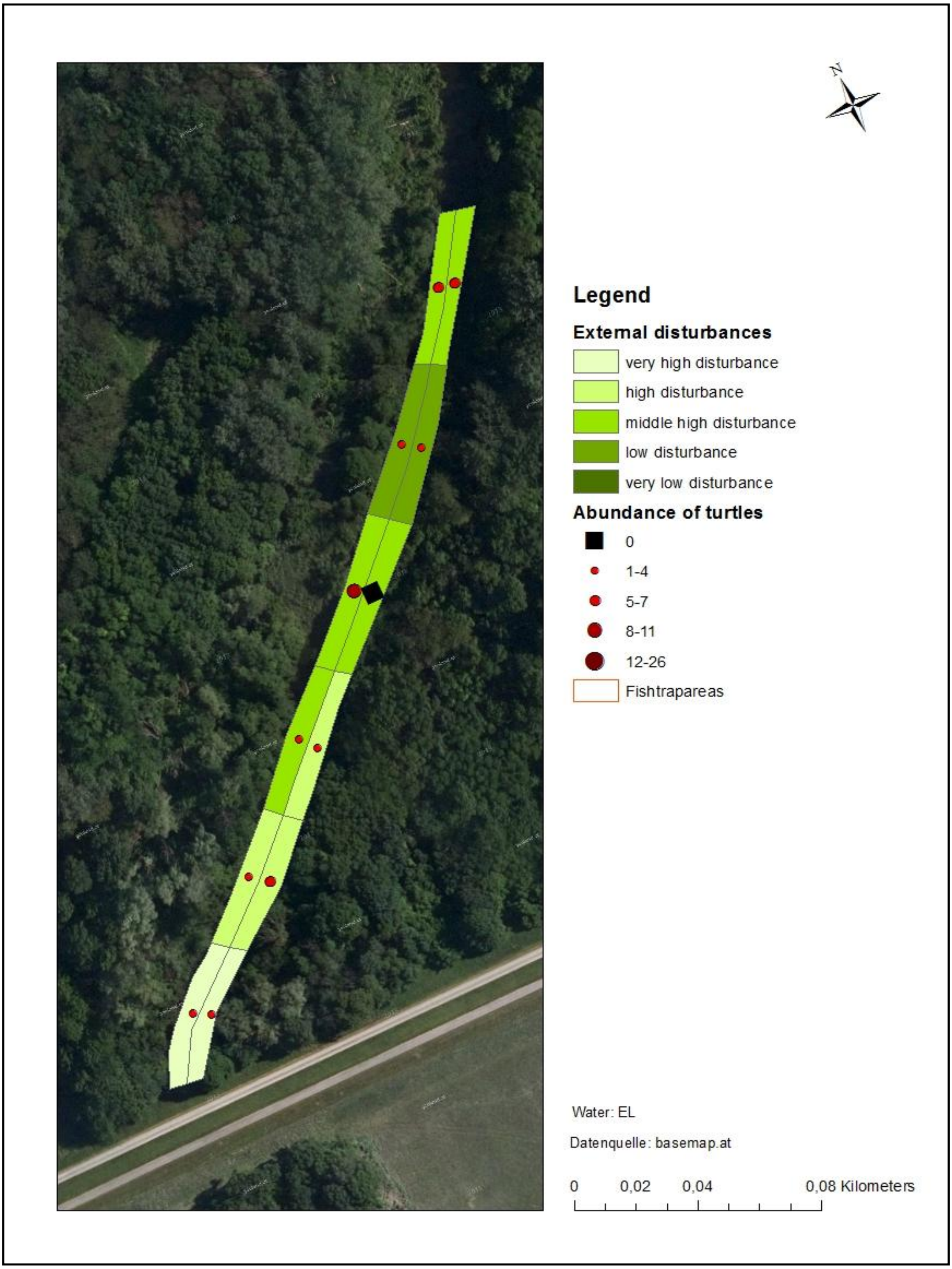


Figure 111 Heterogeneity of the parameter "External disturbances" in EL (Datenquelle: basemap.at).

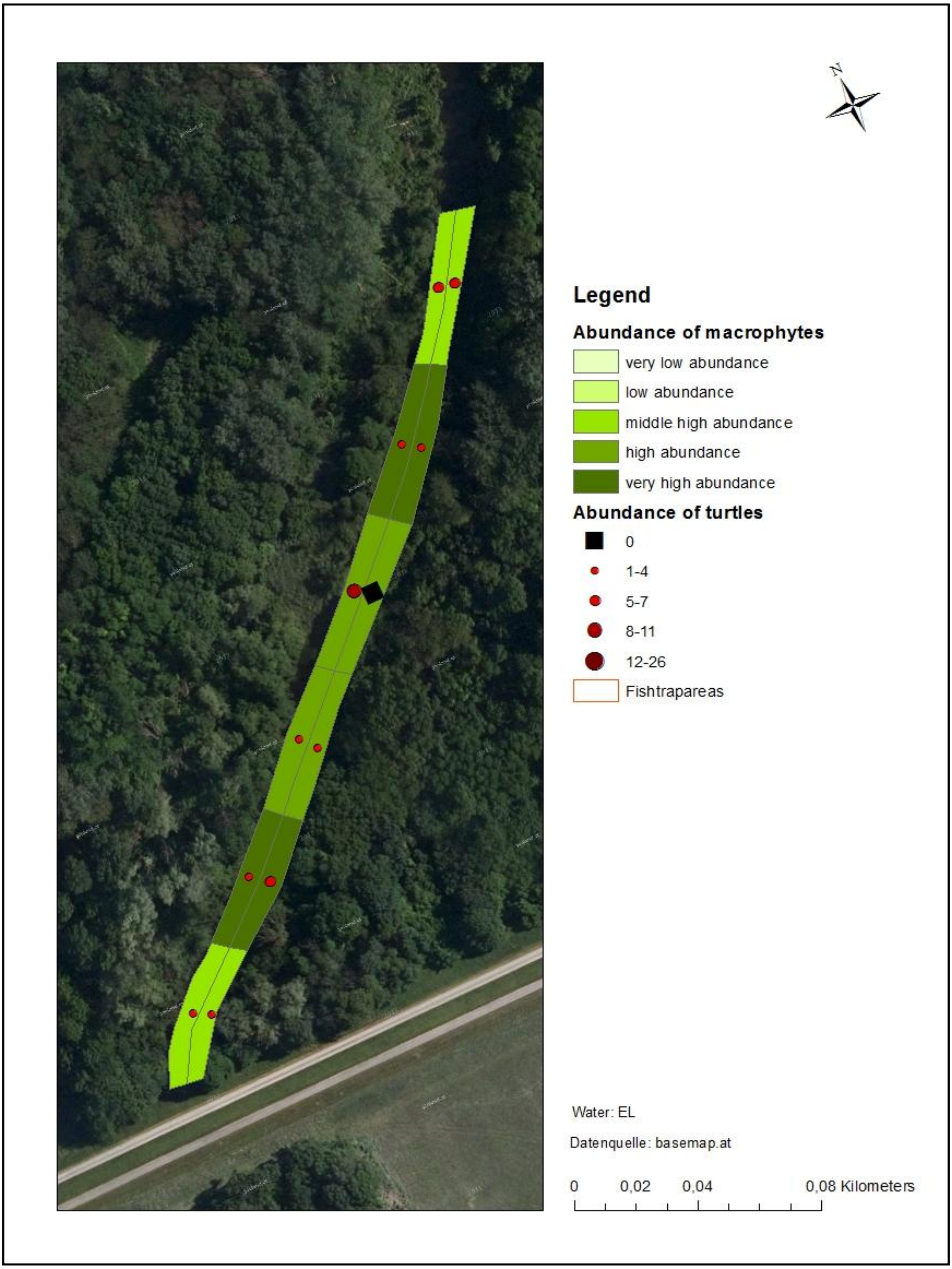


Figure 112 Heterogeneity of the parameter "Abundance of macrophytes" in EL (Datenquelle: basemap.at).

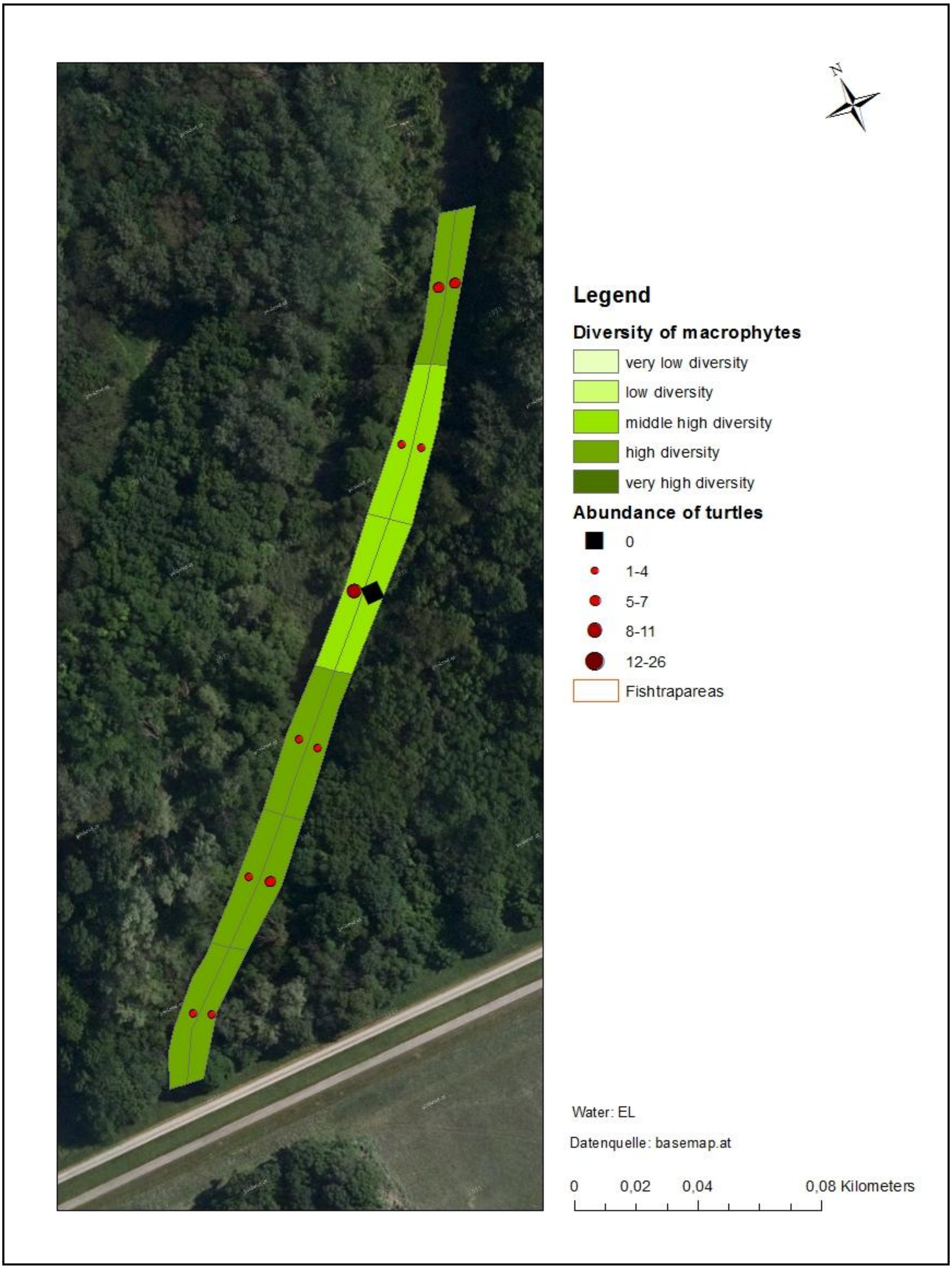


Figure 113 Heterogeneity of the parameter "Diversity of macrophytes" in EL (Datenquelle: basemap.at).

Heterogeneity of the parameters in the water WD:

Figure 114 Heterogeneity of the parameter "Degree of softness of the ground" in WD (Datenquelle: basemap.at).

Figure 115 Heterogeneity of the parameter "Degree of vegetation of the shoreline" in WD (Datenquelle: basemap.at).

Figure 116 Heterogeneity of the parameter "Abundance of dead wood" in WD (Datenquelle: basemap.at).

Figure 117 Heterogeneity of the parameter "Steepness of the shoreline above water" in WD (Datenquelle: basemap.at).

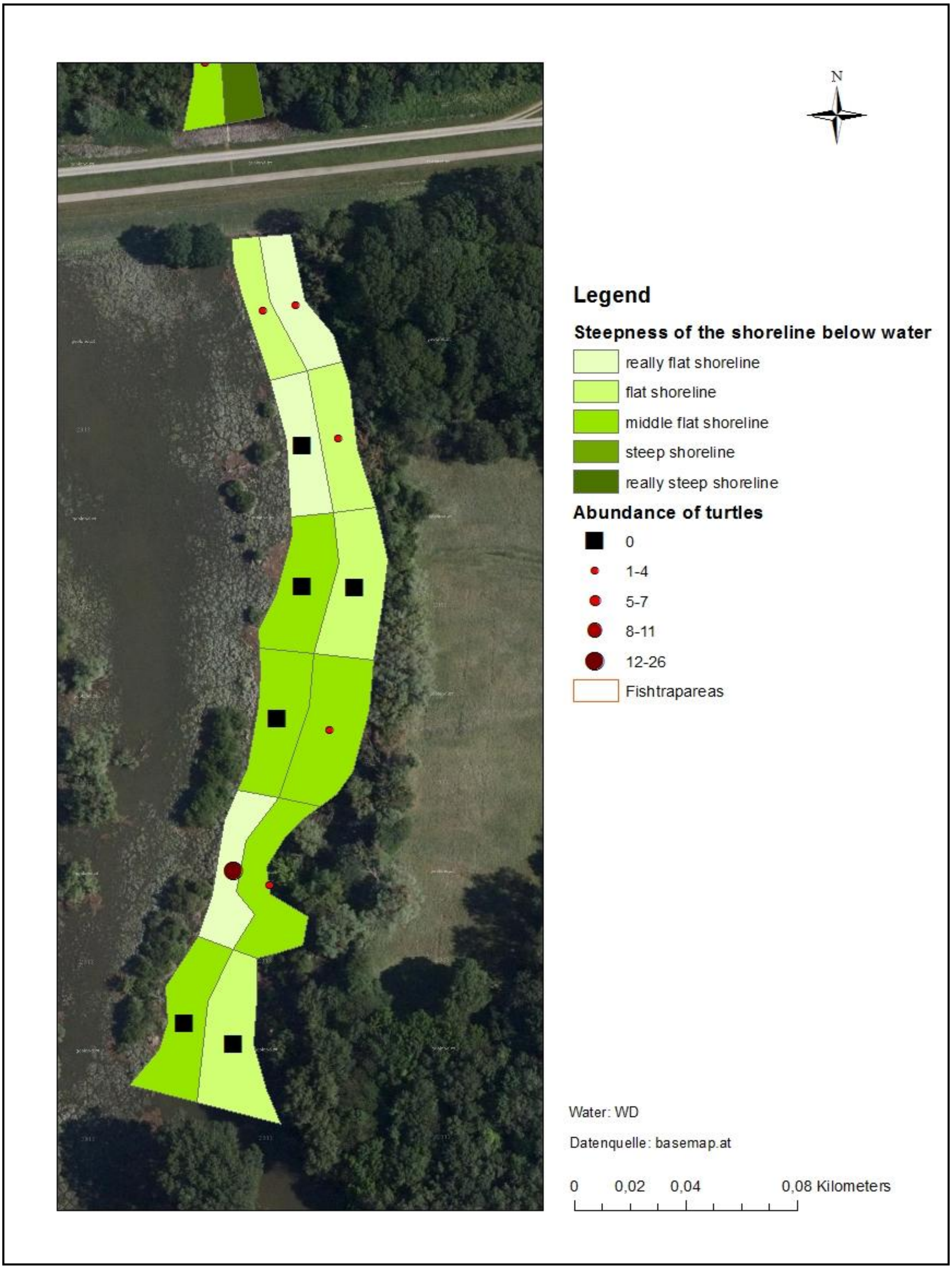


Figure 118 Heterogeneity of the parameter "Steepness of the shoreline below water" in WD (Datenquelle: basemap.at).

Figure 119 Heterogeneity of the parameter "Depth at the middle of the water" in WD (Datenquelle: basemap.at).

Figure 119 Heterogeneity of the parameter "Depth at the middle of the water" in WD (Datenquelle: basemap.at).

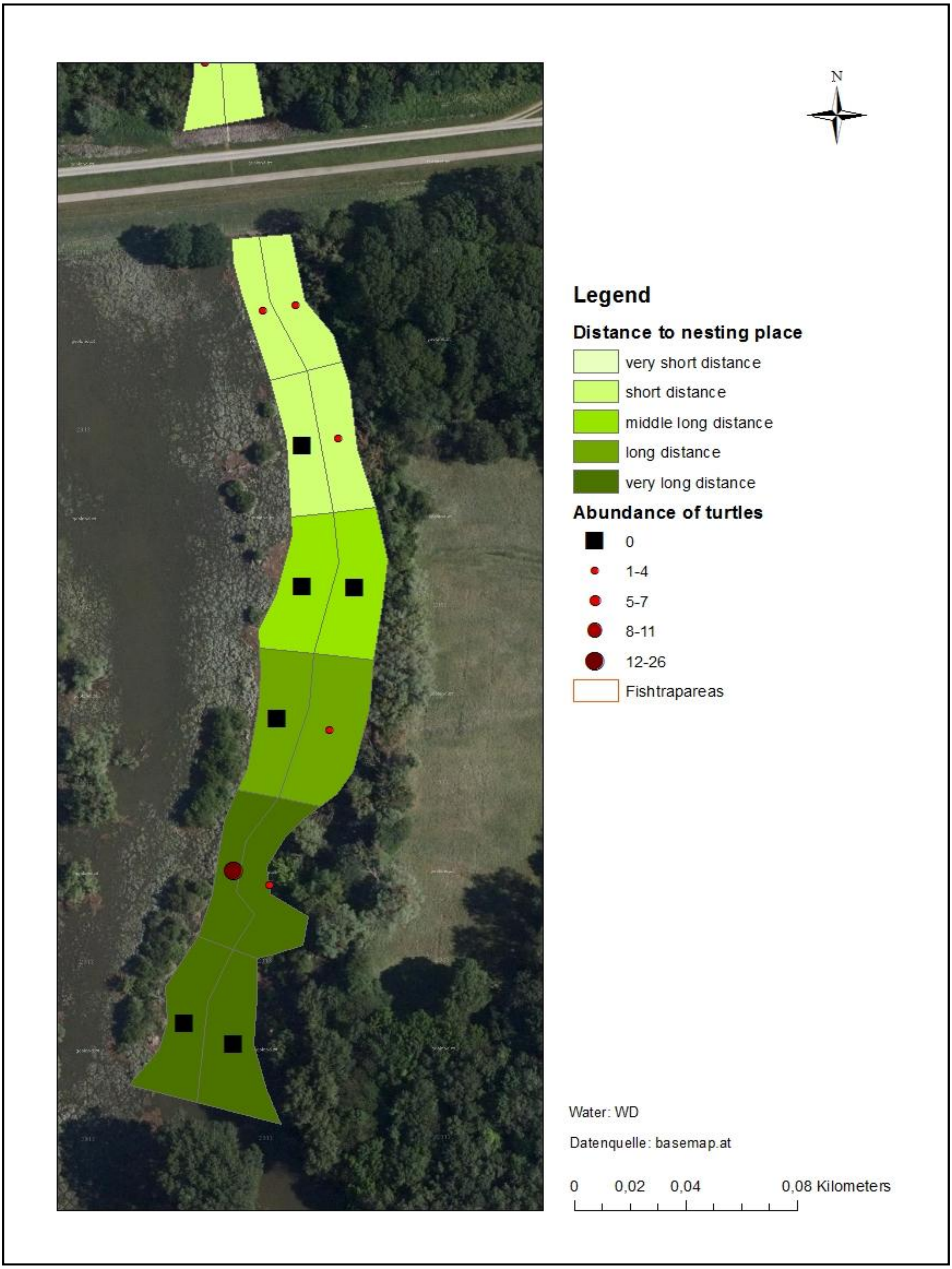


Figure 120 Heterogeneity of the parameter "Distance to nesting place" in WD (Datenquelle: basemap.at).

Figure 121 Heterogeneity of the parameter "External disturbances" in WD (Datenquelle: basemap.at).

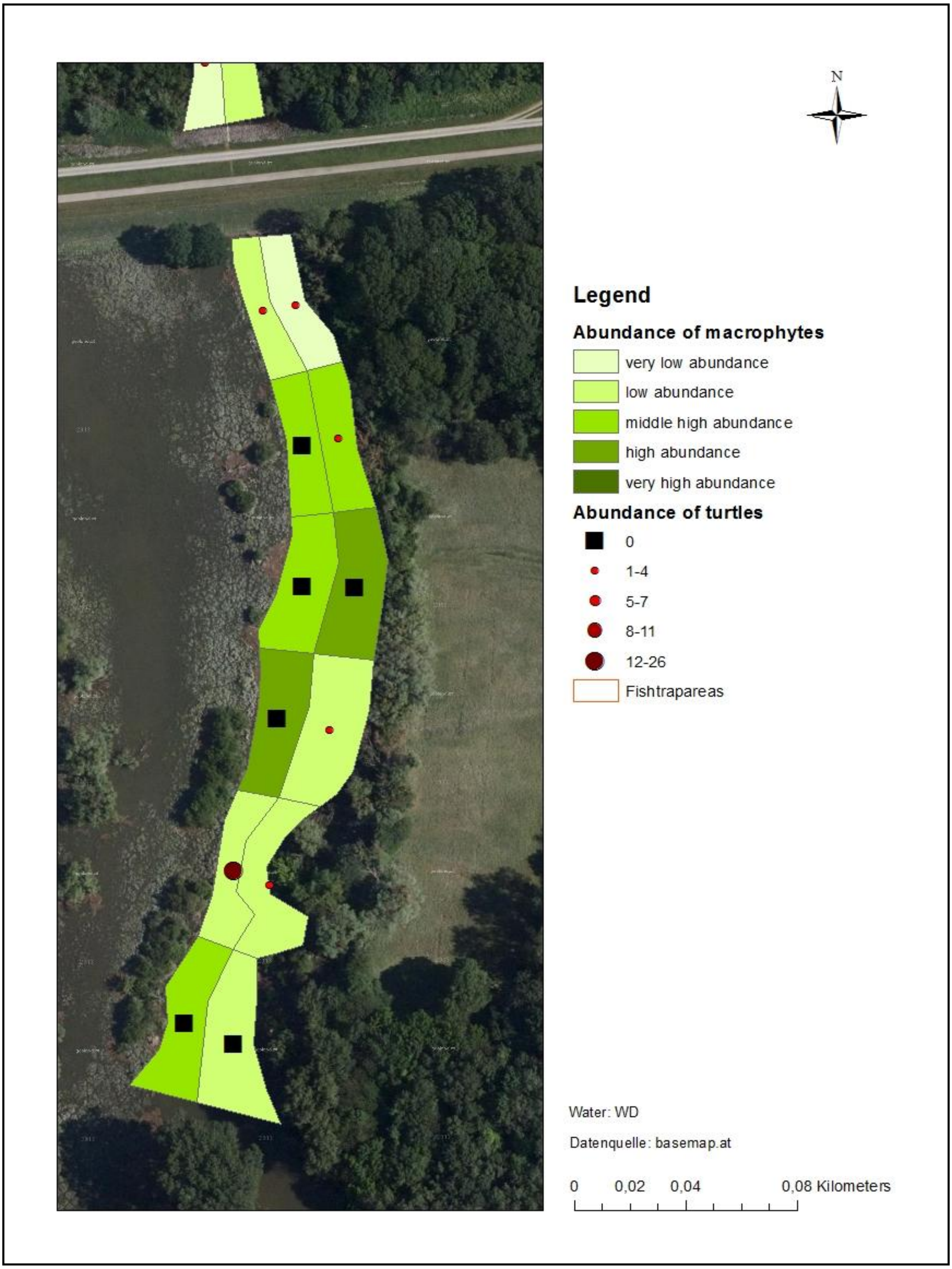


Figure 122 Heterogeneity of the parameter "Abundance of macrophytes" in WD (Datenquelle: basemap.at).

Figure 123 Heterogeneity of the parameter “Diversity of macrophytes” in WD (Datenquelle: basemap.at).

Heterogeneity of the parameters in the water WL:

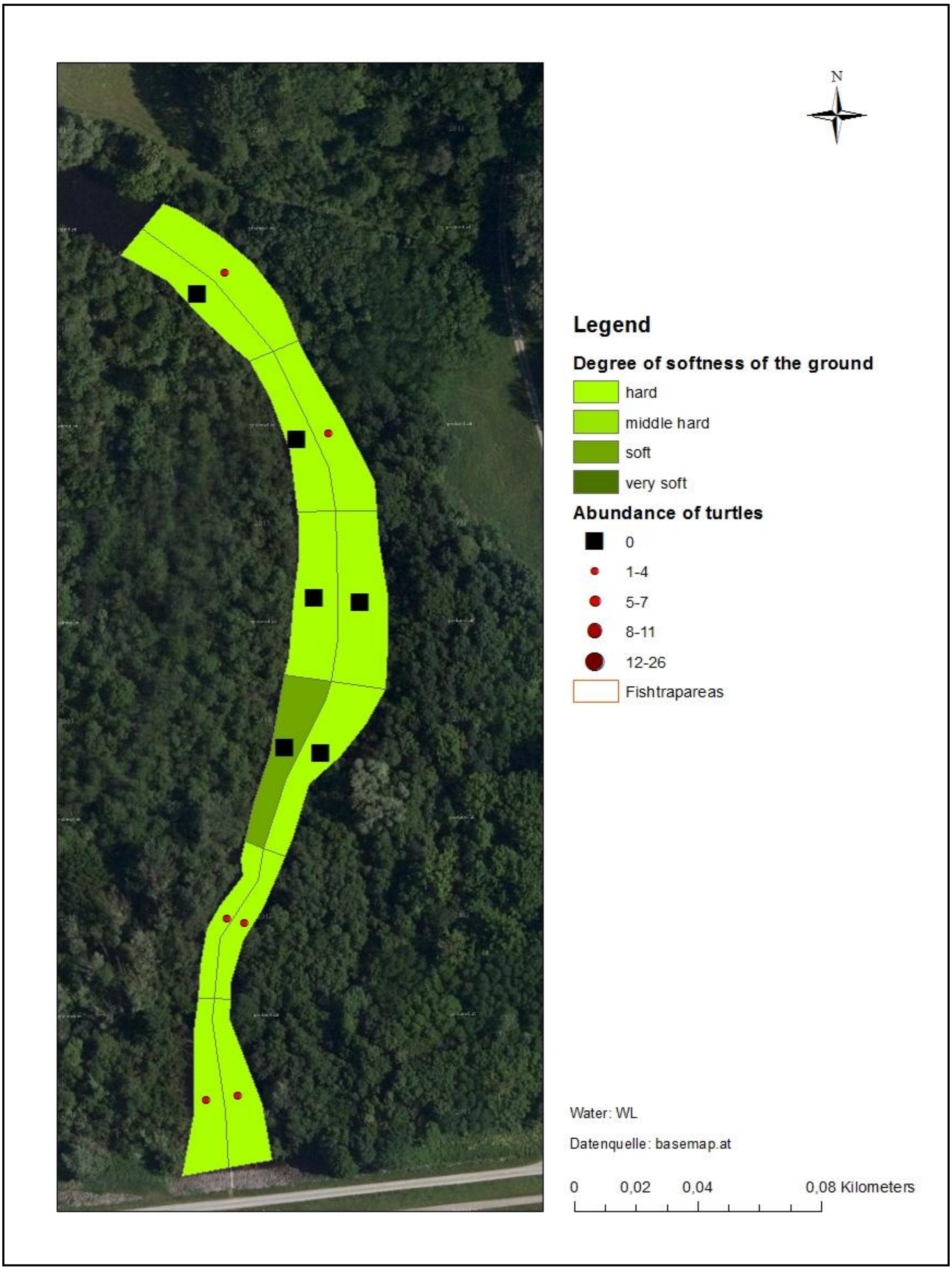


Figure 124 Heterogeneity of the parameter "Degree of softness of the ground" in WL (Datenquelle: basemap.at).

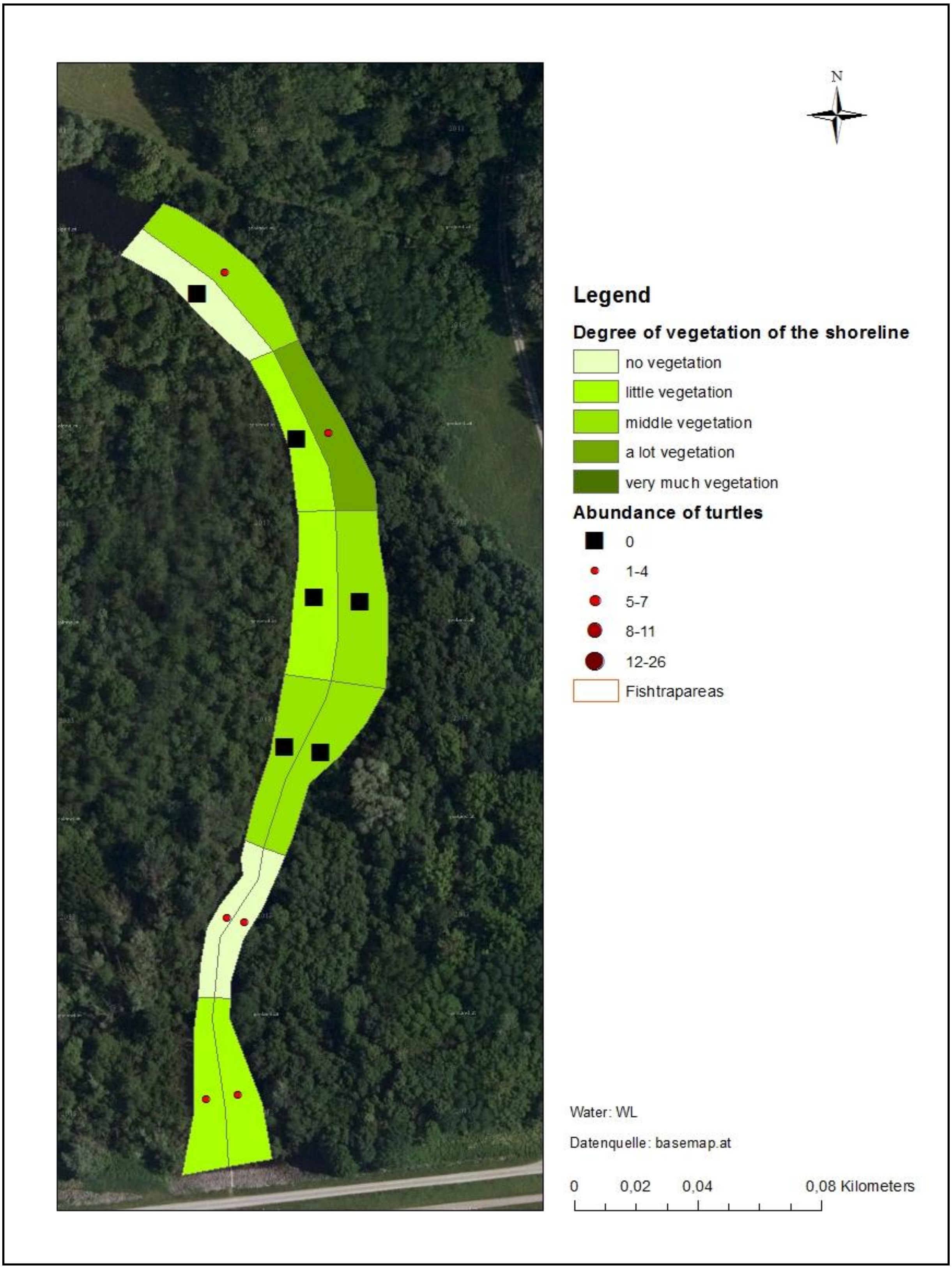


Figure 125 Heterogeneity of the parameter "Degree of vegetation of the shoreline" in WL (Datenquelle: basemap.at).

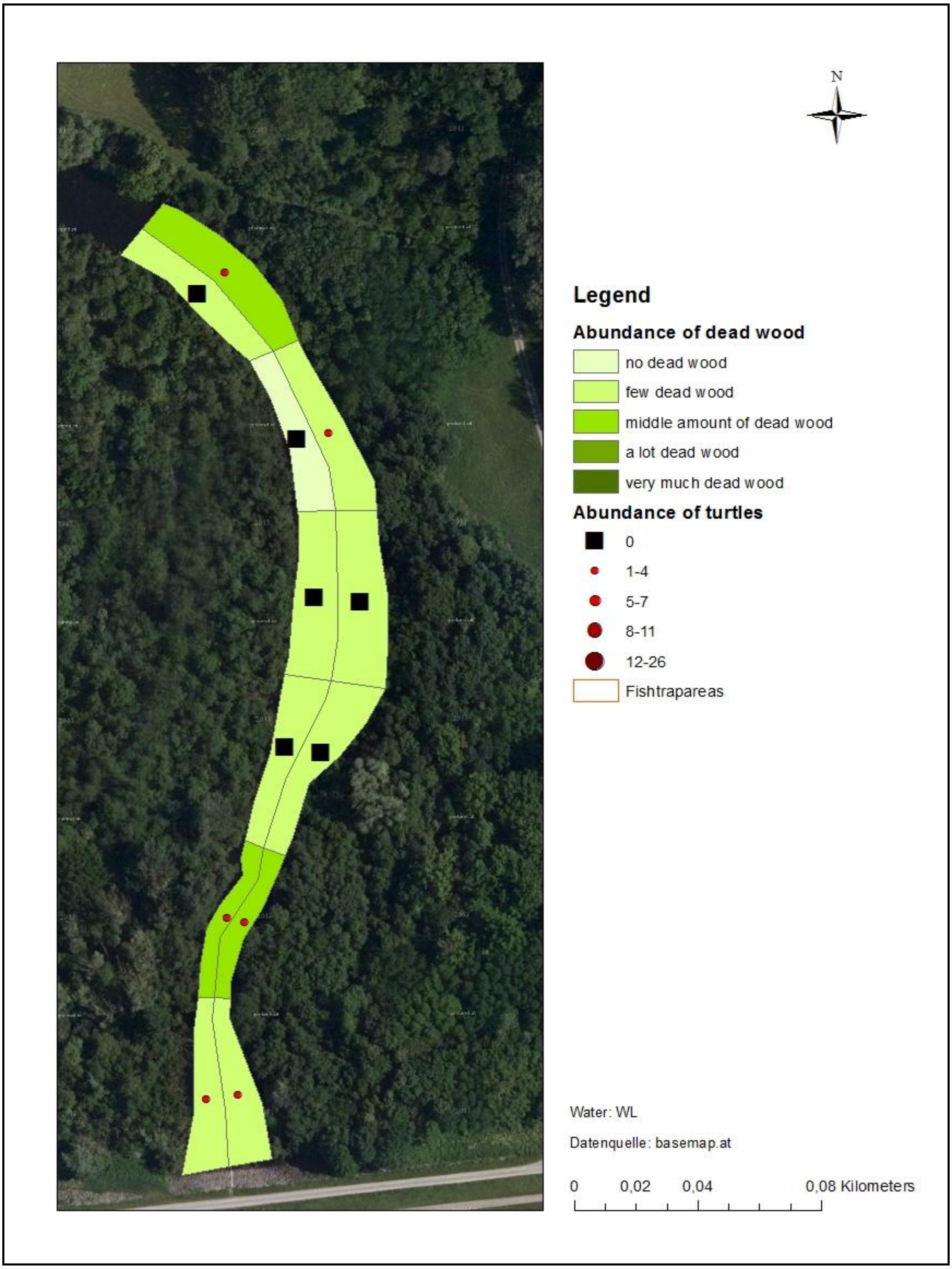


Figure 126 Heterogeneity of the parameter "Abundance of dead wood" in WL (Datenquelle: basemap.at).

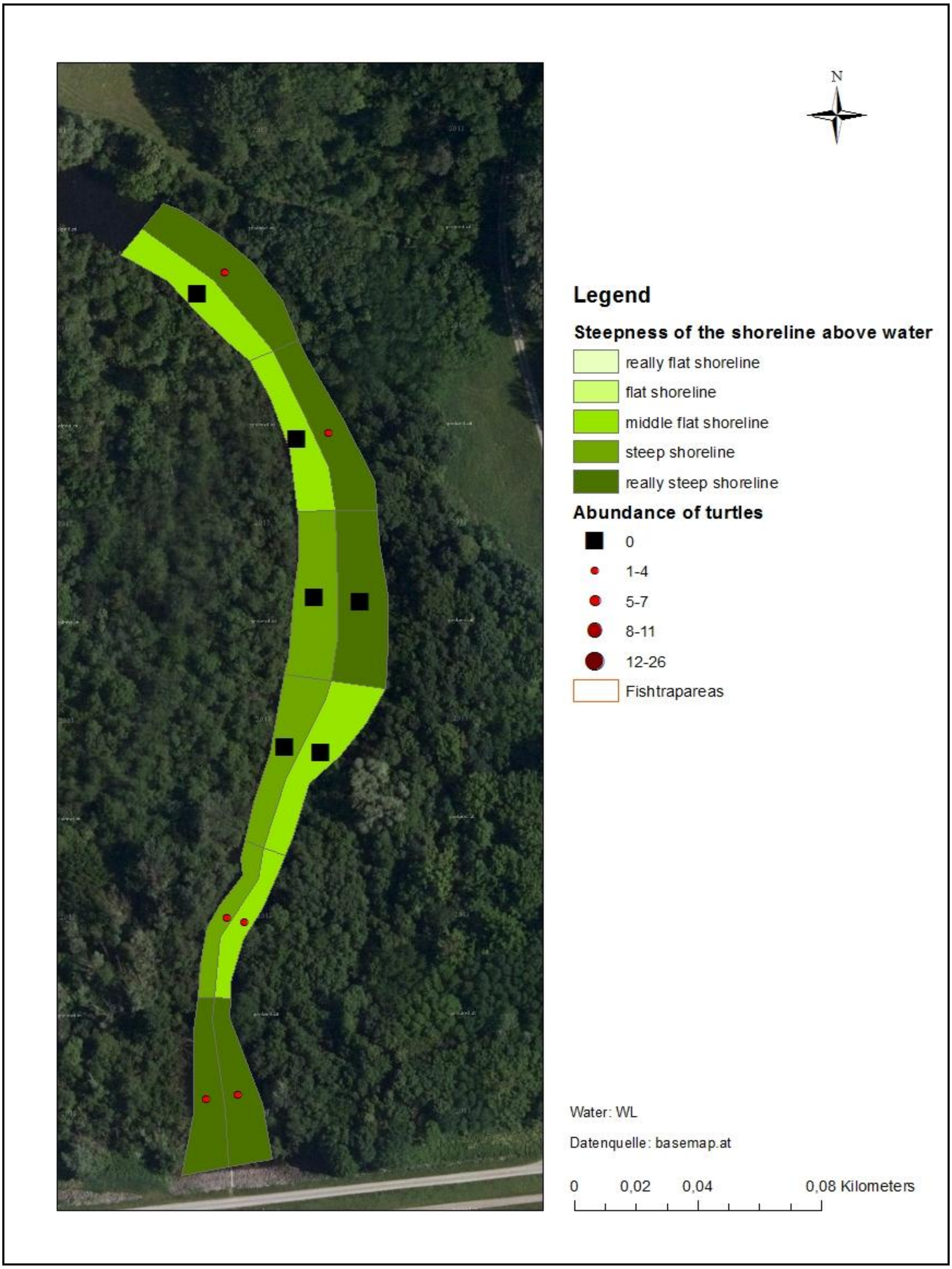


Figure 127 Heterogeneity of the parameter "Steepness of the shoreline above water" in WL (Datenquelle: basemap.at).

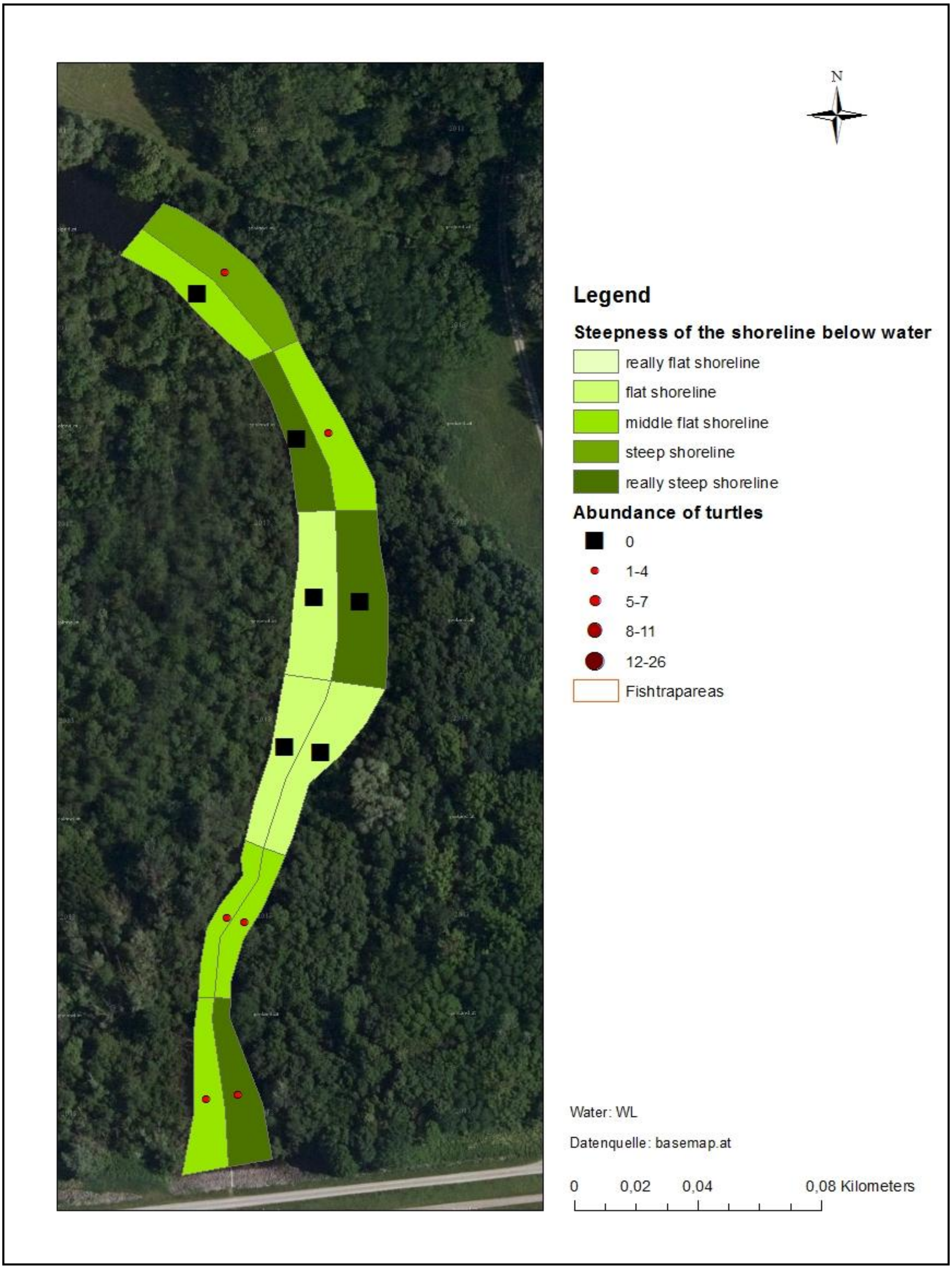


Figure 128 Heterogeneity of the parameter "Steepness of the shoreline below water" in WL (Datenquelle: basemap.at).

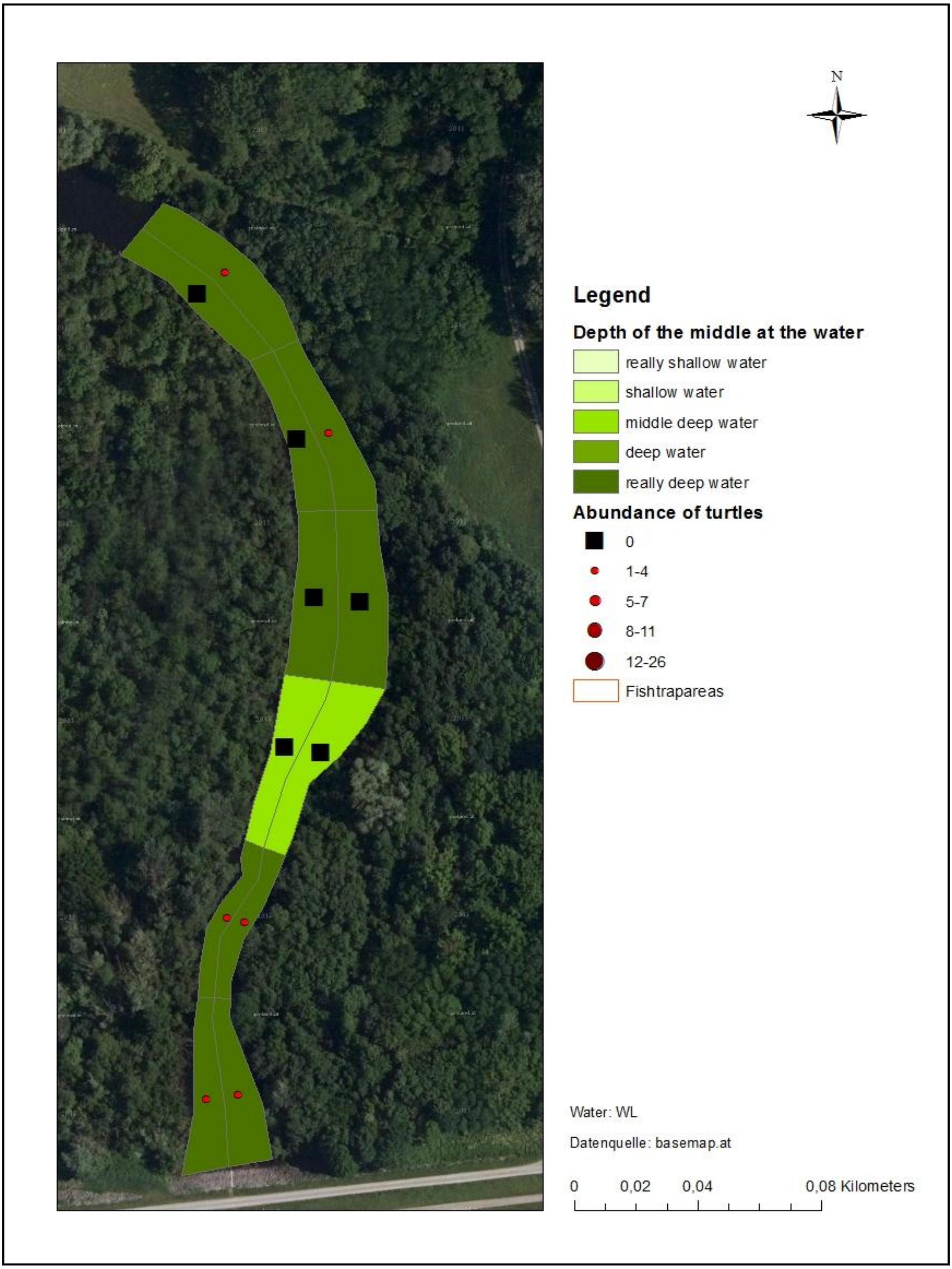


Figure 129 Heterogeneity of the parameter "Depth at the middle of the water" in WL (Datenquelle: basemap.at).

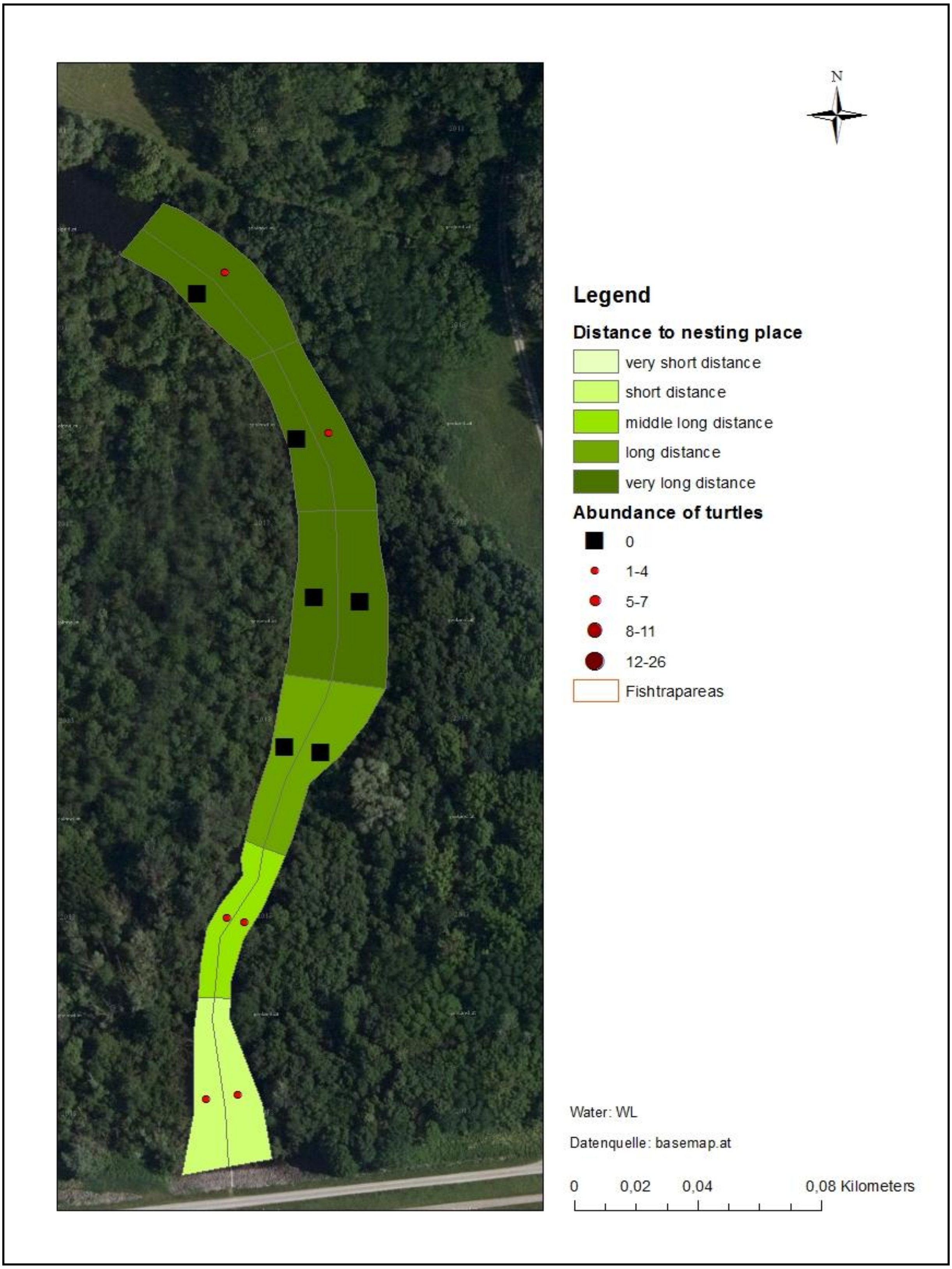


Figure 130 Heterogeneity of the parameter "Distance to nesting place" in WL (Datenquelle: basemap.at).

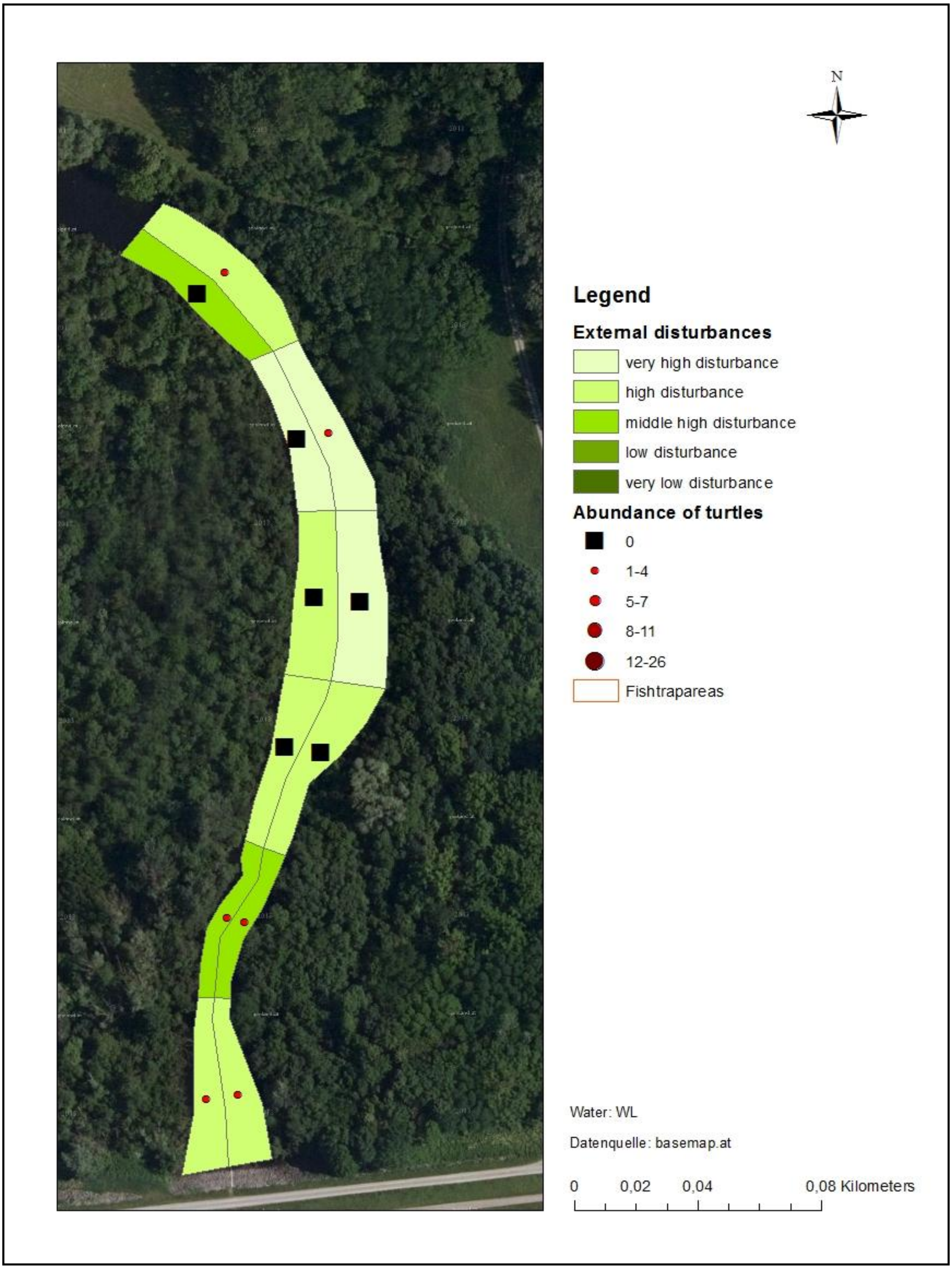


Figure 131 Heterogeneity of the parameter "External disturbances" in WL (Datenquelle: basemap.at).

Figure 132 Heterogeneity of the parameter "Abundance of macrophytes" in WL (Datenquelle: basemap.at).

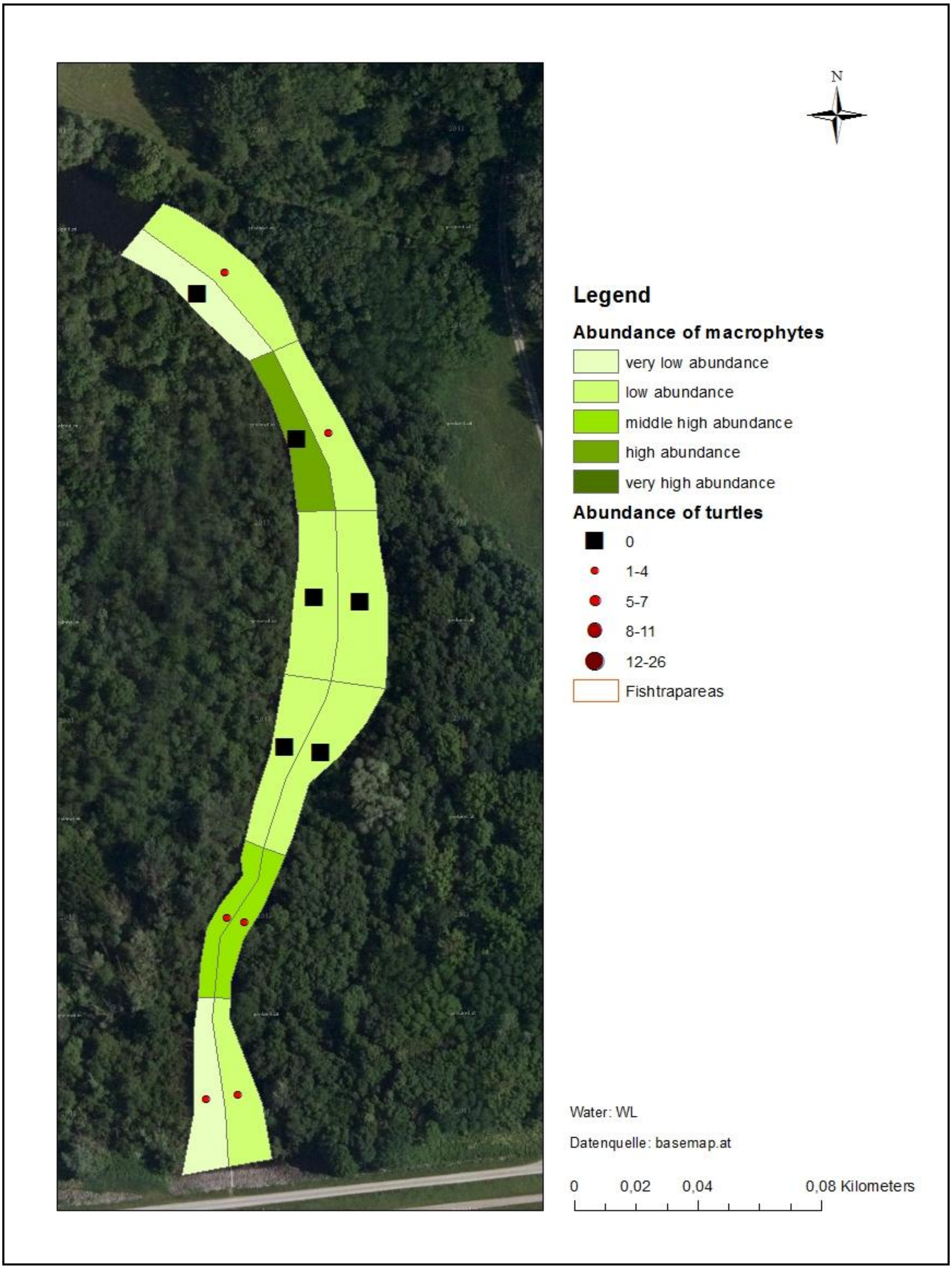


Figure 132 Heterogeneity of the parameter "Abundance of macrophytes" in WL (Datenquelle: basemap.at).

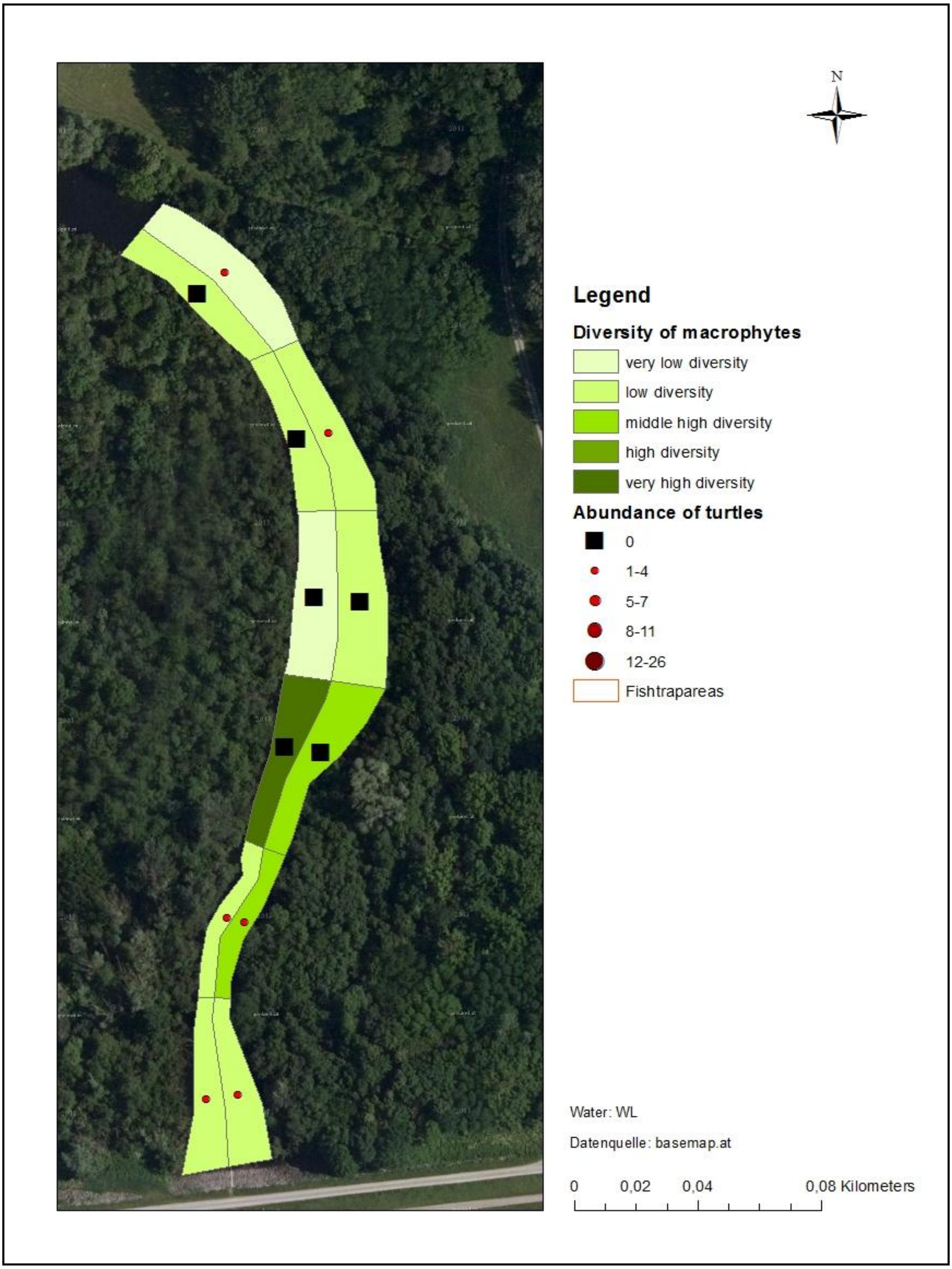


Figure 133 Heterogeneity of the parameter "Diversity of macrophytes" in WL (Datenquelle: basemap.at).

In the following the parameters which were measured for the whole waters are illustrated. Therefore, the abundances of the whole studied water are used.

Heterogeneity between the waters in the temperature:

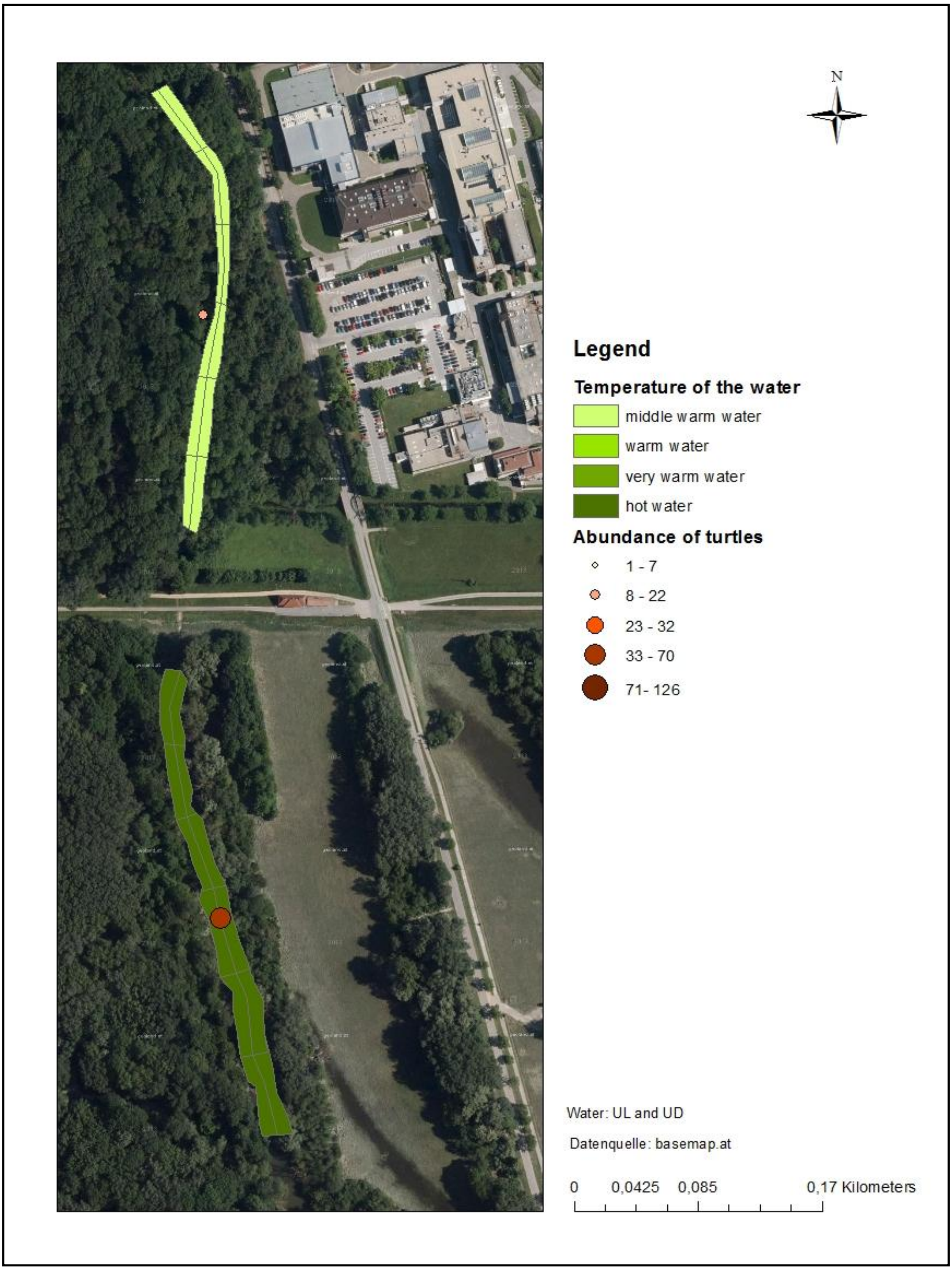


Figure 134 Temperature of the waters UL and UD (Datenquelle: basemap.at).

Figure 135 Temperature of the waters OL and OD (Datenquelle: basemap.at).

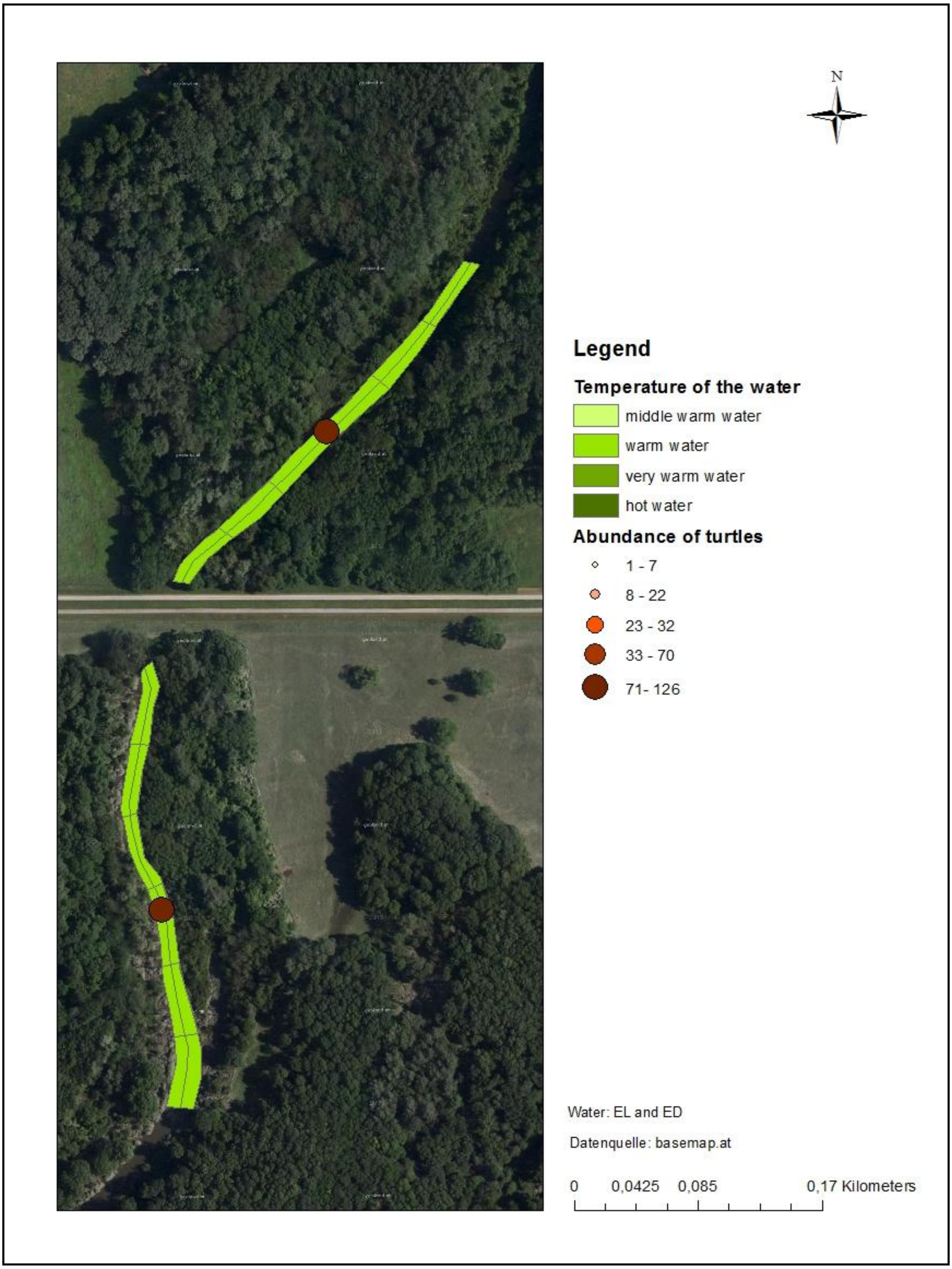


Figure 136 Temperature of the waters EL and ED (Datenquelle: basemap.at).

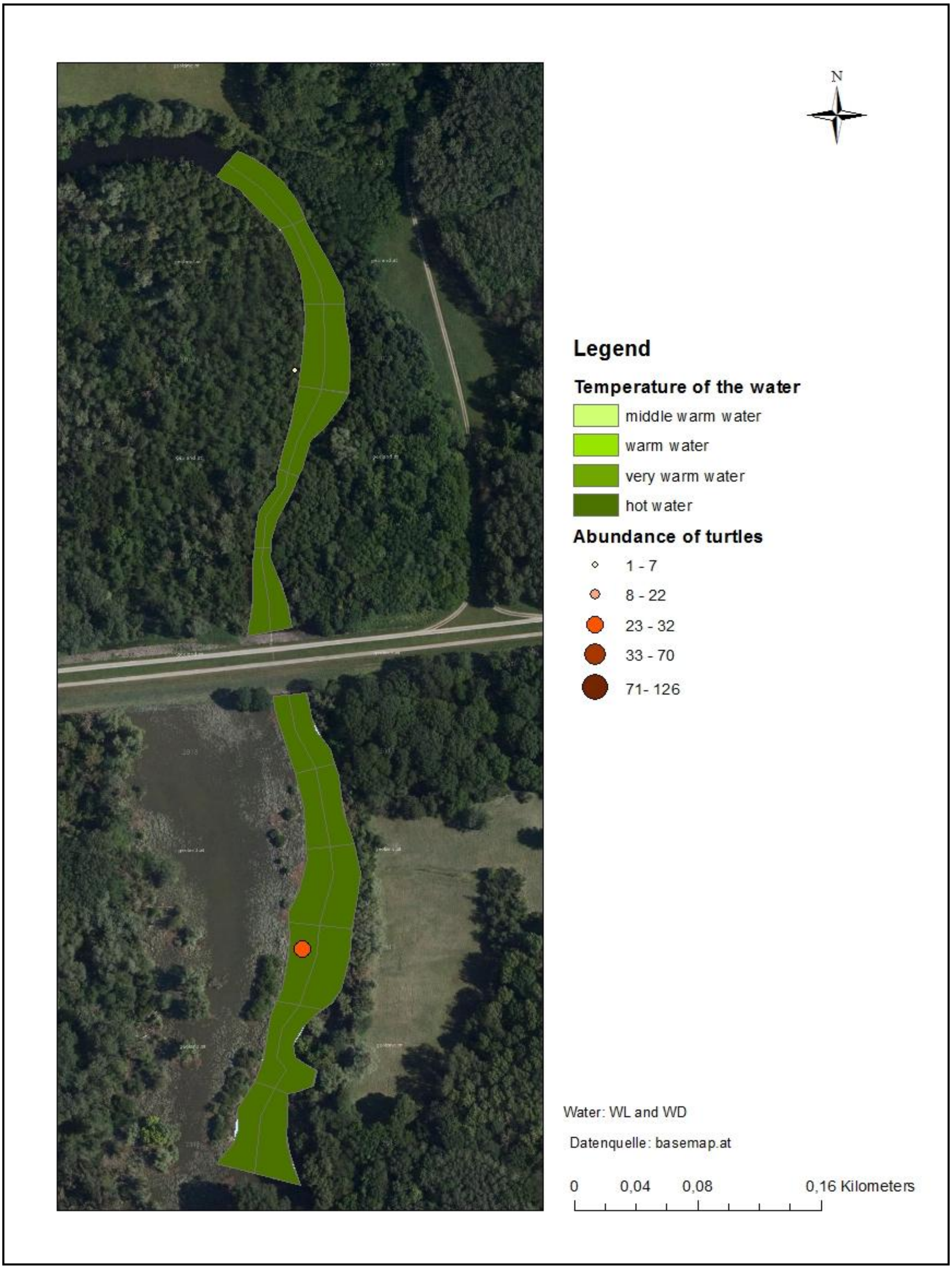


Figure 137 Temperature of the waters WL and WD (Datenquelle: basemap.at).

Heterogeneity between the waters in the pH-value:

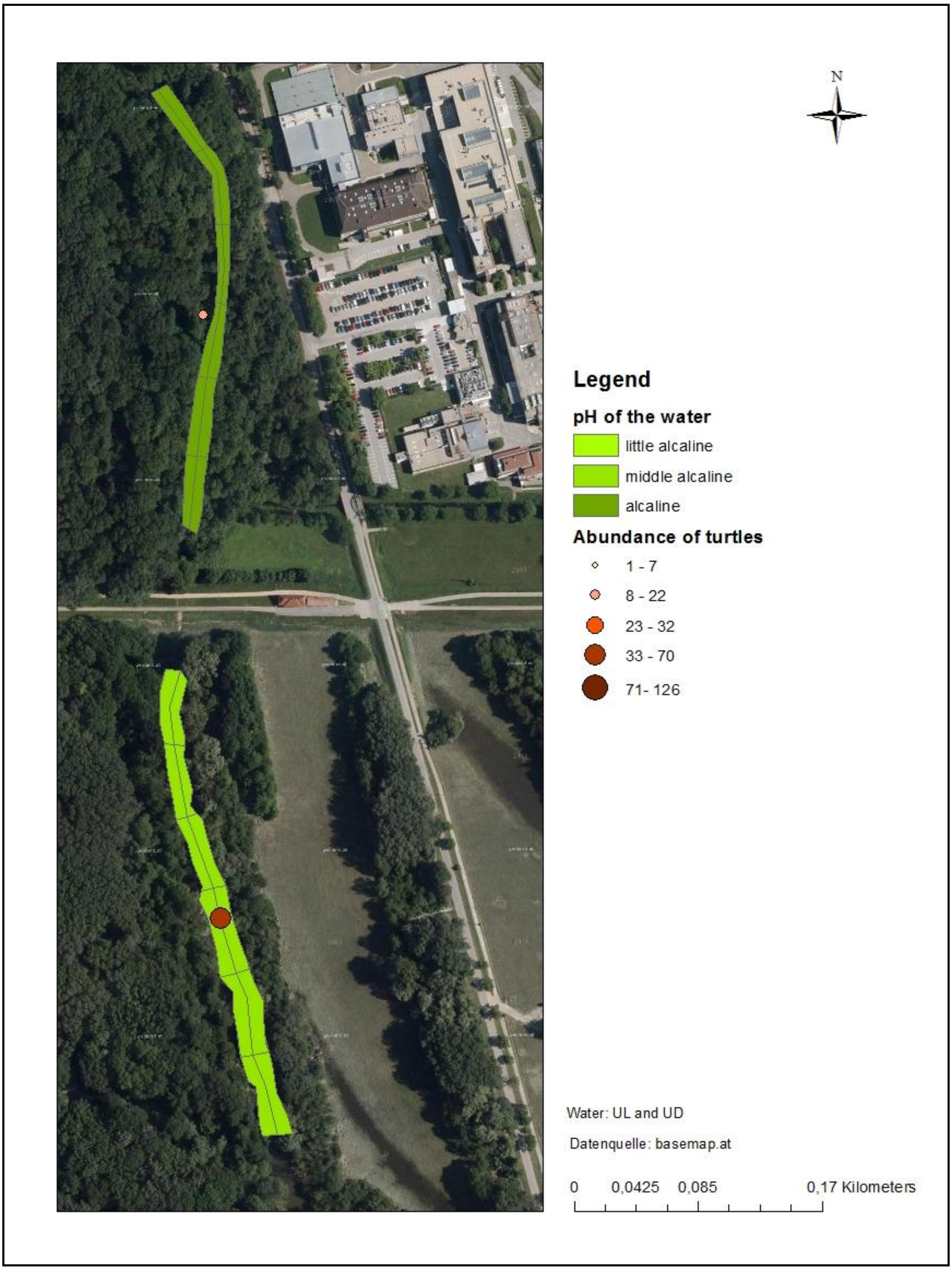


Figure 138 pH-value of the waters UL and UD (Datenquelle: basemap.at).

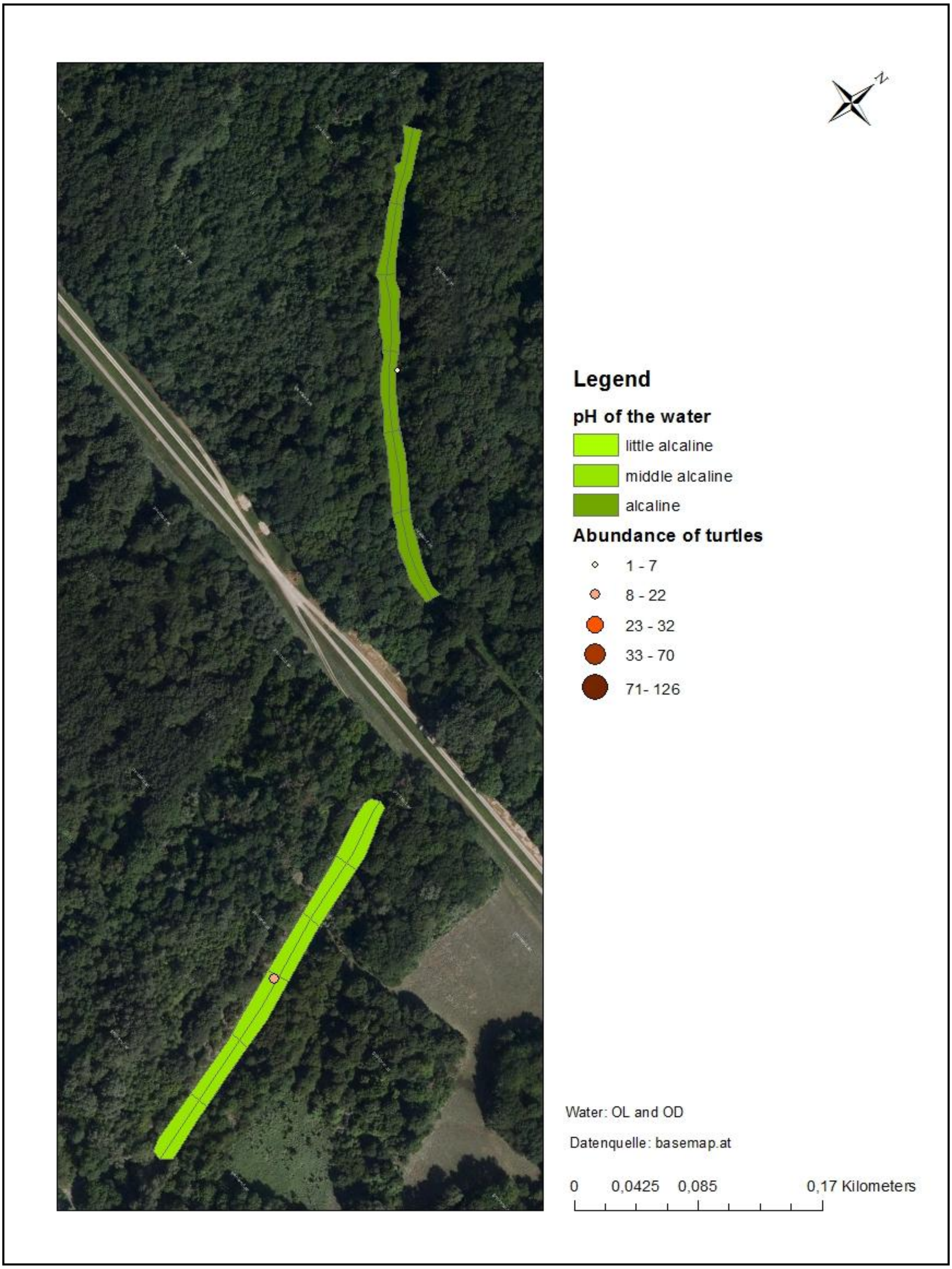


Figure 139 pH-value of the waters OL and OD (Datenquelle: basemap.at).

Figure 140 pH-value of the waters EL and ED (Datenquelle: basemap.at).

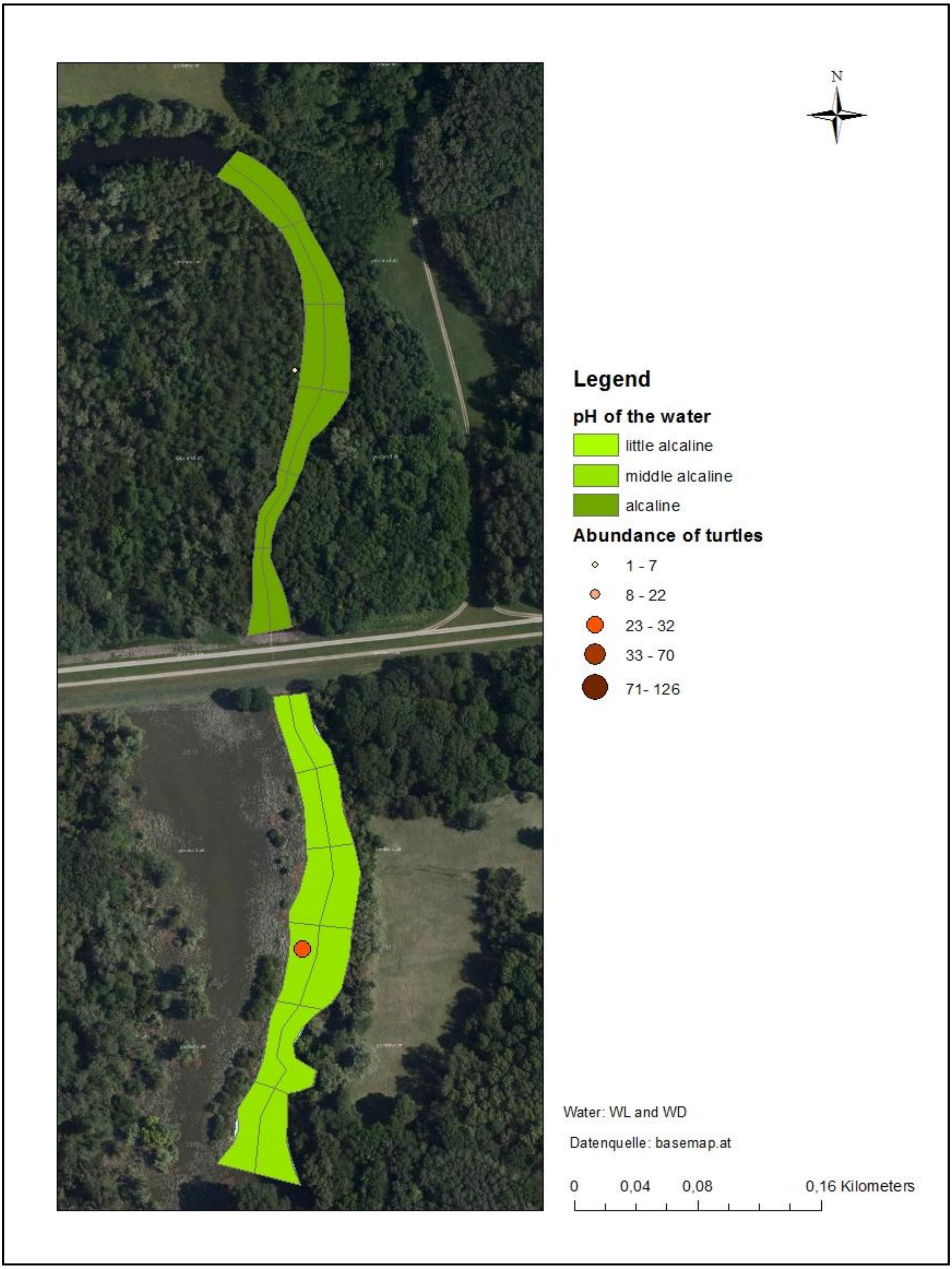


Figure 141 pH-value of the waters WL and WD (Datenquelle: basemap.at).

Heterogeneity between the waters in the amount of nutrition (macrozoo-benthos):

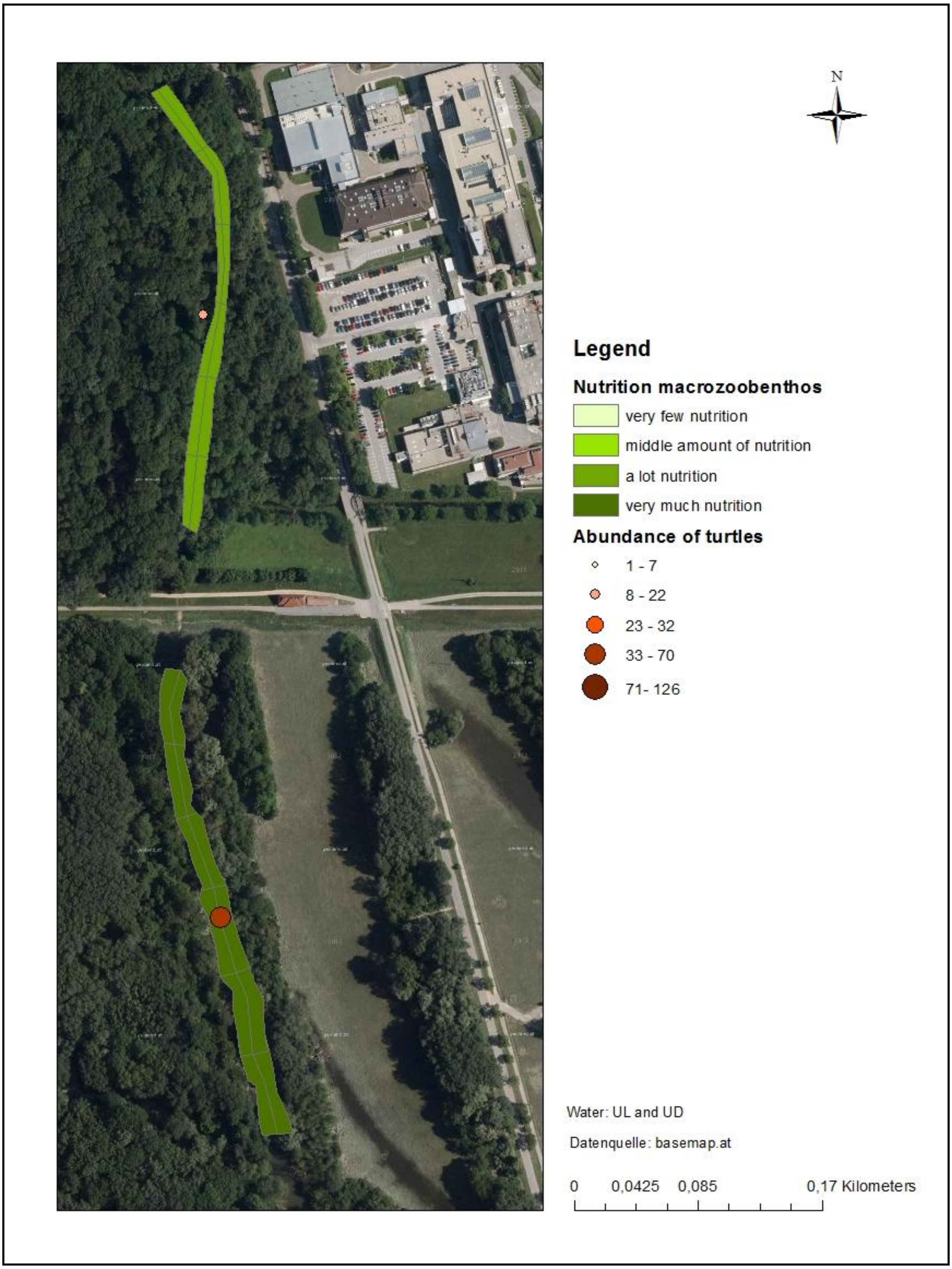


Figure 142 Amount of nutrition of the waters UL and UD (Datenquelle: basemap.at).

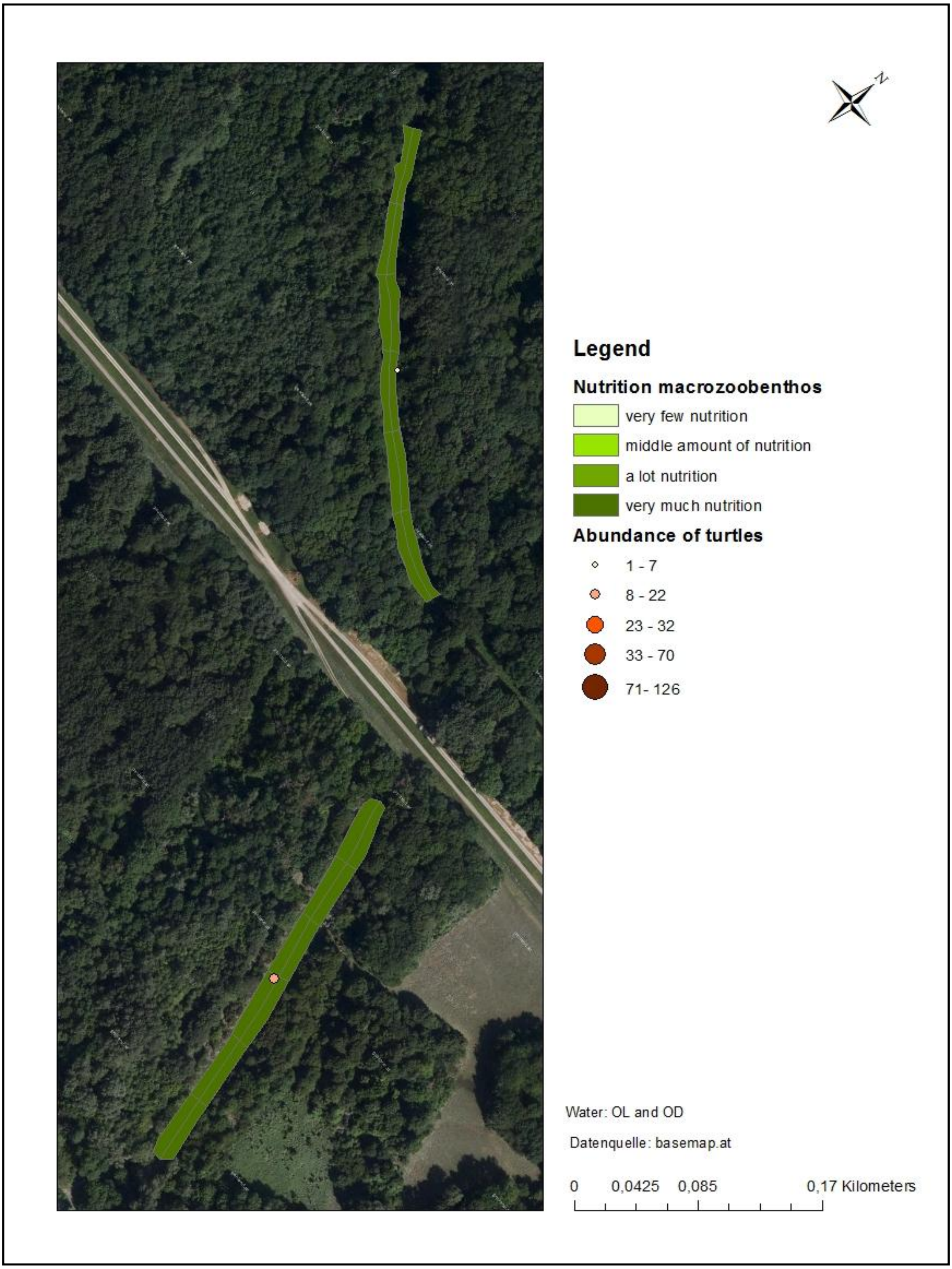


Figure 143 Amount of nutrition of the waters OL and OD (Datenquelle: basemap.at).

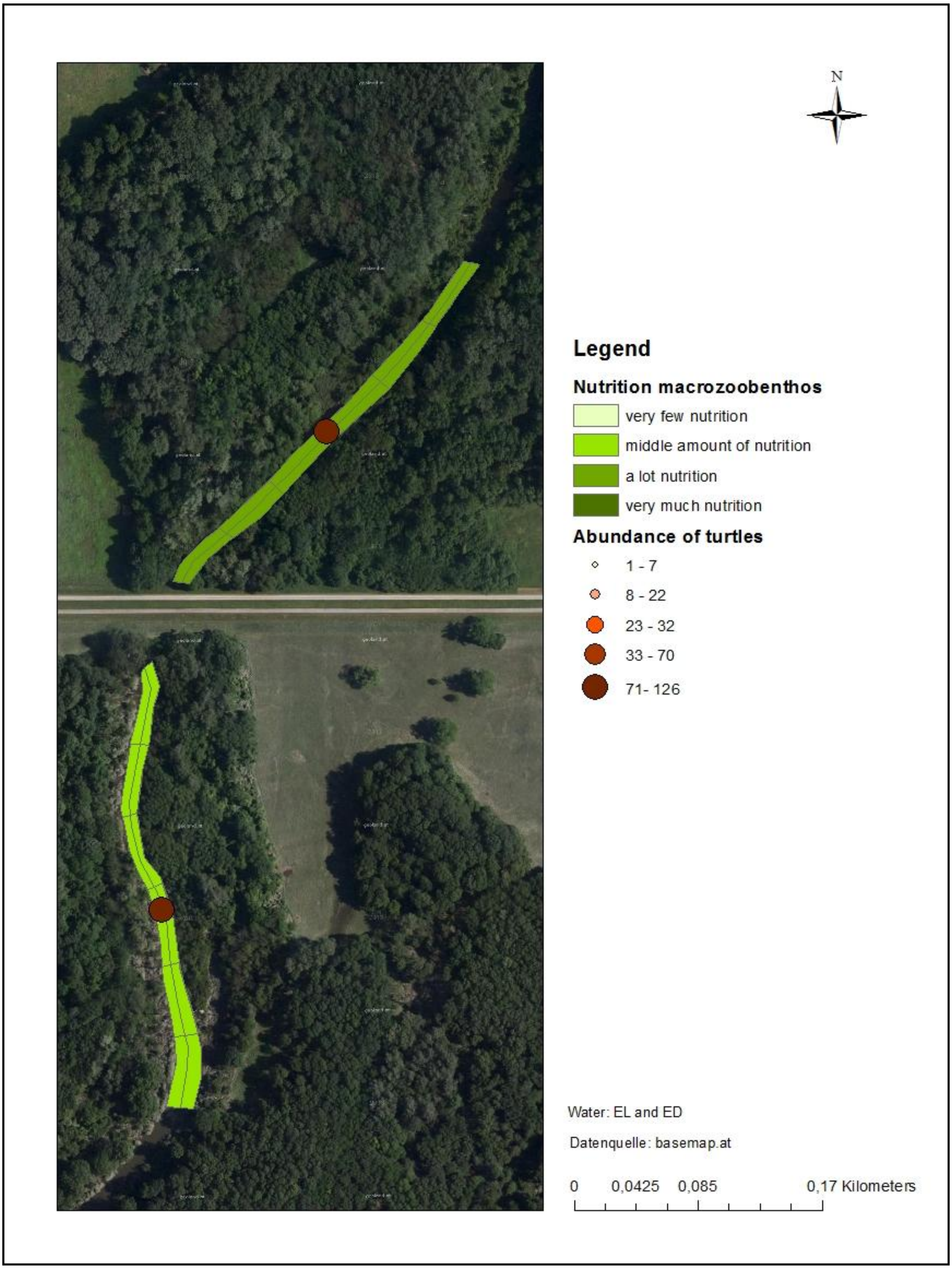


Figure 144 Amount of nutrition of the waters EL and ED (Datenquelle: basemap.at).

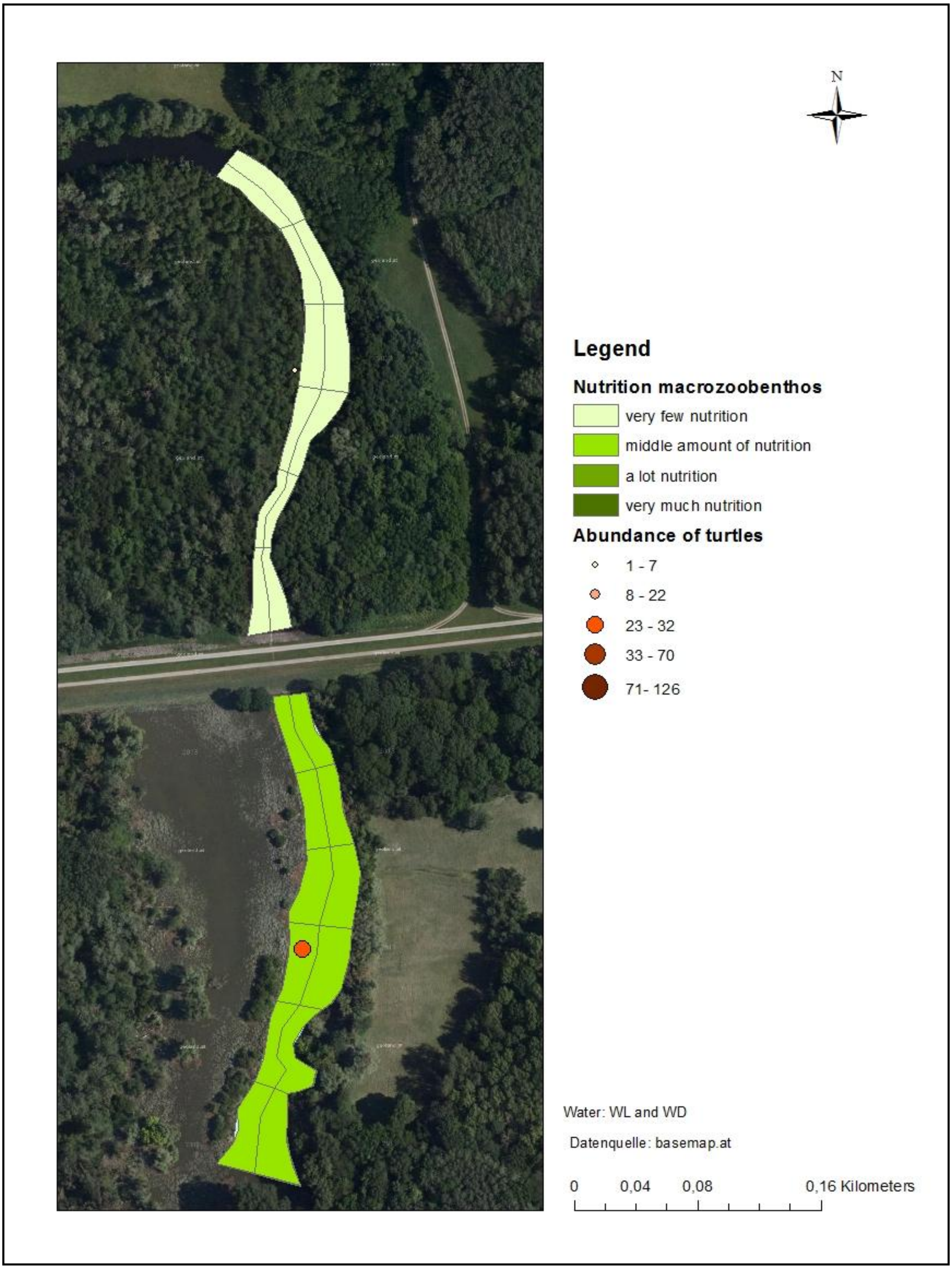


Figure 145 Amount of nutrition of the waters WL and WD (Datenquelle: basemap.at).

Appendix VII Habitat preferences of females, males and juveniles

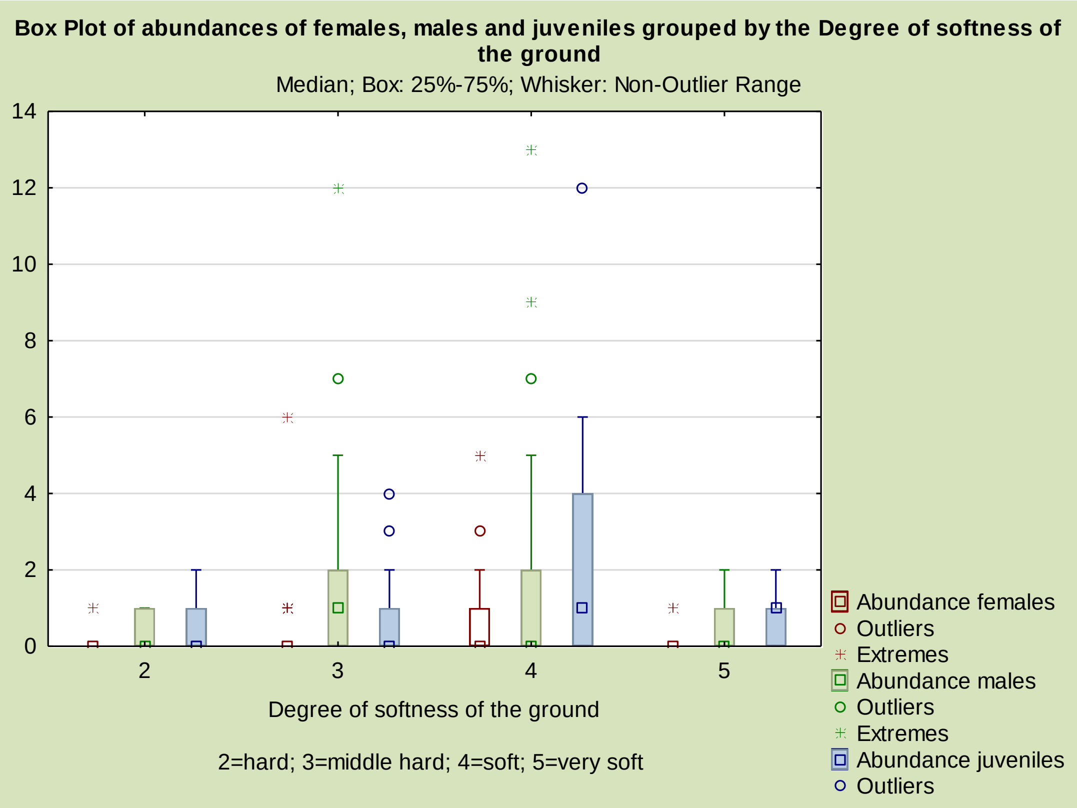


Figure 146 Box plot of abundances of females, males and juveniles grouped by the degree of softness of the ground.

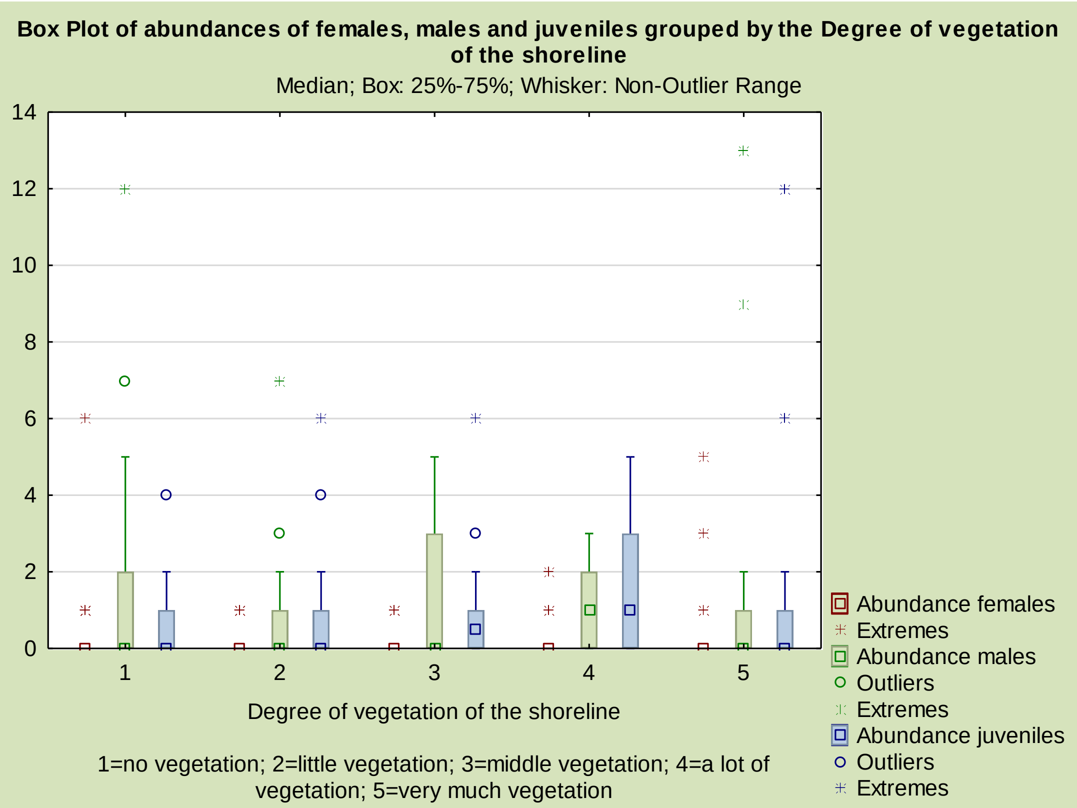


Figure 147 Box plot of abundances of females, males and juveniles grouped by the degree of vegetation of the shoreline.

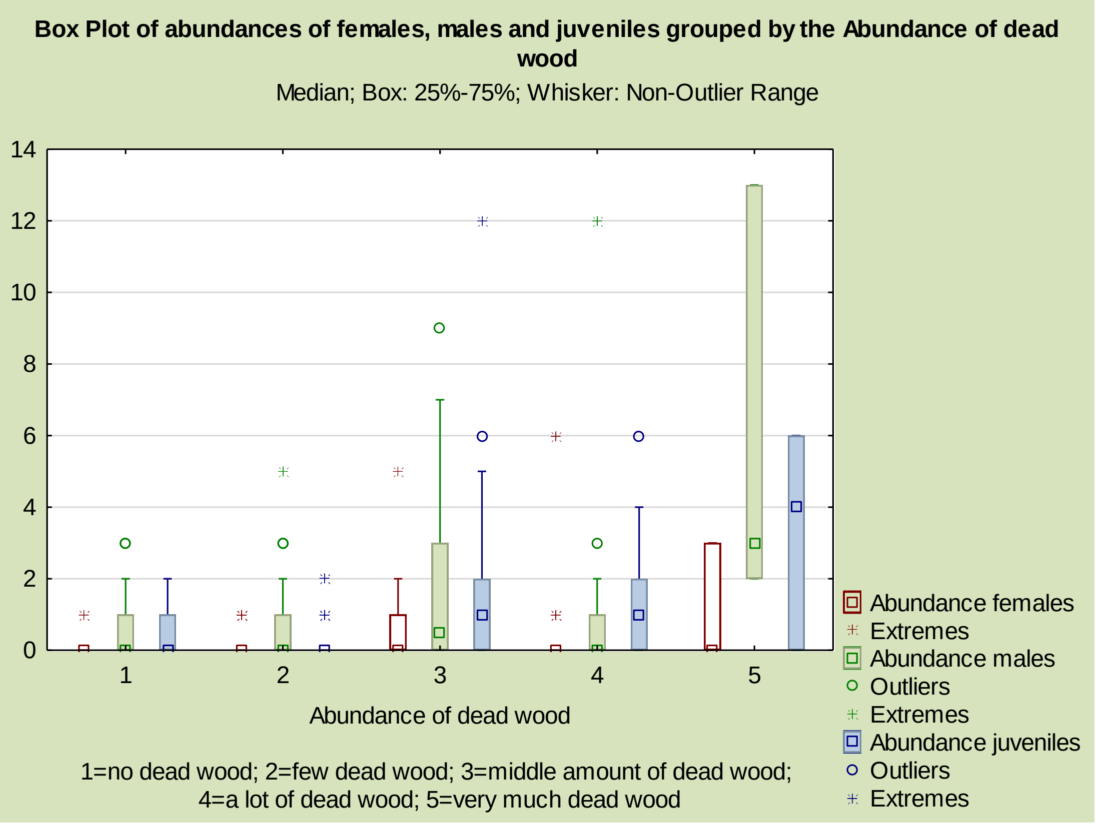


Figure 148 Box plot of the abundances of females, males and juveniles grouped by the abundance of dead wood.

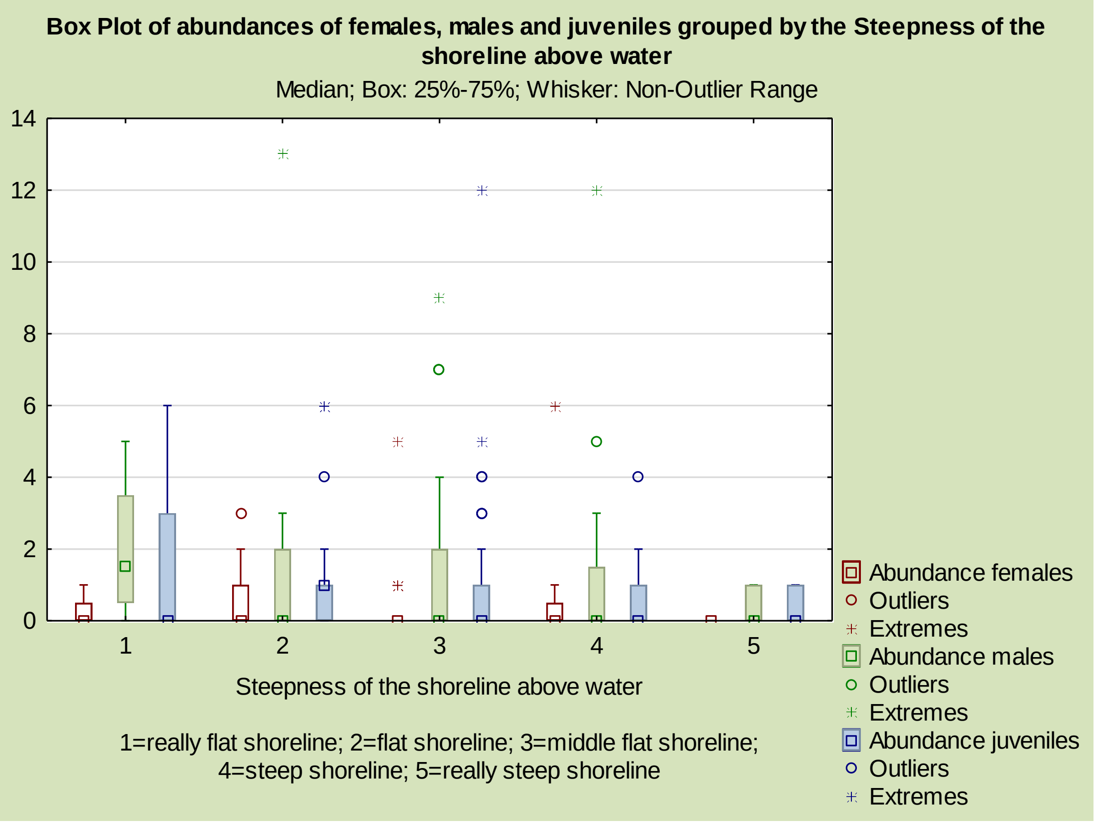


Figure 149 Box plot of the abundances of females, males and juveniles grouped by the steepness of the shoreline above water.

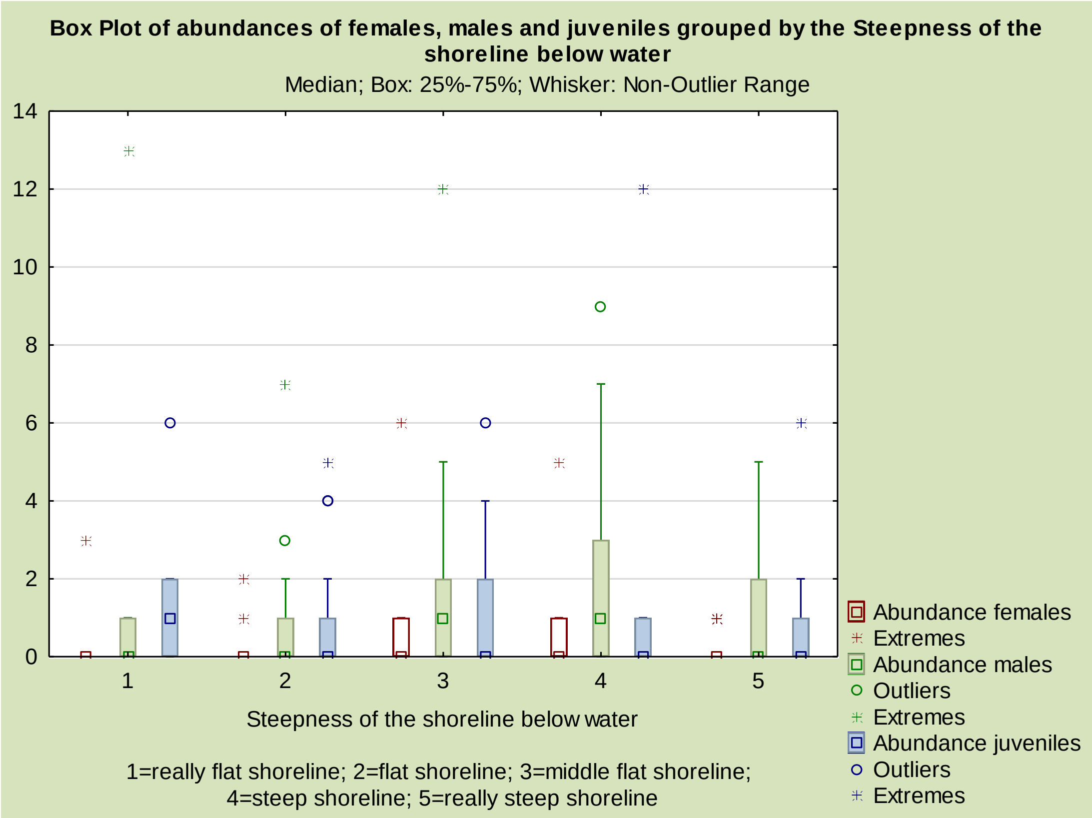


Figure 150 Box plot of the abundances of females, males and juveniles grouped by the steepness of the shoreline below water.

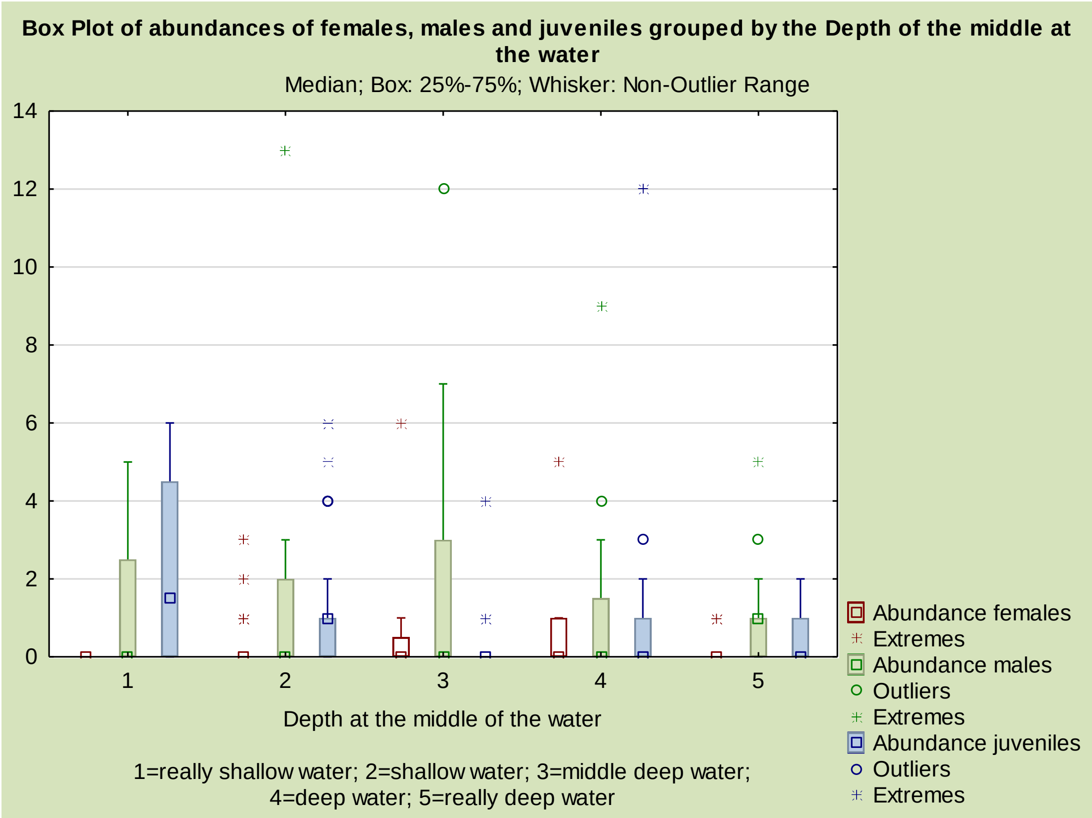


Figure 151 Box plot of the abundances of females, males and juveniles grouped by the depth at the middle of the water.

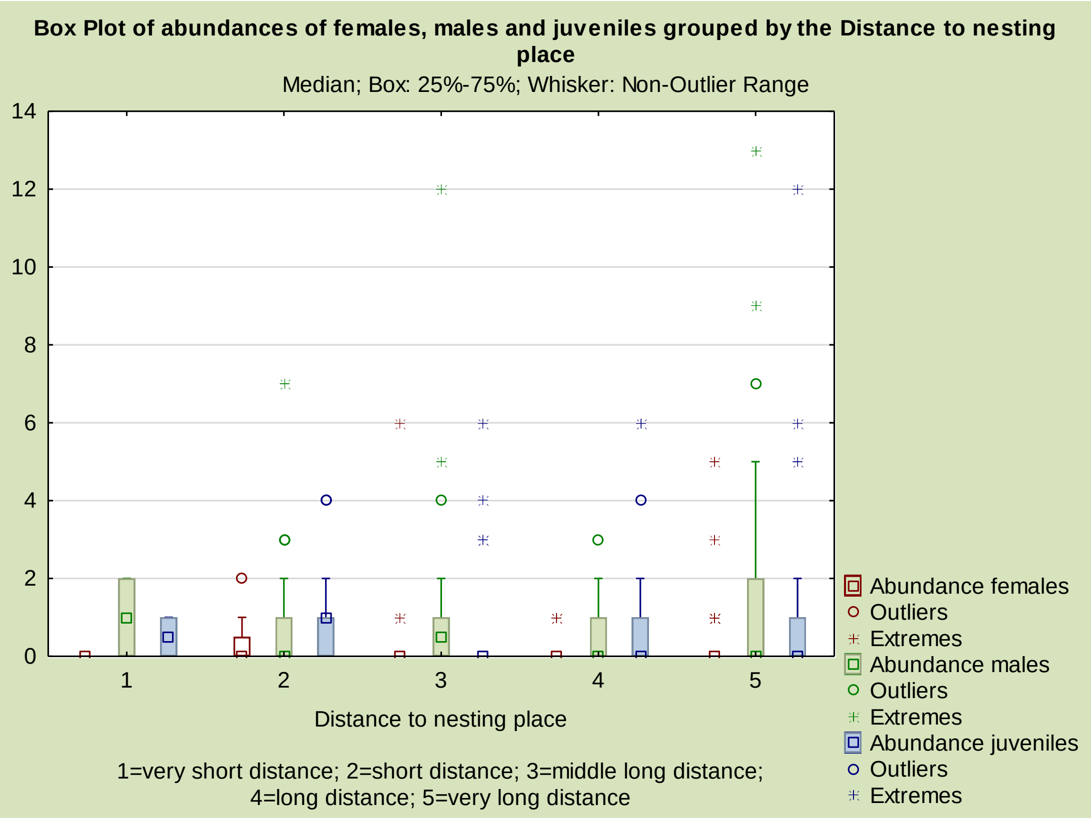


Figure 152 Box plot of the abundances of females, males and juveniles grouped by the distance to nesting place.

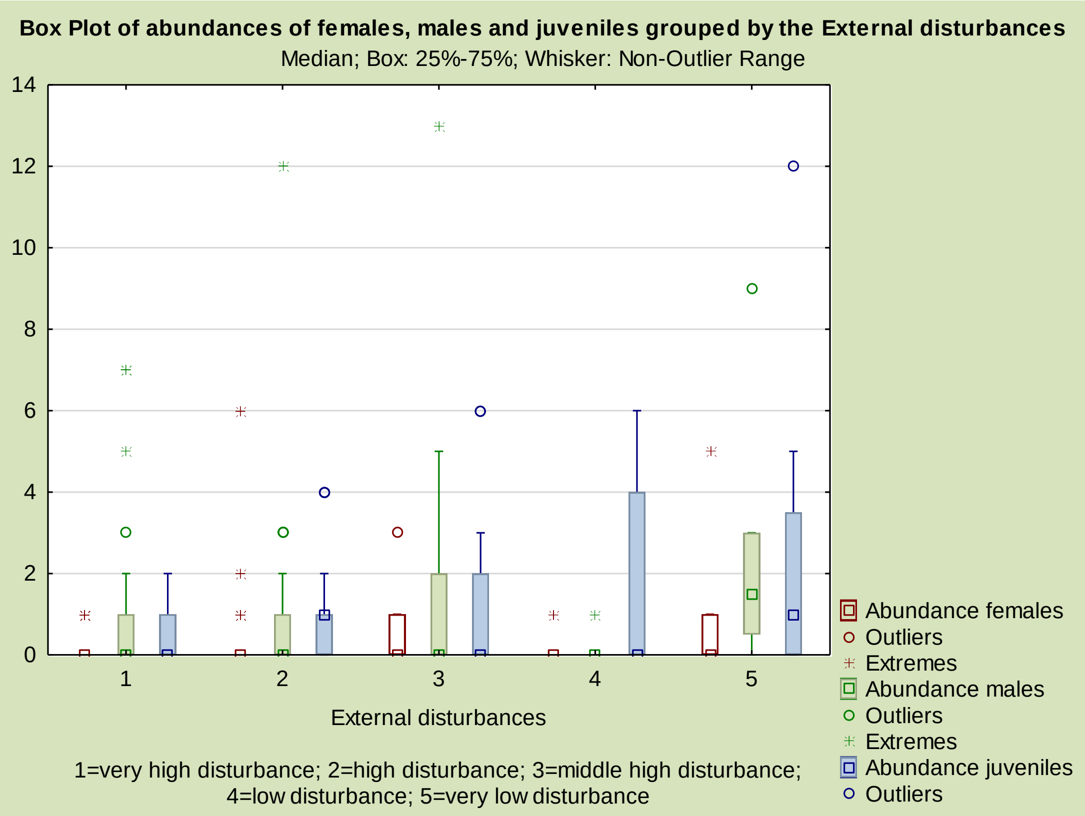


Figure 153 Box plot of the abundances of females, males and juveniles grouped by the External disturbances.

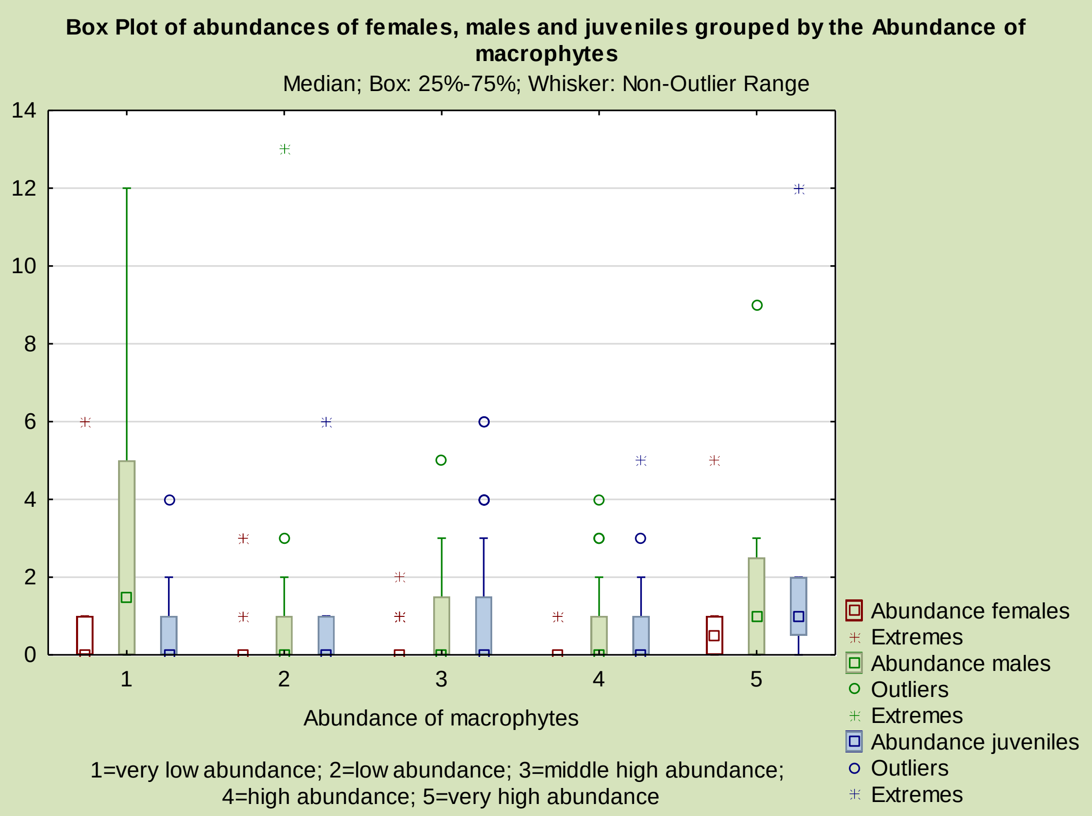


Figure 154 Box plot of the abundances of females, males and juveniles grouped by the abundance of macrophytes.

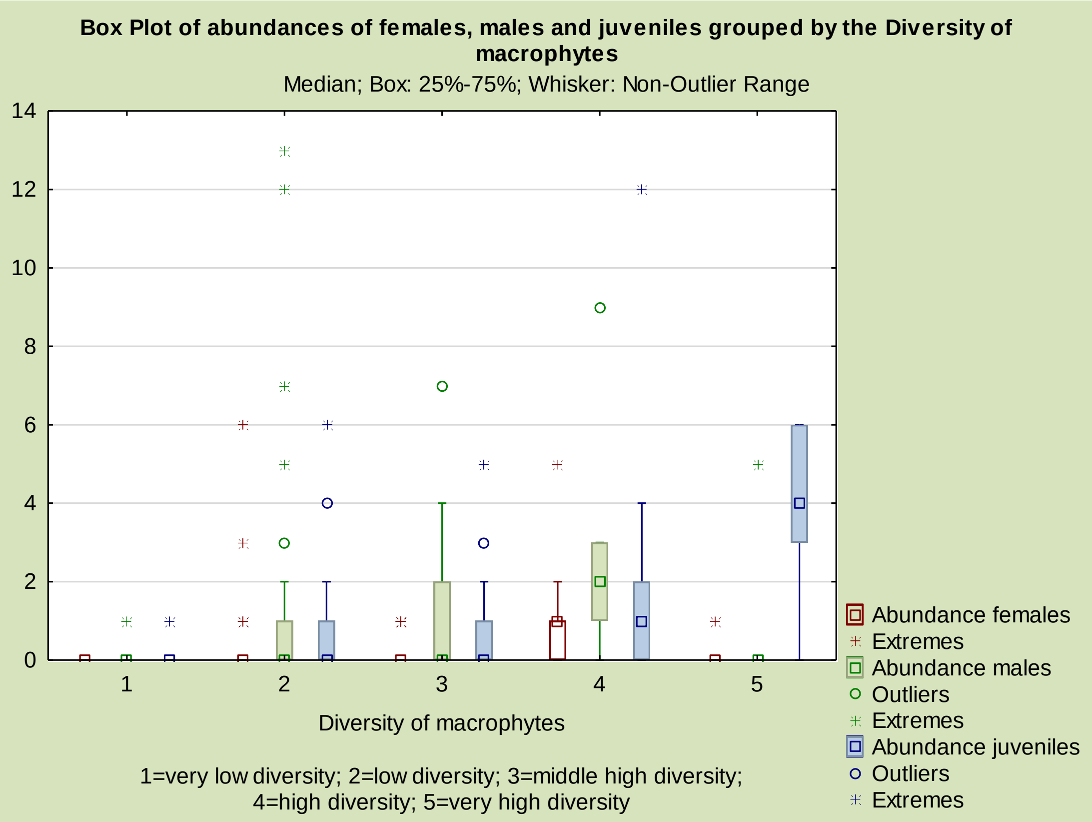


Figure 155 Box plot of the abundances of females, males and juveniles grouped by the diversity of macrophytes.

The following features were measured for the total waters and not for the single fish trap sections. Therefore, they show the abundances of the single waters. However, the abundances are the measured abundances (recaptures excluded) and not the calculated.

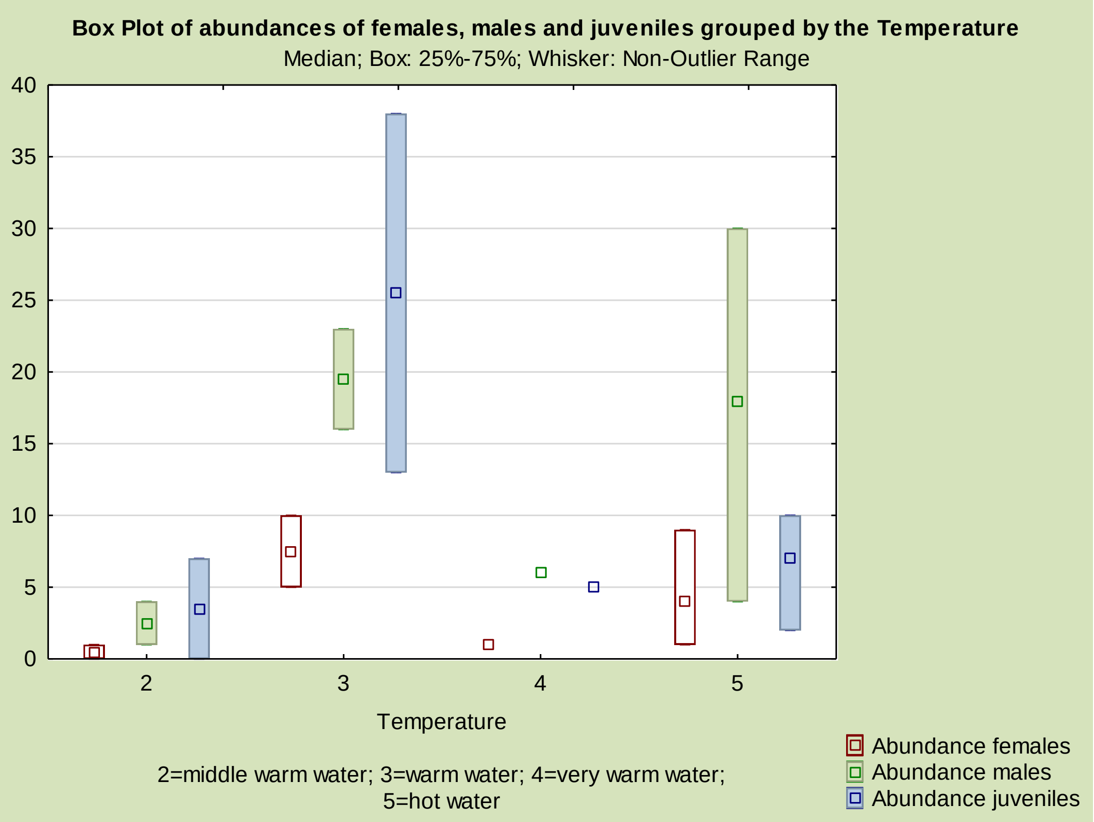


Figure 156 Box plot of the abundances of females, males and juveniles grouped by the temperature.

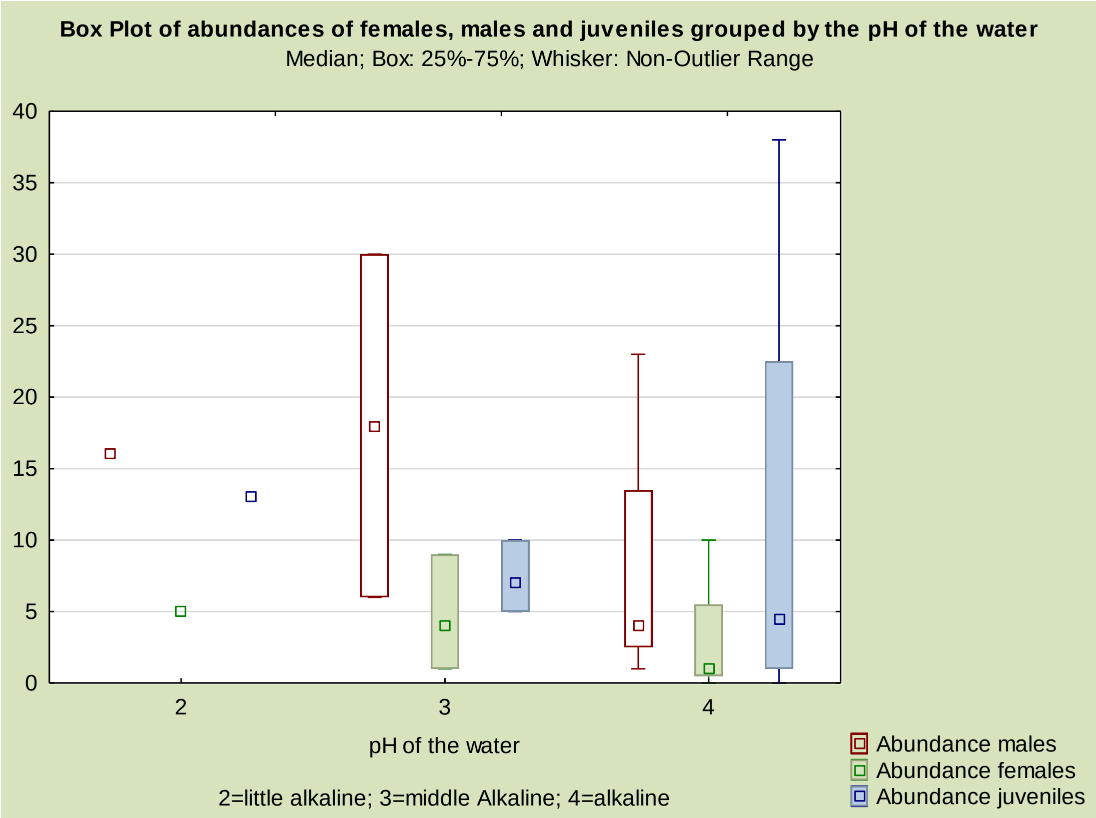


Figure 157 Box plot of the abundances of females, males and juveniles grouped by the pH-value of the water.

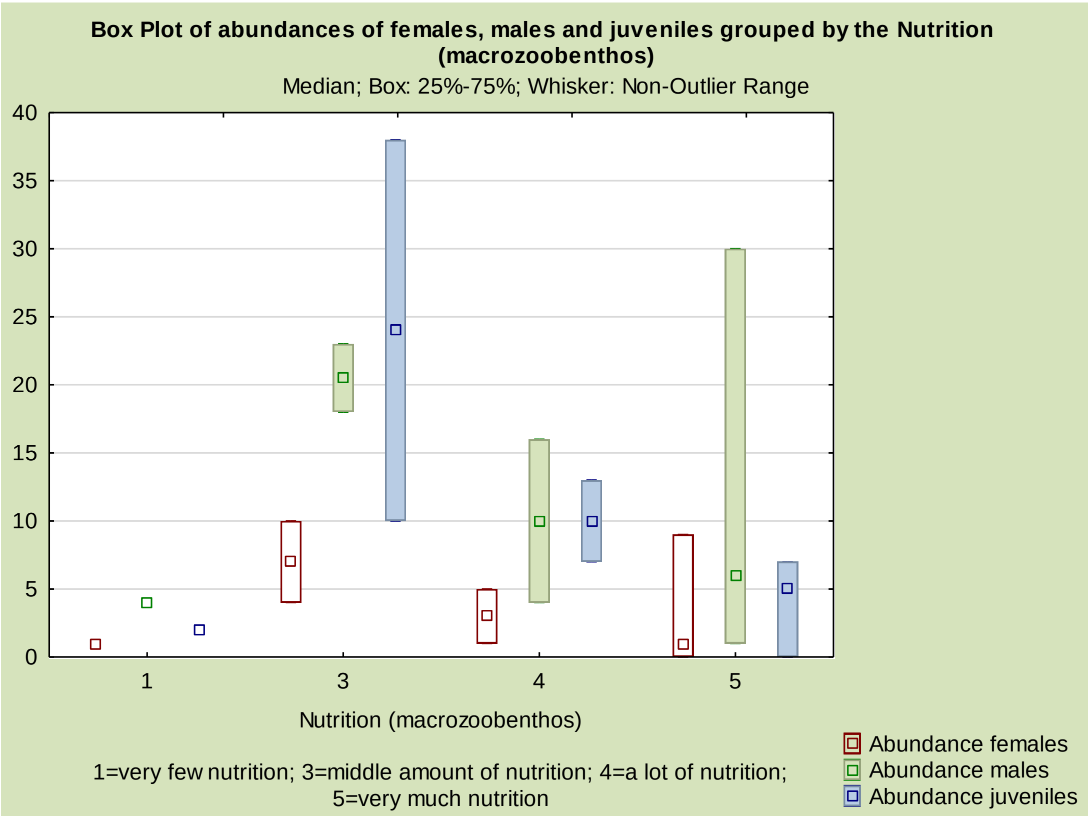


Figure 158 Box plot of the abundances of females, males and juveniles grouped by the nutrition (macrozoobenthos).

The tendency that males are smaller than females is also illustrated in Figure 159 and Figure 160. This tendency is found in several other studies (inter alia Auer, Taskavak 2004; Mosimann 2002b; Rovero et al. 1999).

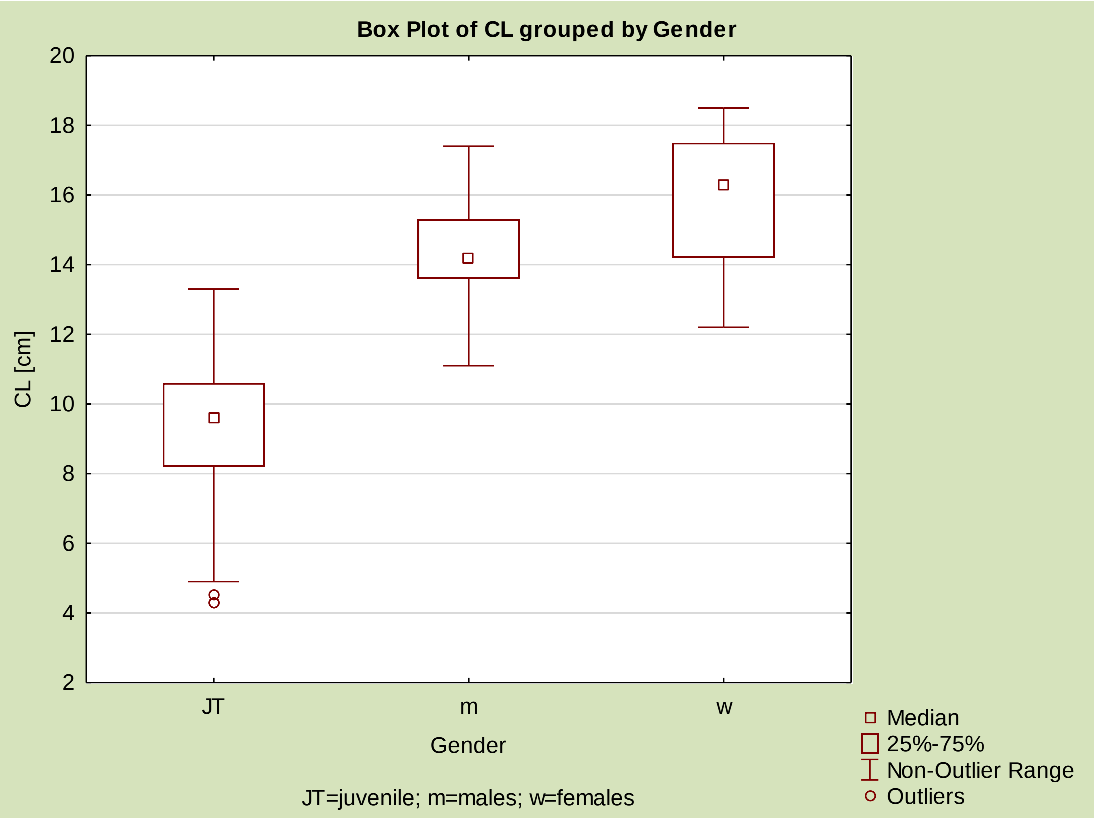


Figure 159 Box Plot of CL grouped by gender.

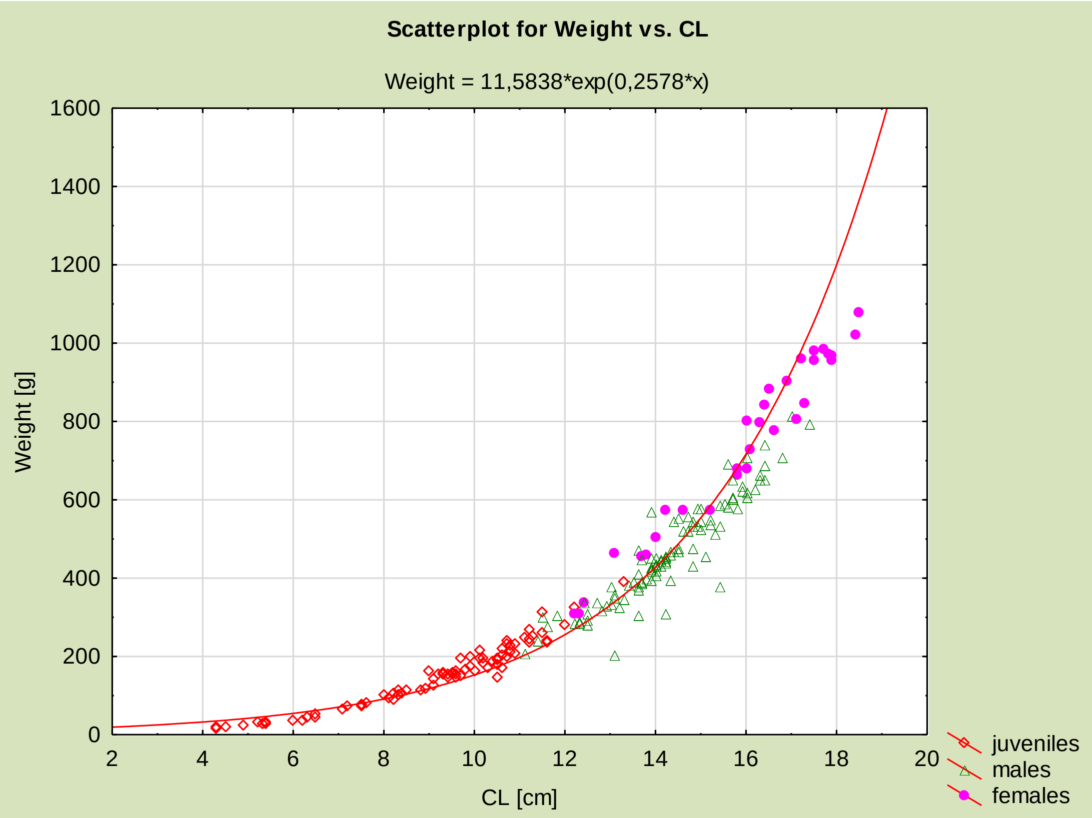


Figure 160 Scatterplot for Weight vs. CL i. e. growth curve

Furthermore, are other important measurements summarized in Table 12.

Table 12 Measurement values of the Doau-Auen National Park population of European pond terrapin grouped by gender.

	females			*males*			*juveniles*		
	N	*Mean*	*Std. dev.*	*N*	*Mean*	*Std. dev.*	*N*	*Mean*	*Std. dev.*
CL [cm]	31	15.894	1.872	102	14.315	1.326	82	9.146	2.026
CW [cm]	31	12.403	1.439	102	11.194	1.001	82	7.496	1.529
PL [cm]	31	15.242	2.455	102	13.077	1.203	82	8.737	2.028
PW [cm]	31	9.607	1.211	102	8.178	0.785	82	5.521	1.270
Height [cm]	31	6.203	0.786	102	4.972	0.444	82	3,.685	0.757
HW [cm]	24	2.767	0.475	86	2.519	0.290	41	1.881	0.323
Weight [g]	31	712.44	262.97	102	470.42	132.19	82	153.41	79.62

In Figure 161 the relation between head width and age is illustrated. It can be seen that the older a turtle, the broader is its head width (Figure 24).

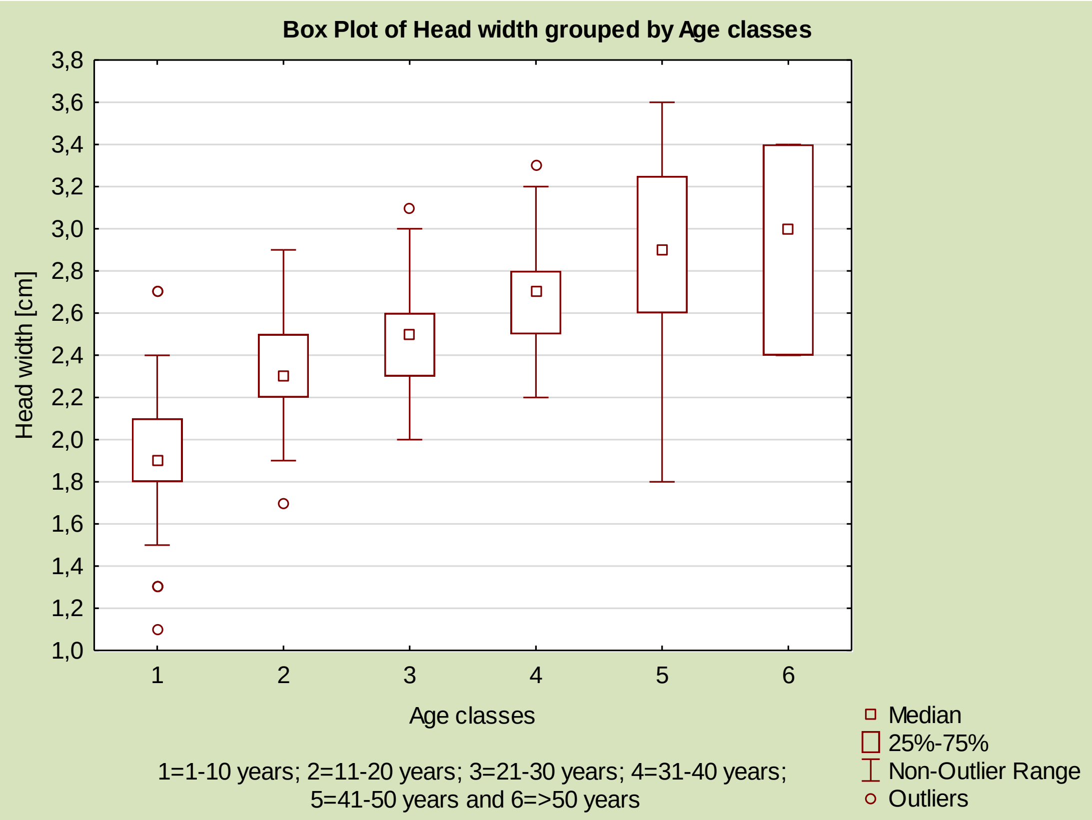


Figure 161 Box plot of head width grouped by age classes.

Appendix VIIII Method for calculating the population size of the lower Austrian part of the Donau-Auen National Park

The population size of the lower Austrian part of the Donau-Auen National Park was calculated with help of densities (i. e. turtles per 300 meter shoreline, both sides). However, the densities for the mean of all calculated abundances of the waters (300 meters, both sides) as well as the minimum and maximum densities were used. Then the length of all potentially suitable waters in the National Park was calculated with help of ArcGis 10.4 and multiplied with the three density values.

Potentially suitable waters were waters which were not connected to the Danube by middle water and on the north side of the Danube since there are no verified sightings of the European pond terrapin at the south side of the Danube (pers. com. Maria Schindler)[19] and waters which were connected to the Danube by middle water will probably be too cold for the European pond terrapin.

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[19] Why there are no turtles at the south side of the Danube is not known. However, after Dr. Christian Baumgartner it may be mainly a consequence of the higher intensity of utilization (pers. com. Dr. Christian Baumgartner).

Declaration of Originality

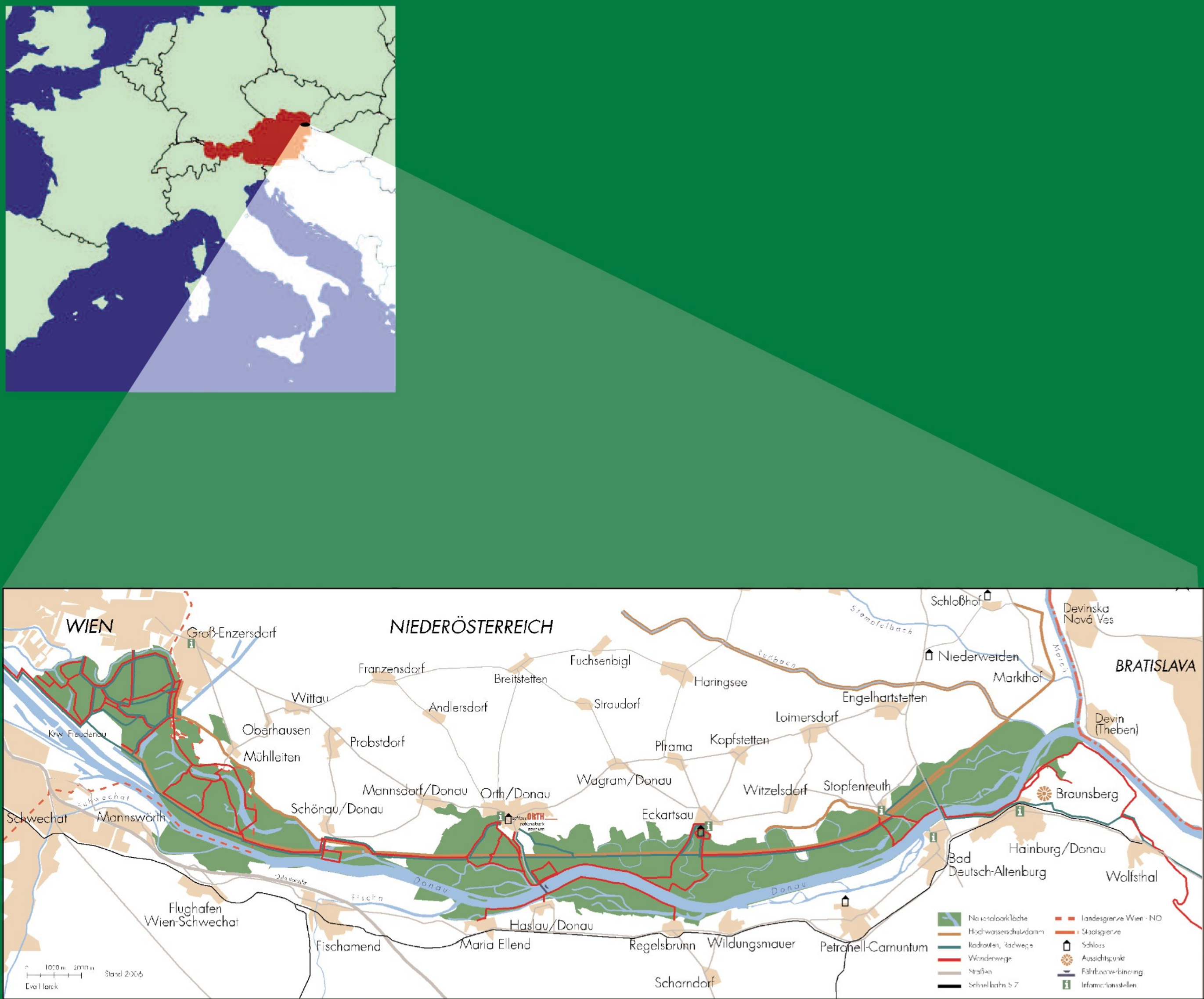
I declare that this thesis is my own work and that, to the best of my knowledge, it contains no material previously published, or substantially overlapping with material submitted for the award of any other degree at any institution, except where due to acknowledgement is made in text.

Date and Signature of student

- Herausgeber: Nationalpark Donau-Auen GmbH
- Titelbild: S. D. Schmidt
- Für den Inhalt sind die Autoren verantwortlich

- Als pdf-Datei direkt zu beziehen unter www.donauauen.at

- Zitiervorschlag: SCHMIDT, S. D. (2017) Evaluation of habitat features influencing turtle abundance in the Donau-Auen National Park. Wissenschaftliche Reihe Nationalpark Donau-Auen, Heft 70



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