Monitoring of the highly endangered eel in Montenegro due to the assessment of the state and potential changes to the law on fisheries in accordance with EU

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Financed by

The Rufford Foundation
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In Montenegro supported by:

nacionalni parkovi CRNE GORE

VLADA CRNE GORE
Ministarstvo poljoprivrede i ruralnog razvoja

nacionalni park SKADARSKO JEZERO

ABSTRACT

Anguilla anguilla L. is on the IUCN list of threatened species as critically endangered, (IUCN,2010). Also included in appendix II of the Red List of endangered species list (CITES), and on the Annex III of the Barcelona Convention. There are also recommendations by the Commission of the EU, for its constant monitoring. It is important to point out that the eel was included in appendix II Red List of Threatened Species (CITES), implying drastic restrictions on trade (Maes and Volckaert, 2007), which tells how much is necessary to raise public awareness of the conservation status of this species. As an additional mechanism for its preservation should be noted and the EU directive on eel EC. NO 1100/2007.

The European eel (*Anguilla anguilla* L.) represents an economically very important species in the whole world where it occurs, as well as in Montenegro. Adults are fished throughout the year, in Western Europe, especially in Great Britain and Ireland, except for adults, glass eels are also fished, which are considered to be exceptional delicacies.

Eel population have been declining worldwide over the last decade (Stone 2003). European eel numbers have dropped as much as 99% since the early eighties of previous century. Due to excessive overfishing it has become critically endangered species to the whole world. In Montenegro, there is very little research carried out so that accurate data on the actual situation of the population do not exist.

In Montenegro, as in other countries where the native species, adults are hunted throughout the year because it is considered an exceptional delicacy, because the price of this kind reaches 15-20 euros per kilogram and is an important resource for local hunters, but its overfishing led the eels on the brink of extinction.

For this reason we wanted to do more detailed and precise research for better understanding of the biology of this species, and the data we collected will serve as a basis for future work on its preservation and research.

Taking all of these into account, we had the desire to do this research in order to better understand the biology of this species, and that the data we collect serve as a basis for future research aimed at protecting this species in Montenegro.

The project also includes scientific educational workshops in order to involve as many people as possible in further research in order to establish monitoring that provides long-term protection of both the eel and other fish species in Montenegro.

The projects research team cosists of biology students Jelena Brnović and Miloš Džiknić.

The project is funded by The Rufford Foundation, and it is supported in Montengero by the Ministry of Agriculture and Rural Development of Montenegro and National parks of Montenegro.

Contents

1 INTRODUCTION

1.1 Basic characteristics of eels:

The eel has a snake like body, elongated and laterally flattened. The unpaired fins (dorsal, caudal and anal/cloacal) have been modified so that they build a continuous line or frame around the body. There are no dorsal fins, and only the pectoral fin indicate that this animal belongs to the fishes. The lower jaw is longer than the upper, and the scales are deeply embedded in the skin, which is characterized by the large mucus, so that the eel can crawl from one of water part to the other water through the moist grass. The maximum weight of the eel is 6.6 kg, and the maximum recorded age is 88 years. The average lifespan is 15-20 years (Froese & Pauly, 2014)

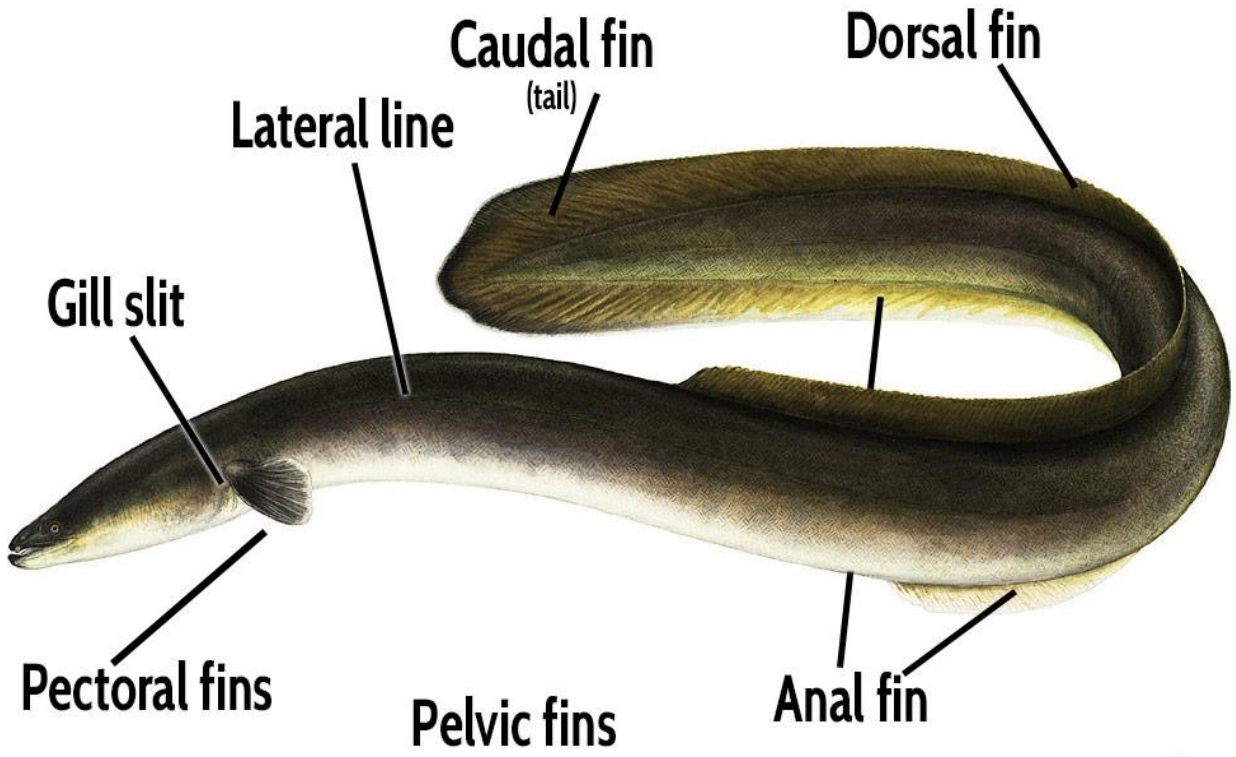

Figure 1. Eel anatomy (https://www.google.com/search?q=anatomiz+body+of+anguilla+anguilla&client)

1.2 Biology and ecology of eels:

Eels are catadromous fish, whose life begins in the Sargasso Sea. After reaching full maturity, eels migrate to the Sargasso Sea, where they are spawning at a depth of 100 to 200 feet. Migration begins in the late summer until the winter, when adult males and females that are fully mature, migrate to the breeding spots, in the northern part of the Atlantic Ocean (Sargas Sea). Full maturation usually occurs at the age of 6-30 years, depending on sex and area, although immature eels that are age over 60 years (females) have been found in some localities. Male eels mature much earlier, at a smaller and fixed size (about 40 cm), and females mature later and at a length of more than 60 cm. (Marić, 2019)

By the arrival in Sargasso, the eels stop feeding, but they use fat reserves as a source of nutrition and energy. After the spawn, the eels die, and their larvae are called lepsecephalus, which does not have the characteristics of an adult. Larvae called leptocephalus are with laterally symetry, transparent and have a body as a leaf. Larvae start remigration back to the continental basins, when their length reaches about 70 mm. Then young larvae that are worn by the Gulf Stream current travel to Europe and when they reach Europe's shores, they metamorphose in glassy, transparent eels, 5-10 cm long (glass eels). It takes 1-3 years from the spawning to the transformation into glassy young eels. (Maric, 2019). The migration of glass eels is the main hunting period, when they are also been overfished!

During migration, pigmentation increases, so in this stage they are called elvers. After the stage of the "elever", the stage of yellow eel is followed, and by reaching full maturity, yellow eels are transformed into silver eels, which again migrate to the Sargasso Sea, leaving their offspring and die afterwards. (Tesch, 2003; Dekker, 2004; Bevacqua, 2008).

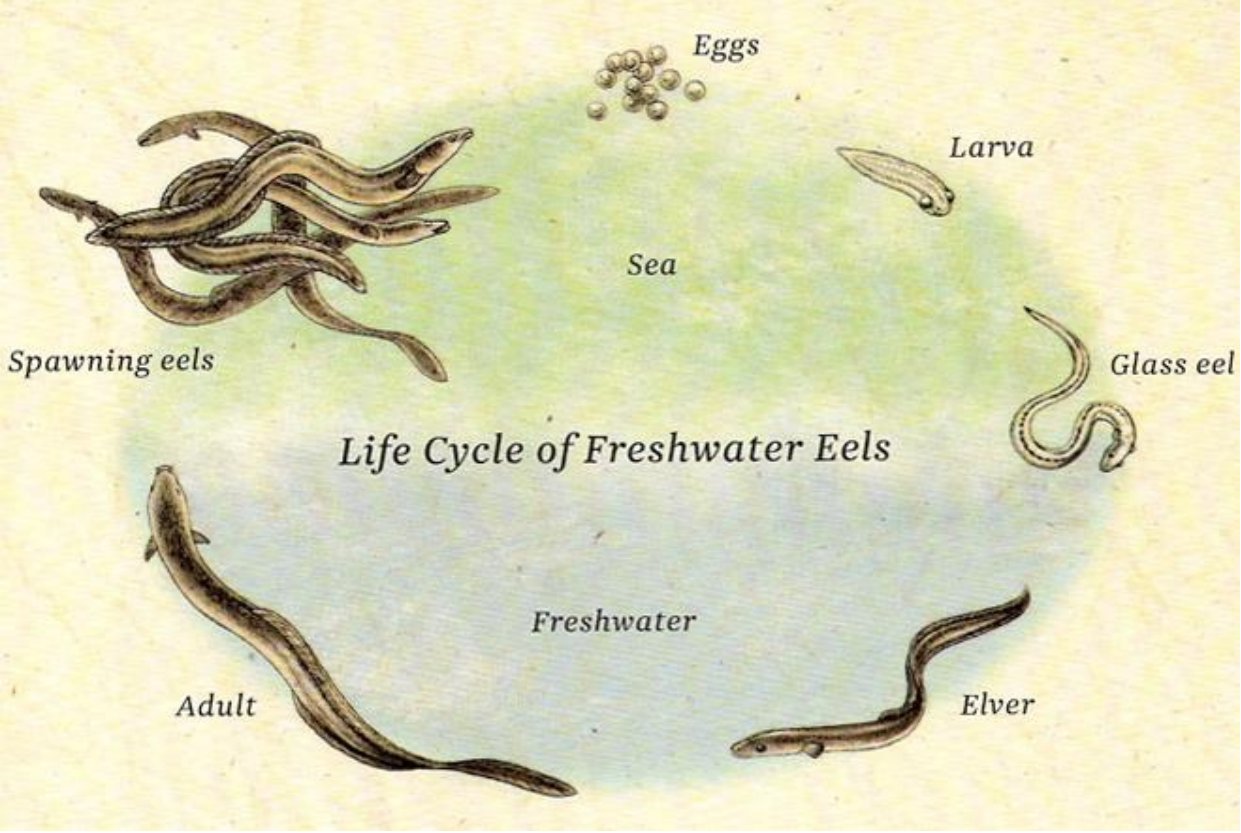

Figure 2. Life cycle of freshwater eels (https://featuredcreature.com/ever-wondered-what-a-baby-eel-looked-like-theyre-made-out-of-glass/)

1.3 Economic significance:

European eel is hunted throughout the year in Skadar Lake and represents an economically important species in Montenegro. The largest eel specimens caught in the Skadar Lake was 107.3 cm in length and weighed 2.650 grams. When making a food dish from eel, the eel is used in fresh and smoked condition. This fish is a valued species in Montenegro and its great demand is during religious holidays, due to the preparation of traditional dishes.

In Europe, from the 1980s, consumes 15-20,000 tons of eel annually. Everywhere on the market is especially appreciated smoked eel, which has surpassed the famous smoked Salmon at the price range. Depending on the country, all eels weighing more than 50 g are considered as consumable. (Maric, 2019)

Figure 3. European eel important commercial freshwater fish species (http://www.illegalwildlifetrade.net/2018/07/27/europes-largest-wildlife-crime-illegal-trade-of-the-european-eel/)

2 DESCRIPTION OF THE RESEARCHED AREAS

Skadar Lake is located in the southeastern part of Montenegro on the Montenegrin-Albanian border. About 60% of the lake is on the territory of Montenegro, while the remaining part belongs to Albania. The Skadar Lake is located on the karst terrain, in the inner part of the southeastern dinarides and is the largest lake on the Balkan peninsula. The main tributary is the Moraca River on the north coast, and the main outflow is the Bojana River in the south.

Figure 4. View of the Skadar Lake (https://www.halotours.rs/package/crna-gora-bosna-hrvatska/skadarsko-jezero-agencija/)

Skadar Lake represents a unique ecosystem, providing a variety of conditions for the ichthyofauna. For example, in the lake you can find diverse habitats (swamps, tributary springs), and the biomass is great because, due to its low depth (mean depth about 5.0 meters), most aquatic the mass belongs to the photic zone, and it ensures both high productivity and high oxygen concentrations. Consequently, and in combination with Mediterranean climatic conditions, the lake is characterized by warm water fishs (Ciprinids) and cold water fishs (Salmonids). Based on the results of the past research in the Skadar Lake basin, 50 species of fish have been registered, of which 37 are autochthonous and 13 are alochthons (Marić & Milošević, 2011). The dominant ichtyofauna consists of the members of the Cyprinidae family with 22 species.

3 MATERIAL AND METHODS

Sampling of the European eel was done in April from 2018 to March 2019 on 9 different sites on the Skadar Lake (Veliko Blato, Malo Blato, Virpazar, Vranjina, Rijeka Morača, Rijeka Crnojevića, Dodoši, Karuč and Grlo Blato) (Figure 4).

Figure 5. Map of project investigated sites

For sampling, non-invasive passive methods were used. The pots or special trap for the eels whose length was 7.90 meters in diameter of 5.4 meters, and also a smaller ones with 3 meters length and 80cm in diameter. On the lower part of the pot/traps is also a metal iron which allows them to be placed at the bottom standing right, and nothing can be beneath them. They are placed from the boat at a depth of about 2-3 meters in the lake, and about 60 cm into the river. We marked pots with floating buoys, which were stolen very soon, so because of that we later marked our pots/traps with a simple plastic bottles filled with water that were less easier to be found by the fish poachers.

Figure 6. Our eel pots/traps

A total of 84 individuals from four locations were collected: Veliko Blato (21), Malo Balto (25), Rijeka Morača (29) and Rijeka Crnojevića (9). We measured the total length of the body by using the ichthyometer (TL) and body weight. This length-weigth relationship formula makes it easy to estimate the weight of an individual based on its length, by translating the equation growth into a length, in the equation of weight gain.

Figure 7. Eel specimens measurement

The length-weight relationship of a fish species is calculated on the basis of functional regression:

$$\boldsymbol{logW = loga + b * logTL}$$

in which:
W – total weigth
TL – total length
a i *b* - constants

One of the most common and most important examples of the length-weight ratio is reflected in the estimation of the growth model of the population surveyed. On the basis of the obtained values of the constant b, an isometric or allometric model of population growth is estimated. Exponent b is the logarithm of growth in relation to length and mass/weigth. If b = 3 it means isometry, that is, If b = 3, this means isometry, that is, that fish are obtaining on both mass and weight by retaining their body shape. In the alometric ratio (W / TL) the values of the constant b are greater than 3 , and they show us positive alometry, while values less than 3 denote the negative alometry. A positive allometry suggests that the fish grows faster in length rather than in the mass/weigth, while the negative alometry indicates that the fish grows faster in the weigth than in the length. If b = 3 then the ratio W / Tl is isometric.

To compare weight and length on a single sample or individual, a **conditional factor or nutrition index** is used. Fulton's conditioning factor is often considered a standard conditioning factor. Calculated by the formula:

$$\boldsymbol{K = \frac{W}{TL^3}}$$

If the fish is with a higher weight at a certain length, that means that the conditioning factor is also a higher, and therefore the "condition" of the fish is better. Fulton's factor is also suitable for comparing different fish samples of the same species. It also indicates differences in relation to sex, season, or place of catch. The condition of the fish (K) and the associated long-weight relationship are widely used parameters that enable a better understanding of the general state of the fish species, its growth, survival, maturity and reproduction (Le Cren, 1951).

Length-weight ratio and conditioning factor are closely related. While the conditioning factor is a suitable method for estimating the weight variation of individuals, the length-weight ratio is a suitable method for estimating the weight based on the given length (Hile, 1936).

4 RESULTS AND DISCUSSION

4.1 Location – River Morača

We have caught the largest number of individuals in the Morača River. One of the possible reasons for this is the isolation of this area, where there are very few local fishermen, and for those who are fishing there, they all use also this non-invansive pasive method for catching the eel with the net, which is very good because there is no electroagregate whay of hunting at that location.

In our eel nets/pots, besides the eel, we found other types of fish, of which the most common is barbus, roach and barbell. The total length of the body ranged from 27-62 cm, while the weight ranged from 50-650 grams. The ratio of the total length and weight of the body of the individuals analyzed in this region showed that the values of the regression coefficient b are 3.136, while the values of the correlation coefficient are R^2 0.9363. The results obtained by analyzing the length-weight ratio of the total number of individuals from this site showed the minimal deviations of the value of parameter b, 3.136 indicating a positive alometric growth, which is probably due to the presence of larger individuals.

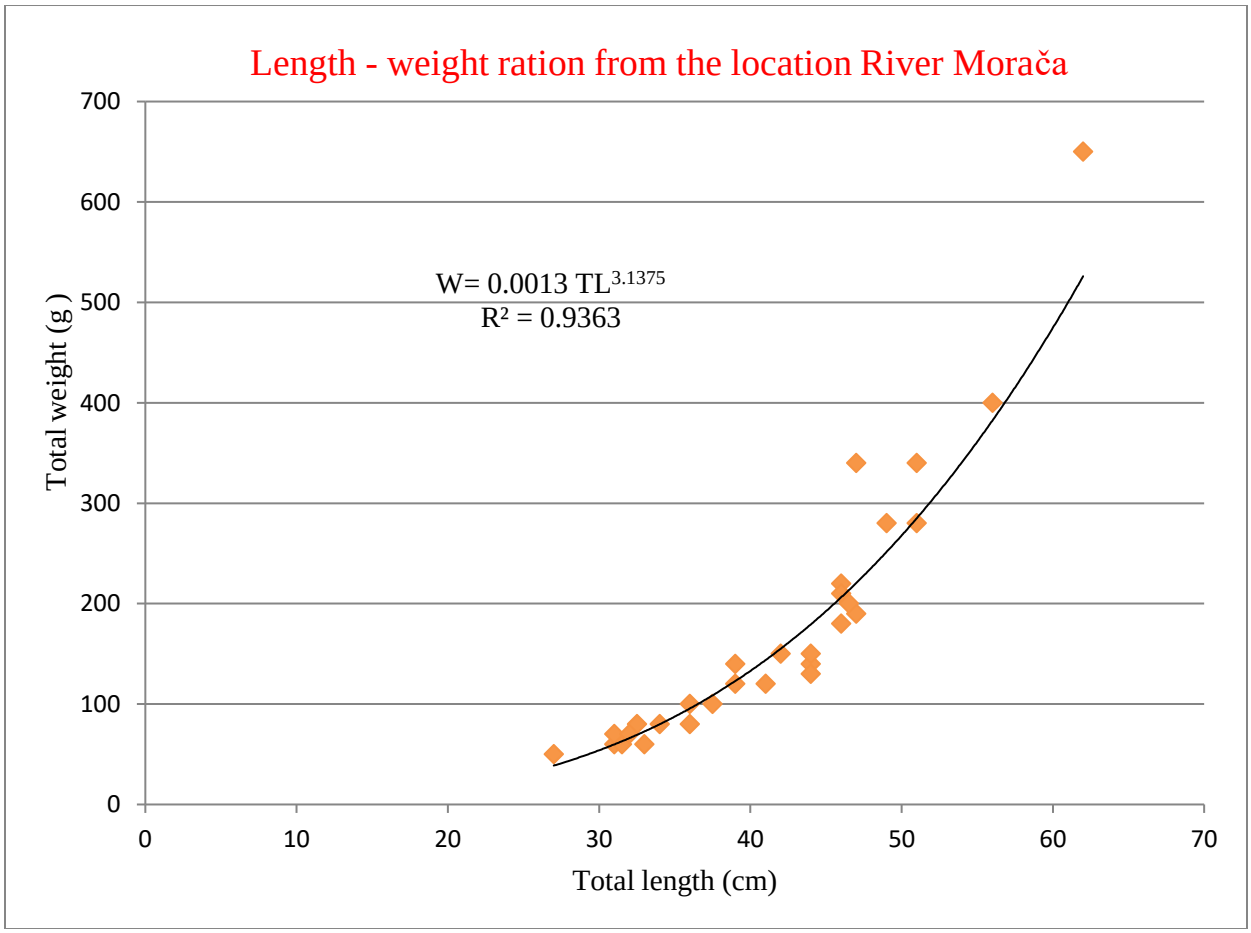

Figure 8. Graphic representation of the length - weight ratio of eels from the River Morača location

4.2 Location – Malo Blato

The next site where we caught the largest number of eel specimens was in a location that is called Malo Blato (25). Beside eels, we also found huge quantities of other fishs. At this site, one of the big problems were also water snakes (*Natrix natrix* L.). In the eel pots, if we found a water snakes, eels we didnt found. In a conversation with local fishermen, we found out that this is a common phenomenon, and they told us that eels enters only "clean pots/traps", or into pots where there are no snakes.

The total length of the body was in the range of 27-60, while the weight ranged from 50-440 grams. The ratio of total length and weight of body of specimens in this area showed that the values of the regression coefficient b are 2.5028, while the values of the correlation coefficient are 0.9387. The results obtained by analyzing the length-weight ratio of the total number of individuals from this site indicate a greater deviation from the value of parameter b, indicating a negative alometry, that is, that the individuals grow faster in length than in the mass. We assume that one of the reasons is the presence of a larger number of smaller individuals.

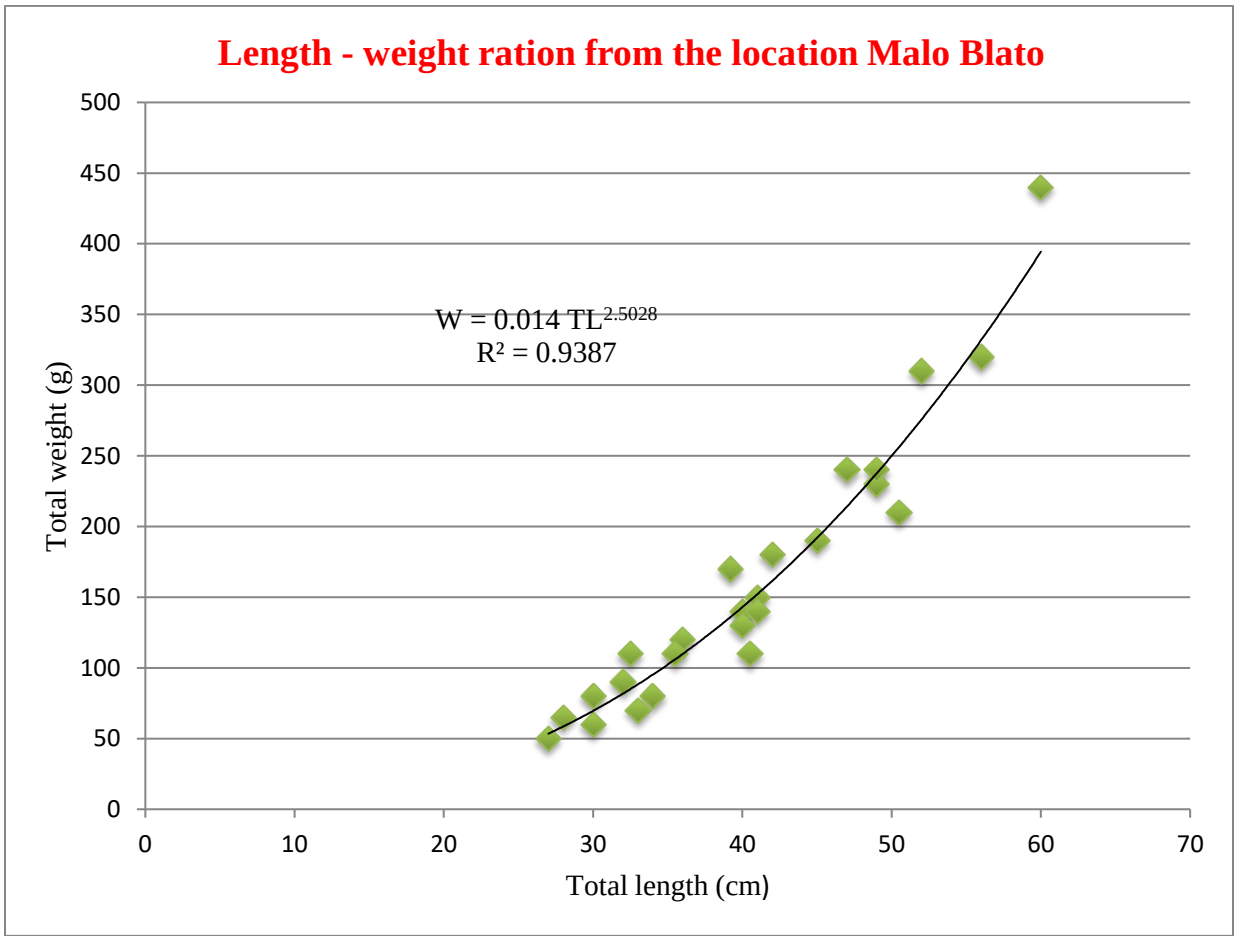

Figure 9. Graphic representation of the length - weight ratio of eels from the location Malo Blato

4.3 Location - VELIKO BLATO

We caught 21 individuals on Veliko Blato. The total length of the body ranged from 30 to 64 cm, and the total weight ranged from 40-440 grams. The total length - weight ratio showed that the

values of the regression coefficient were b 2.9665 which indicates that the individuals at this site have an isometric form of growth. The isometric growth model, as Froese (2006) explains, describes a population in which both smaller and larger individuals are characterized by the same body shape and equally good condition. Values of the correlation coefficient are 0.9518.

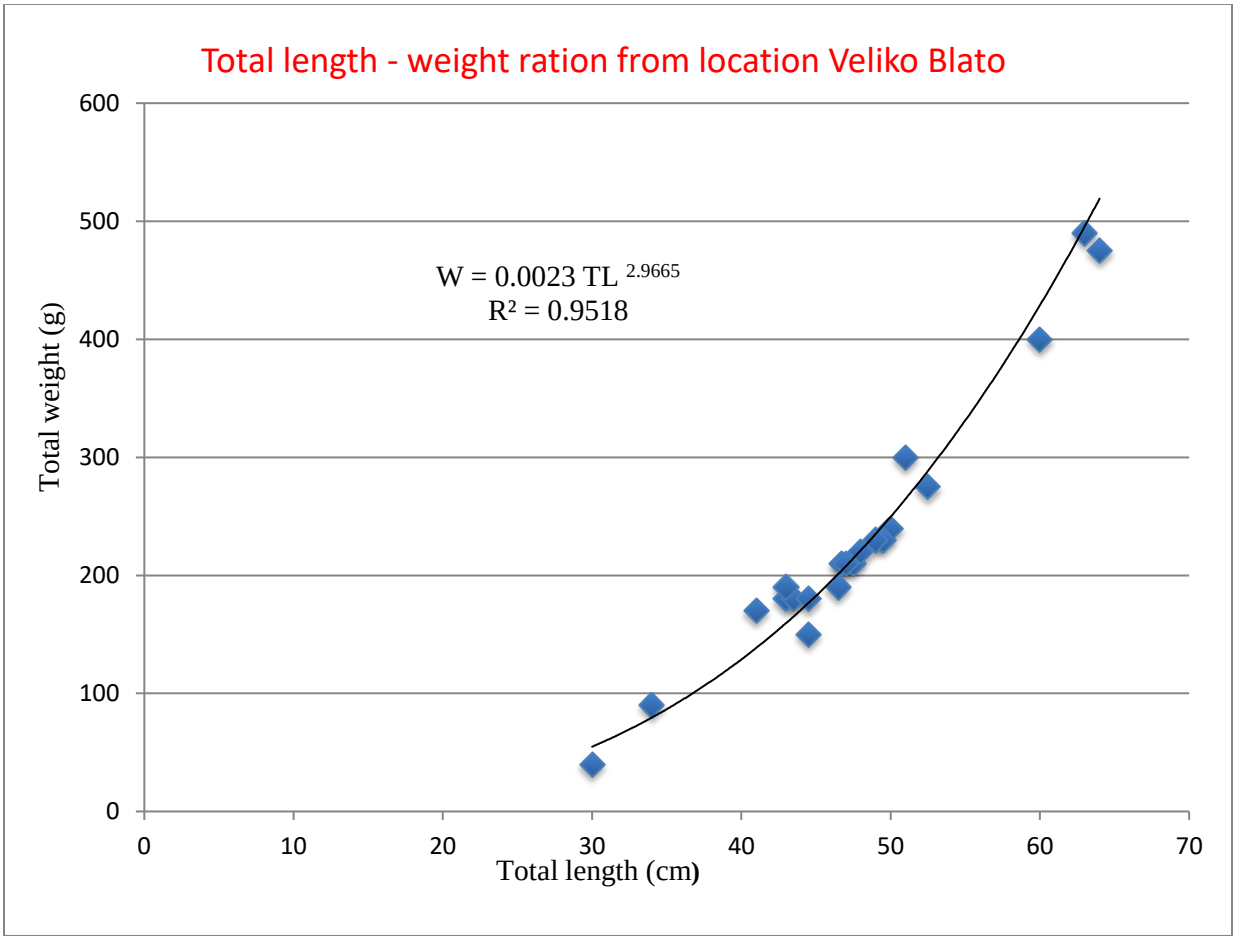

Figure 10. Graphic representation of the length - weight ratio of eels from the location Veliko Blato

The problem at this locality is electrofishing, and a large number of illegal fishermen who hunt at night. We set the pots/nets by day, and after two days we visited them. We found that they were being moved, and poachers they probably took the eel from them and the rest of the fish. The problem is that they hunt at night, they have a large lamp that illuminates at 25 meters, and they can see the whole bottom, and so find the pot easily. Although the fishing ban started from March 15 and lasts until May 15, in our last fild work we spotted one boat with an electric fishing gear. Under other illegal fishing gear, we mean converters, dynamite and eel spear. In a conversation with fishermen we learned that this "converters" sucks the fish from 15 meters from the bottom up to the surface. This site is close to the village houses, and this is probably one of the reasons why we caught a small number of individuals.

4.4 Location - RIJEKA CRNOJEVIĆA

At this location, we caught the smallest number of specimens (9). The reasons for this are multiple. First of all, the River Crnojević is a turbulent place, where on every five meters there are fish restaurants, which means a huge number of fishermen. Then, in the summer months, the water level decreases, so it makes our pots visible, and the characteristics of our pots used during this research was that the length of 7 meters, so it was very easy visible when the water level decreases. It is very difficult to explain to people who live from fishing the importance of preserving the eel, not just this fish species, but also a complete ichthyofauna, but with our visits and organization of workshops this awareness process has begun.

The total length of the body ranged from 35-69.5, while the weight ranged in the range of 110-670. The ratio of total length and weight showed that the values of the regression coefficient b amounted to 2.804, with minimal deviations, indicating that the individuals from this site are characterized by an isometric growth model, that is, that the individuals retain the usual shape of the body during the growth pattern, and consequently it can be concluded that the individuals from the territory of Skadar Lake live in satisfactory conditions.

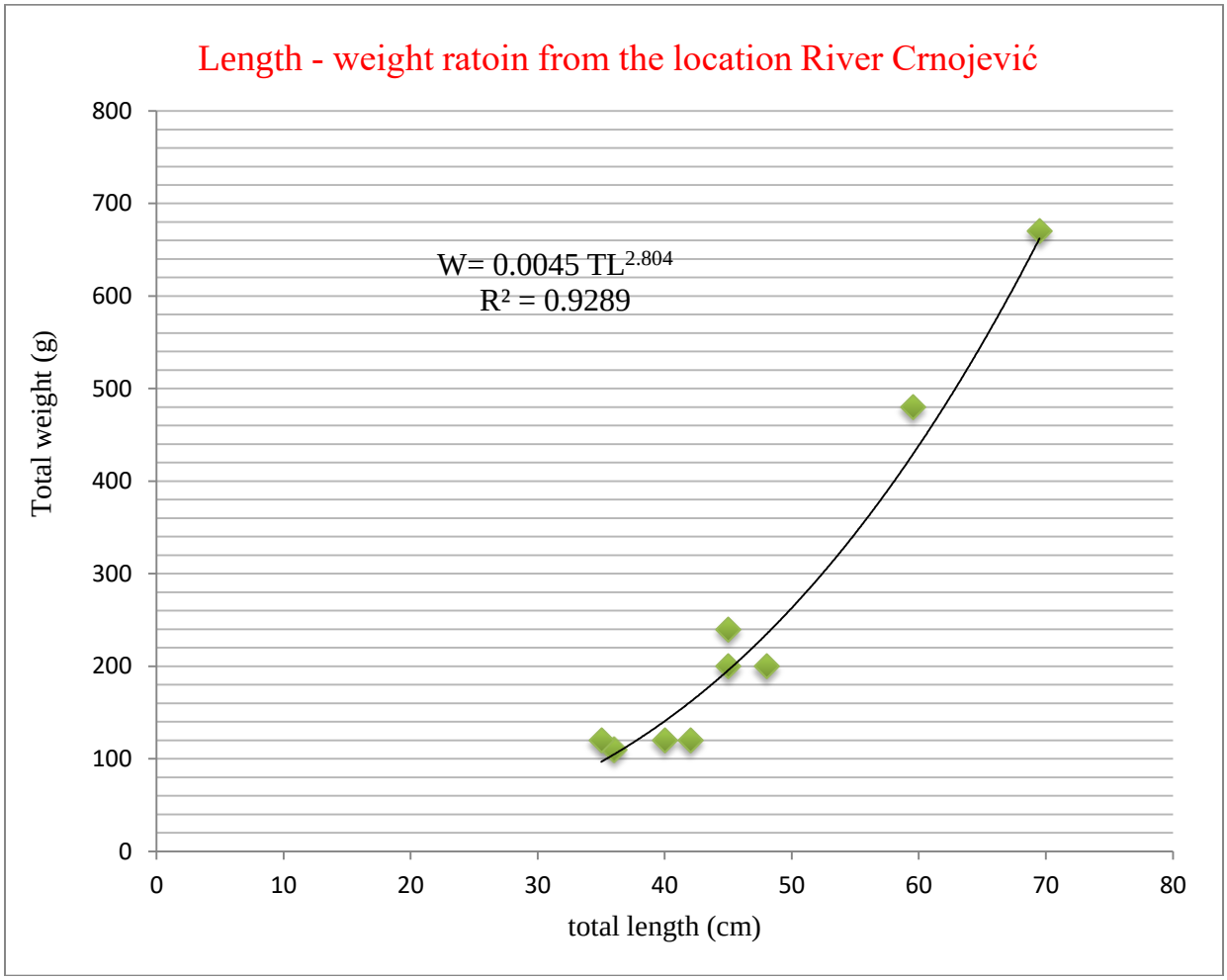

Figure 11. Graphic representation of the length - weight ratio of eels from the location River Crnojević

The results obtained by analyzing the length-weight ratio of the total number of individuals for this study indicate minimal deviations from the value of parameter b, which suggests that the individuals from the Skadar Lake area are generally with isometric growth model b = 2.810. Certain variation of the coefficient b between the locally identified sites confirms once again the fact that different sites reflect the different ecological conditions in Skadar Lake.

Table 1. Descriptive statistics of the length and weight ratio of *Anguilla anguilla* sampled from four different sites in Skadar Lake: (**n**-number of specimens, **TL**-total length, **W**-total weight, **SD**-standard deviation, ***a*** i ***b*** -regresion coefficient, **R^2**-corelation coefficient)

Localities	**n**	**TL (cm)**		**W(g)**				
		Min-Max	SDTL	Min-Max	SDW	a	b	R2
River Morača	29	27-62	8.3	50-650	131.54	0.0013	3.1365	0.9363
Malo Blato	25	27-60	8.9	50-440	94.84	0.014	2.5028	0.9387
Veliko Blato	21	30-64	8.1	40-490	109.81	0.0023	2.9665	0.9518
River Crnojevića	9	35-69.5	11.2	110-670	195.15	0.0045	2.804	0.9289
Ukupno	84	27-69.5	9.168	40-670	127.19	0.0043	2.8105	0.9336

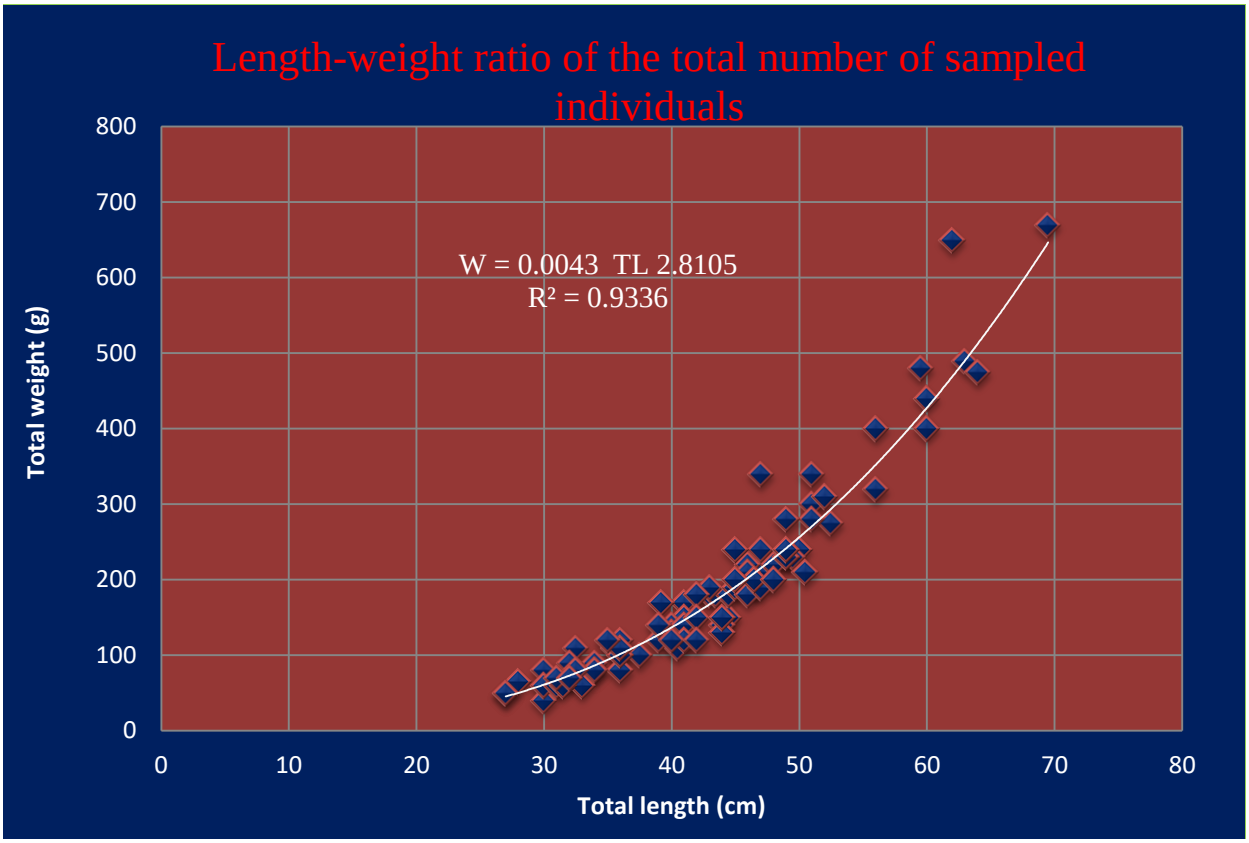

Figure 12. Graphical representation of the length-weight ratio of the total number of individuals

Our results are in a line with the results of Milošević and Mrdak 2015, whose research also suggests that individuals on the Skadar Lake Territory are characterized by an isometric growth model, that is, the environmental conditions in Skadar Lake are at a satisfactory level, and in

contrast to these results, eels for the 19 selected fishbase research that have positive allometric growth.

4.5 Analysis of length - weight relationship by seasons

During the spring we have caught the largest number of individuals (54). First of all, one of the possible reasons is the possibility of having a large number of fild works for collection of specimens in this period due to more batter and favorable weather conditions.

The results of the length-weight ratio and the conditioning factor from this period indicate that the eel species have a **negative allomeric growth**, that is, the values of the regression coefficient are 2.68. The negative allometric growth can certainly be influenced by a larger number of caught smaller individuals.

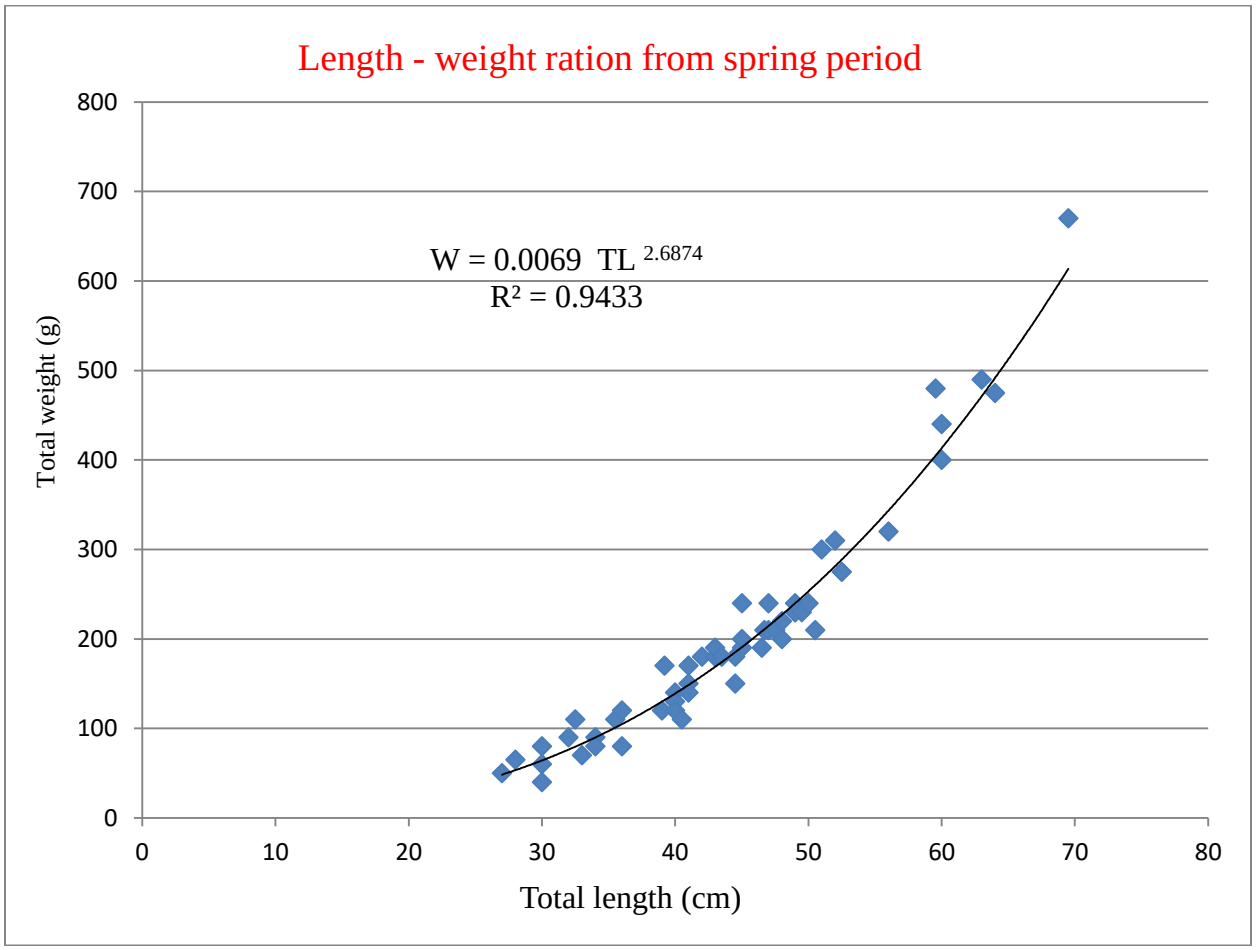

Figure 13. Graphical representation of the length-weight ratio of the total number in spring

During the summer period we caught a total of 8 individuals. We consider that one of the possible reasons for this is certainly a very low water level, a higher visibility of our eel pots/nets in the water and therefore their steal by the poachers, and a notable number of water snakes caught in the nets have been noticed.

The results of the length-weight ratio and the conditioning factor from both periods indicate that the individuals have an **isometric growth model**, as indicated by the values of the regression coefficient of 2.79, while the values of the coefficient of correlation amount to 0.94. We assume that the above mentioned growth model is influenced by a larger number of medium-sized individuals. However, this can not be said with certainty because of the small number of caught specimens.

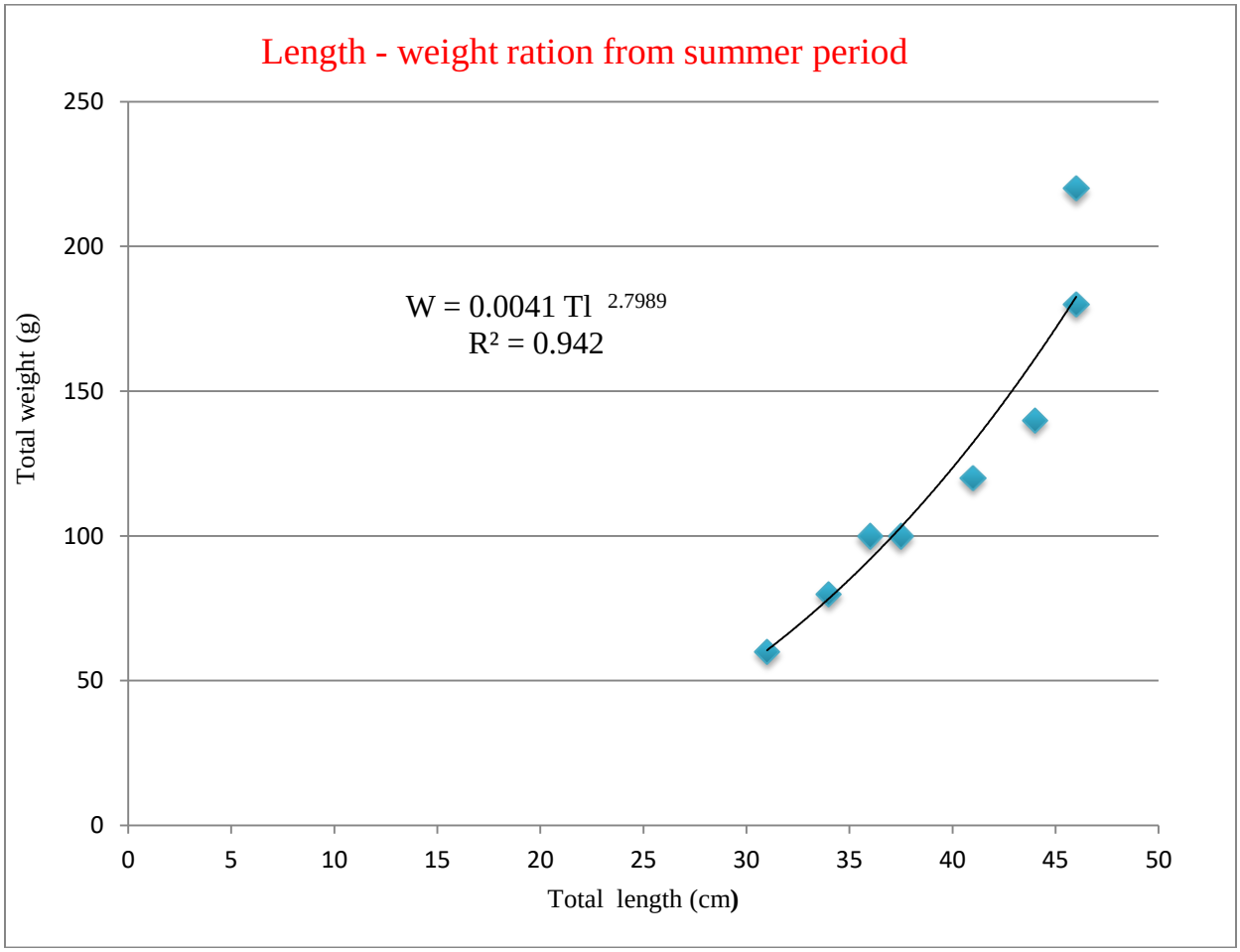

Figure 14. Graphical representation of the length-weight ratio of the total number in summer

In the autumn period, we caught 15 individuals in total. The water level was evidently higher compared to the summer period, and therefore we had more possibilities for a greater number of puting pots/nets in the lake.

The results of the length-weight ratio and the conditioning factor from this period indicate that the individuals have an **isometric growth model**, as indicated by the values of the regression coefficient of 2.97, while the values of the coefficient of correlation amount to 0.95. As we have previously stated for the summer period, we assume that the same growth model here in autumn is influenced by the same factors, but this can not be said with certainty because of the small number of caught individuals.

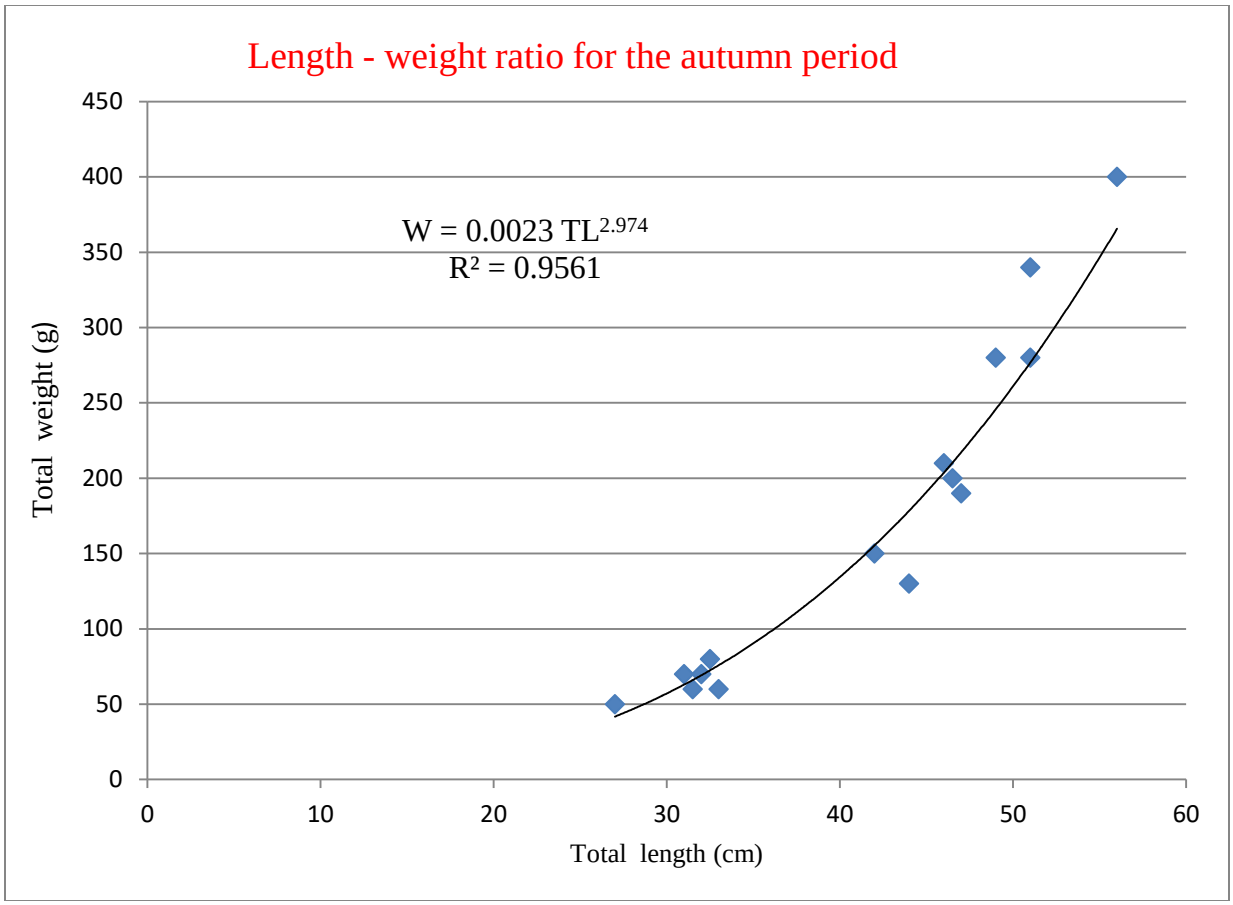

Figure 15. Graphical representation of the length-weight ratio of the total number in autumn

For the winter period, it is characteristic that we caught the smallest number of individuals - a total of 7 specimens. The least number of fild work, due to the bad weather conditions (strong winds and rain, waves and a very high water level), certainly affected this small number.

The results of the length-weight ratio and the conditioning factor from this periods indicate that the individuals have a **positive allometry**, that is, the values of the regression coefficient are 3.21 while the values of the correlation coefficient are 0.86. Positive alometriy was probably influenced by a significantly larger eel individual that was caught with a body weight of 650g.

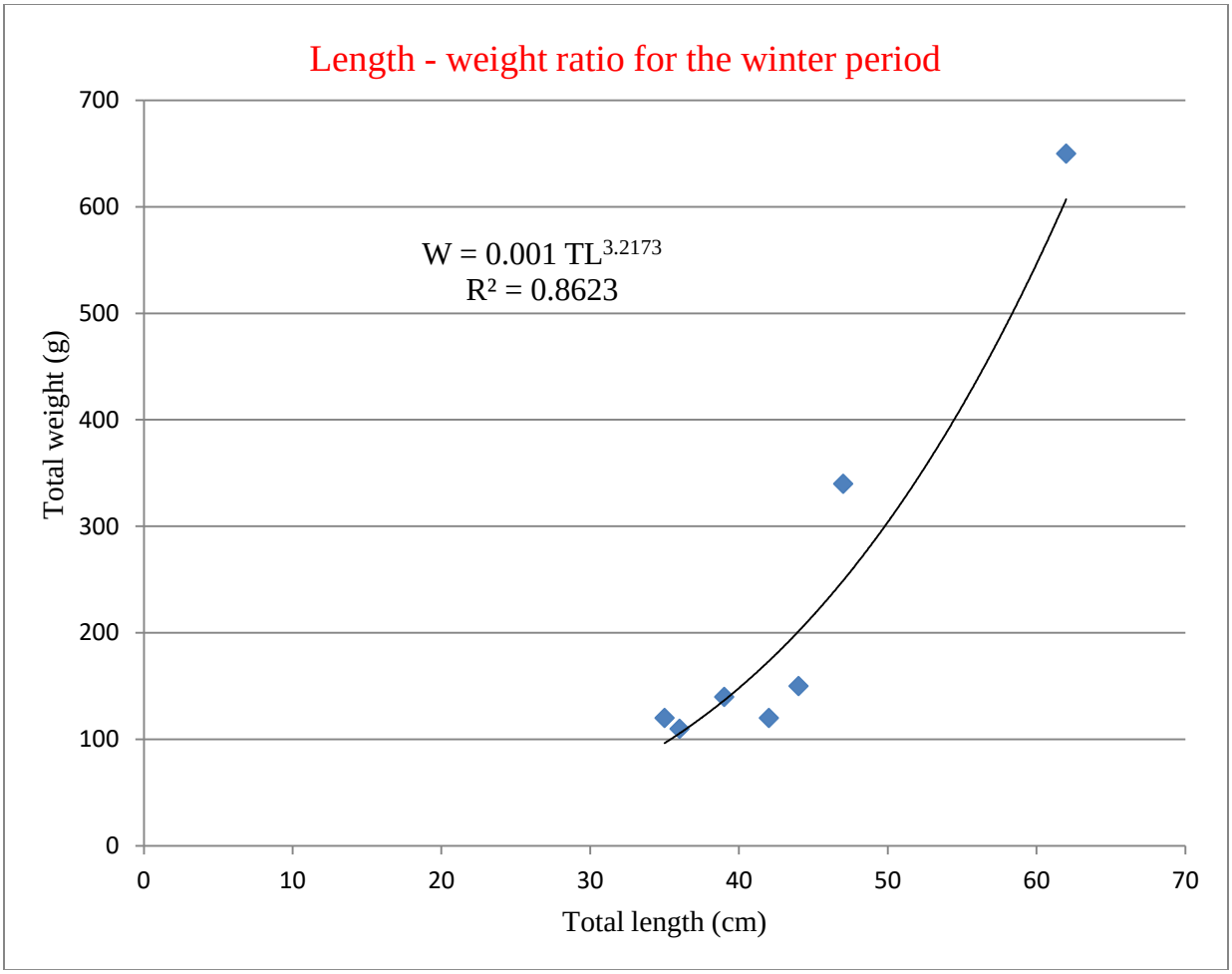

Figure 16. Graphical representation of the length-weight ratio of the total number in winter

4.6 Condition of fitness factor and body length

The condition factor (K) showed an average value of 0.21, while the analysis of the conditioned factor by the investigated sites showed the following values: K = 0.20 for the site Veliko Blato; K = 0.22 for the locality of Malo Blato; K ==, 21 for the location of Rijeka Morača; K = 0.21 for Rijeka Crnojević site.

When we compared the conditioning factor and body length of eels in disturbed locations, we noticed the growth of a conditioned factor with an increase in body length, as shown by the following graphic.

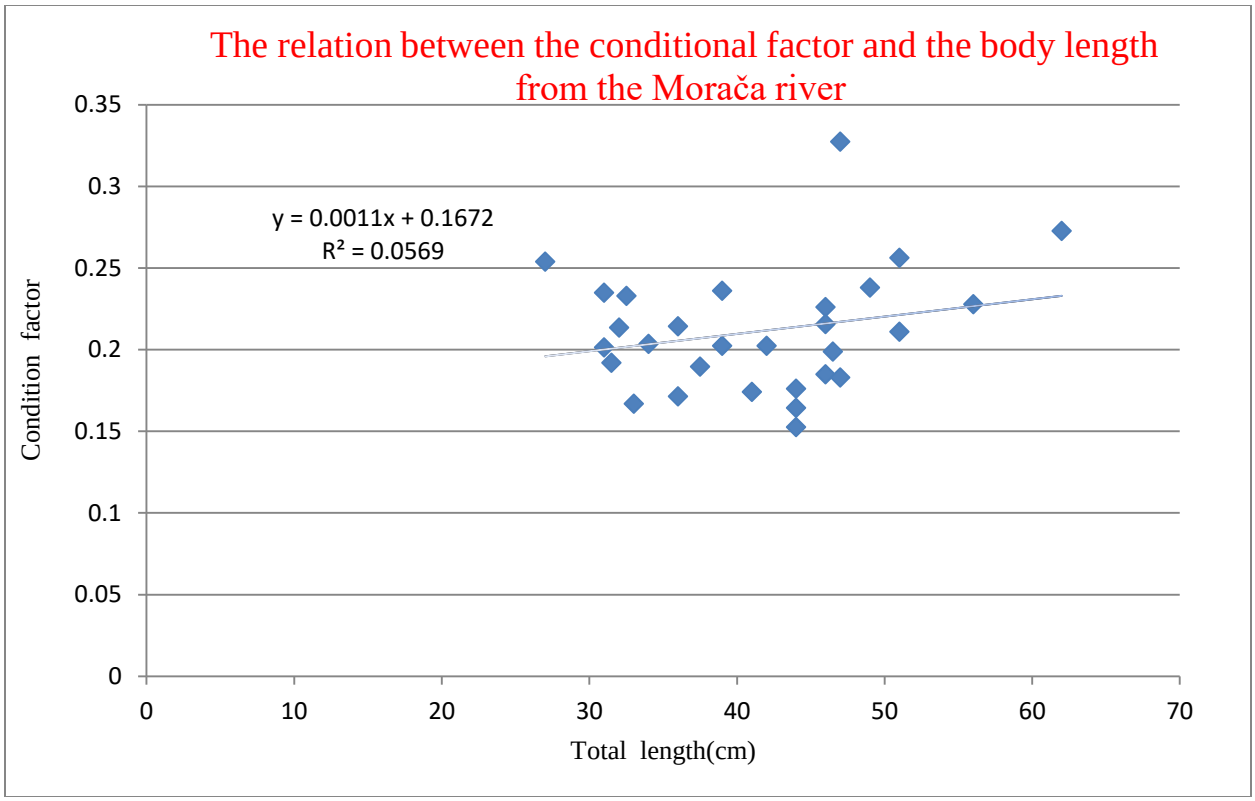

Figure 17. The relationship between conditional factor and body length from the Moraca river site

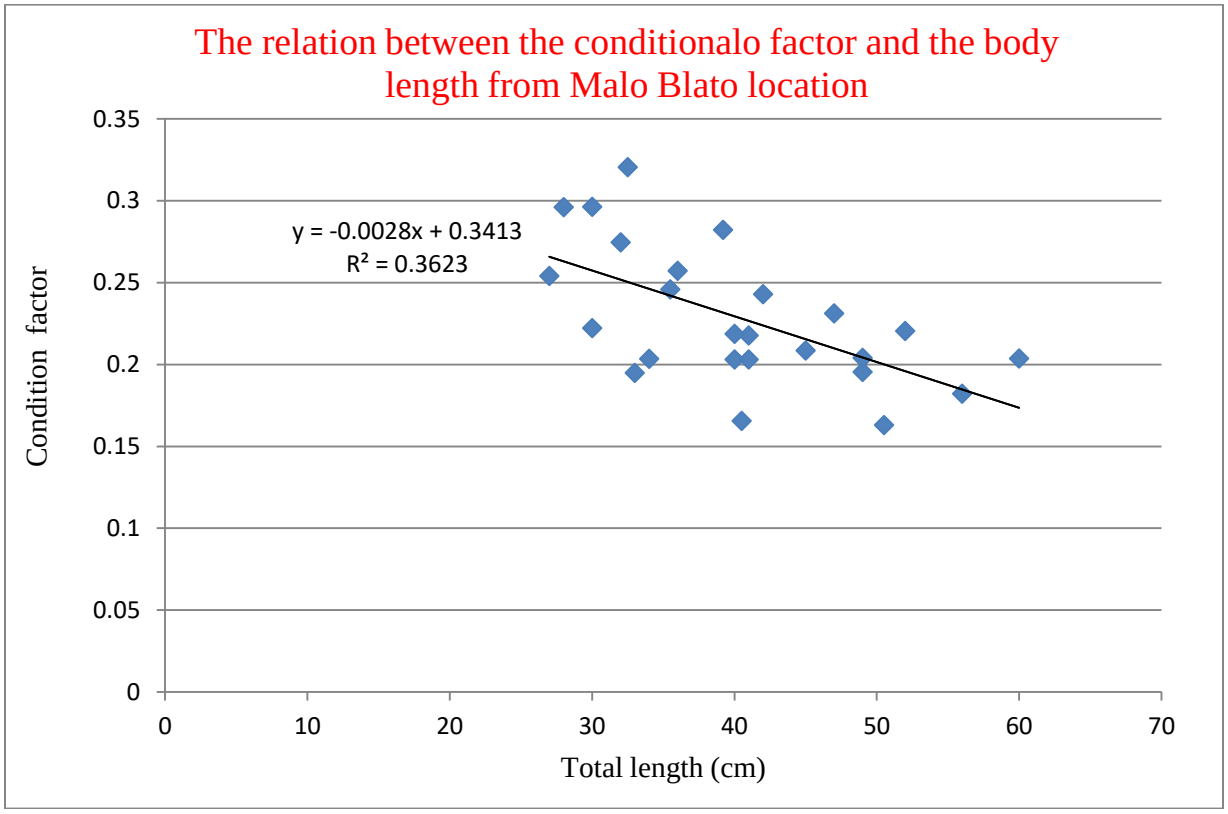

Figure 18. The relationship between conditional and body length from the site of Malo Blato

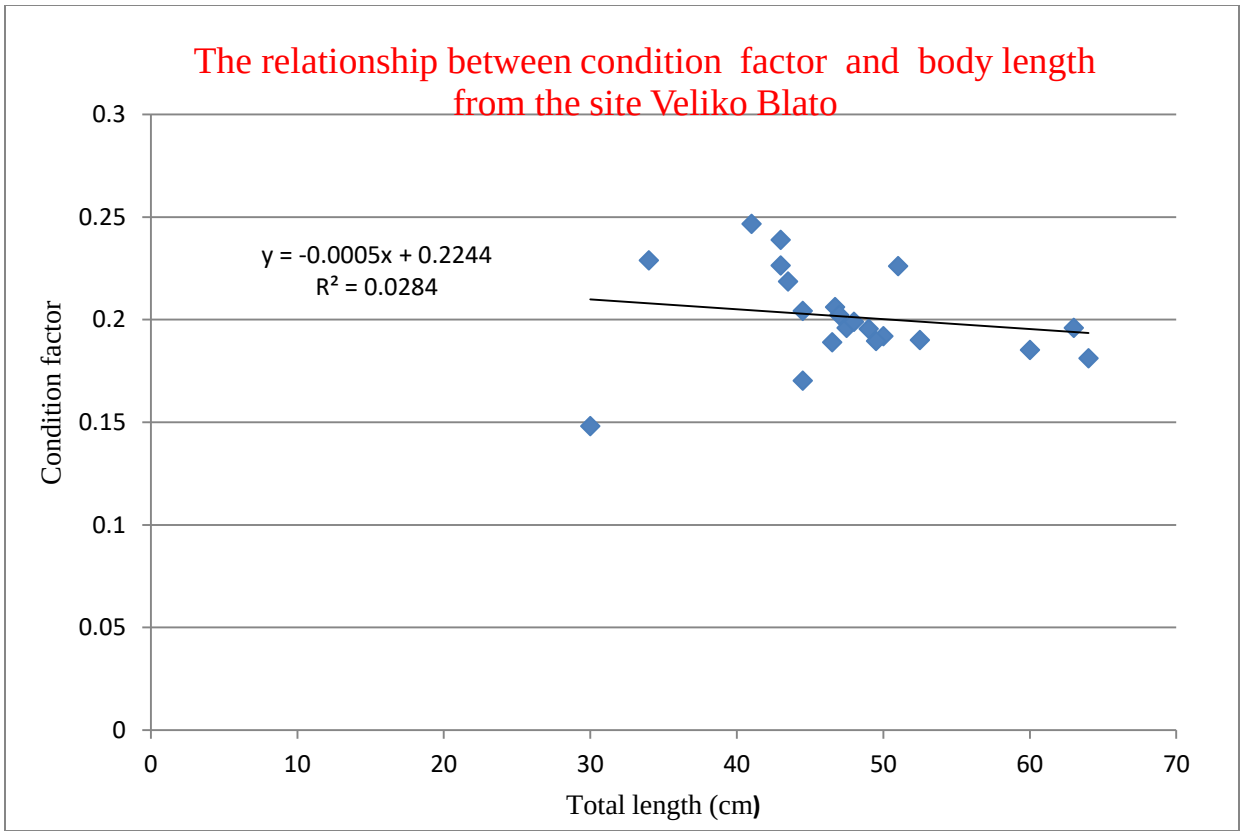

Figure 19. The relationship between condition factor and body length from the site Veliko Blato

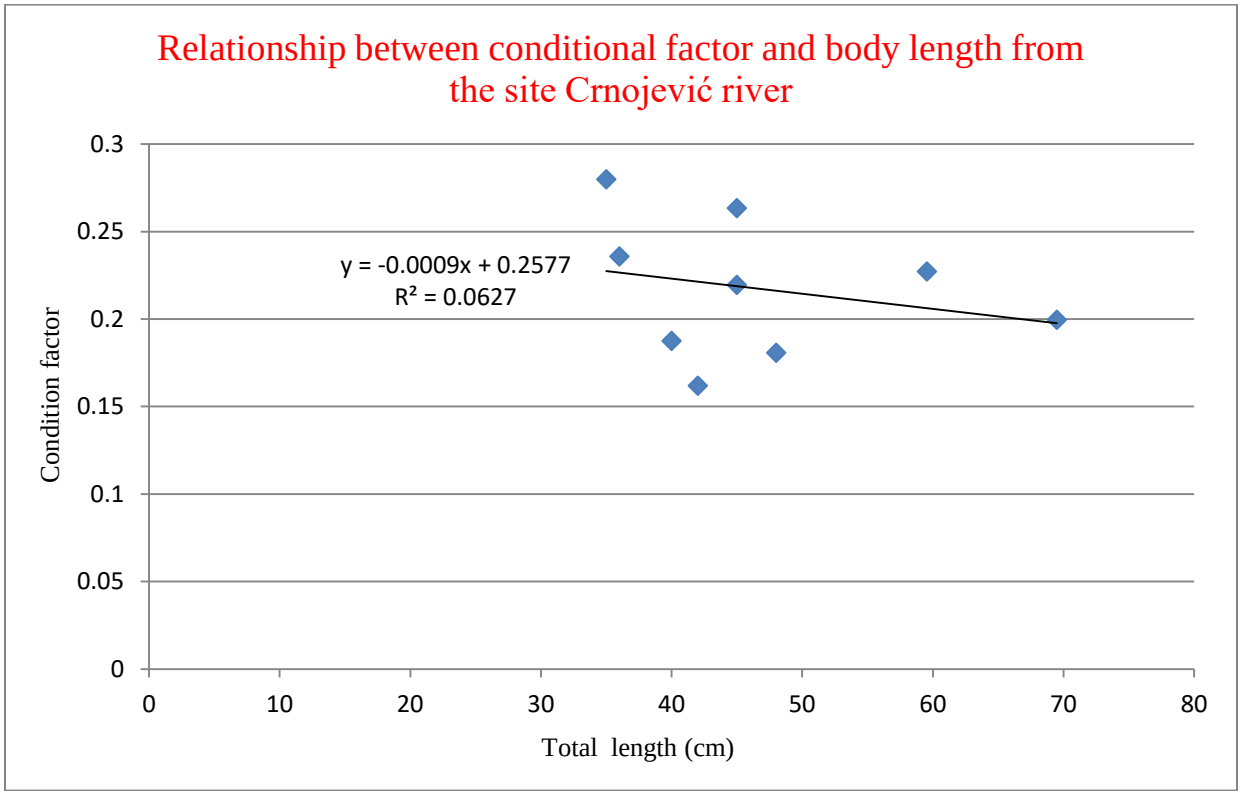

Figure 20. Relationship between conditional factor and body length from the site Crnojević river

The results of the correlation of the eel conditional factor and their body lengths at the investigated site indicate an increase in the conditioning factor with an increase in body length. By comparing our results with the results of Piria et al. (2016) for eels from the Jadro and Žrnovica rivers in Croatia, where the data of the conditioning factor of the individuals from the mentioned sites show a decrease in fitness relative to the total length. This indicated changes in growth resulting from poor feeding conditions due to changes in the environment. In this regard, the results obtained during this research show that eels in Skadar Lake live in optimal environmental conditions that affect the good eel condition.

At other locations, we caught two or three individuals, but that was not enough to enter statistical data processing.

4.7 Structural analysis by length and weight groups

Sorting the total number of samples of caught individuals by length and weight groups, is presented with the following graphs (figures 21 and 22):

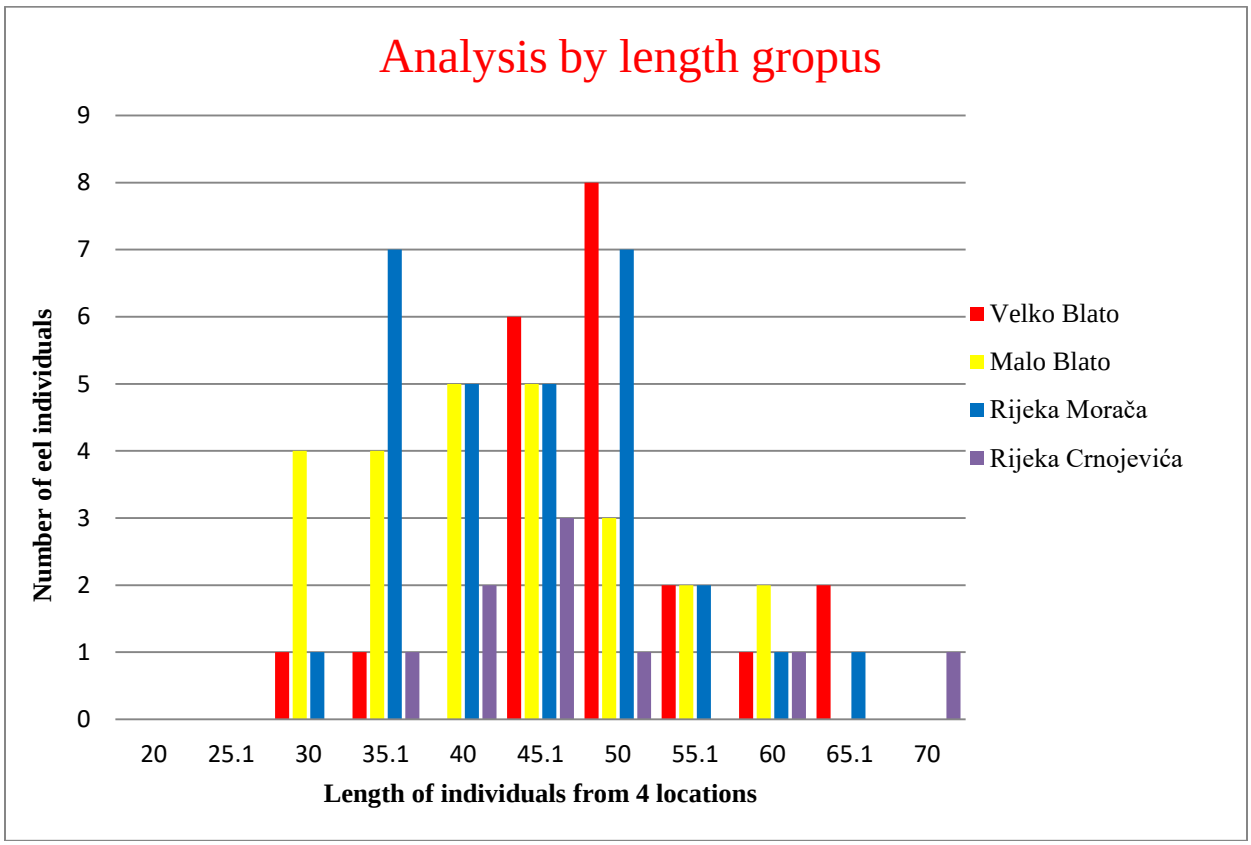

Figure 21. Graphical representation of individuals by length

From the graph we note that the individual with the least recorded body length is caught at the site of Veliko Blato, and the largest one is caugth on the locality of Rijeka Crnojevića. The largest number of caught individuals were from the site of Veliko Blato and Rijeka Moraca, the length of which ranged from 45 cm to 55 cm.

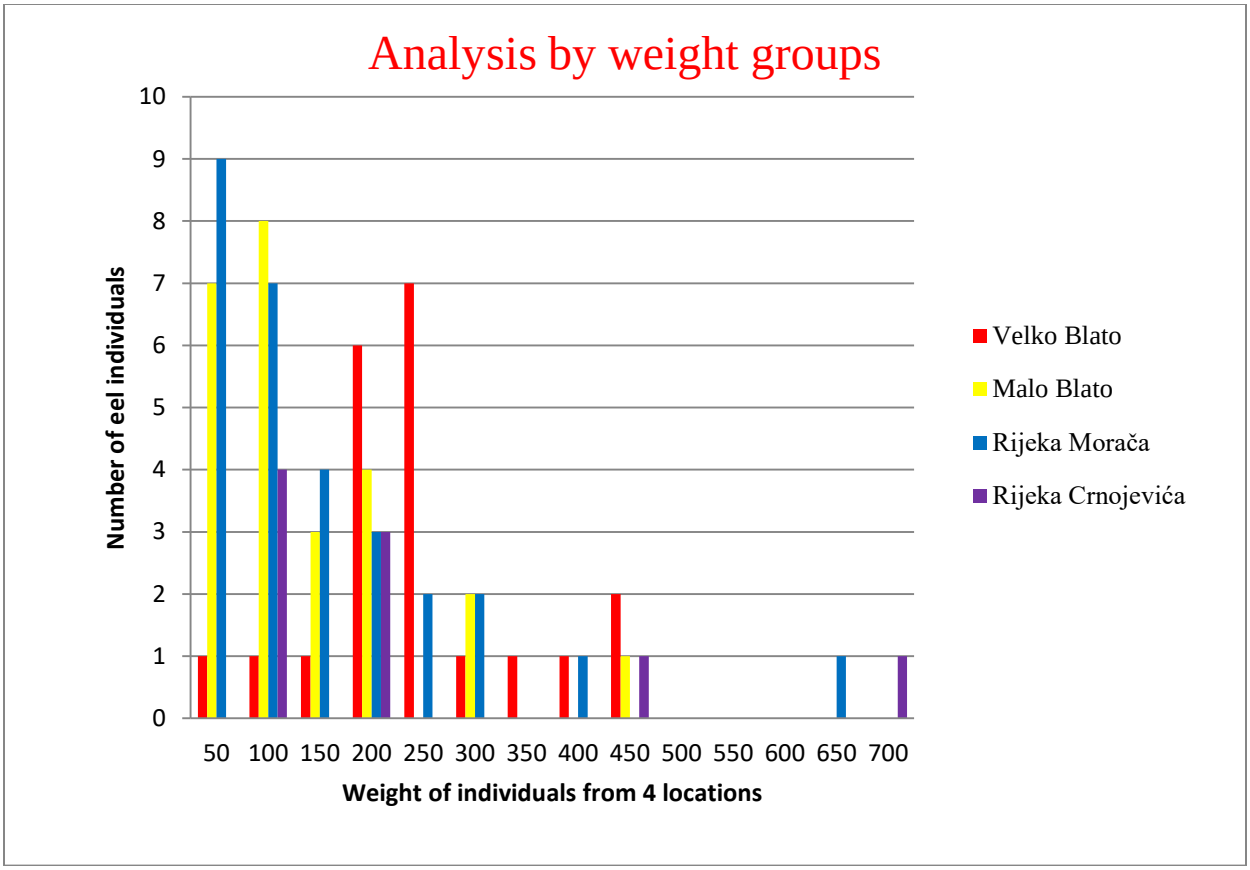

Figure 22. Graphical representation of individuals by weight

From the graph, we note that the individual with the lowest recorded body weight was captured at the site of Veliko Blato, and the largest individual is caught on the locality of Rijeka Crnojevića. The largest number of trapped individuals were from Rijeka Morača and Malo Blato, the weight of which ranged between 50 and 100g.

Considering that, depending on the country, the consumption size is considered to be an eel weight of more than 50g, we conclude that most of the caught eels on our terrains can be considered as consumable and that predominantly younger ones prevail.

5 CONCLUSION

- The variance of the coefficient b and K between the locality suggests that different sites reflect the different conditions in Skadar Lake

- Eels from the Morača River shows the least deviation from the ideal growth model, as well as the best conditioned condition

- Eels from Malo Blato site , they show the greatest deviation from the ideal growth model and poorer fitness condition, which accordingly have a worse condition factor

- Individuals of eels that are caught from the Skadar Lake region show an isometric growth model; in other words, during growth, they retain their usual form of the body, obtaining equally in length and mass.

- European eel is a critically endangered species on a global scale. Until thirty years ago, the Skadar Lake had a great number of the eel populations, but the present shows that the number is getting smaller, and its reduced number is primarily influenced by illegal fishermen, and given that it is a global species, the smaller number also is affected by dams, mini hydroelectric power plants, and an illegal catch of young glass eels for artificial breeding.

- Knowing the state of the population and the total biomass of eel in Skadar Lake is very desirable, and an even more important eel management plan is also part of Aquis communautarie, and the elaboration of such a plan is a prerequisite for EU accession

- The fish fund of the Skadar Lake should be used only in the manner and under the conditions prescribed by the Law on Freshwater Fisheries

- The biggest threat to the fish fund is the increasingly organized illegal fishing that make up 60% of total fishing, and in combination with corruption, it certainly brings species up to the limits of the bilogic minimum.

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