

Comparison between IMTA and monoculture farming of mussels (*Mytilus galloprovincialis* L.) in the Boka Kotorska Bay

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*This paper presents the results of growth rate and condition index analysis of *Mytilus galloprovincialis* in integrated system and monoculture. The aim of this study was to show if there are differences in growth and condition index of mussels between integrated multi-trophic aquaculture (IMTA) and monoculture farming. The growth rate and condition index were monitored during a 13-month study at three different sites: 1) close to fish cages (NBL), 2) 100 m removed from fish cages (NUD), 3) at a monoculture mussel farm (SVN) around 8 km far away from cages. The most intense growth of mussels was recorded in spring, and the least intense in summer. After 13 months, monitored individuals at all three locations achieved commercial size. The growth rate was very similar at all sites. The condition index showed spatial and temporal differences. Condition index values on site NUD were mostly higher compared to SVN and NBL, which were very similar, except for the period from October to December when CI was similar on NBL and NUD site and higher in comparison with SVN. CI values on NBL and NUD site during cold period indicate on fact that mussels probably feed on the nutrients from fish farm origins. The highest mortality rate was recorded at the NBL site, probably due to the effects of fouling organisms.*

Key words: *Mytilus galloprovincialis*, integrated multi-trophic aquaculture (IMTA), monoculture, Boka Kotorska Bay

INTRODUCTION

Marine aquaculture or mariculture is a very important fish, crustacean, mollusc and algae production sector, which has the possibility to replace the reduced potential of natural resources (FAO, 2010). Nowadays, terms such as “integrated” and “multi-trophic” are increasingly used in relation to the concept of mariculture and aquaculture in general (CHOPIN & ROBINSON, 2004). Integrated multi-trophic aquaculture

(IMTA) can be defined as the form of aquaculture where unconsumed fish food and fish metabolic products, which otherwise would have negative impact on the environment, can be used as a food source in another subsystem, leading to the increased productivity of the entire system under the complete control of the farmers (FAO, 2009; TROELL *et al.*, 2009; CHÁVEZ-CROOKER & OBREQUE-CONTRERAS, 2010). According to FAO (2004), one of the main goals of the aquaculture industry in the near future would be to minimize

negative impacts on the environment in order to achieve long-term viability. IMTA can be a good mechanism for achieving this goal, while also achieving another benefit — the increased economical productivity of the entire system (SARÀ *et al.*, 2009; RENDMOND *et al.*, 2010; SARÀ *et al.* 2011; ŽUPAN 2012; MACDONALD *et al.*, 2013; HOLDT & EDWARDS, 2014; AL-HAFEDH *et al.*, 2014; RATCLIFF *et al.*, 2015).

Integrated multi-trophic farming systems of various marine organisms are known worldwide (FAO, 2009; ABREU *et al.*, 2009; NAVARRETE-MIER *et al.*, 2010; REID *et al.*, 2010; HUGHES & KELLY, 2011; HANDÁ *et al.*, 2012; LANDER *et al.*, 2012; IRISARRI *et al.*, 2014a). The possibility of implementation of the integrated multi-trophic farming in the Mediterranean was well studied in the last ten years (PEHARDA *et al.*, 2007; NAVARRETE-MIER *et al.*, 2010; SARÀ *et al.*, 2011; ŽUPAN, 2012; ŽUPAN *et al.*, 2012; ŽUPAN *et al.*, 2013; ŽUPAN *et al.*, 2014; ISARRI *et al.*, 2014a). Bivalves are known as filter feeders and they could potentially remove organic matter as well as uneaten fish food from water (RENDMOND *et al.*, 2010). According to SARÀ *et al.* (2009) and MAZZOLA & SARÀ (2001) this process can reduce negative impact on environment. Some studies have shown that the farming period for achieving market size in integrated farming of mussels (*Mytilus galloprovincialis*) and fish is similar to that in commercial monoculture (PEHARDA *et al.*, 2007). On the other hand, SARÀ *et al.* (2011) demonstrated higher growth rate of mussels (*M. galloprovincialis*) and the European flat oyster (*Ostrea edulis*) found close to fish farms compared to those found at the open sea. Higher condition index values of Noah's Ark shell (*Arca noae*) near fish farm, and the nearly identical periods for achieving market size of mussels (*M. galloprovincialis*) in integrated farming and monoculture have been proven by ŽUPAN (2012).

Mediterranean mussel, *M. galloprovincialis* Lamarck 1819, is a widely distributed species, autochthonous to the Mediterranean (GISD, 2016). The mussel lives in colonies in the tidal zone, fastened to the substrate by byssal threads. It feeds on phytoplankton, bacteria, zooplankton and detritus (DAVENPORT *et al.*, 2000; PRATO *et al.*, 2010). Genders are separated, and the spawning occurs mostly in spring and autumn. The mussels

are considered to be of market size when they are at least 5 cm in length (OFFICIAL GAZETTE OF MONTENEGRO, 8/2011; 56/2009, 47/2015).

The mussel farming tradition in the Boka Kotorska Bay area started about thirty years ago, although the first experiments regarding mussel and oyster farming begun in the 1960's (STJEPČEVIĆ, 1968). Today, there are 20 mussel farms in the Bay, all using floating park systems (long-lines). Gilthead sea bream (*Sparus aurata* Linnaeus, 1758) and European sea bass (*Dicentrarchus labrax* Linnaeus 1758) farming in the area started in the late nineties, and currently there are two farms (Orahovac and Stoliv) using the floating cage system farming method. The integrated farming of mussels and fish is used on both farms. In 2014, the mariculture production amounted to 45 t of sea bass, 38 t of sea bream, and 178 t of mussels (MONSTAT, 2015).

The main goal of this study was to obtain some data on IMTA farming, due to fact that this kind of farming has not been sufficiently studied in neither the Adriatic nor in the Mediterranean.

MATERIAL AND METHODS

Study area

The study was conducted on two locations in the Boka Kotorska Bay, Montenegro (South Adriatic) (Fig. 1). One location was the fish and mussel farm "COGImar" in the settlement of Orahovac, Kotor municipality, 42° 29' 07.79" N, 18° 44' 42.47" E. The second location was Sveta Nedelja mussel farm in the Kamenari settlement, municipality of Herceg Novi, 42° 27' 30.89" N, 18° 40' 21.42" E. The straight-line distance between the two study locations is 8 km. The COGImar farm farms Gilthead sea bream, European sea bass, Mediterranean mussel and European flat oyster in polyculture. On the COGImar localtion two sites were chosen for the experimental part of the study: the mussel long-line closest to the floating fish cages (NBL), which was 10 m removed from the cages, and the mussel long-line furthest from the fish cages (about 100 m removed) (NUD). Sveta

Nedelja farm is a monoculture bivalve farm which produces Mediterranean mussel as well as the European flat oyster, and therefore only one site was selected (SVN).

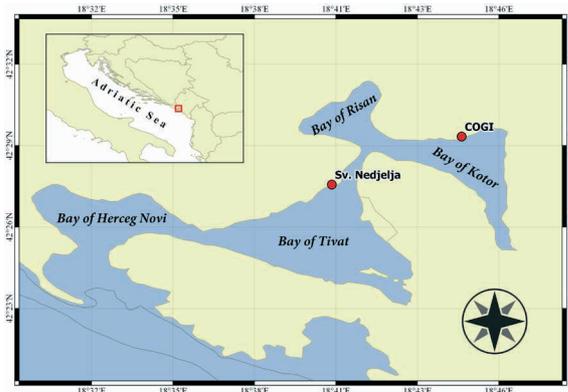


Fig. 1. Map showing the locations of sampling sites (NBL and NUD at COGI, SVN at Sv. Nedelja)

Experimental design

The growth experiment was set during a 13-month period, from January 2015 until January 2016. In January 2015, mussels of approximately the same size (mean length 4.27 ± 0.4 cm) and age (around 8-10 months) were taken from the experimental farm at the Institute of Marine Biology, University of Montenegro, in Kotor. Mussels were cleaned of fouling organisms the same day, and shell lengths, widths and heights were measured using vernier caliper to the nearest 0.1 mm. Individual mussels were marked using improvised tags. The tags were made from kitchen plastic waterproof mats (WelkHOME, Italy). The mats were cut to rectangles, approx. 12×5 mm in size, and markings etched on the surface using scalpel and soldering iron, with the markings visibility improved using waterproof felt-tip marker. Numbered tags were bonded to mussel shells with two-component waterproof adhesive (ABRO EPOXY STEEL, U.S.A.). During the marking process, duration of air exposure was around 2-3 minutes, until the adhesive hardened. Marked and measured mussels were placed in plastic baskets ($48 \times 29 \times 5$ cm, with 2 cm stretched mesh size) and suspended in water at depths between 2 and 3 m. At the COGI location, 110 individuals were placed together

on a farming line closest to the fish cages (NBL), and another 110 individuals on a farming line furthest from the fish cages (NUD). At the Sveta Nedelja location, 112 individuals were set together on a farming line (SVN). The mussels were checked every other month, removed from water, measured (length, width, height), cleaned from fouling organisms and resuspended in water.

Temperature and salinity on both localities were recorded monthly using the Multiline P4 WTW probe.

For condition index estimation, a total of 1,560 individual mussels of similar size and age (around 8-10 months) were taken from the experimental farm at the Institute of Marine Biology. Mussels were placed in nylon mesh nets (2-3 cm stretched mesh size). Fourty individual mussels were put in each net, with 13 nets per site (i.e. 39 nets in total). Nets were placed on NBL, NUD and SVN sites at depths between 2 and 3 m. Once per month, one net from each site was taken. From each net 30 individual mussels were taken and processed in the laboratory the same day. The condition index was determined as the ratio between wet mass of meat (WMM) and total weight (TW), according to ALMEIDA *et al.* (1999).

Statistical analyses

Growth ratios were tested using repeated-measures two-way ANOVA with Tukey post-hoc test. Parameters of von Bertalanffy's growth equation ($L_t = L_\infty [1 - e^{-k(t-t_0)}]$) were estimated with analysis of growth increment data using Munro's method in the FISAT II v.1.2.2 statistical package (GAYANILO *et al.*, 2005).

The condition index samples were tested for normality of distribution of differences between each observation and the mean of its group using Kolmogorov-Smirnov test with Lilliefors significance correction.

The homogeneity of variance was tested using Fligner-Killeen test for samples that did not follow normal distribution, and with Bartlett test for those that did. Homoscedastic samples were then tested using one-way ANOVA, with

Tukey HSD (Honestly Significant Difference) used as a *post hoc* test. Heteroscedastic samples were analysed using Kruskal-Wallis rank sum test, with Dunn's test as a *post hoc* test.

RESULTS

Temperature and salinity

Minimum and maximum temperatures at the COGImar location ranged between 11.6°C in February 2015 and 27.9°C in July 2015. Temperature on the Sveta Nedelja location ranged between 10.5°C in January 2016, and 26.5°C in August 2015 (Fig. 2A). Salinity on the COGImar location was between the minimal value of 13.8‰ in February 2015, and the maximum value of 35.2‰ in December 2015. On the Sveta Nedelja location, the minimum salinity value of 19.8‰ was recorded in February 2015, and the maximum values of 37.1‰ in December 2015 (Fig. 2B).

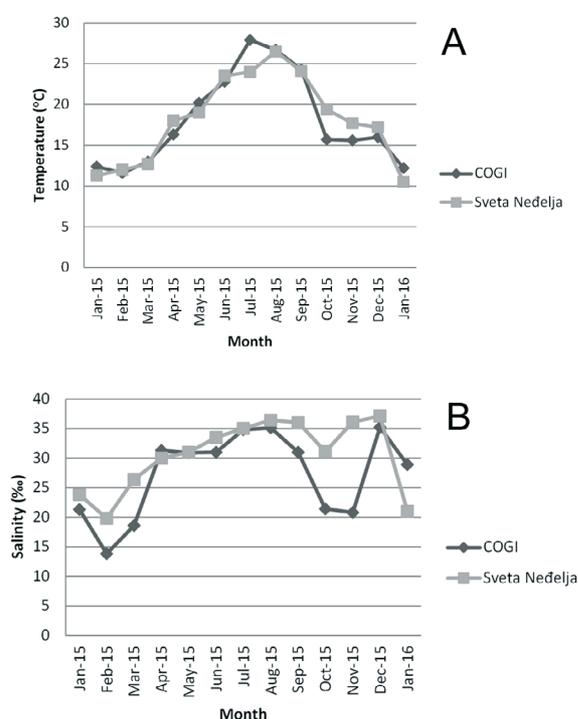


Fig. 2. Monthly temperature (A) and salinity (B) values on both localities (COGI and Sv. Nedelja)

Survival, mortality and growth rate

Table 1 shows number of dead individuals at each site for each measuring period. The highest mortality was observed during the first two measuring periods (Jan 15 - May 15) on all three sites.

The mean mussel length increase during the study period is given in Table 2. At all sites, all surviving individuals reached the prescribed market size (5 cm in length, as defined in the OFFICIAL GAZETTE OF MONTENEGRO (8/2011; 56/2009, 47/2015)) after 13 months. At the start of the experiment, the mussels were estimated to be around 8-10 months old. At the SVN site, all surviving individuals reached market size after only 8 months, which could indicate production cycle of around 16-18 months in monoculture conditions. After the same period at site NUD 81% of survived individuals reached market size, and on site NBL 76% of survived individuals reached market size for the same period.

Growth rate analysis (length, width, height) showed a statistically significant difference in both sampling period and sampling location (Table 3 - 5; Fig. 3). The growth in length was slowest during summer period (July-September), and the most rapid in spring (Mart-May) at all sites. The same results were obtained for growth in width and height. During all periods, mussels from the SVN and NUD sites showed similar growth in length, width and height, which was significantly higher compared to the NBL site.

Table 6 shows that the estimated growth rate parameters were highest for mussels from the SVN site ($L_{\infty} = 69.18$ mm, $k = 1.95$ year⁻¹), and lowest for the NBL site ($L_{\infty} = 62.52$ mm, $k = 1.709$ year⁻¹). On the NUD site estimated asymptotic length was $L_{\infty} = 65.27$ mm, with $k = 2.079$ year⁻¹.

Condition index

The highest values (34.47) of the condition index (CI) were recorded at the NUD site in May 2015, while the lowest values (19.28) were on the NBL site in September 2015. On all three sites, the lowest values of CI were in September

Table 1. Number of dead individuals at each site for each measuring period

Position	NBL	NUD	SVN
Jan'15-Mar'15	4	15	19
Mar'15-May'15	25	13	4
May'15-Jul'15	4	4	5
Jul'15-Sep'15	9	3	7
Sep'15-Nov'15	2	2	2
Nov'15-Jan'16	0	1	2

Table 2. The mean mussel length on the beginning and after 13 months

Position	NBL	NUD	SVN
Jan'15	4.38±0.39 cm	4.20±0.45 cm	4.23±0.35 cm
Jan'16	5.97±0.47 cm	6.37±0.56 cm	6.57±0.54 cm

Table 3. Analysis of growth increments for length using repeated-measures ANOVA with Tukey post hoc comparison

Factor	d.f.	F	P	Post hoc comparison
Period	5	179.63	<0.001	4 < 3 < 6 < 5 = 1 < 2
Site	2	36.32	<0.001	NBL < NUD = SVN
Interaction	10	5.34	<0.001	
Error	1248			

1 = Jan-Mar, 2 = Mar-May, 3 = May-Jul, 4 = Jul-Sep, 5 = Sep-Nov, 6 = Nov-Jan '16

Table 4. Analysis of growth increments for width using repeated-measures ANOVA with Tukey post hoc comparison

Factor	d.f.	F	P	Post hoc comparison
Period	5	138.87	<0.001	4 < 3 = 6 = 5 < 1 < 2
Site	2	36.55	<0.001	NBL < NUD = SVN
Interaction	10	10.16	<0.001	
Error	1248			

1 = Jan-Mar, 2 = Mar-May, 3 = May-Jul, 4 = Jul-Sep, 5 = Sep-Nov, 6 = Nov-Jan '16

Table 5. Analysis of growth increment for height using repeated-measures ANOVA with Tukey post hoc comparison

Factor	d.f.	F	P	Post hoc comparison
Period	5	91.91	<0.001	4 < 3 < 6 < 5 = 1 < 2
Site	2	32.18	<0.001	NBL < NUD = SVN
Interaction	10	8.27	<0.001	
Error	1248			

1 = Jan-Mar, 2 = Mar-May, 3 = May-Jul, 4 = Jul-Sep, 5 = Sep-Nov, 6 = Nov-Jan '16

Table 6. Growth parameters for mussels per sampling site

	SVN	NUD	NBL
L_{∞} (mm)	69.18	65.27	62.52
k (year ⁻¹)	1.95	2.079	1.709

Table 7. Analysis of condition index according to site and month

Year	Month	ANOVA/KW	Post hoc comparison
2015	January	F = 1.744 ^{NS}	—
	February	H = 4.267 ^{NS}	—
	March	F = 13.99***	NUD=NBL, SVN>NBL, SVN>NUD
	April	F = 17.22***	NUD>NBL, SVN=NBL, NUD>SVN
	May	F = 21.39***	NUD>NBL, SVN=NBL, NUD>SVN
	June	F = 5.439**	NUD=NBL, SVN=NBL, SVN<NUD
	July	F = 11.99***	NUD>NBL, SVN=NBL, NUD>SVN
	August	F = 4.224*	NUD=NBL, SVN=NBL, NUD>SVN
	September	H = 2.3446 ^{NS}	—
	October	F = 13.8***	NUD=NBL, NBL>SVN, NUD>SVN
	November	F = 20.74***	NUD=NBL, NBL>SVN, NUD>SVN
	December	F = 31.65***	NUD=NBL, NBL>SVN, NUD>SVN
2016	January	F = 5.235**	NUD=NBL, NBL=SVN, NUD>SVN

* <0.05; ** < 0.01; *** <0.001; ^{NS} – not statistically significant

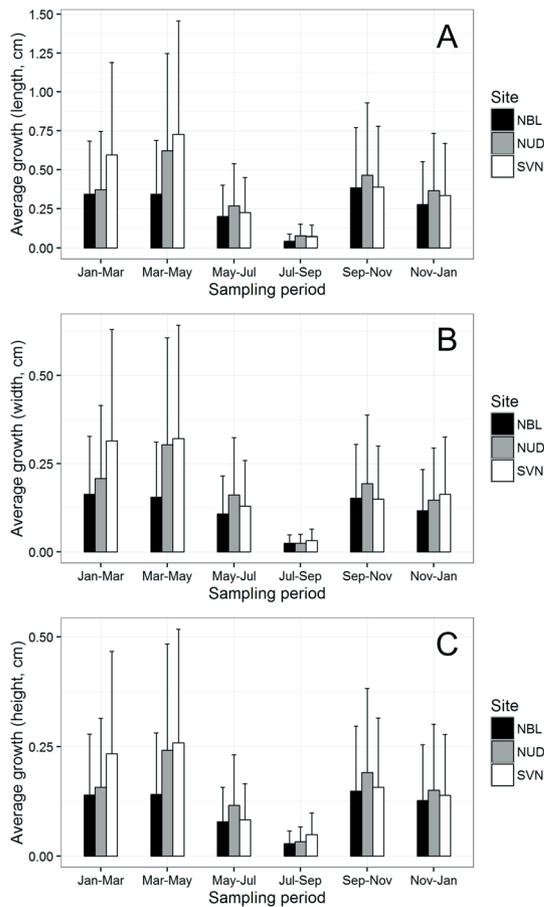


Fig. 3. Average growth increments and standard deviations for length (A), width (B), and height (C) according to sampling period and location

2015 (19.28 NBL; 21.18 NUD; 19.35 SVN). During the entire monitoring period the mean values of CI were higher on the NUD site compared to the other two sites (Fig. 4), except for February and March 2015. The analysis of condition index according to site and month is given in Table 7 and shows that there was no statistically significant difference in CIs at different sites during January, February and September 2015. From April until August 2015, as well as in January 2016, the CIs at the NBL and SVN sites were similar, while in the period from October to December the individuals from the NBL site had CI values which were statistically significantly higher than the CI values of individuals from the SVN site.

DISCUSSION

The results of this study revealed statistically significant difference between sampling period and sampling location in both growth and condition index of mussels.

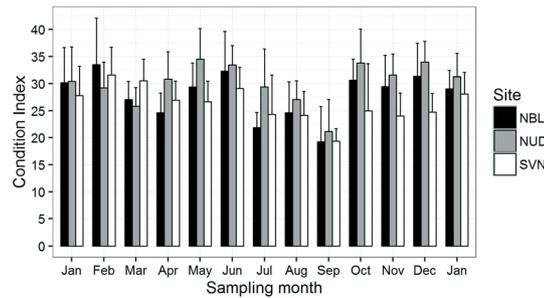


Fig. 4. Average monthly condition index and standard deviations according to month and sampling site

The obtained results indicate that growth in length, width and height at all three sampling sites was most intense in spring, and least intense in summer. These results agree with PEHARDA *et al.* (2007), who found the highest growth rates of mussels in period from March to May, which could indicate that the highest growth during the spring period can be the result of increased food availability. On the other hand, results of this study partly agree with results reported by IRISARRI *et al.* (2014a), who found maximum growth in mussels during both spring and summer period. According to VAN ERKOM SCHURINK & GRIFFITHS (1992) as well as ŽUPAN & ŠARIĆ (2014), highest availability of food is at temperatures between 10°C and 20°C, when the recorded mussel growth is most intense, while the growth slows at temperatures above 20°C. Temperatures in the 10-20°C range are typical for the Adriatic in spring, with temperatures above 20°C typical for summer (AZCÁRATE *et al.*, 2005), which can help explain the results obtained.

Salinity has an indirect influence on growth, with lower salinity having a positive influence, but through the fact that areas with higher influx of freshwater (and thus lower salinity) have increased amount of nutrients (ŽUPAN & ŠARIĆ, 2014). Salinity values at the COGMar location were significantly lower during winter

and spring seasons, compared to Sveta Nedelja (Fig. 3). The NUD site, which is about 100 m removed from fish cages, is under a significant influence of underwater freshwater sources, as well as the freshwater influx from the land (BELLAFIORE *et al.*, 2011), and the higher growth rates (in length, weight and height) at this site could be attributed, at least partially, to the increased amount of freshwater.

High growth rates in length, weight and height, which were recorded at the SVN site, similar to NUD, can be connected to the strong water currents in the Verige strait (>20 cm/s) (BELLAFIORE *et al.*, 2011). The Sveta Nedelja mussel farm is located just off the mouth of the strait. KARAYÜCEL & KARAYÜCEL (2000) report higher growth rate of *Mytilus edulis* individuals exposed to water current influence, as stronger currents carry more nutrients. BAJNOCI (2014) found that mussels which were placed on the farthest point from fish cages had the highest growth rates in length, weight and height compared to those which were placed close to fish cages, but the differences were not statistically significant. NAVARRETE-MIER *et al.* (2010) also did not report significant differences in shell length growth of mussels on six different distances from fish cages. Results from IRISARRI *et al.* (2014a) showed similar shell length between mussels close to the fish farm and mussels distant from the fish farm.

Lower growth rates at the NBL site compared to SVN and NUD site could be affected by the large amount of fouling organisms detected during the entire year on this site. STJEPČEVIĆ (1974) reports that a large amount of fouling organisms "suffocates" the mussels, which stalls their growth, and can also cause increased mortality. Dominant fouling organism on NBL site was the White sea squirt (*Phallusia mammilata*, Cuvier 1815). Other fouling organism which were noted are: *Botryllus* spp., *Balanus* spp., European fan worm (*Sabella spallanzani*, Gmelin 1791), Keel worm (*Pomatoceros triqueter*, Linnaeus 1758) and Bryozoa (*Schizobrachiella sanguine*, Norman 1868). All of those organisms were also recorded on the other two localities,

but in different abundances. On the SVN site Keel worm was more abundant than any other organisms, as well as the European fan worm, while on NBL and NUD site White sea squirt was the dominant organism. Also, on the NBL and NUD sites the green algae *Chaetomorpha* spp. and *Cladophora* spp. were abundant, especially during spring months. These differences in fouling can be explained by the differences in sea currents at different localities.

The highest mortality in our study was recorded during the first two measurement periods on all three sites, which can be explained by stress and adaptation of individuals to the new conditions (ŽUPAN, 2012). On the other hand, higher mortality at the NBL site during the entire monitoring period could be explained by an increased presence of fouling organisms due to the proximity of fish cages.

It is known that condition index is an important parameter indicating the quality of shellfish (ŽUPAN & ŠARIĆ, 2014). The results of this study indicate that location did consistently influence the CI of mussels, with individuals 100 m removed from fish cages (NUD) showing higher CI values for the major part of the study compared to individuals at the other two sites (NBL, SVN), which were quite similar among themselves, except for the colder period (October-December) when sites NBL and NUD were similar and had higher CI values. These results can indicate the fact that in colder months, when primary production is lower and there is little food available in water, mussels feed on the nutrients originating from fish farms. The benefits on mussels feeding on fish farm effluents were noted by MACDONALD *et al.* (2011).

This study's results regarding the CI are in accordance with those reported by SARÁ *et al.* (2009), LANDER *et al.* (2012) and ŽUPAN *et al.* (2014), who found a positive correlation between CI values in bivalves and their proximity to fish farms. IRISARRI *et al.* (2014b) found significantly higher CI in IMTA mussels than in monoculture individuals. On the other hand, the results of this study are not consistent with the results of TAYLOR *et al.* (1992) and CHESHUK *et al.* (2003),

who showed that there is no influence of salmon farming on CI of *M. edulis* and *M. planulatus*. IRISARRI *et al.* (2014a) has not found differences in CI values among mussels close to the fish farm and those distant from the fish farm. Also, NAVARRETE-MIER *et al.* (2010) did not report significant differences in dry weight of mussels farmed on six different distances from fish cages.

The results of this study also showed the lowest CI values during September 2015 at all three sites. This can be explained by the common spawning period of the mussel, which reaches its peak during spring and autumn (DARDIGNAC-CORBEL, 1990). However, even if the bibliographical data refer to spring spawning closely following the drop in CI values (MASON, 1976; OKUMUŞ & STIRLING, 1998; PEHARDA *et al.*, 2007), this was not recorded in this study. Rather, the CI values were relatively high at all three sampling sites. According to HRS-BRENKO (1980), water temperatures above 16°C have a significant effect on the reduction of sexual activity of mussels. It is important to mention that method for CI calculation in this study was based on “wet” method (ALMEIDA *et al.* 1999), while calculation of CI in most other studies was based on dried or cooked meat (FREEMAN, 1974; DAVENPORT & CHEN, 1987).

CONCLUSIONS

This study analysed the growth rate and condition index of *M. galloprovincialis* in integrated system and monoculture. The growth rate and condition index were monitored during a 13-month study at three different sites: 1) close to the fish cages (NBL), 2) 100 m far from fish cages (NUD), and 3) at a monoculture mussel farm (SVN). Significant differences in growth rate and condition index according to sampling period and location were found. The results

showed a similar production cycle in monoculture and integrated multi-trophic systems. The highest mortality rate was recorded at the NBL site. The results of the study refer to the minimum market size of mussels in Montenegro (5 cm shell length) (OFFICIAL GAZETTE OF MONTENEGRO, 8/2011; 56/2009, 47/2015). As such, the results of the study might not be directly applicable to areas with different minimum market sizes e.g. in Croatia, where mussel minimum market size is 6 cm (OFFICIAL GAZETTE OF THE REPUBLIC OF CROATIA, 63/10, 68/10, 145/10, 18/12, 29/12), although they should be considered indicative. CI results indicate the possibility that mussels feed on the nutrients from fish farm during periods when little food would naturally be available in water.

It is known that, besides temperature and salinity, the other important factors influencing growth in mussels are the availability of food, water current direction and population density (GOSLING, 1992), and that food availability and changes in the reproduction phases are the most important factors in CI variations (GOSLING, 1992), the obtained results suggest that a much more detailed study, which would include abiotic and biotic parameters on all sampling locations, should be performed in order to get more relevant results.

ACKNOWLEDGMENTS

This study was been supported by the Ministry of Science of Montenegro and the HERIC project through the BIO-ICT Centre of Excellence (Contract No. 01-1001), and also by the Ministry of rural development and agriculture – Monitoring of water quality at mussel and fish farms for the period 2014-2015, financed through the Agro-budget.

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Received: 30 January 2017

Accepted: 27 July 2017

Usporedba između IMTA i uzgoja dagnje u monokulturi (*Mytilus galloprovincialis* L.) u Bokotorskom zaljevu

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SAŽETAK

Cilj ovog istraživanja bio je pokazati postojanja mogućih razlika u rastu i kondicijskom indeksu dagnji (*Mytilus galloprovincialis*) u integralnom multi-trofičkom uzgoju i uzgoju u monokulturi. Rast i kondicijski indeks praćeni su tijekom razdoblja od 13 mjeseci na tri postaje: 1) u blizini uzgajališta ribe (NBL), 2) 100 m od uzgajališta ribe (NUD), 3) u monokulturi (SVN) na uzgajalištu koje je oko 8 km udaljeno od kaveza sa ribom. Najintenzivniji rast zabilježen je tijekom proljetnog razdoblja, a najmanje intenzivan tijekom ljetnog. Nakon 13 mjeseci, praćene jedinice su na sve tri pozicije dostigle komercijalnu dužinu. Stopa rasta je bila slična na sve tri pozicije, dok je kondicijski indeks pokazao prostorne i vremenske razlike. Vrijednosti kondicionog indeksa na postaji NUD bile su više od vrijednosti na postajama SVN i NBL, koje su međusobno bile prilično slične, osim u razdoblju od listopada do prosinca kada su vrijednosti kondicijskog indeksa bile slične na postajama NBL i NUD, a veće u usporedbi sa vrijednostima na postaji SVN poziciji. Vrijednosti kondicionog indeksa na postajama NBL i NUD tijekom hladnog perioda godine ukazuju na to da se dagnje vjerovatno hrane nutrijentima porijeklom sa uzgajališta riba. Visoki mortalitet zabilježen je na postaji NBL, najvjerojatnije zbog obraštajnih organizama.

Ključne riječi: *Mytilus galloprovincialis*, integralna multi-trofička akvakultura, monokultura, Bokotorski zaljev