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Pectinid settlement on collectors in the Krka River Estuary

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Spat collector bags were suspended in the water at two week intervals from February 1987 to January 1988 in Šarina draga Bay. Eight spat collector bags filled with monofilament were suspended at 2.5 m intervals, at depth from 1 to 18.5 m above the sea bed. Collectors remained in the same position for three months.

Four Pectinids settled on the collectors: Chlamys varia *L.;* Chlamys (Flexopecten) flexuosus *Poli;* Chlamys (Aequipecten) opercularis *L. and* Pecten jacobaeus *L. Only* C. varia *and* P. jacobaeus *were examined in this paper.*

The intensive settlement of Chlamys varia *occurred from June to August 1987, although settlement was recorded throughout the year. The spat maximum of 2451 per spat bag was found at a depth of 12.5 m.* Pecten jacobaeus *settled in high numbers from the end of March to the beginning of July 1987, with the maximum of 80 per spat bag at a depth of 15 m.*

INTRODUCTION

Four commercial species of Pectinids are represented off the east coast of the Adriatic Sea: pilgrim's scallop (*Pecten jacobaeus* L.), variant scallop (*Chlamys varia* L.), queen scallop (*Chlamys (Aequipecten) opercularis* L.) and scallop (*Chlamys (Flexopecten) flexuosus* Poli).

Scallop fishery or culture industry are not developed in Croatia. The annual scallop landing from natural stocks does not exceed 30 t and only as bycatch (GRUBIŠIĆ, 1982). The fishing gears are various types of dredges and bottom trawls. Pectinid shells are more used for handwork of decorative articles than for human consumption, consequently economic importance of pectinids is very low and they are very rare on the fish market.

Recently, only two estimation attempts of pectinid biomass have been undertaken in the Adriatic Sea. The first one was conducted during 1982-1984, as a part of the bilateral research programme on monitoring and assessment of Adriatic multispecies demersal resources, organized by Laboratorio di Biologia Marina e Pesca in Fano and the Institute of Oceanography and Fisheries in Split. Material was collected by the standard Italian bottom trawl from 20 to 62 m depths in the northern Adriatic Sea. Relative biomass, distribution and abundance of *Chlamis opercularis* (L.) and *Pecten jacobaeus* L. were estimated (PICCINETTI, 1985). The highest abundance (landings) values (number of scallops per hour fishing) for *Chlamis opercularis* were recorded at sea depths between 40 and 49 m with mean landing value of 474.3 kg per hour.

Scallop (*Pecten jacobaeus*) landings ranged from 0.28 to 1.2 kg/hour. On the basis of pectinid species landings with bottom trawl, not to cover coastal considerably more abundant areas, relative biomasses of these two shellfishes for the north Adriatic Sea area were calculated by the authors, that is 21987 t of *Chlamis opercularis* (L.) per 8989 sq. km and 89 t of *Pecten jacobaeus* per 11394 sq. km.

During 1984 and 1987 some other studies were carried out as a part of the research programme of the River Krka estuary, that was organized by the Center for Marine Research, "Ruđer Bošković" Institute, Zagreb. Material was collected by divers, using standard SCUBA equipment at 30 stations at depths from 5 to 25 m (MARGUŠ, 1985, 1990a, 1990b). Sampled scallops (*Pecten jacobaeus*) ranged from 48 to 141 mm (mean length), and age class 1+ to 9+. The highest abundance values were recorded at sea depths from 12-18 m on a silt/sand with shell substratum along the slopes of the mud region along the estuary. On the basis of mean landing a relative biomass was calculated being approximately 500 tons per 50 sq. km (MARGUŠ, 1991).

No previous studies were undertaken to investigate the extent of settlement of scallop larvae along the Adriatic coast of Croatia. The aim of the present paper was to establish the best time and collecting depths of spat settlement, using techniques developed in Japan (VENTILLA, 1982).

MATERIAL AND METHODS

Eight spat collector bags (75 x 45 cm) filled with monofilament were suspended beneath buoys at 2.5 m intervals at depth from 1 to 18.5 m above the sea bed (bottom 21 m). The lines were weighed at the bottom to ensure they hung vertically in water. Collectors were suspended in water at two week intervals from February 1987 to January 1988 in Šarina draga Bay (Fig. 1). After being suspended for three months collectors were taken to the laboratory, submerged in a 4% formaldehyde solution for 3 hours, and collected material was sieved trough

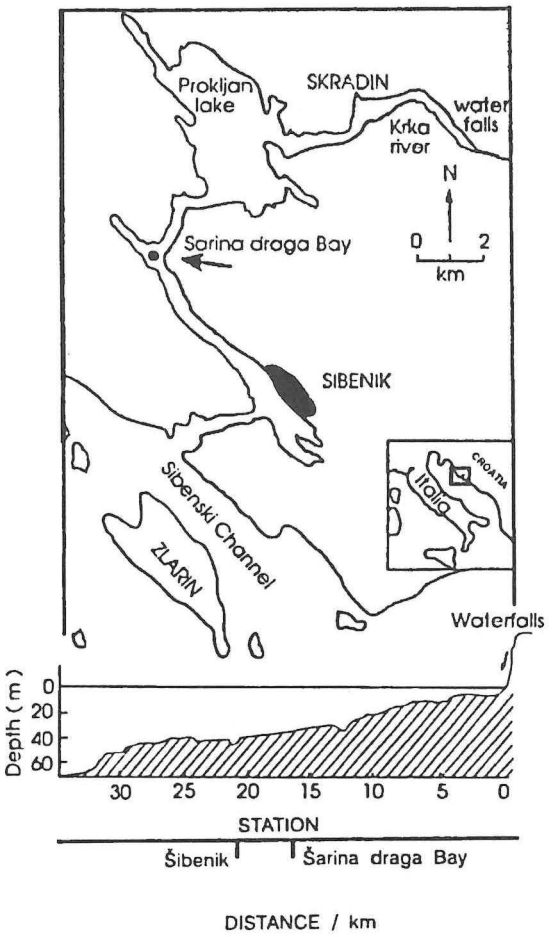

Fig. 1. The map of the Krka River Estuary in the Adriatic Sea with the depth profiles, distances in km and the location of study site of Šarina draga Bay.

sieve with 1 mm mesh size. All Pectinid spat were identified to species level, counted, and the shell height was measured to the nearest mm under a binocular microscope.

Salinity of the water was measured using an "Atago" Japan refractometer and water temperature by standard thermometer with scale from 0 to 40 °C at nine depths every month during the period from February 1987 to December 1988.

RESULTS

Four species of Pectinids were found in the collector bags: *Chlamys varia* L.; *Chlamys (Flexopecten) flexuosus* Poli; *Chlamys (Aequi-*

pecten) opercularis L. and *Pecten jacobaeus* L. A total of 36191 scallop spat with the mean of 188 individuals per collector bag was collected in 192 collector bags. *Chlamys varia* made up 97.57%, *Chlamys flexuosus* 2.48%, *Pecten jacobaeus* 1.90% and *Chlamys opercularis* 0.05% of the total of collected spat. Only *Chlamys varia* and *Pecten jacobaeus* were analyzed in detail.

Chlamys varia L.

A total of 34587 *Chlamys varia* spat were collected from eight depths. Minimum number of 73 or 0.21% individuals occurred at a depth of 2.5 m, and maximum number of 9141 or 26.43% at 12.5 m (Fig. 2). The settlement peak

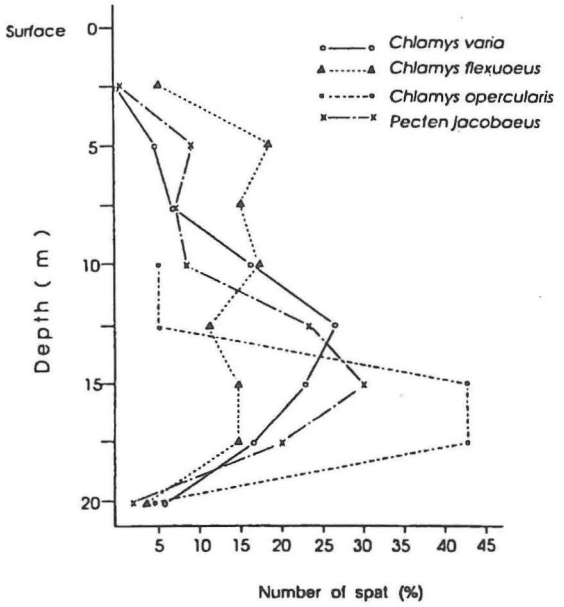

Fig. 2. Relationship between depth and number of scallop spats in percentages. The best settlement of *Chlamys varia* occurred at 12.5 m, *Chlamys (Flexopecten) flexuosus* from 5 to 10 m, *Chlamys (Aequipecten) opercularis* from 15 to 17.5 m and *Pecten jacobaeus* at 15 m depths.

happened in August 1987 with 41.6% of the total collected spat (Fig. 3). The highest spat settlement of 31.5% occurred in November 1987 and 52.5% in April 1988 at 2.5 and 5 m depths respectively contrary to other depths where they ranged from 35.5% to 50.4% in August of both years (Fig. 4). The mean spat shell height increased from 2.3 mm ± 0.9 mm in June 1987

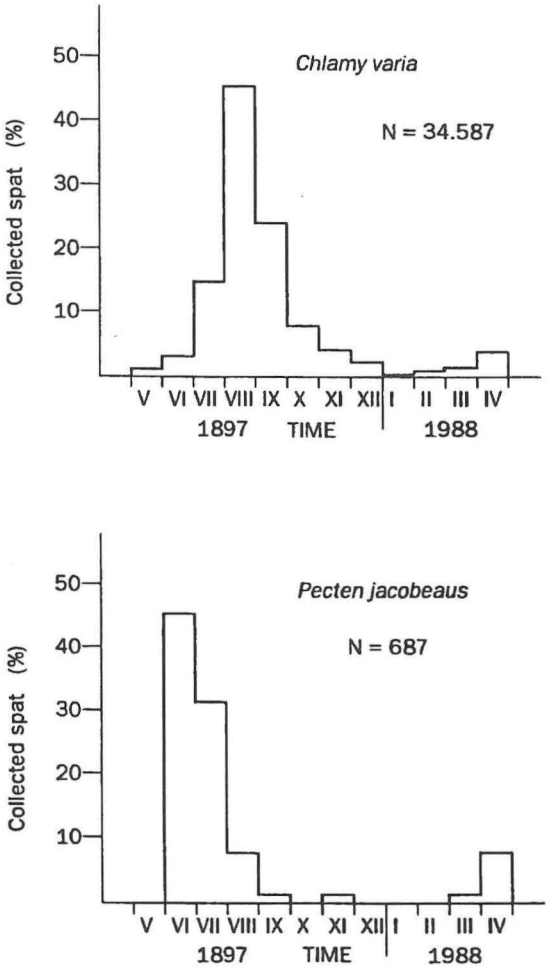

Fig. 3. Monthly distribution of *Chlamys varia* and *Pecten jacobaeus* spat in percentages in 1987 and 1988. *C. varia* settled on the collectors throughout the study period with maximum in August 1987. The spat of *P. jacobaeus* was found in summer 1987, and spring 1988.

to 6.9 mm ± 2.9 mm in December 1987. The shell height varied considerably in spat collected from January to April 1988. Percentages of the spat in 1-2 mm length class decreased from 61.0% in June to 2.4% in December 1987, but the percentages varied considerably from January to April 1988 (Fig. 5).

Pecten jacobaeus L.

A total of 687 *Pecten jacobaeus* spat were collected at eight depths. Minimum number of 1 or 0.15% individuals occurred at a depth of 2.5 m, and maximum number of 132 or 29.55% at

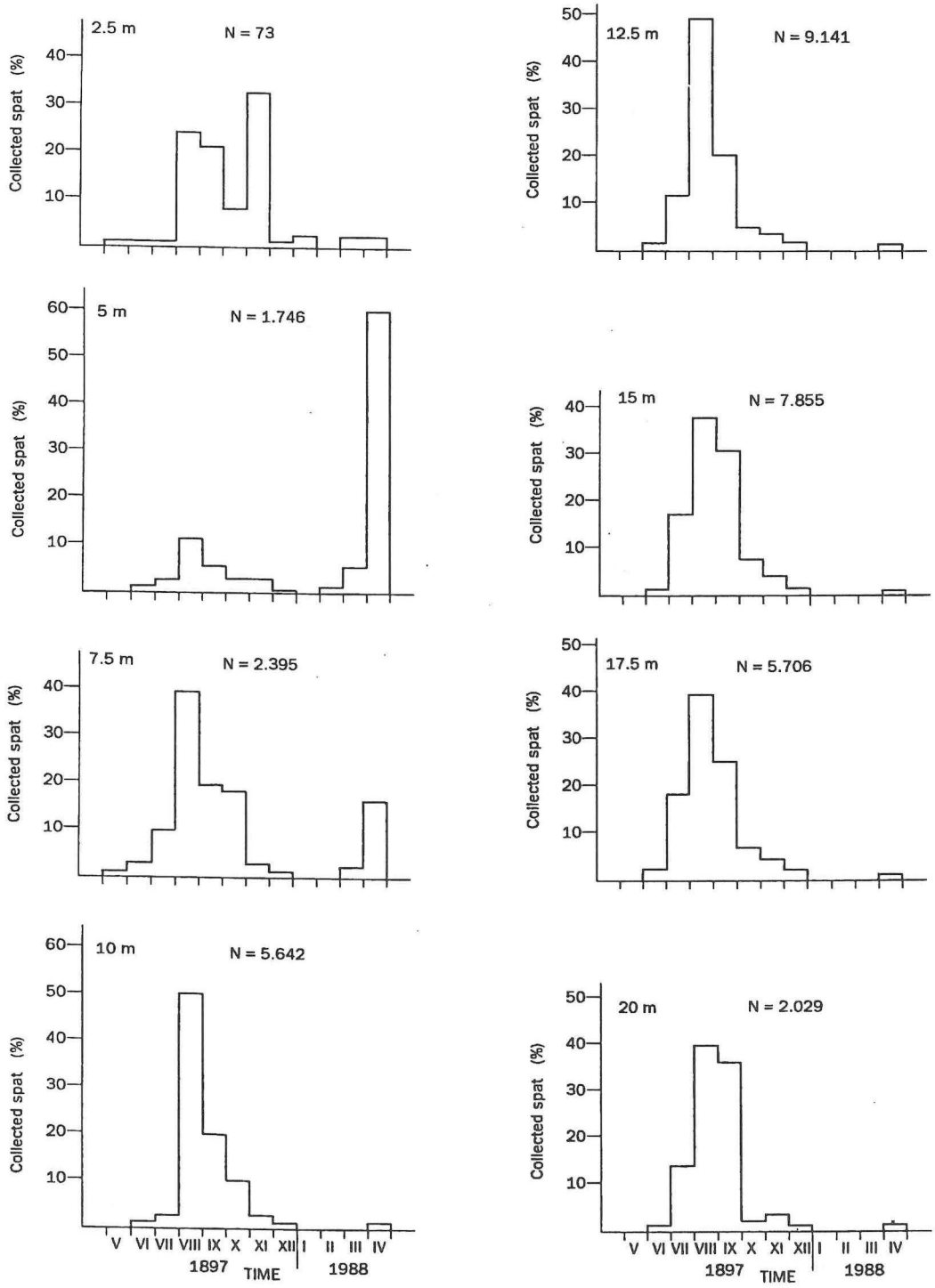

Fig. 4. The percentage of *Chlamys varia* spat by depth in Šarina draga Bay in 1987 and 1988. Maximum settlement at the 2.5 and 5 m depths occurred in November 1987 and April 1988 contrary to other depths in August.

15 m (Fig. 2). The settlement peak was recorded in June 1987 with 45.9% of the total collected spat (Fig. 3). The settlement maximum at all depths occurred from April to July 1987 (Fig. 6). Mean spat shell height increased from 3.9 mm ± 1.7 mm in June to 12.8 mm ± 5.3 mm

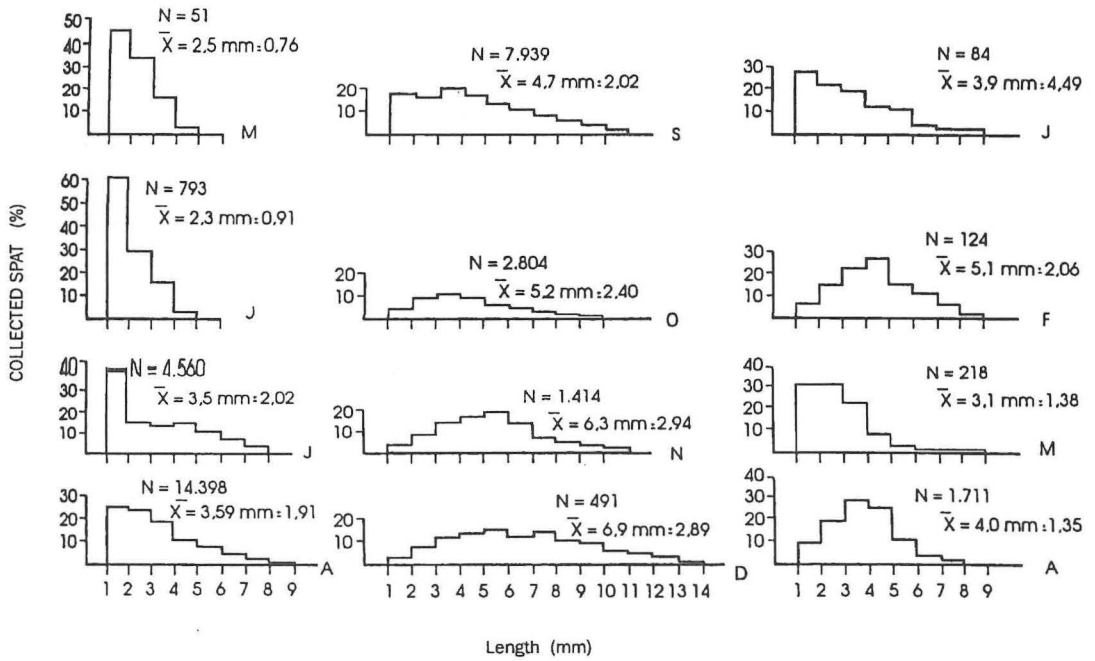

Fig. 5. Size frequency distribution of *Chlamys varia* spat in Šarina draga Bay in 1987 and 1988. Mean spat shell height increased from 2.3 ± 0.91 mm in June to 6.9 ± 2.89 mm in December1987. There was a considerable variation in shell height of spat collected from January to April 1988.

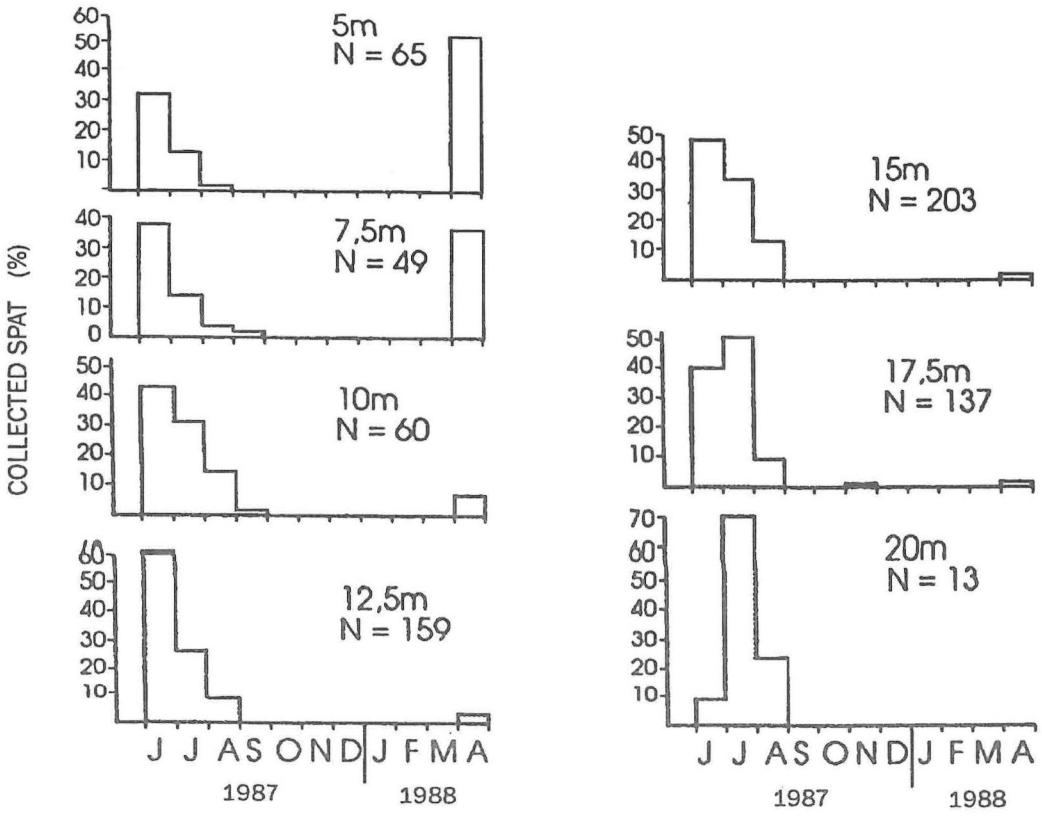

Fig. 6. The percentage of *Pecten jacobaeus* spat by depth in Šarina draga Bay in 1987 and 1988. The peak settlement at all depths occurred from April to July 1987.

and 12.6 mm ± 2.6 mm in August and September 1987, respectively (Fig. 7). No spat settlement was found in autumn or winter.

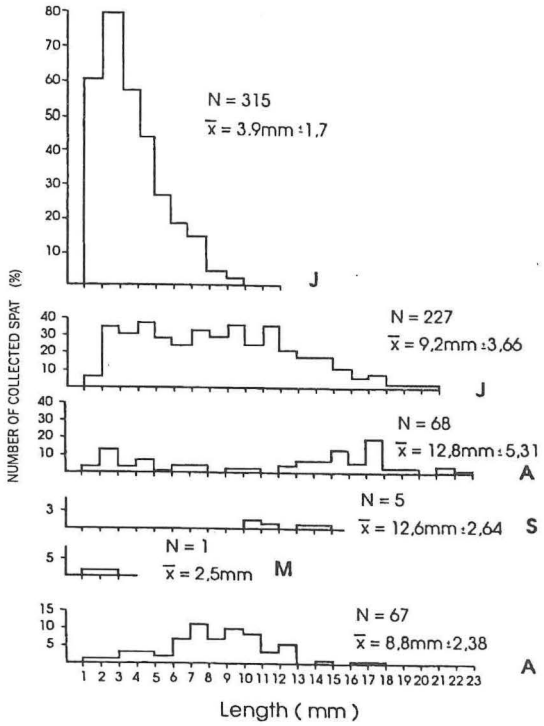

Fig. 7. Size frequency distribution of *Pecten jacobaeus* spat in Šarina draga bay in 1987 and 1988. Mean spat shell height increased from 3.9 ± 1.7 mm in June to 12.8 ± 5.31 mm in August and 12.6 ± 5.31 mm in September 1987. No settlement occurred in autumn or winter.

Temperature and salinity

Temperature and salinity gradients occurred during most of the year (Table 1 and 2). The highest temperature was recorded from the surface layer in summer with a maximum of 26.1 °C in August 1988 and the lowest one 7.2 °C in winter, in December 1988. Salinity was always higher at deeper layers with maximum of 39 x 10^{-3} and the minimum of 4 x 10^{-3} from the surface to 2.5 m in March and at 0.5 m in May 1988.

DISCUSSION

Settlement of Pectinids depends on horizontal and vertical distributions of larvae in plankton, wind directions and sea currents as well as on physical and chemical characteristics of a particular locality (ITO *et al.*, 1975). Several authors have reported that scallop larvae settle on a variety of organisms and artificial material provided that the surface is free of silt (NAIDU and SCAPLEN, 1976; VENTILLA, 1977; BRONSON *et al.*, 1980; PAUL *et al.*, 1984). In the recent years spat collectors used in Europe have been usually spat bags filled with a variety plastic materials (BUESTEL, 1976; MINCHIN, 1976; BRAND *et al.*, 1980; PAUL *et al.*, 1981).

Scallop recruitment has been shown to vary both spatially and temporally (BAIRD, 1966; GRUFFYDD, 1973; MINCHIN and MATHERS, 1982). Knowledge of dynamics and intensity of scallop spat settlement is the basic prerequisite for an estimate of biological potential in a particular ecosystem, and for determination of controlled growth possibility.

The time of larval settlement out of the collectors has been reported by ITO *et al.* (1975) and VENTILLA (1982) who used mostly a size composition of the swimming larvae for predicting their spatfall. In the present study, the settlement of *Chlamys varia* occurred throughout the year but most intensively from June to August 1987. Differences in the size frequency distribution of juveniles at different depths indicate two settlement peaks, in the period from the end of March to the end of July and at the beginning of August 1987. These results agree with those for *Chlamys varia* settlement patterns in Spain (ROMAN and CANO, 1987). The maximum settlement of *Pecten jacobaeus* occurred from the end of March to the beginning of July 1987, there was no settlement after August 1987.

The depth distribution of the settled spat in the collector bags reflect the distribution and behaviour of larvae in plankton or is the result of the spat survival after settlement (BRAND *et al.*, 1980). The distribution depth of *Chlamys varia* spat in this study was in agreement with results reported by the other workers (LATROUTE and LOREC, 1976; VENTILLA, 1977; BRAND *et al.*, 1980). The maximum of 2451 spat per bag occurred in the mid-water zone, approximately betwen 4 and 11 m above the bottom

Table 1. Temperature values (°C) of the sea at the investigated locality at various depths during 1987 and 1988

	Depth (m)								
Month	0.5	2.5	5	7.5	10	12.5	15	17.5	20
									1987
II	8.5	8.5	9.8	10.3	10.5	10.8	10.8	10.8	10.8
III	10.4	12.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2
IV	13.0	13.2	13.4	13.4	13.4	13.4	13.4	13.4	13.4
V	16.9	16.9	16.3	16.2	16.2	15.8	15.8	15.8	15.8
VI	21.6	20.8	20.2	20.0	19.6	19.1	19.1	19.1	18.8
VII	25.8	25.2	22.6	21.6	21.2	21.0	20.5	20.2	19.8
VIII	24.6	25.4	24.8	24.6	24.4	24.3	24.2	24.2	24.2
IX	23.2	25.4	23.1	22.4	20.8	20.3	19.6	18.5	18.1
X	17.7	20.4	21.2	21.2	20.4	20.2	20.2	19.9	20.4
XI	14.7	15.3	16.0	16.7	16.8	16.8	17.0	17.4	17.9
XII	9.7	15.4	15.5	15.5	15.5	15.5	15.5	15.5	15.5
									1988
I	10.2	11.8	13.4	14.0	14.3	14.3	14.3	14.3	14.3
II	9.1	9.6	12.6	13.2	13.2	13.2	13.2	13.2	13.2
III	12.5	12.7	13.2	13.2	13.7	13.7	13.7	14.4	14.2
IV	15.6	15.6	15.4	15.3	15.1	15.1	15.0	14.8	14.8
V	19.7	19.7	19.2	19.0	18.0	17.5	17.5	17.5	17.0
VI	21.0	22.5	20.7	20.2	18.7	18.6	18.5	18.5	18.5
VII	25.0	24.9	24.2	23.6	21.8	21.8	21.6	21.6	21.6
VIII	26.1	24.4	22.3	22.2	22.2	22.2	19.1	19.1	18.2
IX	18.8	20.6	20.4	20.4	20.4	20.2	20.0	20.0	20.9
X	17.9	18.0	19.2	19.6	19.6	19.8	19.8	19.8	19.8
XI	12.4	14.2	16.0	16.5	17.3	17.3	17.3	17.3	17.4
XII	7.2	8.7	11.0	12.3	12.4	12.8	12.8	13.0	13.5

Table 2. Salinity values (x 10^{-3}) of the sea at the investigated locality at various depths during 1987 and 1988

	Depth (m)								
Month	0.5	2.5	5	7.5	10	12.5	15	17.5	20
									1987
II	6	7	18	31	26	29	38	39	39
III	7	20	39	39	39	37	34	39	36
IV	10	10	10	27	34	34	35	39	39
V	7	9	27	30	38	34	35	39	38
VI	12	22	34	34	38	38	38	39	39
VII	16	35	38	39	39	39	39	39	39
VIII	20	27	33	36	37	35	37	37	38
IX	17	30	37	39	39	39	39	39	39
X	10	28	37	37	38	39	39	39	39
XI	33	35	36	37	38	39	39	39	39
XII	5	35	39	39	39	39	39	39	39
									1988
I	7	14	36	39	39	39	39	39	39
II	6	15	32	39	39	39	39	39	39
III	4	4	33	28	33	38	38	32	36
IV	5	12	23	33	39	39	39	39	39
V	4	8	30	33	37	37	37	37	38
VI	5	24	34	35	37	38	37	37	37
VII	12	32	38	39	39	39	39	39	39
VIII	17	25	27	34	30	27	36	38	38
IX	25	32	34	38	38	38	38	38	39
X	21	21	32	35	35	35	35	35	36
XI	34	34	34	38	39	39	34	34	39
XII	29	29	31	34	36	36	36	37	39

which is at 21 m depth. The depth distribution of *Pecten jacobaeus* spat was similar to that of *Chlamys varia*, with lower settlement near the bottom and the surface. Maximum number of *Pecten jacobaeus* spat were found in the collector bags in the water approximately from 4 to 9 m off the bottom.

The less intensive Pectinid spat near the surface was probably caused by the low surface salinity values of the Krka River which were below the optimum levels for larval metamorphosis, survival and growth. Under the laboratory conditions according to scallop growth rates it was determined that salinity of 16-20 x 10^{-3} is the survival limit for larvae of several scallop species (VERNBERG *et al.*, 1963; MACKENZIE, 1979; PAUL, 1980). Spat settlement did not occur at the salinities below 20 x 10^{-3} in the Krka River, as shown by the age structure of scallop and the portion of spat in 1-2 mm size classes in material collected. Salinity of 20 x 10^{-3} is probably the lower limit for normal development and survival of larvae and spat in the Krka River estuary.

The effects of wave action and heavy fouling also may have caused a decline in settlement bellow the surface layers. A spat decrease near the bottom is more difficult to explain but silting may affect settlement and survival as suggested by NAIDU and SCAPLEN (1976) and BRAND *et al.* (1980).

CONCLUSIONS

The vertical distribution of scallop spat varied in time. The seasonal dynamics is affected by physical and chemical factors. Ecological tolerancy to salinity of both shellfish species was established. Spat quantity of *Chlamys varia* and *Pecten jacobaeus* increased with depth and it was reduced immediately above the bottom.

According to the results of investigation there is a potential of *Chlamys varia* and *Pecten jacobaeus* spat which could be used in culture operations in the Šarina Draga Bay or to restock natural beds in the Krka River estuary.

The investigations have a preliminary character and a continuation of more detailed investigations of larval settlement and their survival with reference to seasonal variations of scallop spat settlement are suggested.

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Prihvaćanje češljača na kolektore u ušću rijeke Krke

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KRATKI SADRŽAJ

Kolektori za prihvat mlađi češljača postavljani su u uvali Šarina draga dva puta mjesečno u razdoblju od veljače 1987. do siječnja 1988. godine. Kao kolektor za prihvaćanje mlađi češljača korištena je vreća za povrće 75 x 50 cm, ispunjena plastičnom mrežom, promjera niti 0,5 mm, ukupne težine oko 200 grama. Osam kolektora u nizu postavljeno je u more u razmaku od 2,5 m na dubine 1 do 18,5 m iznad morskog dna. Kolektori su vađeni nakon tri mjeseca imerzije u moru.

Istraživanjem prihvaćanja mlađi češljača u kolektorima su utvrđene četiri vrste školjkaša porodice češljača (Pectinidae): *Chlamys varia* L.; *Chlamys (Flexopecten) flexuosus* Poli; *Chlamys (Aequipecten) opercularis* L. i *Pecten jacobaeus* L. U radu su obrađeni rezultati prihvaćanja mlađi *Chlamys varia* i *Pecten jacobaeus*.

Prihvaćanje mlađi *Chlamys varia* zabilježeno je tijekom cijele godine s maksimumom u razdoblju od lipnja do kolovoza. Maksimum prihvaćene mlađi (2451 jedinki po kolektoru) zabilježen je u kolovozu na dubini 12,5 m.

Najintenzivniji prihvat mlađi *Pecten jacobaeus* zabilježen je od kraja ožujka do početka srpnja s maksimumom od 80 jedinki po kolektoru u lipnju na dubini 15 m.