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SURVEY ON *CHAMELEA GALLINA* BEDS IN THE LIGNANO AREA (GULF OF TRIESTE, ADRIATIC SEA)

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ABSTRACT

*Following the mass mortality which occurred in 1996, the rebuilding of the Striped Venus clam (*Chamelea gallina*) stock was complicated due to recruitment failure and low growth rate, as suggested by seasonal surveys. Thin sections of shell were obtained from twenty clams randomly extracted for every survey and it was observed that the cleft was formed in the autumn as ascertained in previous surveys. Stock management based on minimum size and quantities only is discussed. At present, in spite of the efforts to manage the population made by both the Public Authority and fishermen soon after 1996, the depletion of the area is almost complete as resulted from surveys done in 2009 and 2011.*

Keywords: *Chamelea gallina*, Gulf of Trieste, growth, clam fishery, management

INDAGINE SU *CHAMELEA GALLINA* NELL'AREA DI LIGNANO (GOLFO DI TRIESTE, MARE ADRIATICO)

SINTESI

*La vongola comune (*Chamelea gallina*), risorsa ampiamente sfruttata nel corso degli anni, ha subito nel 1996 una moria particolarmente disastrosa ed estesa lungo le coste adriatiche. Questo ha in parte ostacolato la piena realizzazione dell'autonomia gestionale da parte dei Consorzi di gestione con lunghi periodi di fermo pesca, ma ha anche messo in evidenza che la ripresa dello stock è stata pesantemente influenzata sia dal reclutamento, sia dal tasso di crescita, che sembra aver subito vistosi rallentamenti negli anni immediatamente successivi al fenomeno, imponendo una riflessione sulle modalità di sfruttamento. Di fatto la situazione è precipitata a partire dal 2009, ed il declino è confermato dai rilievi speditivi effettuati nel 2011.*

Parole chiave: *Chamelea gallina*, Golfo di Trieste, crescita, pesca di vongole, gestione

INTRODUCTION

The Striped Venus clam (baby clam) *Chamelea gallina* (L. 1758), widely distributed along European coasts (Fischer *et al.,* 1987) has long been a very important resource on the western Adriatic coast. This species is also exploited in Spain and Morocco (Ramon & Richardson, 1992), Portugal (Gaspar *et al.*, 2004; Rufino *et al.*, 2010) and in Turkey (Alpbaz & Temelli, 1997). In Italy, the fishery is facing a long decline which had already started during the 1980s and is still in progress, as reported by, *e.g.*, Romanelli *et al.* (2009). Froglia (1989) indicates a maximum of 100,000 tons in estimated landings and the 2010 last SISTAN official report (www.irepa.org/index.php?option=com_phocadownload&view=category&id=57&Itemid=52&lang=it, visited 24 March 2012) estimates only 21,794 metric tons. The quantity referred to the hydraulic dredges sector (the razor clam *Ensis minor*, *C. gallina* and the Smooth Venus *Callista chione*). The clam fishery in the Adriatic has been studied since the early 1980s thanks to a program financed by the Italian government involving many scientific teams. At the time, concern was on the rise regarding possible stock depletion (*e.g.*, Froglia, 1975, 1989; Bombace, 1985).

In the Gulf of Trieste, the species distribution and exploitation pattern were and still are quite different from those of the other maritime districts and the species may now be found from the coast line only to a depth of 5 m. Up to 1994, many vessels of the Monfalcone District were fishing *C. gallina* in the Venice District and *E. minor* was exploited instead. For that reason the *C. gallina* exploitation history in the Gulf of Trieste cannot be compared to the rest of Adriatic (Del Piero, 1994, 1998; Del Piero *et al.*, 1998). From the beginning of the scientific surveys the stock in the Gulf of Trieste was subject to significant changes and the worst change was induced by the mass mortality which occurred in 1996 (Anonymous, 1997; Del Piero, 1998; Froglia, 2000; Romanelli *et al.*, 2009, among others) along the whole western Adriatic coast. Over the last few years, a partial recovery was observed in 2007 (D. Del Piero, *pers. observation*) followed by a depletion in 2009 (1.1 ind. m^{-2} at Lignano) (Burca *et al*. 2010; de Flego, 2011) and confirmed after the surveys done in 2011 (no clams collected at Lignano; D. Del Piero, *pers. observation*). The 2011 campaign however, was designed to evaluate the commercial fraction only.

This paper presents the data collected in the Lignano area from November 1997 (soon after the mass mortality) to February 2000 (nine surveys) where a strong depletion in the commercial fraction (≥ 25 mm) was observed together with a slowing in the clam growth, compared to the previous years. The study was financed by the national Agriculture Ministry (1997/98 and 1999/2001) and the 2009 and subsequent surveys were done in force of the Agreement between the Fishermen Consortium (CO.GE.MO) of the Monfalcone Maritime District and the Life Science Department.

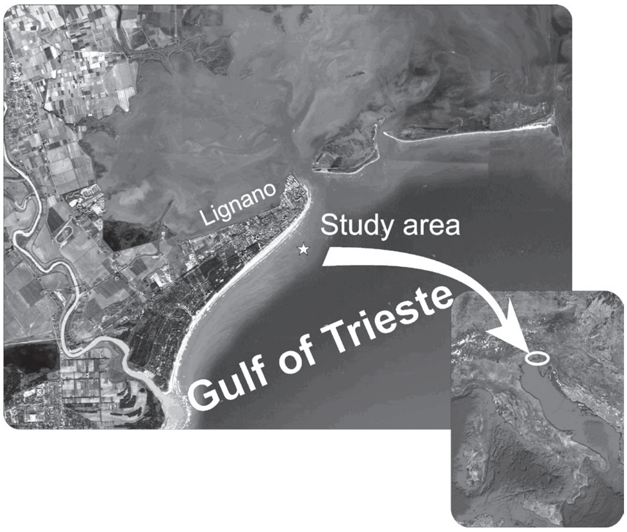

Fig. 1: Schematic map of sampled area (courtesy Dr. P. Rossin, ARPA-FVG).
Sl. 1: Shematični prikaz območja vzorčenja (avtor: dr. P. Rossin, ARPA-FVG).

MATERIAL AND METHODS

The samples were collected in front of Lignano, Gulf of Trieste (Fig. 1) by a commercial fishing vessel of Marano Lagunare equipped with a modified hydraulic dredge (Del Piero, 1994) during experimental tows from a depth of 2 to 6 meters (1 m intervals). The tow length was fixed at 50 m, except for November 1997, when the scarcity of clams suggested a 100 m length instead. The modified dredge has three sectors and the central one is 78 cm wide with a 6 mm gap among steel bars in order to collect individual clams ≥ 1 cm (C. Froglia, *pers. comm.*). Only the clams lying in the central section were sampled and frozen in the laboratory at -18 °C. The measurements were done on individuals using vernier callipers to the smallest mm and the frequency classes were fixed at 1 mm in amplitude.

The frequency classes over 25 individuals were pair-tested with Kolmogorov-Smirnov (Sokal & Rohlf, 1997) in order to evaluate the probability that they were extracted from the same statistical population. Based on past experience (Scaricci, 1995-96; Keller *et al.,* 2002) it was decided to study thin sections from the samples collected at a depth of 4 m.

Twenty individuals were extracted using a random process, re-measured to the second decimal and the right valve, after inclusion in *Araldite*®, was sectioned along the umbo-ventral axis in the laboratory of the Department of Geological, Environmental and Marine Sciences (DISGAM and now the Department of Mathematics and Geosciences) and sections of 30-40 μm were obtained (M. Cafau, *pers. comm.*). In the Microscopy Laboratory of the Department of Mathematics and Geosciences, the sections were examined for age evaluation based on the occurrence of the V-shaped structure (Fig. 2) generally known as the cleft (Ramon & Richardson, 1992; Gaspar *et al.*, 2004) that involves all the carbonate strata of the aragonitic shell of *C. gallina*. The aragonitic form of calcium carbonate in *C. gallina* had previously been ascertained (F. Princivalle, *pers. comm.*). The carbonate layers are: a) the superior composite prismatic layer, b) the crossed lamellar layer and the innermost so-called homogeneus layer (Alemany, 1986). The cleft

Tab. 1: *Chamelea gallina* ***density (ind. m^{-2}) and frequency distribution (cm); in italic: 1999 cohort.***
Tab. 1: Gostota vrste *Chamelea gallina* ***(ind. m^{-2}) in frekvenčna porazdelitev (cm); v kurzivu: kohorta iz leta 1999***

cm	Nov 97	Feb 98	Jun 98	Feb 99	Apr 99	May 99	Jul 99	Nov 99	Feb 00
0.5								*0.545*	*0.083*
0.6								*0.571*	*0.090*
0.7								*0.474*	*0.096*
0.8								*0.378*	*0.212*
0.9								*0.468*	*0.449*
1	0.017	0.082	0.314	0.051	0.051	0.031	0.156	0.551	0.468
1.1	0.030	0.110	0.558	0.141	0.046	0.062	0.168	0.186	0.269
1.2	0.049	0.123	0.622	0.167	0.062	0.108	0.168	0.135	0.263
1.3	0.017	0.069	0.596	0.154	0.082	0.174	0.261	0.090	0.179
1.4	0.017	0.051	0.404	0.115	0.072	0.221	0.321	0.090	0.071
1.5	0.015	0.041	0.449	0.154	0.067	0.272	0.433	0.071	0.083
1.6	0.017	0.067	0.282	0.147	0.036	0.277	0.381	0.045	0.083
1.7	0.059	0.064	0.353	0.173	0.051	0.174	0.447	0.077	0.096
1.8	0.074	0.108	0.429	0.167	0.046	0.195	0.399	0.064	0.090
1.9	0.099	0.136	0.750	0.199	0.103	0.210	0.324	0.045	0.122
2	0.111	0.190	0.917	0.147	0.067	0.123	0.247	0.058	0.103
2.1	0.062	0.172	0.955	0.096	0.056	0.113	0.197	0.071	0.051
2.2	0.057	0.123	0.987	0.064	0.077	0.046	0.138	0.058	0.128
2.3	0.025	0.090	0.949	0.038	0.062	0.041	0.091	0.109	0.083
2.4	0.007	0.038	0.840	0.026	0.031	0.036	0.038	0.122	0.109
2.5	0.005	0.013	0.660	0.077	0.021	0.031	0.035	0.135	0.186
2.6	/	0.003	0.295	0.064	0.021	0.031	0.018	0.115	0.038
2.7	0.005	/	0.128	0.032	0.026	0.031	/	0.109	0.058
2.8	0.002	0.003	0.077	0.064	0.026	0.015	0.015	0.096	0.026
2.9	0.005	/	0.038	0.045	0.015	0.036	0.013	0.083	0.026
3	0.005	0.003	0.013	0.013	0.015	0.026	0.007	0.058	0.006
3.1	/	0.003	0.013	0.032	/	/	/	0.051	/
3.2	/	0.003	0.006	/	0.005	/	/	0.064	0.006
3.3	/	/	0.006	/	/	/	/	0.032	/
3.4	/	/	/	/	/	/	0.005	/	/
3.5	0.002	0.003	0.013	/	/	/	/	0.013	/
3.6	/	0.003	/	/	/	/	/	0.019	/
3.7	0.002	/	/	/	/	/	/	/	/
3.8	/	0.005	/	/	/	/	/	0.006	/
3.9	/	/	/	/	/	/	/	/	/
Total	0.683	1.500	10.654	2.167	1.036	2.251	3.861	2.551	2.545

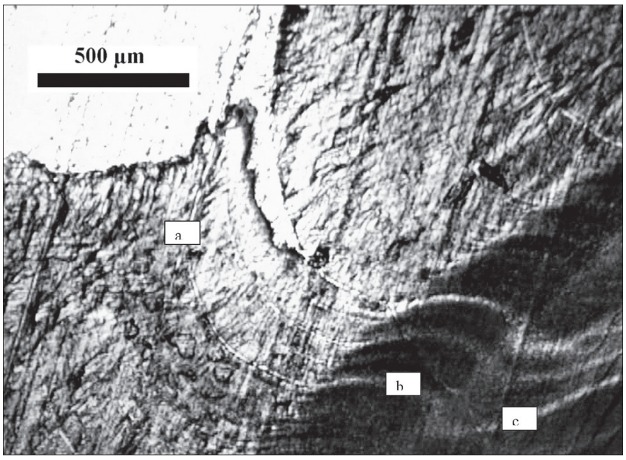

Fig. 2: Cleft detail of* Chamelea gallina *(100x, photomicrography courtesy of Prof. Valli). Section from umbo to ventral margin (left valve) of a 18 mm in length specimen. The brighter area is the a) superior prismatic sub-layer; growth increments are visible in b) inferior crossed lamellar sub-layer and in the c) homogeneous layer.

Sl. 2: Detajl zajede pri vrsti* Chamelea gallina *(100x, fotomikrografija, avtor: prof. Valli). Predel od vrha lupine do trebušnega roba (leva lupina) pri primerku, dolgem 18 mm. Svetlejši predel je a) zgornji prizmatični podsloj, vidijo se prirastki; b) spodnji prečni lamelarni podsloj; c) homogeni sloj.

in the northern Adriatic is formed in fall, generally at the end of October or the beginning of November (Scaricci, 1995-96) and the same pattern was observed by Ramon & Richardson (1992) and Gaspar *et al.* (2004) for Spain and Portugal.

RESULTS AND DISCUSSION

The overall density is reported in Table 1, average length and standard deviation in Table 2, the cleft number in the thin sections are shown in figure 3.

November 1997. Overall density resulting after pooling the four hauls were 0.68 ind. m^{-2} only. Frequency distributions after the Kolmogorov-Smirnov test differ significantly and so are not reported in Table 3, where only non significant differences are shown. From the 20 thin sections, only 17 were suitable for age evaluation, even after sectioning the left valve. The results are summarized in figure 3 where it can be observed that 5 specimens from 15.05 to 18.85 mm have only one cleft, 7 from 19.3 and 20.9 mm have 2 clefts, 3 have 3 clefts and the 30.05 mm individual shows 4 clefts.

February 1998. Clams were found in all five tows, overall density is 1.5 ind. m^{-2}. One cleft was present in clams from 12.55 to 15.40 mm in length, 2 clefts in 3 clams from 16.55 to 22.15 mm. Clams from 22.55 to 23 55 mm exhibit 3 clefts.

Tab. 2: Sample mean length (avg., in cm) and standard deviation (s^2).

Tab. 2: Povprečna dolžina vzorca (avg., v cm) in standardni odklon (s^2).

	Depth (m)	2	3	4	5	6
Nov 97	avg.	3.09	2.07	2.00	1.32	
	s^2	0.506	0.305	0.235	0.244	
Feb 98	avg.	2.68	2.11	2.00	1.34	1.07
	s^2	0.854	0.262	0.249	0.281	0.040
Jun 98	avg.	2.33	2.01	1.33		
	s^2	0.341	0.371	0.190		
Feb 99	avg.	2.53	2.22	1.66	1.44	
	s^2	0.346	0.273	0.134	0.121	
Apr 99	avg.	2.12	2.06	1.87	1.37	
	s^2	0.691	0.585	0.440	0.245	
May 99	avg.	1.86	2.01	1.54		
	s^2	0.403	0.439	0.237		
Jul 99	avg.	2.05	1.74	1.52	1.23	
	s^2	0.387	0.350	0.257	0.314	
Nov 99	avg.	2.93	2.46	1.26	1.23	
	s^2	0.402	0.417	0.290	0.044	
Feb 00	avg.	2.30	2.21	1.48		
	s^2	0.395	0.427	0.495		

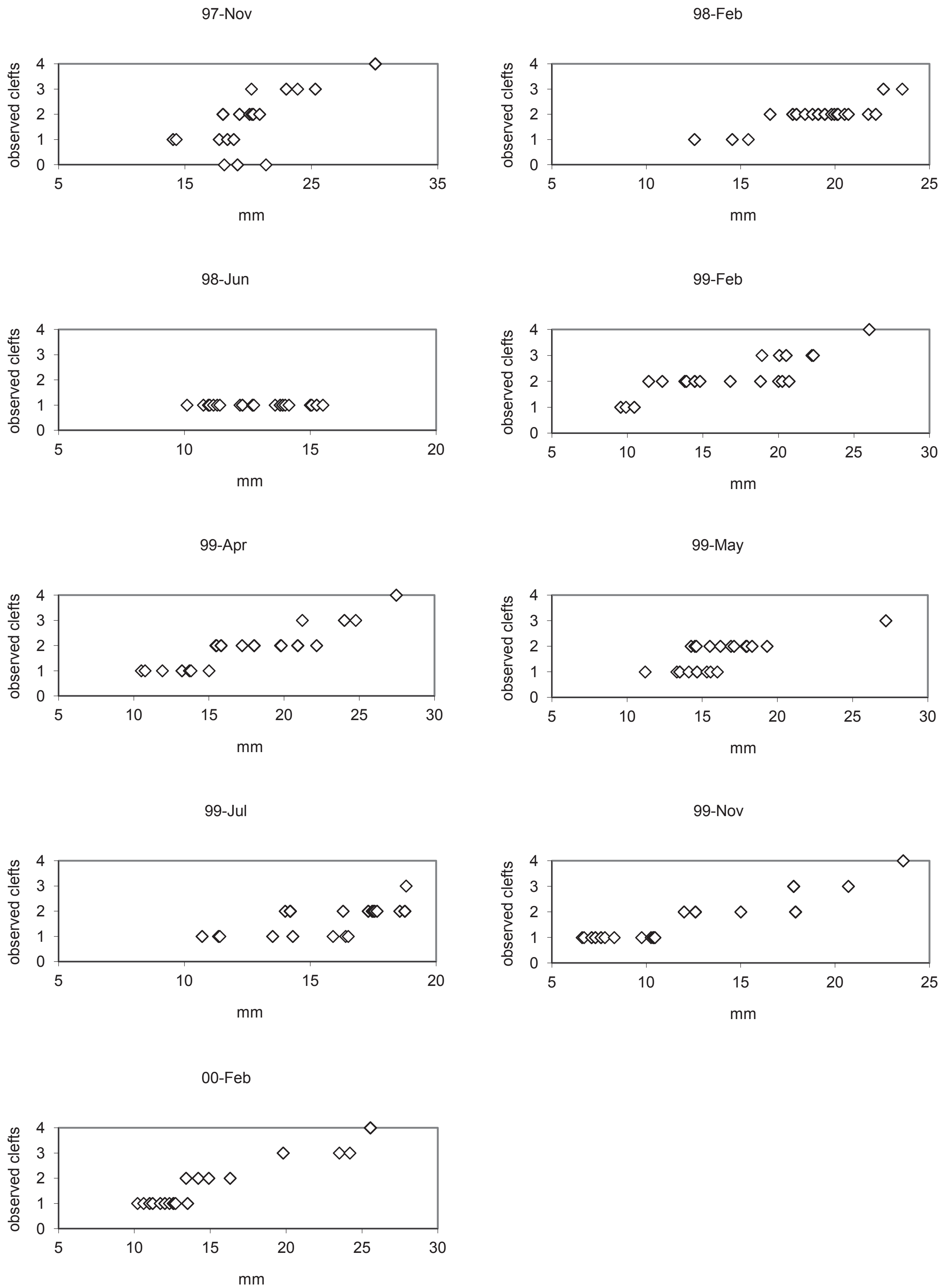

Fig. 3: Length in mm and cleft numbers observed in the samples.
Sl. 3: Dolžina v mm in število zajed pri vzorčnih primerkih.

June 1998. Clams were found in three samples, overall density is 14.11 ind. m^{-2}, the majority being undersized. All the individuals in the third sample were from 10.1 to 15.5 mm in length, a quite anomalous result and so only the growth after cleft formation was observed.

February 1999. Due to the emergence of serious bureaucratic problems mainly involving insurance protocols, the surveys were suspended in 1998 and restarted in February 1999. The clams were found in 4 samples and the overall density was estimated at 2.17 ind. m^{-2}. All the thin sections revealed a cleft near or proximate to the shell margin. From the samples obtained in this survey, it emerged that clams very close in length may account for different ages, *e.g.* 2 or 3 years.

April 1999. Data were referred to four hauls and the overall density was 1.04 ind. m^{-2}. The frequency distributions obtained from sample 2 and 3 (Tab. 3) were not significantly different ($D_{0.05}$ = 0.234, D_{max} = 0.226). One cleft (Fig. 3) was present in individuals from 10.5 to 15 mm. In the interval between 14.45 and 22.15 mm, two specimens had 2 clefts but one clam 21.2 mm in length had 3 clefts.

May 1999. Another survey was done in May and three samples were obtained. The overall density was estimated at 2.25 ind. m^{-2} and the littlest individual observed with 2 clefts was 14.10 mm in length, the largest with one cleft was 16.00 mm (Fig.3).

July 1999. Clams were found in four samples and the density was 3.86 ind. m^{-2}, higher than previously found. One cleft was observed in clams from 10.7 to 16.3 mm, 2 were present in specimens from 16.40 and 17.55 mm, and 3 between 18.55 and 18.75 mm.

November 1999. The results were referred to four samples and the estimated density was less: 2.55 ind. m^{-2}. All the sectioned clams had a cleft near the shell margin, in 12 of 20; the marginal cleft was very close to the margin. The clams in the interval 6.60 and 10.40 had only one cleft, 2 clefts were found in clams from 12.00 and 17.90 mm, 3 in two clams 17.8 and 20.7 mm in length. Four clefts were observed in the largest clam measuring 23.6 mm.

February 2000. The last survey was done and the clams were collected in only three hauls, with 2.54 ind. m^{-2} estimated density. The first cleft was present in 12 specimens (Fig. 3) (10.20-13.50 mm in length), 2 clefts were observed in clams from 13.40 and 16.30 mm, 3 were present in clams between 19.80 and 24.20 mm in length. The only clam with 4 clefts was 25.50 mm in length.

The nine surveys done on the Lignano clam beds outline alternate results, the maximum density being observed in June 1998, two years after the mass mortality. The low densities generally observed in autumn and winter may be an effect of clams burrowing due to low temperatures (the same happens in summer to avoid heat). The 1997 results (when low densities were observed) seem to indicate that the depletion caused by the 1996 mortality was far from being recovered. Beyond seasonal variation within the sample amounts, the fishery was suspended in the Monfalcone Maritime District very early in 1997 (February) until January 1998. The data obtained from the February 1998 survey show

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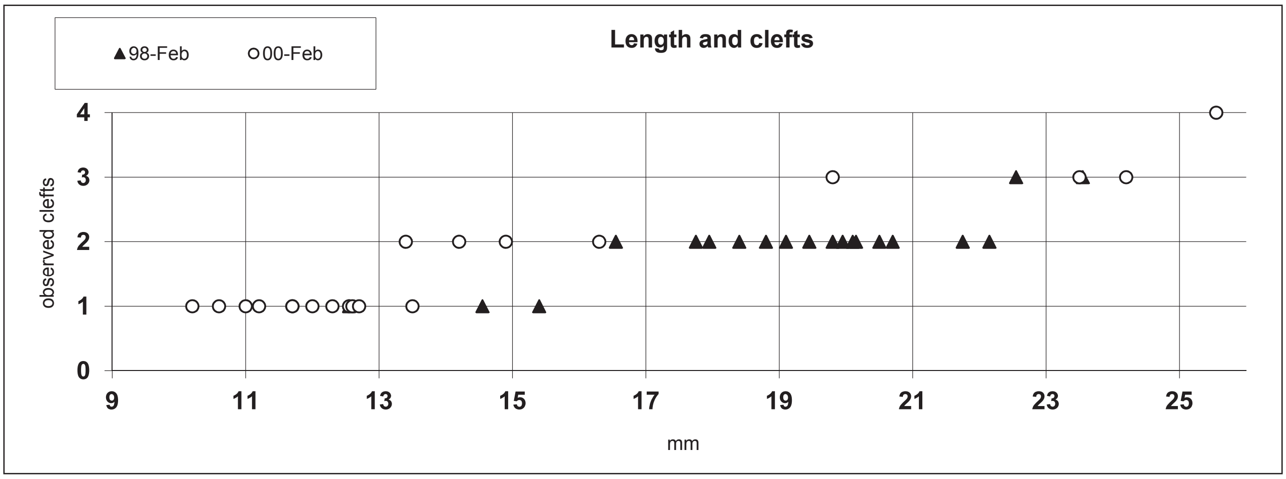

Fig.4: Cleft number February 1998 and February 2000.
Sl. 4: Število zajed februarja 1998 in februarja 2000.

an increase in the estimated density but a scarcity of full size clams. More increase in density was observed in June, but the commercial fraction was steadily low. No clear pattern was observed in 1999 and the most important fact is the entry of the young-of-the-year, split into two semi-cohorts confirming the results observed by Keller *et al*. (2002). It must be considered, however, only indicative of the presence of specimens under the theoretical gear selectivity, specimens not included in estimated density, computed only for clams from 10 mm onwards. The data from the last survey didn't vary substantially in density and the decrease in average length (Tab. 2) is an effect of the presence of juveniles. The average length calculated for each haul diminished with increasing sea depth, as previously observed in other areas as well (Del Piero *et al.*, 1998) and this fact was attributed to the fishery pressures exerted year after year in the deeper area, being the fishery formally banned from 3 m depth to the coastline during the entire period when the sampling was done. On the other side, the experimental dredge was designed in 1983 by Dr. Froglia from ISMAR (Ancona, Italy) especially for the dominant pure sand substrate of Central Italy, and where the substrate changes suddenly as in the Gulf of Trieste, it may be less efficient as observed in previous studies (D. Del Piero, *pers. observations*). Following that, the clam population at different depths is quite different and only ca 22 % of the frequency distributions tested (16 from 73 paired tests, Tab. 3) belong to the same statistical population ($p < 0.05$) even if the area explored is limited.

The thin sections (177 with distinct marks out of the 180 in total) showed that cleft formation starts in November as in Scaricci (1995-96), but the author (*ibid.*) never observed a cleft in shells less than 9 mm in length, as reported in the present study. The commercial fraction (≥ 25 mm) was overall low in the samples (Tab. 1) and the individuals had 3 or 4 clefts. It must be underlined that the commercial fishery deals with minimum size, but as Keller *et al*. (2002) stressed, there is time to ask if minimum size still has significance. Keller *et al*. (2002) found important differences in age for *Callista chione* sampled in different areas, but the length was the same. There are differences in the growth rate among areas but the minimum size is the same.

Another critical point is the size reduction related to settlement year, estimated from the number of clefts (Fig. 3): for example, the 2000 sample done in February (when the formation process is considered to be concluded, Scaricci (1995-96) showed two clefts in clams between 14 and 16.3 mm in length, then belonging to the cohort (or semi-cohort) settled in 1998, but specimens with two clefts in February 1998 (settled in 1996) have a higher size between 16 and 22.5 mm (Fig. 4). The difference between the two series is significant (Kruskall-Wallis test: 22.42, $p < 0.001$, $n = 34$). In February 1998 three clams between 12 and 16 mm had only one cleft, and are part of the 1997 cohort. So it can be affirmed that the growth of 1997 recruits is comparable to the results of the previous years (Keller *et al.*, 2002) but the cohorts settled after following a different pattern. Recent elaboration of data samples done in 2009 compared to the present data on shell weight/length rate show a significant difference between the series, being 0.58 for this set and 1.03 for the 2009 set (Dwass-Steel-Chritchlow-Fligner test for Pairwise Comparisons $p < 0.000$, Systat 13, G. Valli *pers. comm.*), other comparisons still in progress regarding all the data set collected from 1975 confirm the anomaly of the present set.

CONCLUSIONS

Stock management of *Chamelea gallina* (a species progressively impoverished and with wide variability in growth rate and recruitment) should be addressed only after cohorts are recognized and carefully evaluated.

At the present, it seems there are no conceptual frames satisfying that and the practical application could be very difficult, but for a stock depleted in quantity and demographic structure, this should be the only way to follow. The minimum size only (fixed at 25 mm in 1963 by a national law) without the age estimation obtained from the shell, appears to be unsatisfactory. Valli *et al.* (1985) argued that the average size of fished clams was higher, so a revision is urgent. This is not a suggestion for landing size diminution, but instead, for careful consideration regarding what to do when organisms have a low growth rate, no matter the reason why. Furthermore, the average length was and is higher where the fishery activity is formally banned (2 m depth) but the exploitable area decreased year after year (Del Piero *et al.*, 1998; de Flego, 2011) so derogation was conceded to the fleet (with yearly renewal) for the exploitation in the area between 2.5 and 3 m depth. The new rules in force since June 1st, 2010 (Reg. (CE) 1967/2006) fix in 0.3 nm from the coast the minimum distance for exerting that fishery so the more productive areas of the Monfalcone Maritime District are *de facto* excluded. The 2009 and 2011 surveys confirmed the critical status of the clam population in spite of the efforts made by the Consortium to shorten the fishing season and quantities.

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PREGLED RASTIŠČ ŠKOLJK VRSTE *CHAMELEA GALLINA* NA OBMOČJU LIGNANA (TRŽAŠKI ZALIV, JADRANSKO MORJE)

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POVZETEK

Školjka vrste Chamelea gallina *je v sedimentu živeča školjka, ki uspeva v vseh evropskih obalnih vodah, najpogosteje na peščenem dnu. Že dolgo je izredno pomemben morski vir za italijansko školjkarstvo, zlasti ob zahodni jadranski obali. Školjkarstvo v Tržaškem zalivu, najsevernejšem delu Jadranskega morja, se sooča z velikim upadanjem njenega števila. Po njenem množičnem poginu jeseni 1996 je ni bilo dovoljeno nabirati do januarja 1998, toda ponovno vzrejo njenega zaroda sta otežila zmanjšano rekrutiranje in nizka stopnja rasti, kot so pokazale sezonske raziskave, izvedene na peščenem dnu nasproti Lignana med leti 1997 in 2000. Raziskave so bile narejene vzdolž diagonale s pomočjo ribiške ladje, opremljene s prilagojeno hidravlično vlačilno mrežo, v skladu s protokolom za poskusno gojenje školjke: 50 m vleke, zajemanje vzorcev na vsakem metru globine od 2 do 6 m. Starost školjk smo ocenili na podlagi prereza desne lupine pri dvajsetih primerkih, naključno izbranih iz vzorca, zajetega na globini 4 m. Zajede na tankem predelu 177 (od vsega skupaj 180) primerkov kažejo na razliko med rastnimi vzorci kohorte in počasnejšo rastjo po letu 1997. Kot smo opazili na območju Lignana leto dni pred tem, zajede običajno nastanejo jeseni. Prvič smo jih opazili tudi pri školjkah, manjših od 9 mm, pri čemer so bile nekatere leto dni starejše od drugih podobne velikosti. V času vzorčenja je bila njihova gostota (ind. m^{-2}) majhna. Razen enkratnih visokih vrednosti, izmerjenih leta 2007, se gostota školjk v Tržaškem zalivu ni povečala. Upravljanja staležev morskega vira, kot je* C. gallina*, za katero ni značilno le progresivno zmanjševanje tako gostote kot demografske strukture, marveč tudi izredno raznolika rast in rekrutiranje, se je treba ustrezno lotiti ter našteti kohorte in jih skrbno opazovati. Po drugi strani so se območja, primerna za nabiranje školjk (školjkarstva ni* *mogoče izvajati na globinah, manjših od 3 m), bistveno skrčila v osemdesetih letih 20. stoletja. V Tržaškem zalivu so pred leti zaradi posebnih značilnosti območja določili mejno globino 2,5 m, vendar pa je nova uredba, ki velja od 1. 6. 2010 (Reg. (CE) 1967/2006), za hidravlične vlačilke določila mejno oddaljenost 0,3 NM od obale, zaradi česar se na preostalih školjčiščih v Tržaškem zalivu ne sme nabirati školjk.*

Ključne besede: *Chamelea gallina*, Tržaški zaliv, rast, gojenje, upravljanje

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