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Age, Growth and Condition Index of *Venerupis decussata* (Linnaeus, 1758) in the Eastern Adriatic Sea

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Abstract

Age, growth and condition index of commercially important chequered carpet shell *Venerupis decussata* (Linnaeus, 1758) were studied in the Pag Bay - eastern Adriatic Sea. Monthly samples were collected from commercial catch from January to November 2007. Age and growth were determined from internal growth bands of 69 shells ranging in length from 17.7 to 43.5 mm. Marginal increment analysis performed on 68 shells (26.4±3.4 mm) confirmed that growth bands are annually formed in February. Condition index was determined monthly on 30 specimens, and maximal value was recorded in April. Formation of growth bands corresponded to a period of slow growth which was recorded prior to the increase of condition index. Distance from the umbo to the each visible growth ring was measured and growth parameters L_∞ and k were estimated using the Gulland-Holt method (38.73 mm and 0.52 year^{-1}, respectively) and by fitting length at age data to a von Bertalanffy growth curve (37.91 mm and 0.57 year^{-1}). Majority of analysed specimens were two years old and the oldest specimens analysed had six years. In conclusion, these data suggest that *V. decussata* is a short – living species with the most intensive growth occurring during the first two years.

Keywords: Bivalve, Mediterranean, commercially important, marine.

Introduction

The chequered carpet shell *Venerupis decussata* (Linnaeus, 1758) is an infaunal bivalve that inhabits sand and muddy – gravel bottoms from mid – tide level to a few meters deep. Habitat of this species ranges from West Africa to Europe, including Mediterranean and the coast of England (Poppe and Goto, 2000). *V. decussata* is one of the commercially most important bivalve species that is harvested across the Mediterranean and in 1980s it was introduced in aquaculture in the lagoon areas, mainly in Italy (FAO, 2011). Since than *V. decussata*, together with other clams presents one of the main components of mollusc production and makes up about 25 % of total mollusc production in the world (FAO, 2010). *V. decussata* is also commercially valuable species in the eastern Adriatic Sea where the most important harvesting locations are the Pag Bay and east coast of Istria. Minimal landing size for carpet shell clam in Croatia is 25 mm (Official Gazette 63/2010). According to fisherman logbooks annual catch of this species in Croatia, in period from 2001 to 2007, ranged from 0.8 t to the maximum of 6.4 t. However, this data must be considered with caution because it is assumed that illegal catch might be several folds higher than the official statistic data (Vrgoč *et al*., 2009).

There are numerous studies on the biology and ecology of chequered carpet shell including its growth and reproduction (Perez Camacho, 1980 in Chryssanthakopoulou and Kaspiris, 2005; Delgado and Perez Camacho, 2005; Anibal *et al*., 2011), genetics (Hurtado *et al*., 2011; Periera *et al*., 2011), juvenile development (Fernandez-Reiriz *et al*., 2011; Matias *et al*., 2011), and diseases (Dieguez *et al*., 2011, Moreira *et al*., 2012). However, there is no information about populations in the eastern Adriatic including age and growth parameters what is crucial for setting up a long term sustainable management of natural populations as well as its aquaculture. The aim of this study was to ascertain age, growth and condition index of *V. decussata*, and compare our data with results from other populations.

Materials and Methods

Monthly samples of *Venerupis decussata* were collected in Pag Bay (Figure 1.) in a period from January to November 2007. Sampling was performed by commercial SCUBA divers. For the purpose of data analyses all samples collected were kept,

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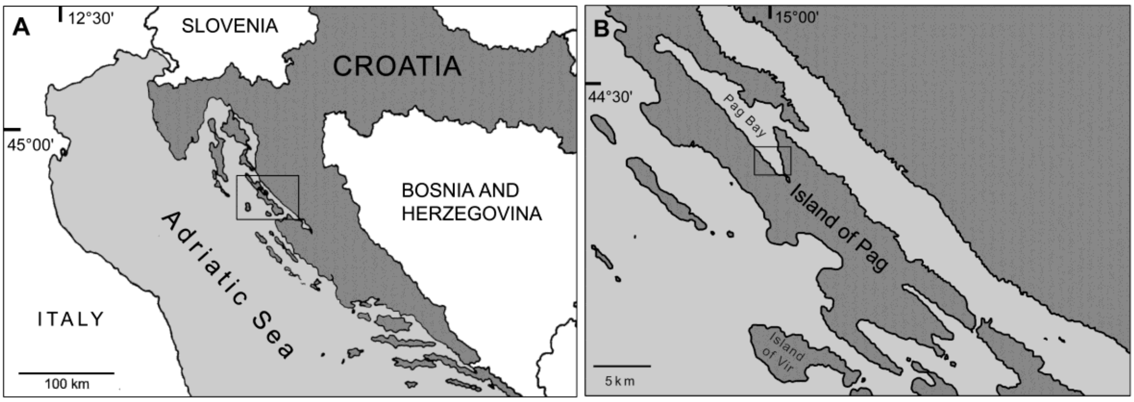

Figure 1. Map of the study area: A) Position of the Pag Bay in the Adriatic Sea B) Map of the sampling location in Pag Bay

including those below minimum landing size of 25 mm (Official Gazette, 63/2010). Total of 4338 specimens were collected and shell length of each was measured with Vernier calipers to the nearest 0.1 mm. Shell length frequency plot of commercial catches was constructed only for specimens above the minimal landing size. Condition index as indicator of reproduction cycle was determined monthly on 30 specimens (mean±st.dev = 34.0±1.4 mm). Individuals were cooked for 2 minutes in boiling water, the soft tissue was removed from the shell and both the tissue and shell were left to dry in the air for one hour. The weight of the flesh and shell of each individual was determined to the nearest 0.01 g, whereas the condition index (CI) was determined as the ratio between wet flesh weight and the sum of flesh weight and shell weight (Davenport and Chen, 1987; Peharda *et al*., 2012). The non-parametric Kruskal–Wallis test was used to investigate significant differences in CI between months.

Marginal increment analysis was applied on smaller specimens (N=68; mean±st.dev=26.4±3.4 mm) to determinate time of band formation (Richardson, 2001; Peharda *et al*., 2012). For this analysis the distance between the last growth band on the outer shell surface and edge of the shell was measured. For age and growth determination we analyzed right valves of 69 specimens ranging in length from 17.7 to 43.5 mm (mean±st.dev=31.9±5.5 mm) that were collected in February. Each specimen was embedded in epofix resin (Struers), sectioned from the umbo to the ventral edge, ground, polished and etched for 45 seconds in 0.1 M HCl, and acetate peel replicas were prepared (Richardson, 2001; Peharda *et al*., 2002). Growth rings were not visible in 5% of analysed specimens and these were omitted from further analysis.

The distance between the umbo and each growth line in the prismatic shell layer was measured to the nearest 0.1 mm. Age growth parameters, including asymptotic height (H_∞) and the growth constant (k) were estimated from a Gulland-Holt plot using the annual increment data. Asymptotic length (L_∞) was estimated based on relationship between length and height of individuals used for age and growth increments analysis: L=1.504H-1.128 (r^2=0.965, N=135). Further, the von Bertalanffy growth equation $L_t = L_\infty(1-e^{-k\,(t-to)})$ was fitted to the length-at-age data using non-linear least-squares parameter estimation, where L_t is the length at time t and t_0 is the age at which L_t = 0 and k is the growth constant (Gulland, 1983). Growth performance index (ø' = log k + 2log L_∞) was applied for a comparison of inter-different population growth (Sparre and Venema, 1998).

Results

Lengths of *Venerupis decussata* in a commercial catch ranged from legal minimum landing size of 25 to 49 mm (Figure 2). Mean length was 32.4±4.3 mm and 85% of commercial catch was between 27 mm and 39 mm in length. Individuals that were below minimal landing size had a mean length of 23.4±1.4 (N=27) and the smallest individual collected was 19.3 mm in length.

Kruskal–Wallis test revealed significant differences in condition index during the investigated period (H_{10}=227.08, P<0.001). Mean maximal value of CI occurred in April (29.65±2.65), followed by continuous decrease until September (15.25±3.13) when minimal values were recorded (Figure 3). These results indicate that *Venerupis decussata* probably has one prolonged spawning period per year.

Results of marginal increment analysis show that growth bands, are formed annually in February (Figure 4) when mean distance from the edge of the shell and the last formed band was the smallest (0.59±0.63 mm). Age was successfully estimated using growth lines in the inner shell layer (Figure 5) of the 69 specimens collected from the Pag Bay in February 2007. Age of *Venerupis decussata* ranged from 1 to maximally 6 years, with the majority of specimens being 2 and 3 years old (67%). Estimated growth parameters (L_∞=38.73 and k=0.52) generated using Gullant – Holt method on the growth increment data are presented in Figure 6. Length - at - age data were fitted to the von Bertalanffy growth equation: $L_t=37.91(1-e^{-0.57(t-0.04)})$, which is illustrated in Figure

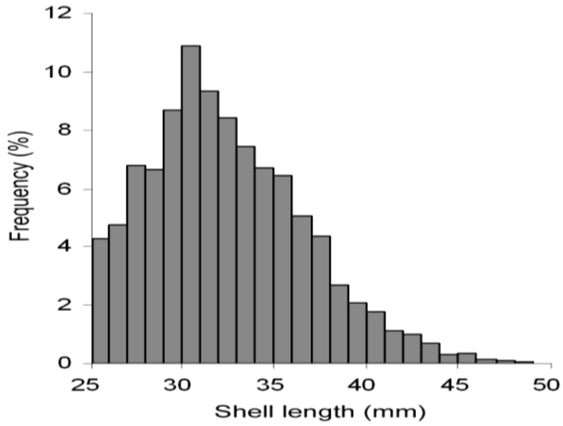

Figure 2. Shell length frequency plot of commercial catches of *Venerupis decussata* from Pag Bay.

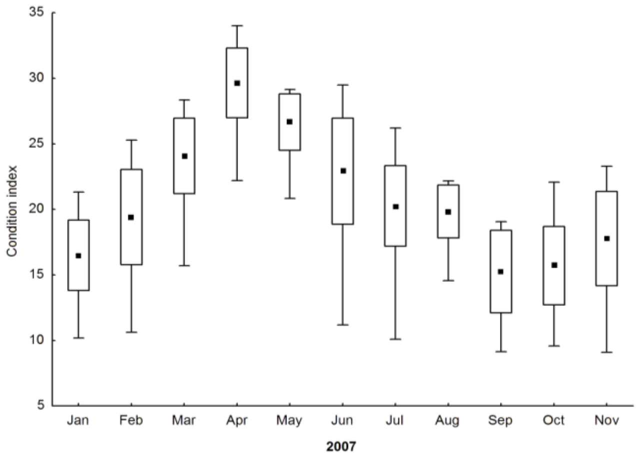

Figure 3. Seasonal variations in the condition index of *Venerupis decussata* from Pag Bay. Values are means, standard deviation (box) and minimal and maximal value (whisker).

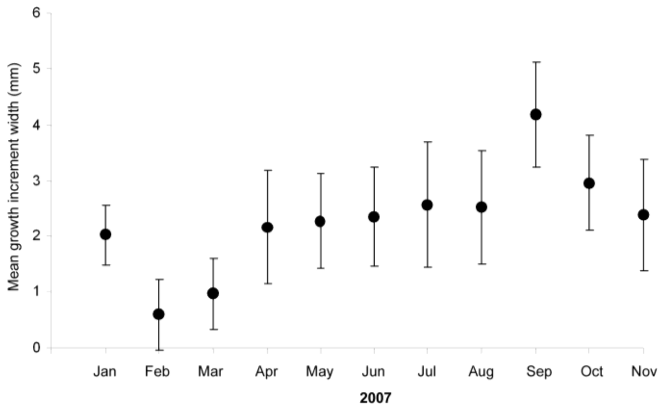

Figure 4. Marginal increment analysis of *Venerupis decussata* performed on the smallest specimens collected in period from January to November 2007 from the Pag Bay, including standard deviation of the data.

7. The most intensive growth occurred during the first two years of life, when *V. decussata* reached a length of approximately 25 mm. Shell growth rate significantly decreased after the 4^{th} year of life when growth was only few millimetres per year. Calculated growth performance indices (ø'=2.89 and ø'=2.91, respectively) indicate fast growth in investigated population.

Discussion

This study investigated structure of commercial catch, age, growth and condition index of *Venerupis decussata* population from the Pag Bay, eastern Adriatic Sea. Condition index analysis was conduced as an indirect estimate of reproductive activity of *V. decussata* as suggested by Ojea *et al*. (2004). In this

Figure 5. Photomicrographs of acetate peels of inner shell layer of *Venerupis decussata* from Pag Bay. Black arrows indicate the position of growth lines. Scale bar = 5 mm.

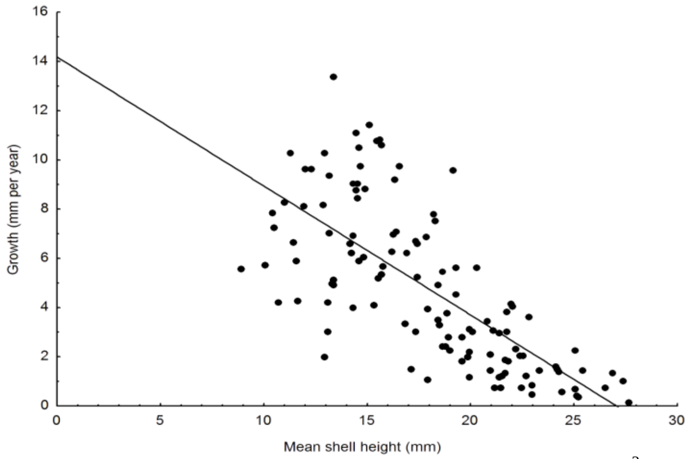

Figure 6. Gulland – Holt plot of *Venerupis decussata* from Pag Bay: y=-0,524x + 14,185, r^2=0,513.

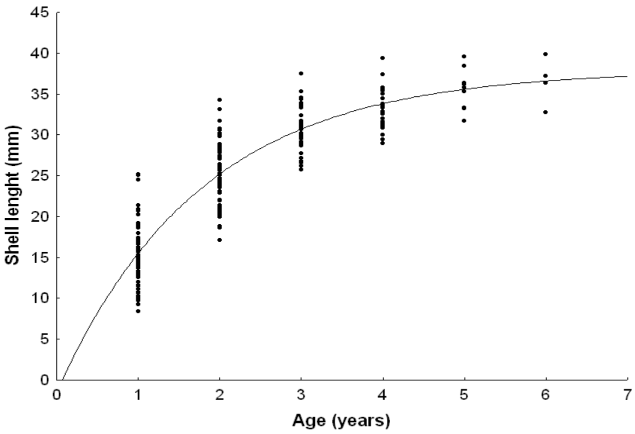

Figure 7. Von Bertalanffy growth equation of *Venerupis decussatus* from Pag Bay obtained from length-at-age data analysis: L_t=37.91(1-$e^{-0.57t-0.04)}$).

study condition index started to increase in January, reached maximal values in April and decreased from May to September indicating continuous period of gametes releasing. Previous histological studies showed that reproductive cycle, duration of gametogenesis and spawning season of clams *V. decussata* and *Venerupis philippinarum* are affected by both, geographical location and metabolic activities (Rodriguez-Moscosco *et al*., 1992; Laruelle *et al*., 1994 in Serdar and Lök, 2009). In the Mediterranean gametogenesis begins in January, whereas in northern Europe gamete maturation starts in March (Xie and Burnel, 1994 in Serdar and Lök, 2009). According to Ojea *et al*. (2004) there are two phases of gametogenic cycle in population of chequered shell clam from Galicia (Spain): resting phase (November-December) and gametogenesis during the rest of the year. Spawning season of *V. decussata* from Urdaibai Estuary, Spain (Urrutia *et al*., 1999) and Sufa Lagoon, Turkey (Serdar and Lök, 2009) started in July. On the Atlantic coast of Morocco Shafee and Daoudi (1991) reported two major spawning events, partial one in May-June and complete spawning in September-October. These authors also suggest that although *V. decussata* habitat and distribution vary from protected bays to tidal lagoons and from cold temperate to warm temperate regions, this species shows remarkably little variations in its seasonal reproductive activity. Our results of condition index analysis suggest that *V. decussata* from Adriatic Sea is probably following the reproductive pattern of this species from the other part of the Mediterranean Sea. However, since reproductive activity can not be precisely determined from the analysis of condition index, future study should use histological techniques to analyze reproduction of this species in the eastern Adriatic.

The formation of annual growth bands as a result of seasonal changes in shell deposition is common in bivalve species (Richardson, 2001; Peharda *et al*., 2002). Temperate water bivalves show reduced growth mostly in winter months due to adverse environmental conditions; declining of water temperature and lack of food (Richardson, 2001), but there are also some species in which formation of growth bands took place in summer months; such as *Callista chione* (Ezgeta-Balić *et al*., 2011) and *Acanthocardia tuberculata* (Peharda *et al*., 2012). Formation of growth bands in *Venerupis decussata* for majority of specimens in this study took place in February, although in some individuals growth bands were visible at the shell edge from November to March. According to Chryssanthakopoulou and Kaspiris (2005), bands formation in *V. decussata* population from Araxos Lagoon (Greece) also took place in February, while Urrutia *et al*. (1999) obtained bands formation in January for population from Urdaibai Estuary (Spain). Formation of growth bands corresponded to a period of slow growth which was recorded prior to the increase of condition index, indicating that during that period *V. decussata* invests more in tissue biomass than in shell deposition which was previously recorded by Urrutia *et al*. (1999). Age was successfully estimated using growth lines in the inner shell layer. The oldest specimen recorded in this study was six years old (43.4 mm), while dominant age class of analysed specimens was two years (39%). Age and growth data suggest that *V. decussata* is a short – living species with the most intensive growth occurring during the first two years. Growth parameters for *V. decussata* populations from different parts of the Mediterranean shows that the highest asymptotic length values were recorded in Araxos Lagoon (Chryssanthakopoulou and Kaspiris 2005), although the oldest analysed specimen in that population had 51 mm in length. Phi prime values indicate that population from Araxos Lagoon have the fastest growth (ø'=2.99) while population from Urdaibai Estuary (Urrutia *et al*., 1999) have the slowest growth (ø'=1.78). Phi prime values for Pag Bay population obtained by two methods were 2.89 and 2.91, what shows that *V. decussata* is a fast growing species, that reaches commercial length at the age of about two years.

Temperature and food availability are the major determinants of growth rate in bivalves (Urrutia *et al*., 1999; Shafee and Daoudi, 1991). As samples for this study were collected from commercial catches there are no data regarding temperature and chlorophyll *a*. However, climatological data collected in period from 1911 to 1989 in the Pag Bay suggest the highest mean temperature values usually occurred in September while the lowest values were recorded in February (Bićanić *et al*., 1998). Our results showed that growth lines are also formed in February indicating that slowest growth of *Venerupis decussata* corresponded with low sea temperatures. Chlorophyll *a* values obtained from Pag – Konavle project 2007 also had the highest values in September (Antolić *et al*., 2008) what corresponded with the most intensive growth of this species.

Since this is a short living and fast growing species which released gametes during a long period of year *Venerupis decussata* could be considered as a good candidate for aquaculture in the eastern Adriatic. However, further studies are necessary to attain the maximum growth performance of this species under variable conditions and to determine technological conditions needed for setting up profitable and long term sustainable aquaculture.

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