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OSTREA EDULIS (LINNAEUS) AND *CRASSOSTREA GIGAS* (THUNBERG) LARVAE IN THE PLANKTON OF LIMSKI KANAL IN THE NORTHERN ADRIATIC SEA

LIČINKE *OSTREA EDULIS* (LINNAEUS) I *CRASSOSTREA GIGAS* (THUNBERG) U PLANKTONU LIMSKOG KANALA U SJEVERNOM JADRANU

Mirjana Hrs-Brenko

Center for Marine Research, »Rudjer Bošković« Institute, Rovinj

The appearance and heavy settlement of the oyster *Crassostrea gigas* in the intertidal zone on the west coast of Istria Peninsula motivated the study of bivalve meroplankton in the Limski Kanal in 1973, 1975, 1976, and 1980. The length of spawning season, the duration of planktonic larval life and the period of settlement for *Ostrea edulis* and *Crassostrea gigas* were determined by establishing the first appearance of early and mature larvae, and by determining their fluctuations and abundances in plankton samples.

INTRODUCTION

The European oyster, *Ostrea edulis* Linnaeus, is indigenous to the Yugoslav coast of the Adriatic Sea where it is an important commercial shellfish species. Recently, however, larvae of another oyster, *Crassostrea gigas* Thunberg, were observed in plankton samples of the Limski Kanal, and the spat of this species were found among cultured *O. edulis,* as well as in the intertidal zone (Hrs-Brenko, 1977a; Filić and Krajnović-Ozretić, 1978). It seems certain that *C. gigas* was not present formerly in the waters of Limski Kanal, because plankton studies made in 1965 and 1966 contained larvae of only *O. edulis* (Hrs--Brenko, 1969). *Crassostrea gigas* could have been introduced to the Istria Peninsula as a fouling organism on foreign yechts, which are crowded in the Limski Kanal, and other Istrian bays in summer months during the reproductive season of this species. A number of these yachts come from Italy, where *C. gigas* is present. Matta (1969) mentioned the commercial imports of *Crassostrea angulata* Lamarck (= *C. gigas)* from France to various places in Italy. Data on the reproductive period, settlement, and growth of cultured *C. gigas* in the northern Adriatic Sea have

already been published by Renzoni (1975), Filić and Krajnović-Ozretić (1979), Specchi et al. (1978), and Valli et al. (1979).

In this paper the larval stages of *O. edulis* and *C. gigas* are used to determine the length of the spawning season and the period of intensive settlement by establishing the first appearance of early and of mature larvae and by determining their fluctuations and abundances in the plankton samples in Limski Kanal.

METHODS

Plankton samples were collected near the shellfish parks at the end of Limski Kanal by vertical tows from 3 and 5 m depth, with a Hensen 160 μm mesh plankton net (Fig. 1). The samples were taken every 7—8 days from the

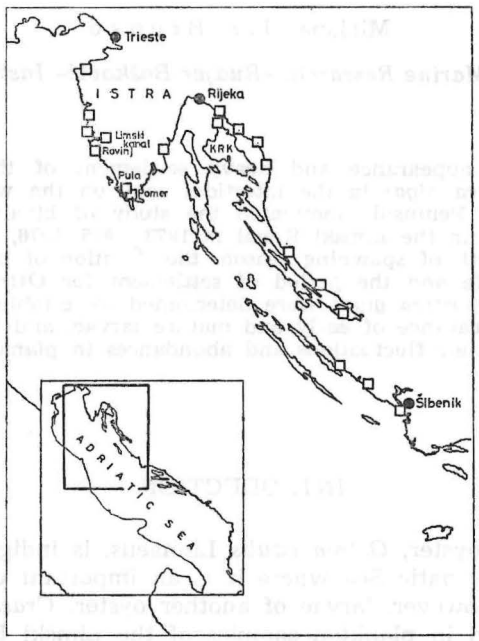

Fig. 1. Distribution of the sample stations on the east coast of the Adriatic Sea.

beginning of April to the end of October in 1973, 1975, 1976, and 1980. In each sample the total number of larvae was counted. Each oyster larva was measured along the longest dimension parallel to the hinge line. The number of mature larvae (hose greater than 250 μm and with an eye spot) was also determined. In 1973, an experimental glass plate (about 140 cm^2) was set out each time a plankton samples was taken; the plate previously set was retreived at this time and the number of oyster spat counted.

RESULTS

In Limski Kanal no plankton studies were made between 1966 and 1973. In 1973 when plakton sampling was resumed, the presence of *Crassostrea gigas* larvae was observed for the first time. *Crassostrea* larvae were at numbers up to 391 specimens per m^3 of filtered sea water in mid-September, of which 327 were mature larvae ready for settlement (Tab. I, Figs. 2, 4).

Table 1. Maximum of total number and number of mature larvae (*Ostrea edulis* and *Crassostrea gigas)* per m^3 of filtered seawater from Limski kanal in 1973, 1975, 1976, and 1980.

		1973		1975		1976		1980	
		No	Date	No	Date	No	Date	No	Date
Ostrea edulis	total	1.391	29. 5.	667	12. 8.	5.013	28. 7.	443	29. 7.
		863	10. 7.	320	5. 8.	3.275	1. 6.	365	8. 7.
		727	17. 7.	244	13. 5.	1.875	6. 7.	222	1. 7.
	mature	127	10. 7.	—	—	987	28. 7.	171	29. 7.
		118	17. 7.	—	—	787	13. 7.	143	8. 7.
		118	28. 8.	—	—	600	6. 7.	107	10. 6.
Crassostrea gigas	total	391	19. 9.	959	2. 9.	17.588	31. 8.	4.011	19. 9.
		64	4. 9.	724	12. 8.	688	28. 7.	3.839	9. 9.
		55	11. 9.	254	16. 9.	550	13. 7.	2.388	2. 9.
	mature	327	19. 9.	—	—	5.738	31. 8.	3.260	9. 9.
		55	4. 9.	—	—	75	17. 8.	2.746	17. 9.
		55	11. 9.	—	—	50	28. 7.	1.287	2. 9.

Both earlier studies and those reported here, *Ostrea edulis* larvae usually first appeared in the second part of April or in the beginning of May. The first *C. gigas* larvae occured later at the beginning of July. A delay in the growth of *O. edulis* larvae was recorded at temperatures lower than 18°C; thus, the first *O. edulis* larvae with eye spots were not observed until the second half of May or the first part of June, depending on the rate of the spring increase in sea water temperatures. The first mature *C. gigas* larvae occurred usually in the second part of July. *Crassostrea gigas* larvae were present in the plankton when temperatures were higher than 20°C. The larvae of both species of oysters disappeared during October (Figs. 2, 3, 4).

Abundant *O. edulis* larvae with a high proportion of mature individuals were recorded regularly in the plankton during June and July, usually with highest numbers in July; in August the abundance of mature larvae fluctuated considerably. Larvae of *O. edulis* always appeared earlier than those of *C. gigas*. Mature larvae of *C. gigas* were rare in July, more frequent in August, and abundant in September (Table I, Figs. 2, 3). Intensive settlement was observed during the greatest abundance of mature larvae in the plankton (Fig. 2). The entire season of plankton larval life of *O. edulis* extended from April to October and that of *C. gigas* larvae from July to October in the Limski Kanal (Figs. 3. 4).

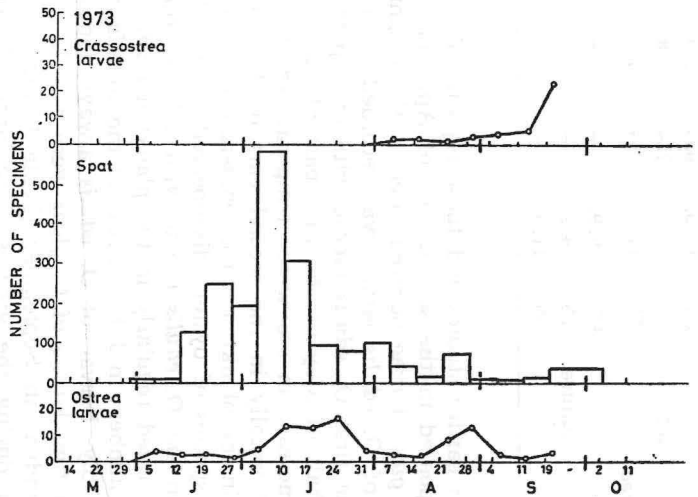

Fig. 2. Number of mature *O. edulis* and *C. gigas* larvae in the plankton, and number of spat on experimental glass plates in Limski kanal in 1973.

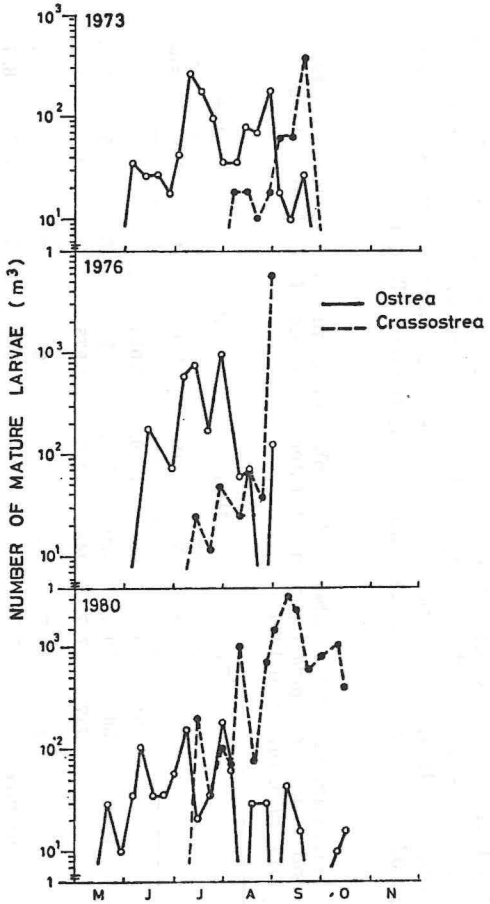

Fig. 3. Number of mature *O. edulis* and *C. gigas* larvae in the plankton of Limski kanal in 1976 and 1980.

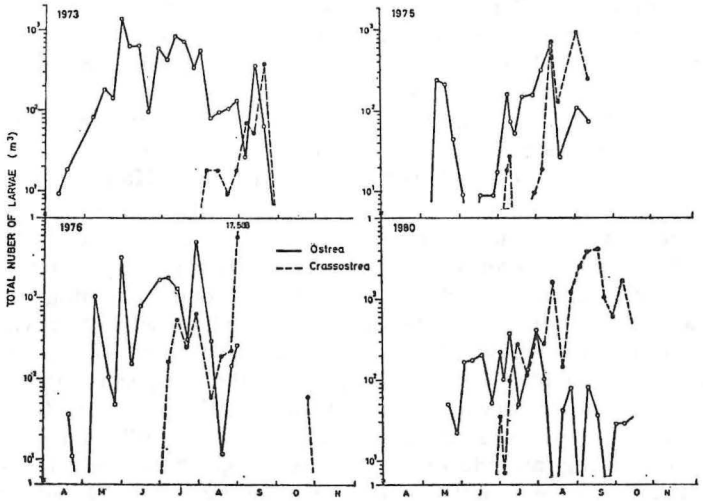

Fig. 4. Total number of *O. edulis* and *C. gigas* larvae in the plankton in Limski kanal in 1973, 1975, 1976, and 1980.

DISCUSSION

Larvae of *Crassostrea* have a more pronounced umbo than those of *Ostrea* and are clearly different from them (Loosanoff and Davis, 1963; Hrs-Brenko, 1977a). Moreover, the adults of the two species differ in morphological, physiological and behavioural characters (Yonge, 1960; Walne, 1974), as well as in their biometry and genetics (Filić and Krajnović-Ozretić, 1978). *Crassostrea gigas,* the Japanese or Pacific oyster which is native to the western Pacific, has been introduced commercially into many countries throughout the world because of its high growth rates. In some countries where the environment is favorable, *C. gigas* has established its stable populations. *Crassostrea angulata* is native to Spain and Portugal. Recently, comprehensive studies have indicated that *C. gigas* and *C. angulata* are the same species (Menzel, 1974; Methers et al., 1974), and the new oyster species that has appeared in the Limski Kanal is regarded here as *C. gigas* (see laso Valli et al., 1979).

Today, *C. gigas* is a widely distributed shellfish either alone or together with mussels (*Mytilus galloprovincialis* Lamarck) in the intertidal zone of the west coast of Istria Peninsula. During a preliminary survey along the east coast of Yugoslavia between Rijeka and Šibenik not a single individual of *C. gigas* was observed in the intertidal zone. Moreover, plankton samples at 3 stations on the west coast of Krk Island yielded only a few *O. edulis* larvae in Omišalj Bay (Fig. 1) (Hrs-Brenko, 1980a). The observed absence of *C. gigas* in that part of the Adriatic coast does not necessarily mean that populations are altogether absent; *C. gigas* could be very scarce and thus overlooked.

Owing to a gap in plankton studies that occurred between 1966 and 1973 the first occurrence of *C. gigas* larvae in the plankton of Limski Kanal has

not been determined. In September 1973 *C. gigas* larvae, mostly mature, were already abundant in the plankton and able to populate the intertidal zone of Limski Kanal (Table I, Fig. 2). Although 1976 was a favourable year for the settlement of mature larvae of both oyster species, 1980 was favorable only for *C. gigas* (Table I, Fig. 3), and observation that confirms that *C. gigas* populations are well established. It appears that at present the presence of *C. gigas* does not disturb *O. edulis* populations in Limski Kanal.

Ostrea edulis begins to spawn early in spring with a few femeles observed carrying white oyster larvae at the end of March (Peruško, 1967; Hrs-Brenko, 1969). The presence of *O. edulis* larvae in the plankton of Limski Kanal from early April to October indicates a long spawning season with several spawning and swarming period, a retarded growth of larvae at times when temperatures are below 18°C, and a long settlement season with several spatfalls ranging from May to October. Due to the long spawning season, the time of peaks of mature larvae can never be exactly predicted for each year. Usually, many mature larvae were observed in June, followed by a peak in July and a decreasing abundance in August (Figs. 2, 3). Similar seasons of planktonic larval life and settlement were observed for *O. edulis* in Vela Draga Bay (Pula) and Pomer Bay (Hrs-Brenko, 1977b, 1980b).

Crossostrea gigas from Limski Kanal showed a relatively short spawning and planktonic season lasting from the beginning of July to October (Fig. 4). The data are similar to the spawning observed in the Po Delta for *C. angulata,* namely, from the last week of June through July (Renzoni, 1974), and for *C. gigas* at Grado, from June to the end of September (Valli et al., 1979). Due to the short spawning season of *C. gigas,* fluctuations of the peaks of mature larvae are less conspicuous and temporally less variable than in *O. edulis,* with the maximum numbers usually occurring in September (Table I, Figs. 2, 3; in 1976 there were no observations for this month): Specchi et al. (1979) cited the intensive settlement of both species at Grado in later summer and early autumn.

The seasonal pelagic larval patterns of both species of oysters are correlated with their temperature tolerances. *O. edulis* can spawn at sea water temperatures less than 15°C (Korringa, 1957; Hrs-Brenko, 1969; Walne, 1974). On the other hand, the minimum temperature at which *C. gigas* spawns is between 19—20°C, and larvae develop normally between 15 and 30°C (Medcof and Wolf, 1975). Because the data show that mature larvae of both oyster species are present in the plankton from July to October (Figs. 2, 3), we could expect the simultaneous settlement of both oyster species on the same collectors during these months but not between May to mid-July vhen only *O. edulis* spat should attach.

The tow oyster species also differ from each other in their salinity tolerances. *Crassostrea gigas* larvae develop normally in salinities ranging from $S = 11$ to 32×10^{-3}, whereas *O. edulis* larvae reach maturity in $S = 20$ to 37×10^{-3} (Korringa, 1941; Davis and Ansell, 1962; Medcof and Wolf, 1975). Due to these differences, the larvae of both oyster species attach at different horizontal levels according to the environmental salinities; thus *C. gigas* settles in the intertidal zone, higher than *O. edulis,* which settles in the sublittoral zone. This spatial distribution of ovster spat of both species was found in oyster beds and on rocky shores in Limski Kanal (Filić and Krajnović-Ozretić, 1978). In the Adriatic Sea the salinity varies bet-

ween S = 36 and 38 × 10^{-3}, except in limited areas near freshwater springs or rivers. An expansion of *C. gigas* into other areas of the Adriatic Sea might be limited by high salinities; however, this speculation is countered by the findings of Medcof and Wolf (1975), who observed *C. gigas* at a salinity as high as S = 35 × 10^{-3}. They proposed that the *C. gigas* specimens that they encountered belong to a physiological race adapted to high salinity. If *C. gigas* from the west coast of the Istria Peninsula are also adapted to salinities higher that S = 32 × 10^{-3} we can expect the future extension of their range into areas of the Adriatic more saline than S = 32 × 10^{-3}. On the rocky shores of Valdibora (Rovinj) only small *C. gigas* specimens were observed, perhaps owing to the salinities there which are not optimal for their growth.

Seasonal differences between the two oyster species in the appearance, maturation, and settlement of the larvae could be used to advantage for commercial purposes. Between June to mid-July only the spat of *O. edulis* would be collected on immersed collectors. In mid-July, the transfer of those collectors with *O. edulis* spat to deeper water or to other bays with prevailing high salinities should prevent an intensive settlement of *C. gigas* on those collectors later in summer. An intensive settlement of *C. gigas* could cover *O. edulis* and smother then due to the rapid growth of *C. gigas* and the resultant competition for space and food. The possibility of separating of *O. edulis* spat from *C. gigas* settlement should be considered in future studies.

CONCLUSIONS

Plankton studies in Limski Kanal showed the presence of *O. edulis* larvae from April to October, with mature larvae occurring between May and October. From the abundances of mature oyster larvae in the plankton, it is suggested that there occurs heavy spatfall in June, the most intensive settlement in July, and only occasional attachment of new spat in August. Larvae of *C. gigas* were observed in the plankton at temperatures higher than 20°C between July and the end of October, with the greatest abundance of mature larvae during September. Differences in the length of spawning, plankton larval life and settlement season of both oyster species are the result of the differences in their salinity and temperature tolerances.

Plankton observations suggest that the recently introduced oyster *C. gigas* has already established stable populations in Limski kanal. Observations of the further expansion of *C. gigas* by natural means to other areas of the Adriatic coast of Yugoslavia as well as the separation of *O. edulis* spat from *C. gigas* settlement will be the subjects of future investigations.

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Mirjana Hrs-Brenko

Centar za istraživanje mora, Institut »Rudjer Bošković«, Rovinj

KRATAK SADRŽAJ

Zapaženo intenzivno širenje kamenice *Crassostrea gigas* u zoni plime i oseke u Istri posljednjih godina kao i obilni nalazi njenih ličinki u planktonu Limskog kanala potakli su intenzivnija istraživanja njenih razvojnih stadija radi boljeg upoznavanja obnavljanja njenih populacija.

Uzorci planktona uzimani su mrežicom tipa Hensen (veličine oka 160 μm), koja je vučena od dna (3—5 m) prema površini, pri dnu Limskog kanala, svakih 7—8 dana od travnja do listopada u 1973, 1975, 1976. i 1980. godini.

Istraživanja su ukazala da evropska kamenica *Ostrea edulis* ima znatno duže razdoblje mriješćenja, boravka ličinki u planktonu i prihvaćanja mladih primjeraka od travnja do listopada, od japanske *Crassostrea gigas* koja je prisutna u planktonu od srpnja do listopada. Zrele ličinke *O. edulis* bile su brojne u planktonu u lipnju, osobito u srpnju, a katkada i u kolovozu, dok su zrele ličinke *C. gigas* bile u planktonu (temperatura iznad 20°C) osobito brojne u rujnu. Zapažene razlike u dužini mriješćenja, planktonskog života i prihvaćanja na čvrstu podlogu rezultat su razlika u temperaturnim i salnitetnim tolerancijama obiju vrsta ličinki kamenica. Istraživanja su utvrdila da se u Limskom kanalu populacije *C. gigas* dobro obnavljaju, te izgleda da do sada nisu ugrozile postojeće populacije evropske kamenice *O. edulis*. Narednim istraživanjima planira se pratiti eventualno širenje ove kamenice u druge lokalitete u Jadranu, kao i mogućnost razdvajanja mladih prihvaćenih kamenica *O. edulis* od kamenica *C. gigas* u svrhu komercijalnog uzgoja.