

## GROWTH OF JUVENILE SHARPSNOUT SEABREAM, *DIPLODUS PUNTAZZO* (TELEOSTEI: SPARIDAE) IN THE KORNATI ARCHIPELAGO, EASTERN ADRIATIC SEA

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JUVENILE GROWTH  
*DIPLODUS PUNTAZZO*  
ADRIATIC SEA

**ABSTRACT.** – Growth of juvenile *Diplodus puntazzo* from the Kornati Archipelago, eastern middle Adriatic Sea was analysed. A total of 663 juveniles, ranging in length from 1.6 to 9.3 cm, were caught. Most individuals (98.80%) belonged to the 0 cohort. The first settlers, aged 2.0-2.5 months, were recorded at the end of November. Relationship between total length and weight indicates positive allometric growth ( $b = 3.181$ ). The condition factor, as a consequence of length-weight relationship, was  $CF = 1.55$ . The Gompertz equation ( $c = 0.038 \text{ mm days}^{-1}$ ;  $R^2 = 0.832$ ) seems to be the most appropriate for the description of young *D. puntazzo* growth.

Data on juvenile fish growth rates are still scarce in the literature, although they are crucial for a better understanding of species population dynamics (Lasker 1985). The potential for fish growth after settlement is intrinsically a product of their genotype, the effects of the individual's pre-settlement environment (food availability, temperature regime; McCormick & Molony 1992), and the characteristics of the post-settlement habitat (food availability, competitive regimes and risk of predation; Ochi 1986, Hixon 1991). Furthermore, in temperate areas, growth is strictly dependent on seasonal changes (Weatherly & Gill 1987). Duration of planktonic stage and period that certain species spend in nursery areas is also related to seasonality (Macpherson 1996). Using the analysis of size-frequency distributions (Barry & Tegner 1989), growth of juveniles can be estimated from the increase of the mean size of fish in a "cohort" within year-classes once they enter marine littoral lagoons (Planes *et al.* 1999). Different growth models from this perspective can be used to construct growth curve.

The sharpsnout seabream, *Diplodus puntazzo* is a demersal marine fish found in groups over rocky and sandy bottoms and seagrass meadows, at depths ranging from 0 to 150 m, but mostly from 5 to 20 m. The species is distributed in the eastern Atlantic, from the Gulf of Biscay to Sierra Leone, as well as in the Mediterranean and Adriatic Seas (Jardas 1996). While the sparids family and especially *Diplodus* genus are widespread in the Mediterranean Sea and constitute an important fishery resource along its coasts, there is a lack of data on *D. puntazzo* biology and ecology. The majority of published studies deal with investigation of its potential for introduction in intensive mariculture (Divanach *et al.* 1993, Abellan & Garcia-Alcazar 1995, Gatland 1995), while its commer-

cial production still remains at an experimental or pre-industrial level due to market prices that cannot justify the production costs (Katavič *et al.* 2000). Settlement and recruitment processes (García-Rubies & Macpherson 1995, Vigliola *et al.* 1998, Vigliola & Harmelin-Vivien 2001) and growth of juvenile sparids (Planes *et al.* 1999, Vigliola *et al.* 2000) have only recently been surveyed in the northwestern Mediterranean Sea. In the Adriatic Sea, only Kraljević (1995) and Katavič *et al.* (2000) investigated feeding and growth performance of *D. puntazzo* in capture, respectively. However, nothing is known about the growth of wild, juvenile sharpsnout seabream in the Adriatic and other parts of the Mediterranean Sea.

Therefore, the objective of the present work was to describe the growth of juvenile *D. puntazzo* from the Croatian waters, and to test different models for estimating juvenile fish growth. Also, for a better understanding of its life cycle and population dynamics, our results were compared with the growth parameters of other juvenile sparids.

### MATERIAL AND METHODS

The Kornati Archipelago with its 147 islands, islets and reefs lies along the central part of the eastern Adriatic coast, between the cities of Zadar and Šibenik. Sampling was conducted on a monthly basis from November 1991 to December 1992 at five coves: Šipnata, Lojena, Studena, Lavsa and Žakan (Fig. 1). The sampling was done on generally hard, only partially sandy substrates that were laterally overgrown by meadows of *Posidonia oceanica* and/or *Cymodocea nodosa*. Sites were carefully selected to encompass a closed recruiting system: a small, shallow bay limited by deeper water area with a

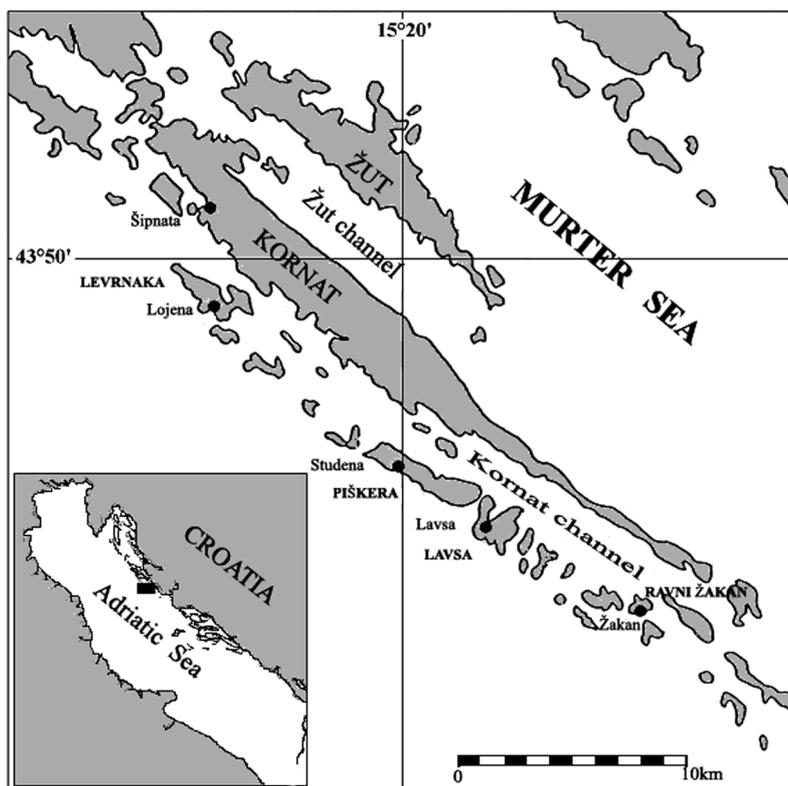


Fig. 1. – Location of the sampling stations in the Kornati Archipelago.

drop-off (appropriate for work with beach seine), according to Planes *et al.* (1999) recommendations. Dulčić *et al.* (1997) statistically confirmed similar hydrological conditions in all five coves and great closure of this archipelago. Also, according to the statistical analysis done by Dulčić *et al.* (1997) the rank of sixty-nine species composition sampled in the Kornati Archipelago was highly correlated with sampling location, so data for *D. puntazzo* from all five coves were combined. Structure of investigated coves precludes the possibility of migration, so juveniles were restricted to shallow inshore habitats and did not migrate to deeper water before recruitment (Harmelin-Vivien *et al.* 1995, Garcia-Rubies & Macpherson 1995, Planes *et al.* 1999).

Fish samples were collected using a 50 m long beach seine. Net depth at the beginning of wings was 30 cm, while at the central part together with the bag this depth was 250 cm. Outer wings were of 8 mm mesh size and central sac of 4 mm. The net was always hauled from the entrance of the cove (max. 2 m depth) to its inner end. Collected juvenile individuals of sharp-snout seabream were preserved in 4% formaldehyde (pH from 8.5 to 9.0). Specimens characterized as juveniles with already formed scales and not older than 14 months were taken for the length analysis.

Due to the time of spawning and the period of intensive settlement, together with the duration of the larval stage of life which varies between one and two months (Raventos & Macpherson 2001), September 25<sup>th</sup> was assumed as birth date (unpubl. data). Age in months was determined as the difference between the birth date and the capture date. In the present paper, the term “cohort” was used to describe groups of *D. puntazzo* of similar

size, identified monthly in each length-frequency distribution.

Empirical total size-frequency distributions were used for constructing age-length key with 3 mm length intervals. The commonly used length-weight relationship ( $W = aL_t^b$ ) and condition factor ( $CF = 100 \cdot W \cdot L_t^{-3}$ ) were applied (Ricker 1979). Several growth models were tested: linear ( $L_t = a + c \cdot t$ ), exponential ( $L_t = a \cdot e^{ct}$ ), logarithmic ( $L_t = c \cdot \ln(t) - a$ ), parabolic ( $L_t = c \cdot t^2 + b \cdot t + a$ ), von Bertalanffy equation ( $L_t = L_\infty \cdot [1 - e^{-c(t-t_0)}]$ ), (Beverton & Holt 1957), the generalized Gompertz growth equation ( $L_t = L_\infty \cdot e^{-be[\exp(-c \cdot t)]}$ ), Ricker 1979) and Laird-Gompertz equation ( $L_t = L_0 \cdot e^{[(a/c) \cdot (1 - e^{-(c \cdot t)})]}$ ), Laird *et al.* 1965). Abbreviations in upper equations are:  $L_t$  = total length (cm) at age  $t$ ;  $L_0$  = total length when  $t = t_0$ ;  $L_\infty$  = asymptotic length (cm) at the end of the first growth season (Katsuragava & Ekau 2003);  $c$  = instantaneous growth rate when  $t = t_0$ ;  $t$  = age (months from birthday or settlement);  $a$ ,  $b$  = constants).

The equation was fitted (all individuals included) by an iterative method with a non-linear (user specified) subroutine (Stat-Soft 1996). The calculation of the coefficient of determination ( $R^2$ ) provided a measure of goodness-of-fit (Sokal & Rohlf 1981).

## RESULTS

A total of 663 juveniles of *D. puntazzo*, ranging from 1.6 to 9.3 cm  $L_t$ , were analysed. Most individuals (98.80%) belonged to the 0 cohort. First juveniles of *D. puntazzo* were sampled (86 individuals, 12.97% of total sample) at the end of November (November 27<sup>th</sup>), and

Table I. – The length frequency distribution (with 3 mm intervals) of juvenile *D. puntazzo* in Croatian waters.

Length intervals (cm)	Age (months)													Total
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	
1.1-1.3														0
1.4-1.6	2	2												4
1.7-1.9	18	11	3	2	1									35
2.0-2.2	24	16	6	5	6	4								61
2.3-2.5	21	25	6	17	5	18								92
2.6-2.8	15	18	35	26	24	17								135
2.9-3.1	6	6	21	10	27	26	2	3						101
3.2-3.4		2	7	12	16	25	2	4						68
3.5-3.7		3	3	4	16	19	6	7						58
3.8-4.0		1	3	6	13	14	3	6						46
4.1-4.3				1	2	6	7	8	1					25
4.4-4.6					1	2	2	3						8
4.7-4.9						1	1	3						5
5.0-5.2							1	3	1					5
5.3-5.5							1	4						5
5.6-5.8														0
5.9-6.1										1				1
6.2-6.4											1			1
6.5-6.7									1					1
6.8-7.0									1					1
7.1-7.3														0
7.4-7.6										2				2
7.7-7.9														0
8.0-8.2										2				2
8.3-8.5											1			1
8.6-8.8											2	1	1	4
8.9-9.1														0
9.2-9.4												1	1	2
Total	86	84	84	83	111	132	25	41	4	5	4	2	2	663
%	12.97	12.67	12.67	12.52	16.74	19.91	3.77	6.18	0.60	0.75	0.60	0.30	0.30	100
mean Lt (cm)	2.27	2.41	2.81	2.84	3.10	3.19	4.01	4.20	6.30	8.23	8.60	8.90	9.05	
SD Lt	0.382	0.486	0.415	0.507	0.519	0.577	0.622	0.801	1.365	0.321	0.141	-	-	
mean W (g)	0.18	0.23	0.34	0.35	0.43	0.44	0.94	1.22	4.35	8.41	10.73	11.34	11.59	
SD W	0.105	0.135	0.163	0.214	0.236	0.299	0.490	0.754	2.396	2.145	0.672	-	-	

Table II. – The results of several different growth models for juvenile *D. puntazzo*.

Models	K (mm day <sup>-1</sup> )	SE	R <sup>2</sup>
Von Bertalanffy	0.009	0.0012	0.479
Gompertz	0.038	0.0032	0.832
Laird-Gompertz	0.528	0.0079	0.139
Exponential	0.038	0.0037	0.577
Linear	0.105	0.0124	0.498
Logarithmic	0.695	0.1108	0.350
Parabolic	0.018	0.0023	0.686

were ranging in length from 1.6 to 3.1 cm (mean value:  $2.27 \pm 0.382$  cm). Total weight of these individuals ranged from 0.06 to 0.46 g (mean value:  $0.18 \pm 0.105$  g). According to the spawning period of sharpsnout seabream, their estimated birth date (September 25<sup>th</sup>) and duration of larval stage, these individuals were probably 2.0-2.5 months old. The length frequency distribution with 3 mm intervals is shown in Table I. Juveniles of *D. puntazzo* were caught throughout the year but they left shallow coves mostly in May-June period (4.0 cm L<sub>t</sub>) and presumably settled in open sea. After July, only 13 specimens were found (1.96% of total sample). Older individuals (> 1) were not recorded.

The slope ( $b = 3.181$ ;  $R^2 = 0.991$ ) of the total length-weight regression indicated a positive allometric growth. The condition factor, as a consequence of length-weight relationship, was  $CF = 1.55$  ( $R^2 = 0.987$ ). The equations of the different growth models are presented in Table II. Among all tested models, the better adjustment was obtained for the Gompertz equation ( $c = 0.038$  mm day<sup>-1</sup>;  $R^2 = 0.832$ ; Fig. 2).

Results of the growth increment analysis showed that growth of *D. puntazzo* is intensive during the first nine months of its life. This rapid growth was recorded until the end of August when maximal annual mean temperature (26.2°C) and maximal annual mean salinity (38.5‰) were recorded. The growth slope was highest in May and July. Its relative fall in June is not logical and probably resulted from an insufficient number of individuals in that sample. In winter, between January (mean 12.5°C) and April (mean 15.8°C), a limited growth was noted. Growth rate also slowed down with the beginning of autumn (after around 8.5 cm L<sub>t</sub>) (Fig. 3a). Few inflection points were evident pointing out that growth is sigmoid. Sharp-snout seabream reached the total length of over 9 cm after its first year. The Gompertz and von Bertalanffy models, as usually used, fitted the data very well only in period between settlement and recruitment (January-June). Before settlement in shallow coves and in period when most of those juveniles left this area, our growth slopes underestimated growth in comparison to the real growth slope that was calculated according to monthly mean length values of cohort (Fig. 3b). However, according to the analysis of residuals and R<sup>2</sup>, Gompertz equation corresponds to the best adjustment with our data concerning young sharpsnout seabream population.

## DISCUSSION

There are numerous contradictory studies dealing with the use of appropriate models for estimating juvenile

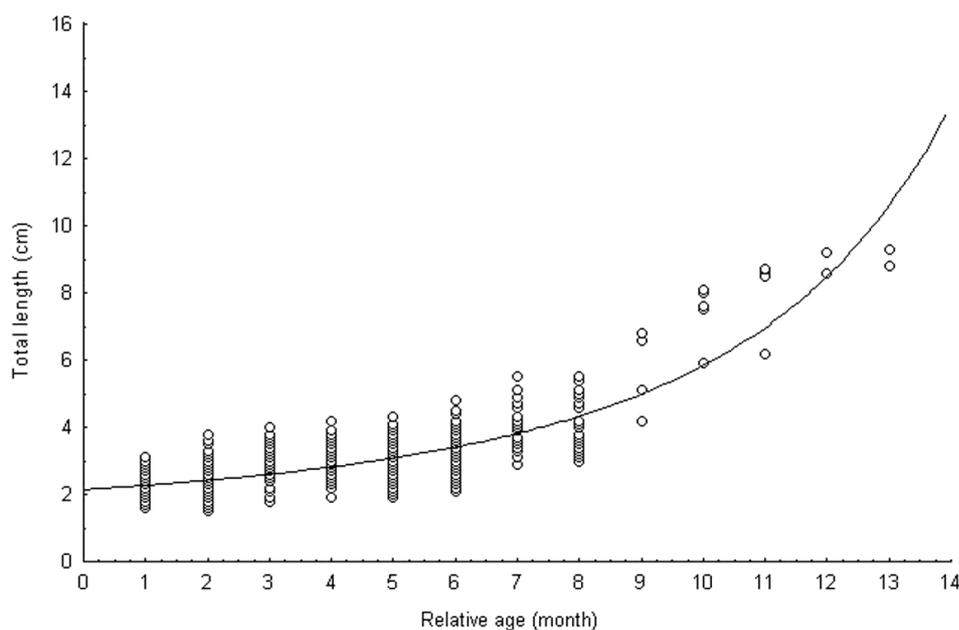


Fig. 2. – Gompertz growth curve of juvenile *D. puntazzo* from the Adriatic Sea ( $L_{\infty} = 13.32 * e^{(-0.479 * e^{(-0.113 * t)})}$ ;  $R^2 = 0.832$ ).

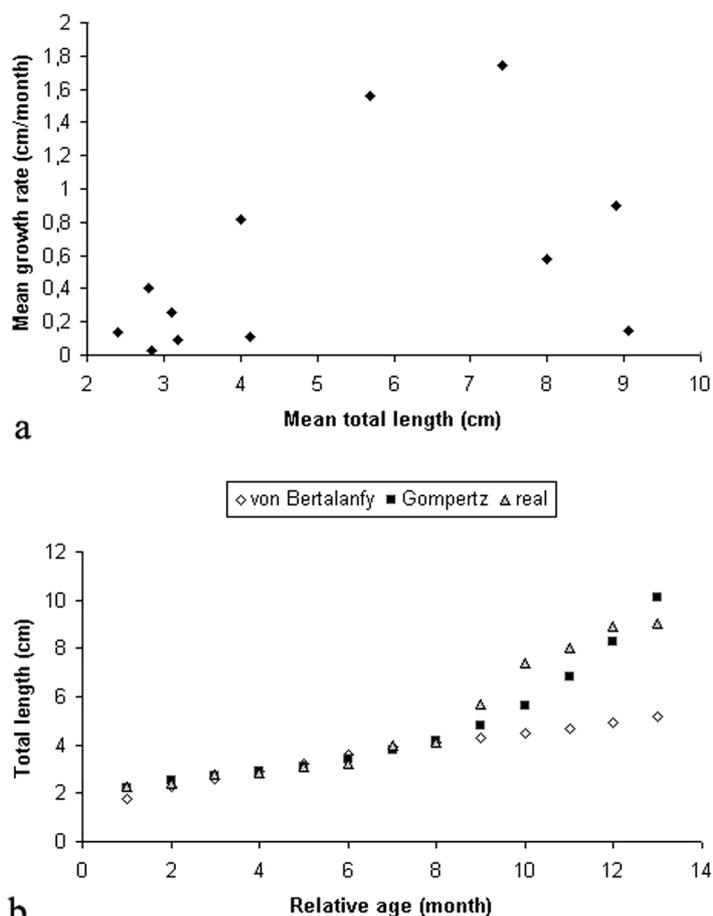


Fig. 3. – A, Monthly growth increment analysis of juvenile *D. puntazzo*; B, Comparison of the real (■) (by monthly mean length), Gompertz (◆) and von Bertalanffy (▲) growth curves of juvenile *D. puntazzo*.

growth. The choice of appropriate growth model usage depends on the life stage of studied species (larvae, juveniles, adults) and also on the aims of the study (Gamito 1998). Some authors (Regner 1980, Monteiro 1989, Andrade 1992, Gamito 1998) suggest using Gompertz equation. Results of the present analysis obtained by applying several growth models to juvenile sharpsnout seabream, during the period after settlement in the littoral zone, indicate that Gompertz ( $c = 0.038 \text{ mm days}^{-1}$ ;  $R^2 = 0.832$ ) and parabolic ( $c = 0.018 \text{ mm days}^{-1}$ ;  $R^2 = 0.686$ ) models best described juvenile growth of this species according to  $R^2$  and its biology. The von Bertalanffy growth equation (VBGC) and its seasonal form are widely used for estimating growth of adult individuals. However, the VBGC gives poor adjustment in the case of this species by underestimating the value of growth slope after first eight months of life. The same conclusions were proposed for other juvenile fish species (Weatherley & Gill 1987, Gamito 1998), with exception for species for which estimated  $t_0$  did not differ from zero, such as *Diplodus annularis* (Gordoa & Molí 1997) that remains in the same area throughout its life (Matić 2001). For species with  $t_0$  different from zero, Gordoa & Molí (1997) recommended the use of the exponential model that gave us the same growth slope ( $0.038 \text{ mm day}^{-1}$ ) as the Gompertz equation but with a lower  $R^2$  (0.577). The Laird-Gompertz model would probably be more appropriate for description of

*D. puntazzo* growth in a period before settlement because Dulčić (1993) and Nixon & Jones (1997) successfully used this model for larval growth analysis. Unfortunately, such analysis was not included in this study. Linear and logarithmic model gave us worst results in terms of the coefficient of determination, although for young sparids linear model have been recommended by Planes *et al.* (1999). Seasonal von Bertalanffy model can also be applied for older specimens or for conventional growth and mortality analysis in relatively cold regions, such as the Adriatic Sea, where growth is a mounting series of smaller sigmoids (Weatherley & Gill 1987). Therefore, a combination of Gompertz equation, to describe the first year of growth, with the seasonal von Bertalanffy model, to describe the following years, might be the outlet for an adequate description of growth (Gamito 1998).

There is a lack of information in the literature about the growth of juvenile fish based on Gompertz models so it was difficult to compare our results to other studies. Using Gompertz model, Pallaoro *et al.* (1998) estimated growth rate of *Oblada melanura* to be 0.083 mm day<sup>-1</sup>, while Gamito (1998) found that *Sparus aurata* has a growth rate of 0.003 mm day<sup>-1</sup>. Matić-Skoko *et al.* (2004) reported a relatively slow growth of juvenile *S. salpa* (0.047 mm day<sup>-1</sup>) in the Adriatic, which settled from the ichthyoplankton in November and spent the whole winter in shallow coves with lower temperatures than the open sea. The slower growth of *D. puntazzo* than that of *S. salpa* can be attributed to the lack of smaller (earlier settled) and larger specimens in the sample. However, it is not recommendable to compare directly growth slopes of different species.

Planes *et al.* (1999) suggested that juvenile growth follows a linear model and their values obtained for *D. puntazzo* (0.160 mm day<sup>-1</sup>) were numerically somewhat similar to ours using the same model (0.105 mm day<sup>-1</sup>). Obtained difference of 0.55 mm day<sup>-1</sup> was not significant due to methodology imperfections caused by use of small beach seine. However, these results pointed its slower growth slope in the Croatian waters. That is not unexpected because Adriatic Sea, as the northern most part of Mediterranean, is a specific oceanographic area, where the influence of geographical, geomorphological, climatic and other different environmental factors, mostly of a hydrographic nature is crucial for its characteristics (Jardas 1996). Moreover, the peculiarities of the Adriatic ichthyofauna depend on these factors which probably also affect growth characteristics of marine organisms (Kraljević 1995). However, the differences in size at age and apparent growth rate between different areas may be the result of wrong age interpretation. Therefore, the otolith techniques to obtain more precise information about the duration of juvenile stage and the daily individual growth proposed by Villanueva & Molí (1997), which can increase confidence in the correctness of the age structure, are welcome.

In the Kornati Archipelago, surface water temperatures follow seasonal cycle with a maximum in July and/or August (24–29°C) and a minimum in February (9–12°C). *D. puntazzo*, *D. vulgaris* and *Sarpa salpa*, which spawn in autumn (Matić 2001), exhibited lower growth than related species such as *D. sargus* settling in May (Planes *et al.* 1999, Matić 2001, Matić-Skoko *et al.* 2004). Growth is then directly and indirectly linked with temperature fluctuations (Weatherly & Gill 1987). In addition, zooplankton abundance decreases during winter in the Adriatic Sea (Regner 1985, Bojanić 2001) and this is also a restrictive factor for the growth of *D. puntazzo* and *D. vulgaris*, which during early life stages feed on zooplankton (Kentouri & Divanach 1982). After hatching, *D. puntazzo* feeds on crustaceans (harpacticoid copepods, amphipods) while at about 2.5 cm length they start feeding on epiphytes. When the individual reaches 13 cm it starts feeding on macrophytes (Cristensen 1978). The ingestion of copepods by juveniles was reported also by Bini (1968), Tortonese (1975) and Lasiak (1986). As no analysis of feeding was undertaken, it was not possible to identify whether temperature or food availability was primarily responsible for the slower growth in the winter period.

As we did not find adult specimens in the investigated area of Kornati Archipelago, we can conclude that juveniles of *D. puntazzo* do not compete with adults for habitat. Juveniles recruit in very shallow water, 1–2 m deep along the coastline, forming a small number of monospecific shoals, while adult individuals inhabit rocks on outer parts of those islands. Macpherson (1998) reported that these monospecific shoals of juvenile sparids never mix with the shoals of adults if they were present in the nursery area. As juveniles grow larger, the shoals fragment, presenting a less clumped distribution over the nursery area, which is characteristic for *Diplodus* species.

Settlement intensity among sparid fishes of the genus *Diplodus* can vary at several scales: spatially and temporally (Vigliola *et al.* 1998). However, in the Kornati Archipelago, first settlers occurred in almost equal percentage at the same time in all five coves pointing there was no such difference. Moreover, combining the data, we concluded that growth of juvenile *D. puntazzo* is the same in the whole investigated area. But, if such difference exists, it can be expected that it will probably have an effect on growth.

Number of *D. puntazzo* specimens declined from one month to the next one, especially after June. We suppose that most of these individuals have been recruited at 40–42 mm of total length, changing shallow coves for deeper habitats. In same time, smaller (later settled) and retard ones still remained in these coves for some period. This is in accordance with the results of Vigliola & Harmelin-Vivien (2001). They reported that *D. puntazzo* began to mix with larger adults in deeper areas by 30–47 mm SL. There may be other reasons. Smaller individuals cannot

be retained in codend while older, more agile individuals are more capable to avoid nets. Also, the impact of sampling by small beach seine on the success of the recruitment have to be clear away. Therefore, using a less destroying technique such as visual census would be more acceptable. A difficulty may appear in size estimation of smaller individuals in first few months after settlement (20-30 mm of total length). Also, such high decrease of sampled individuals after June may result from natural mortality due to predation (Bailey & Houde 1989) or starvation.

Demographic processes that occur in post settlement period are very important in the life cycle of *D. puntazzo*. There are at least two reasons for the fast juvenile fish growth: predator avoidance and earlier sexual maturity achievement. Juveniles *D. puntazzo* exhibit a clear preference for crannies in the rocks in shallow (0-2 m) pebble zones (Vigliola & Harmelin-Vivien 2001), and inhabit such shallow areas for a relatively short time, leaving them before maturity, thereby obviously showing a predator avoidance strategy. For this species, the hypothesis "the bigger is better" proposed by Bailey & Houde (1989) seems to be true. In fact, shallow coves of the Kornati Archipelago are inhabited by species of total length around 20-40 cm (sparids, labrids, mugilids) and since maximal vulnerability was attained when the relative size of the fish larvae was 10% of the predator size (Paradis *et al.* 1996), it is crucially important for *D. puntazzo* juveniles to reach lengths of over 40 mm as soon as possible.

Future studies should attempt to determine how habitat conditions could modify growth patterns of species at different stages of development as proposed by Gordoa & Molí (1997). It is also very important to incorporate juvenile growth into studies of adult population growth.

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