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POPULATION TREND OF THE INVASIVE BLUE CRAB CALLINECTES SAPIDUS RATHBUN,1896 IN PATOKU LAGOON.

KEY WORDS:

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ABSTRACT

The blue crab *Callinectes sapidus* is one of the 23 marine alien species reported for the Albanian coast so far (Beqiraj et al., 2012; Katsanevakis et al., 2011). The first scientific report on the presence of this species in the Albanian coast is in 2009, in Patoku Lagoon. The blue crab population in Patoku Lagoon had grown significantly by 2009 and the blue crab had started to be traded. The data collected in that year showed that this species is assessed to be established in the Patoku Lagoon (Beqiraj & Kashta, 2010). Special attention has been paid to the study of blue crab population in the following years during 2010 - 2015. The aim of this study is to evaluate the development and population trend of blue crab in the Patoku Lagoon referring to the data collected throughout years of study.

INTRODUCTION

Blue crab *Callinectes sapidus* Rathbun, 1896 is a species originating from the West Atlantic, which was introduced to the Mediterranean and first reported in 1949. It has been distributed as a highly aggressive and invasive species to almost the entire Mediterranean. Today it is considered as one of the worst invasive marine species in this region, with an impact on both biodiversity and socioeconomics. The first assessment of the blue crab spread along the Albanian coast was made during 2010 - 2011, based on both factual material and data collected directly on the site, as well as communications and contacts with local fishermen, published by Agolli et al., 2012.

According to these communications, although not scientifically proven, the earliest information about the presence of the blue crab in Albania belongs to the 1975 period, near the mouth of Erzeni river, while its presence has already been observed in most lagoons of Albania as in Vilun, Kune, Patok, Karavasta, Narta, Orikum, Butrint (Agolli et al., 2012), as well as in some mouths of other rivers: Buna, Mat, Ishem, Shkumbin and Bistrica (Milori et al., 2013).

Special attention has been paid to the study of the blue crab in the Patoku Lagoon, because from the initial moment of its appearance in this lagoon in 2006, the crab clearly showed its invasive character, spreading with great speed and high density. Based on the data collected in 2010 this species is considered to be established in the lagoon of Patok (Beqiraj & Kashta, 2010), since, in addition to its high presence, ovigerous females, as well as juvenile individuals were occasionally found.

Material and Method

Patoku Lagoon is situated on the northwest coast of Albania, in the southeastern part of the Adriatic Sea (41 ° 38'N: 19 ° 36'E), between the mouths of the Mat and Ishëm rivers. The average annual water temperature in the lagoon is 17.7 ° C, with a minimum of 6.8 ° C and a maximum of 28.6 ° C. The salinity values are reported from 15.7 to 39.1 psu (Beqiraj & Kashta, 2010). Patoku Lagoon was regularly visited from 2013 to 2015, on average twice a month. The periods of observations and collections of the blue crab in the lagoon was based on the literature on *Callinectes sapidus* in the Mediterranean, according to Cabal et al.., (2006), Florio et al., (2008), Galil et al., (2006), Gennaio et al., (2006); Onofri et al., (2008), Kirincic & Stevcic, (2008), Tuncer & Bilgin (2008). According to these references, the blue crab enters the lagoon in the period March - April and leaves the lagoon in the period October - November.

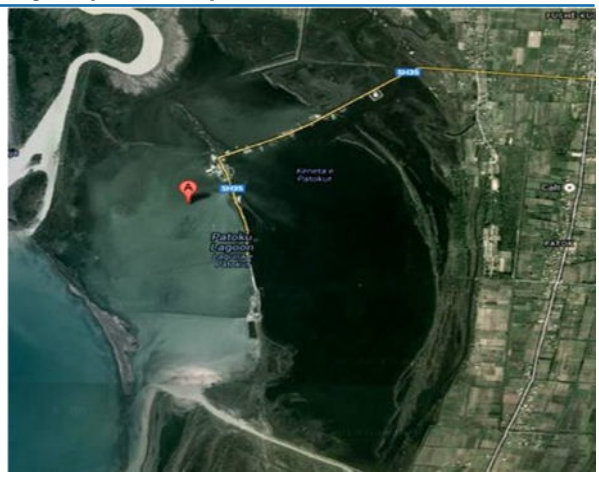

Figure1. Map of Patoku Lagoon

The blue crabs were collected as by-catch from gillnets, fyke nets and pins of local fishermen.

For everyone were assessed: sex (F / M) in order to evaluate the report between males and females (sex ratio), weight (g), carapace width (mm) and carapace length (mm) (figure 3), referring to the methods of Cadman & Weinstein, (1985); Florio et al., (2008). Carapace width and height have been measured, in order to evaluate crabs' age after Hines et. al (1990) and their maturity after Cadman and Weinstein (1985). All collected crabs have also been weighted and Spearman correlation has been evaluated to assess correlation between weight, width and height.

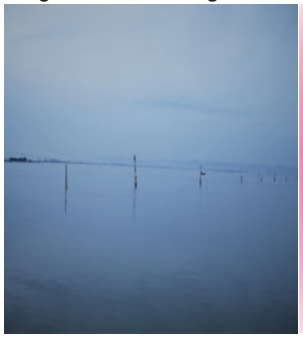

Figure 2. View from the central part of Patoku Lagoon

Figure 3. Measuring carapace width for parametric correlation analysis

Besides direct observation and collection in the studied area, questionnaires have also been distributed to the local fishermen to collect information about the presence of blue crab and its possible impact on the other populations in the Patoku Lagoon.

The data preprocessing and analysis are performed in IBM SPSS Statistics version 26.0 (IBM Corp. Released, 2019). The data is given as mean ± standard deviation unless otherwise stated. The exploration of the data is done through frequency tables and descriptive statistics. The outliers in the data are assessed by inspection of boxplots. The data for all continuous variables for each level of the factors were checked for normal distribution by Shapiro-Wilk's test ($p>0.05$). The homogeneity of variances is tested by Levene's test for equality of variances ($p>0.05$). A Mann-Whitney U test was run to determine if there were differences between two not normally distributed groups. A Kruskall Wallis test with pairwise comparisons is run to determine if there were differences between more than two not normally distributed groups. The Spearman correlation is used to see if there was a correlation between parameters not normally distributed.

RESULTS AND DISCUSSION

Compared to previous publication of this type in Adriatic Sea, as in Beqiraj & Kashta (2010), Beqiraj et al., (2012), Florio et al., (2008), Kirincic & Stevcic (2008), Onofri et al., (2008) the blue crab in Patoku Lagoon in the study years 2013-2015 was found in higher quantities. The population trend is always increasing in this lagoon, which can be confirmed by comparing the results given in the table 1, that show the data collected in four years of study. Referring to table 1 here below, 80 individuals were evaluated in 2010, and it's observed a slight decrease in the number of evaluated individuals in 2013 which was 66, 114 individuals were evaluated in 2014 and the number of individuals collected in 2015 has a significant increase with 459 individuals.

Table 1. Number of males and females of the blue crab collected in Patoku Lagoon

2010	**Sex**	**Total**
	Female	39
	Male	41
	Total	**80**
2013	Female	37
	Male	29
	Total	**66**
2014	Female	68
	Male	46
	Total	**114**
2015	Female	190
	Male	269
	Total	**459**

Therefore, we can say that the population trend is always increasing. This can be explained by the characteristics of the blue crab whose population can show changes in the peak level of the abundance each year but also the regime of entrances and exits to the lagoon conditioned by humans with the change of opening and closing of the wooden fences (locally named "dajlan"), where the change from the 15 days of their closure can also lead to changes in the number of individuals. The regime of migratory animals including the blue crab has been affected by humans. Fluctuations can also occur due to the influence of physical, chemical, and biological factors. This high and persistent presence, as well as the finding of egg-laying females and juvenile individuals, are indicators of the stability of the blue crab in the lagoon. Comparing years of study, the largest number of collected individuals belongs to the central part of the lagoon, where the accumulations are made from fishing nets (trammel nets). The lowest number of individuals was recorded in the parts of the lagoon opposite the canals of communication with the sea, where the collection of crabs was done from the eel-cages (fyke nets). The largest number of individuals are caught from June to November. The largest number of juveniles caught in the lagoon is in May and June, but there are also juveniles caught in September and November. Most of the individuals found in this lagoon could be considered as matured, if referring to classification after Cadman and Weinstein (1985), which stated that maturity is reached at carapace width of 120-170 mm. Five ovigerous females were found in June and July from 2013 until 2015. This situation is expected to happen based on the data of the literature, according to which (Hines et al., 1990), the laying of eggs in blue crabs takes place mainly during May-June and August-September. Closure of communication channels prevents the exit of ovigerous females to the sea but their finding in the lagoon confirms the fact that the release of eggs can be done in the lagoon, and pelagic larvae (zoea and megalopa) emerge in the sea, due to the small size of 0.25-1mm.

The report between males and females (sex ratio) F:M, as it is shown in the table 1, changed across the years, at the 2010 the report between males and females (sex ratio) (F:M) is 1:1, in the 2013 and 2014 the report between male and female (F:M) is was almost 0.4:0.6 and in the 2015 the report changes between male and female (F:M) in 0.6:0.4.

384 individuals out of the total of 719 caught individuals were males and if we evaluate the total number across the period of study, the report between males and females (sex ratio) (F:M) is 1:1.

Figure 3. Blue crab Callinectes sapidus from Patoku Lagoon: a) female dorsal view; b) male ventral view;

According to constant communication with local fishermen, Patoku Lagoon remains closed from late September to early March. This can have a direct impact on the bio-ecology of the blue crab, which, under natural lagoon conditions, migrates to the sea in late autumn or early winter (Hines et al., 1990). During this period, the blue crab in the lagoons can't leave to the sea, since the channels of communication with the sea are closed with wooden fences. However, based on this study, the fact that during winter, exactly in January and February, individuals of the blue crab were collected by the fishing dredges, in a drowsy state, confirms that the crabs hibernate into the sediment, where they stay in an inactive state until early spring. The hibernation of the blue crab in sediment is also mentioned in the literature (according to Hines et al., 1990).

This high and continuous presence, as well as the finding of ovigerous females and juvenile individuals, are indicators of the continuous stability of the blue crab which is confirmed for Patok Lagoon even by Beqiraj & Kashta (2010) and by Agolli et al., (2012).

Table 2. Descriptive statistics by year and sex

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Year	Sex		N	Minimum	Maximum	Mean	Std. Deviation
2010	Male	Height	41	35	82	65.17	14.770
		Width	41	78	188	147.63	35.403
		Weight	41	30	480	233.61	148.271
	Female	Height	39	35	73	60.85	11.139
		Width	39	75	179	146.44	29.843
		Weight	39	25	310	171.33	82.744

2013	Male	Height	29	70	105	85.76	7.204
		Width	29	144	245	176.62	20.496
		Weight	29	202	590	366.79	104.344
	Female	Height	37	41	90	78.41	9.087
		Width	37	50	193	163.30	23.014
		Weight	37	33	368	218.97	58.511
2014	Male	Height	46	50	100	78.04	9.619
		Width	46	114	225	174.00	20.951
		Weight	46	80	650	352.72	105.603
	Female	Height	68	42	92	67.76	8.730
		Width	68	95	190	161.18	20.297
		Weight	68	53	320	219.06	61.303
2015	Male	Height	269	18	97	67.04	15.849
		Width	269	34	202	143.16	38.538
		Weight	269	14	534	230.30	116.157
	Female	Height	190	29	90	65.46	13.456
		Width	190	51	188	143.75	33.757
		Weight	190	13	380	208.93	92.593

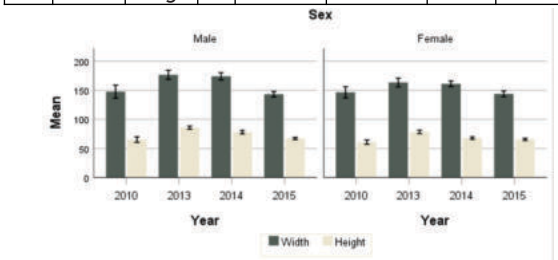

Figure 4. Mean of biometric parameters for males and females across years

The data for height, width and weight for all subgroups were not normally distributed, as assessed by Shapiro-Wilk's test ($p < 0.05$). A Kruskall Wallis test was run to determine if there were differences in height, width and weight between the four years in study. Distributions of the data were similar for all years, as assessed by visual inspection.

For males:

Medians of height for all years were statistically different, X^2 (3) = 87.64, p <0.0001. Multiple comparisons showed significant differences among all pairs (p<0.05), except for years 2010-2015, as we can see at the table 2 and figure 4.

Median of width for all years were statistically different, X^2 (3) = 40.15, p <0.0001. Multiple comparisons showed not significant differences only between years 2012 and 2015 and 2010-2014 (p>0.05), all the other pairs were statistically different referring to the table 2 and figure 4.

For females:

Median of height for all years were statistically different, X^2 (3) = 68.04, p <0.0001. Multiple comparisons showed significant differences for all pairs, except for 2014-2015, table 2 and figure 4.

Median of width for all years were statistically different, X^2 (3) = 20.06, p <0.0001. Multiple comparisons showed significant differences between year 2014 and 2015 (p=0.003), and 2013 with 2015 (p=0.012), table 2 and figure 4.

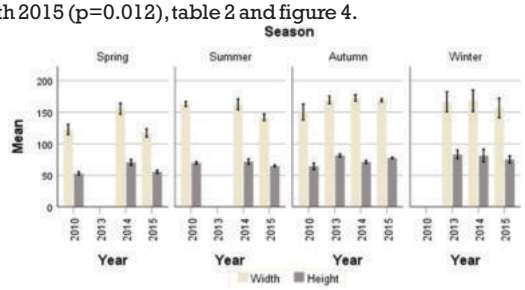

Figure 5. Mean of biometric parameters by seasons across years

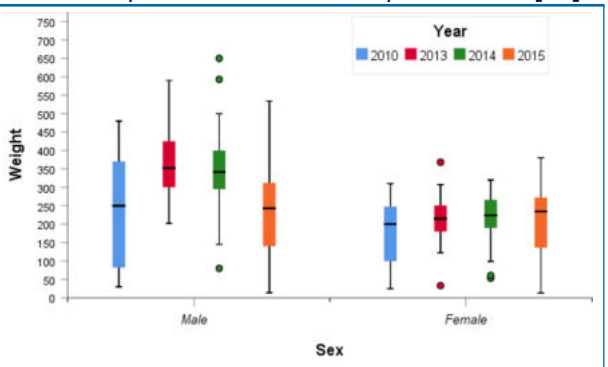

Figure 6. Mean of weight for males and females across years

For males:

Median of weight for all years were statistically different, X^2 (3) = 46.07, p <0.0001. Multiple comparisons showed not significant differences only between years 2010 - 2015 and 2010-2014 (p>0.05), all the other pairs were statistically different (p<0.05), figure 6.

For females:

Median of weight for all years were statistically different, X^2 (3) = 38.79, p <0.0001. Multiple comparisons showed significant differences between all pairs except for years 2010-2013, and 2013-2014 (p>0.05), figure 6.

Table 3. Correlations Matrix by years

Year				Height	Width	Weight
2010	Spearman's rho	Height	Correlation Coefficient		.940**	.957**
			Sig. (2-tailed)		.000	.000
			N		80	80
		Width	Correlation Coefficient	.940**		.947**
			Sig. (2-tailed)	.000		.000
			N	80		80
		Weight	Correlation Coefficient	.957**	.947**	
			Sig. (2-tailed)	.000	.000	
			N	80	80	
2013	Spearman's rho	Height	Correlation Coefficient		.738**	.702**
			Sig. (2-tailed)		.000	.000
			N		66	66
		Width	Correlation Coefficient	.738**		.743**
			Sig. (2-tailed)	.000		.000
			N	66		66
		Weight	Correlation Coefficient	.702**	.743**	
			Sig. (2-tailed)	.000	.000	
			N	66	66	
2014	Spearman's rho	Height	Correlation Coefficient		.691**	.812**
			Sig. (2-tailed)		.000	.000
			N		114	114
		Width	Correlation Coefficient	.691**		.766**
			Sig. (2-tailed)	.000		.000
			N	114		114
		Weight	Correlation Coefficient	.812**	.766**	
			Sig. (2-tailed)	.000	.000	
			N	114	114	

2015	Spearman's rho	Height	Correlation Coefficient		.864**	.855**
			Sig. (2-tailed)		.000	.000
			N		459	459
		Width	Correlation Coefficient	.864**		.906**
			Sig. (2-tailed)	.000		.000
			N	459		459
		Weight	Correlation Coefficient	.855**	.906**	
			Sig. (2-tailed)	.000	.000	
			N	459	459	
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed).						

For males:

Median of weight for all years were statistically different, X^2 (3) = 46.07, p <0.0001. Multiple comparisons showed not significant differences only between years 2010 - 2015 and 2010-2014 (p>0.05), all the other pairs were statistically different (p<0.05), figure 6.

For females:

Median of weight for all years were statistically different, X^2 (3) = 38.79, p <0.0001. Multiple comparisons showed significant differences between all pairs except for years 2010-2013, and 2013-2014 (p>0.05), figure 6.

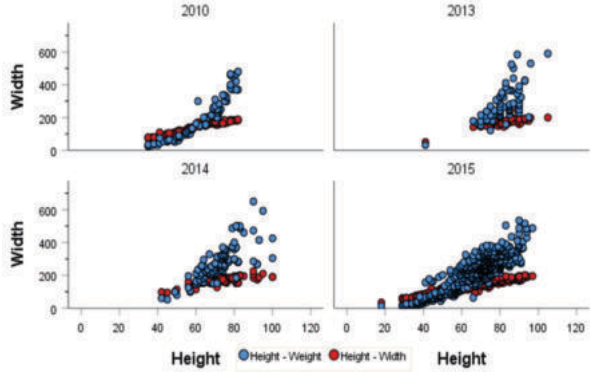

Figure 7. Correlation between parameters for each year.

According to the Table 3 and Figure 7, the evaluation of Spearman correlation shows a strong correlation (p<0.05) between all the biometric parameters for all years of study (see table above). This is an indication of a good development and adaptation of this species over the years in Patoku Lagoon.

Based on the classification system of Harding system (2003), blue crabs individuals were classified as juveniles (CW < 120 mm) and adults (CW > 120 mm) (see Table 4).

Table 4. Classification of individuals into juveniles and adults according to the Harding system (2003).

2010	Sex	Juveniles (CW<120 mm)	Adults (CW>120 mm)	Total
	Female	6	33	39
	Male	13	28	41
	Total	**19**	**61**	**80**
2013	Female	1	28	29
	Male	0	37	37
	Total	**1**	**65**	**66**
2014	Female	3	65	68
	Male	5	41	46
	Total	**8**	**106**	**114**
2015	Female	49	141	190
	Male	80	189	269
	Total	**129**	**330**	**459**

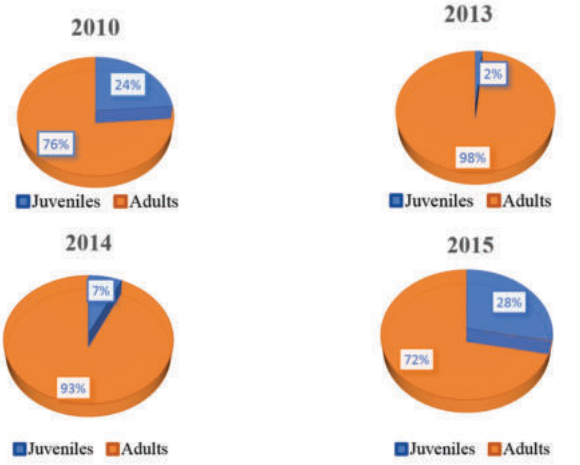

Figure 8. Ratio (in %) between juvenile and adult individuals of the blue crab in Patoku Lagoon collected in 2010, 2013 ,2014, 2015

Analyzed data shown in the figure 8 and the table 4 here above, indicates a different ratio of juveniles and adults in the years of study. The situation changes across the years where we can evaluate a different percentage of juvenile and adult individuals. According to the table 4, it is shown that in 2010 and 2015 the number of juvenile individuals is higher compared to other years. The continuous presence of juvenile individuals with a significant increase in 2015 indicates a high stability of the blue crab in the Patoku lagoon.

Based on carapace width, blue crabs have been classified in small individuals (CW < 80 mm), medium (CW 80 – 120 mm) and large (CW > 120 mm), referring to the classification system of according to Cadman & Weinstein (1985).

Table 5. Classification of individuals by size (based on the Cadman & Weinstein, 1985).

2010	Sex	Small individuals (CW<80m)	Average individuals (CW 80-120mm)	Large individuals (CW>120mm)	Total
	Female	2	4	33	39
	Male	2	11	28	41
	Total	**4**	**15**	**61**	**80**
2013					
	Female	1	0	28	29
	Male	0	0	37	37
	Total	**1**	**0**	**65**	**66**
2014					
	Female	0	3	65	68
	Male	0	5	41	46
	Total	**0**	**8**	**106**	**114**
2015					
	Female	13	37	140	190
	Male	19	62	188	269
	Total	**32**	**99**	**328**	**459**

Analyzed data, as it is shown in the Table 5 and Figure 9, indicates that large individuals predominated significantly each year. We can evaluate that the number of large individuals prevailed in all years where their largest number is in 2014 with 114 individuals and in 2015 with 328 individuals, which is also related to the large number of individuals collected during this year. The high presence of large individuals in the lagoon of Patok shows an increasing trend which leads to a good stability of their presence in this lagoon. The number of medium and small individuals shows an increasing trend from which we can see that in 2010 and 2015 their number is higher.

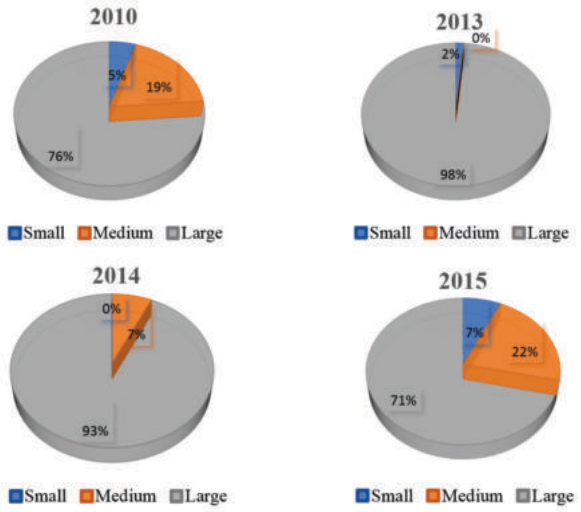

Figure 9. The percentage of individuals according to the size, small, medium and large for each year 2010, 2013, 2014, 2015.

Blue crabs' individuals were classified based on carapace width in up to 1 year (CW <100 mm), individuals between 1 and 2 years old (CW 100-170 mm), and individuals over 2 years (CW> 170 mm), according to Hines et al., 1990.

Table 6. Classification of individuals by age (based on the Hines et al. 1990).

	Sex	Up to 1 year (CW < 100 mm)	Between 1 and 2 year (CW 100 - 170 mm)	Over 2 year (CW > 170 mm)	Total
2010	Female	4	25	10	39
	Male	5	23	13	41
	Total	**9**	**48**	**23**	**80**
2013	Female	**1**	**12**	**16**	**29**
	Male	**0**	**22**	**15**	**37**
	Total	**1**	**34**	**31**	**66**
2014	Female	1	35	32	68
	Male	1	20	25	46
	Total	**2**	**55**	**57**	**114**
2015	Female	28	136	26	190
	Male	45	154	70	269
	Total	**73**	**290**	**96**	**459**

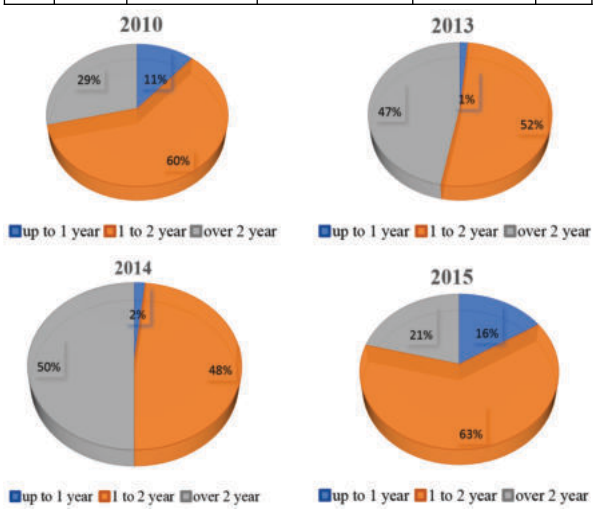

Figure 10. Ratio (in %) between individuals up to 1 year, 1-2 years and over 2 years of the blue crab in Patoku Lagoon collected in 2010, 2013, 2014, 2015.

From the comparison of individuals according to their age referring to the table 6 and figure 10, it can be noticed a change in the percentage and number of blue crabs where we can understand that the largest number of individuals belong between 1 and 2 years, respectively in 2010 with 48 individuals, in 2014 with 55 individuals, and in 2015 with 290 individuals. This increasing trend continues for individuals over 2 years old, where (as shown from the table 6) their number is increasing from 23 individuals in 2010, with 31 individuals in 2013, with 57 individuals in 2014, and 96 individuals in 2015. This growing trend of individuals over 2 years old confirms the growth and stability of the population of blue crab in Patoku Lagoon.

Referring to questionnaires distributed to local fishermen in Patoku area, the blue crab has already impacted populations of native species in the Patoku Lagoon, especially other crabs, like the decapod crab *Carcinus aestuarii* (Nardo, 1847 (the Mediterranean green crab). This decapod has been the most abundant crab in all Albanian lagoons and after blue crab introduction especially in Patoku Lagoon there has been a decline in the population of this decapod. The presence of the blue crab in Patoku Lagoon is already becoming a concern for socio-economic impact to local fishermen community.

CONCLUSIONS

The density of the blue crab population in Patoku lagoon shows an ever-increasing trend with a high number of individuals analyzed. This increasing number of collected individuals is also due to the change of the entry-exit regime of the blue crab in the lagoon, which is conditioned by the fishermen who change the opening and closing of the lagoon communication channels with the sea.

Parameters of height, width, and weight correlated very well with each other throughout the years showing a good development and adaptation of blue crab in Patoku Lagoon.

The blue crab can hibernate in lagoon of Patok in sediment, which was confirmed by the collected individuals inside the lagoon in January and February in a drowsy state.

The ever-increasing density of the number of blue crab individuals, the predominance of adult individuals, the growing trend of individuals over 2 years old, the continued capture of ovigerous females within the lagoon, are data that shows that blue crab population has increased and well developed in Patoku Lagoon. Taking into account these data we can say that Patoku Lagoon is a very good habitat for the development and settlemnet of blue crab population.

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