RECENT RECORDS, GROWTH AND PROPOSED IUCN STATUS OF *Donacilla cornea* (Poli, 1795) FROM THE ROMANIAN BLACK SEA

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ABSTRACT

This is the first record of living *Donacilla cornea* in the Romanian Black Sea since over 25 years. Occuring on most sandy beaches in the 1950s and 60s, with mean densities of 2000 ind.m^{-2}, *Donacilla* suffered a sharp decline following intense eutrophication and pollution during the 70s and 80s, and was considered to be extinct in the Romanian Black Sea. In 2004-2005 we found a strong, healthy *Donacilla cornea* population in Eforie bay, attaining densities of up to 3833 ind.$\bar{}$m^{2}.

The regional IUCN status of Critically Endangered CR A1abc; B1ac(i, ii, iii, iv)+2ab(i, ii, iii, iv) is proposed for *Donacilla cornea* in the Romanian Black Sea, in accord with the IUCN Red List Categories and Criteria: Version 3.1 (2001) and the Guidelines for Application of IUCN Red List Criteria at Regional Levels: Version 3.0 (2003).

The growth function was independently estimated using length-frequency data from the sampled population and length-at-age data from external growth rings of the shell, to test if growth ring readings can provide an accurate estimation of age in *Donacilla cornea*.

Keywords: *Donacilla cornea*, Romanian Black Sea, Critically Endangered, age determination

INTRODUCTION

The corneous wedgeclam *Donacilla cornea* (Poli, 1791) is a fast burrowing bivalve which lives in the midlittoral of exposed sandy beaches with medium to coarse sand and heavy wave action. It occurs in the Eastern Atlantic from Brittany to Madeira, the Mediterranean and Black Sea (GROSSU, 1962; POUTIERS,1987). *Donacilla cornea* is the dominant macrobenthic species of the midlittoral coarse sands biocenosis throughout the

Mediterranean and Black Sea, and it is considered as an indicator species for the Mediterranean midlittoral sands habitat (*Cahiers Natura*, 2000).

In the Black Sea *Donacilla cornea* was regarded by MILASCHEVICH (1916) as a rather rare species, with a fragmented distribution, along the shores of Anatolia, Crimea, the southern sector of the Romanian Black Sea and around Cape Kaliakra. More recent data show that along the Crimean coasts the density varies between 150 to 250. ind m^{-2}, with a maximum of 3100 ind.m^{-2} and a biomass of 690 g m^{-2} (SOROKIN, 2002). In the sandy midlittoral of the Bulgarian coast the dominant species are *Donacilla cornea* and *Ophelia bicornis*, with maximum recorded densities of 9800 ind. m^{-2} and 2000 ind. m^{-2} respectively (KONSULOV, 1998).

In the Romanian Black Sea *Donacilla cornea* was recorded for the first time by BORCEA (1926), under the wrong name *Tellina (Mesidesma) donacina*. It was later recorded as a mass species in the sandy midlittoral by several other authors (CARAUSU, 1957; GROSSU & CARAUSU, 1959; GROSSU, 1962; GOMOIU, 1969, 1976; BACESCU *et al*., 1971). In 1965-1968 it used to be abundant on many sandy beaches with mean grain sizes ranging from 0.17 mm to 1.001 mm: Portita, Chituc, Vadu 2500 ind.m^{-2}, Agigea 800 ind.m^{-2}, Belona 3360 ind.m^{-2}, Costinesti, 2 Mai 1100 ind.m^{-2}, Vama Veche 2400 ind.m^{-2} (BACESCU *et al*., 1971; GOMOIU, 1976).

GOMOIU (1969) described the biocenosis of midlittoral coarse sands from the Romanian Black Sea as "having *Donacilla* as the most characteristic element (sometimes accompanied by the polychaete *Ophelia bicornis*), covering especially the beaches south of Constanta" .

Following habitat destruction (through building of dikes and groins for beach protection, which led to changes in sand grain size and beach morphodynamics) and intense eutrophication in the 1970s and '80s, *Donacilla* has suffered a sharp decline. This situation was acknowledged by the Romanian scientific community as follows:

- „The data recorded by us following the recent prospectings show smaller densities of the species" (GOMOIU, 1968).
- „On peut remarquer la réduction des populations des espèces dirigeantes pour les biocenoses de cet étage: *Donacilla cornea*, autrefois abondante dans les sables grossiers, en 1977 y a manqué entièrement" (ONCIU, 1979).
- "…*Donacilla cornea* and *Ophelia bicornis*, species which have since disappeared" (PETRAN, 1997).
- In a 1997-1998 study of the midlittoral fauna between Mamaia and Eforie, the species has not been found (MUSTATA *et al*., 1998).
- "The midshore biocenosis with *Donacilla cornea* was not found anymore." (NICOARA, 2001).

- "… la faune médiolittorale des sables moyens et grossiers a perdu son identité grâce à la disparition complète des deux espèces dominantes…" (ABAZA, 2001).

During 1998–2003 we consistently found isolated *Donacilla cornea* specimens washed ashore on Belona beach, after violent storms. This aroused our interest, as we have never before found this species alive on any other beach from the Romanian Black Sea, although we have extensively searched for it. Consequently, in 2004 and 2005 we thoroughly surveyed the area, using hand corers for quantitative sampling. We found, for the first time in over 25 years, a strong, healthy *Donacilla cornea* population.

In the Atlantic and Mediterranean *Donacilla* is not currently regarded as a threatened species (SoHelME, 2005). In the Black Sea it was listed as EN Endangered by GOMOIU and PETRAN (in DUMONT, 1999). As shown above, at that time it was widely believed that *Donacilla* was already extinct in the Romanian Black Sea, and the listing as EN was based on the situation from the Ukrainian sector. In the light of our new finds, the regional conservation status of *Donacilla cornea* in the Romanian Black Sea must be reevaluated, against the new IUCN Red List Categories and Criteria: Version 3.1 (2001) and Guidelines for Application of IUCN Red List Criteria at Regional Levels: Version 3.0 (2003).

When assesssing population structure for conservation purposes, a quick method for estimating the age of *Donacilla* on the field was needed. Traditionally, growth rings or annuli on the shell surface have been employed as means of establishing age in many bivalve species. Surface rings are formed during annual periods of growth cessation associated with the colder months (RICHARDSON, 2001). However, the annuli do not necessarily form yearly in all species, and the annual formation of the growth rings needs to be first validated for the given species before they can be used for age determination (BREY & MACKENSEN, 1997). In order to do this, we calculated two independent estimates of the growth function of *Donacilla cornea*, using length-frequency data from the sampled population and length-at-age data from external growth rings of the shell, respectively. The two functions were then compared to see if growth ring readings can provide an accurate estimation of the age in *Donacilla cornea*.

MATERIAL AND METHODS

Study site

Belona (44˚03' N, 28˚38' E) is an exposed microtidal sandy beach in Eforie bay, in the central part of the Romanian Black Sea coast. It is a wide beach of destruction located on a sandbar that separates the sea from Tekirghiol lake, an ancient lagoon. The tides are semidiurnal, with an amplitude of 0.3 m. The most common kind of breakers are spread waves indicating dissipative conditions. Mean grain size is 0.866mm (medium-coarse sand) and the beach slope is 0.008 (GOMOIU, 1969). It is the last large exposed sandy beach from the Romanian Black Sea that did not suffer heavy modifications by man up until now.

Sampling

The sampling operations were carried out on June 25th, July 30th and August 7th 2005. Seven short transects, transverse to the shoreline, were positioned at 300-500 m intervals on the beach as follows, from S to N:

- Cazemata (44˚03'15.9" N),
- Roxy (44˚03'24.5" N),
- La Stuf (44˚03'30.9" N),
- Albatros (44˚03'37.2" N),
- Marina Sud (44˚03'44.9" N),
- Golf I (44˚03'52.7 N),
- Golf II (44˚03'58.7" N).

The last two transects were inside small artificial gulfs contained between groins built for beach protection.

Each transect comprised three sampling points, located at different across-shore levels: on the upper swash limit, the beach sill, and below the swash line (0.7 m depth). At each sampling point three replicates were collected using a 19 cm diameter cylinder corer (283.5 cm^2 base area) to a depth of 25 cm.

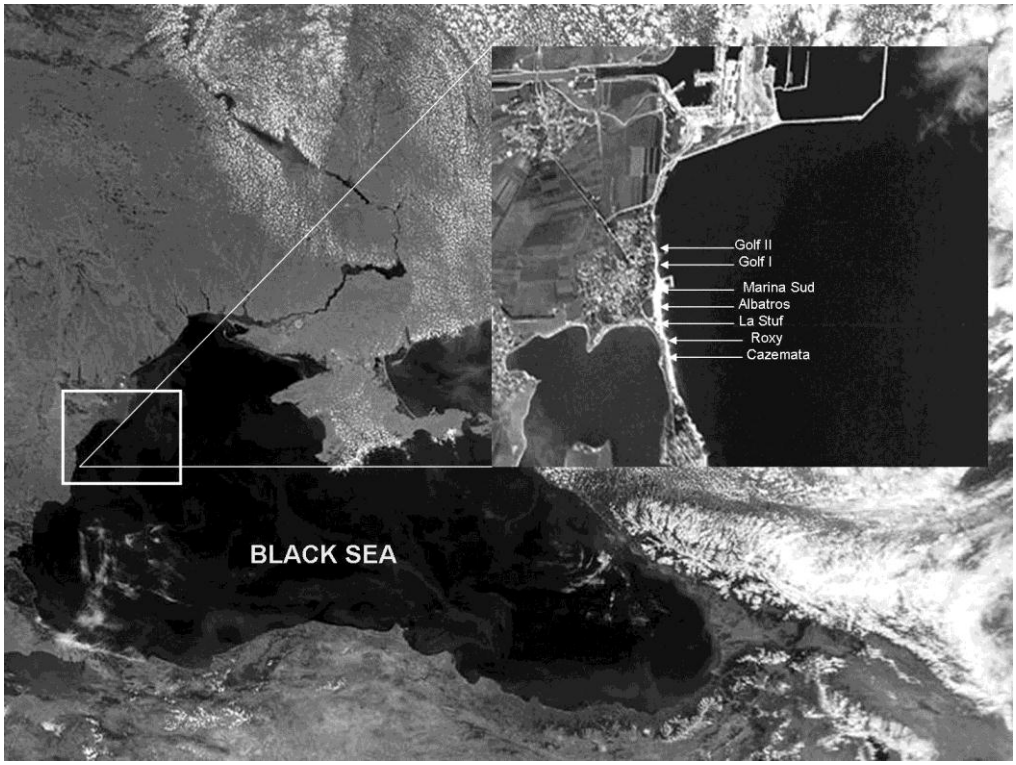

Fig. 1 - Location of study site and sampling points in the Romanian Black Sea

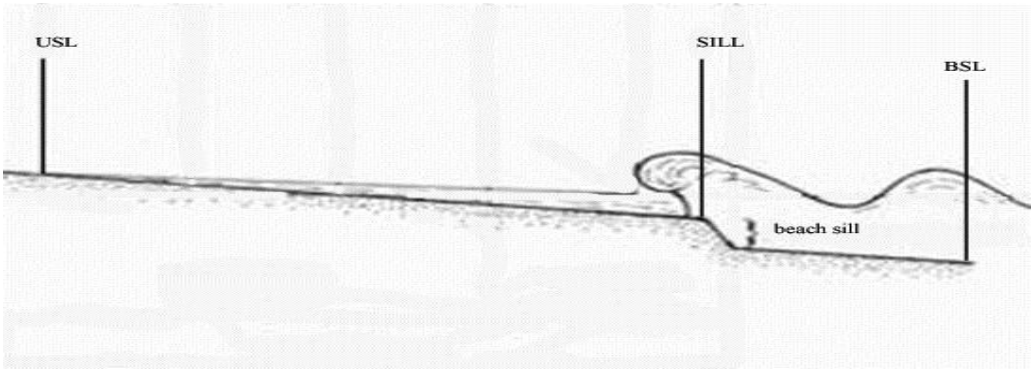

Fig. 2 - Position of sampling points on a transect transverse to the beach: USL= upper swash limit, SILL=beach sill, BSL= below the swash line (-0.7 m depth)

The samples were washed with seawater through a 2 mm mesh size sieve. All wedgeclams were taken to the laboratory and kept in aquaria for measurements. They were returned alive to the beach a few days later.

Growth and age

Shell length (maximum distance along the antero-posterior axis) of all the 1020 wedgeclams found in the samples was measured to the nearest 0.05 mm with a calliper.

Mean lengths were calculated at each sampling point as a weigthed average of the length classes present in the three replicas pooled together.

For the length-frequency analysis we used the ELEFAN I routine of the FISAT II (FAO-ICLARM Stock Assessment Tools) package, which assumes that growth is described by the von Bertalanffy growth function (VBGF) modified for seasonality.

All wedgeclams were carefully visually inspected and those in which the external growth rings were most clearly distinguishable were selected, 16 individuals in total. Shell length corresponding to each growth ring was measured to the nearest 0.05 mm with a calliper. This yielded 80 size-at-age data pairs, from which we estimated the von Bertalanffy growth function using FISAT II and the Population Dynamics in Benthic Invertebrates Virtual Handbook (BREY, 2001).

The growth functions were compared using the growth index phi prime defined as $\varphi' = 2\log_{10}(L_\infty) + \log_{10}K$ (PAULY & MUNRO, 1984), which measures growth performance. This criterion was chosen because of the negative corelation between K and L_∞ (PAULY & MUNRO, 1984), which invalidates comparisons based on individual parameters.

RESULTS AND DISCUSSION

This is the first record of living *Donacilla cornea* in the Romanian Black Sea since over 25 years. As an adaptation to the high energy environment in which it lives, this species lacks a planktonic larval stage. The larvae are incubated in the pallial cavity of the mother, which releases the offspring as small clams (BACESCU *et al*., 1967). This renders impossible long-range dispersal and immigration of propagules from conspecific populations that live in neighboring Bulgarian and Ukrainian waters. Therefore, no possibility for recolonization ever existed and we must accept the *Donacilla cornea* population that we found in Eforie bay as living proof that, contrary to what has been widely believed until now, the species has never disappeared from the Romanian Black Sea.

A population size reduction of ≥ 90% was observed in *Donacilla cornea* from the Romanian Black Sea during the last 30 years (roughly three generations of the bivalve), whose causes are reversible, understood and

ceased. This is based on direct observation, calculation of appropriate indices of abundance, a decline in area of occupancy, extent of occurrence and quality of habitat, potential levels of exploitation and the effects of pollutants.

At present the species exists at a single location (Belona beach) in the Romanian Black Sea and is in impossibility of naturally regaining its native range due to direct development (the lack of a planktonic dispersal stage).

Extent of occurrence is far less than 100 km^2 and area of occupancy is less than 10 km^2. Based on touristic beach development trends, the imminent threat posed by new projects for building groins and dikes on Belona beach and mortalities inflicted by tourists through trampling, we foresee a continuing decline in extent of occurrence, area of occupancy, quality of habitat, number of locations and number of mature individuals.

On the basis of all the abovementioned and of the older listing as "Endangered" in the Black Sea Red Data Book (DUMONT, 1999) we propose the regional IUCN status of: Critically Endangered CR A1abcde; B1ab(i, ii, iii, iv, v)+2ab(i, ii, iii, iv, v) for *Donacilla cornea* in the Romanian Black Sea, in accord with the IUCN Red List Categories and Criteria: Version 3.1 (2001). Given that this species lacks a planktonic larval stage, thus rendering impossible long-range dispersal and immigration of propagules from conspecific populations that live in neighboring Bulgarian and Ukrainian waters, applying the Guidelines for Application of IUCN Red List Criteria at Regional Levels: Version 3.0 (2003) did not result in a downgrading of the category.

Table 1

Two-factor ANOVA of the log-transformed number of *Donacilla cornea* m^{-2} on different profiles and beach levels

Source of variation	SS	df	MS	F	P-value	F crit
Across-shore levels	2.400732	2	1.200366	4.271241	0.039735	3.885294
Transects	2.435863	6	0.405977	1.444581	0.276235	2.99612
Error	3.372414	12	0.281034			
Total	8.209009	20				

A two-factor ANOVA of the log-transformed number of *Donacilla cornea* m^{-2} on the 7 transects and 3 across-shore levels showed that densities do not significantly differ ($P > 0.05$, $F < 2.99$) among transects, but they are significantly different ($P < 0.05$, $F > 3.88$) between the three sampled levels along the beach.

Densities ranged between: 0-1047 m^{-2} at the upper swash limit, with an average of 215 m^{-2}; 36-3833 m^{-2} at the sill, with an average of 1328 m^{-2}; 0-788 m^{-2} below the swash line, with an average of 315 m^{-2}.

Densities at USL for the first three transects (Cazemata, Roxy, La Stuf) were extremely low because they were sampled on exceptionally calm weather, with virtually no swash. They are highest on the 4th and 5th tansects, which were sampled on a day with strong easterly wind and intense wave action.

Wedgeclams seem to have a predilection for the sill, concentrating here all along the beach and on most occasions.

The largest average density per transect recorded by us was of 1524.45 m^{-2} (La Stuf), less than half of 3292.50 m^{-2}, recorded by BACESCU *et al.* (1971) on the same beach in 1966. The species has survived and the population is expanding, but it has yet to reach the reference levels.

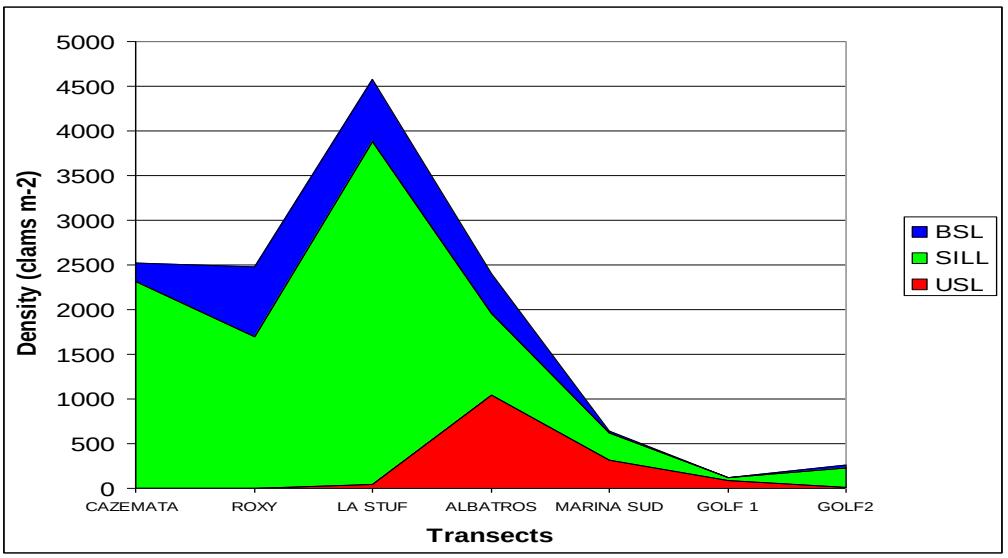

Fig. 3 - Distribution of *Donacilla cornea* densities at the three levels sampled along Belona beach (BSL= below the swash line, SILL= beach sill, USL=upper swash limit)

Densities show a sharp drop for the last three transects, situated in the vicinity (Marina Sud) or even between (Golf I, Golf II) the groins for beach protection. Between the groins beach dynamics are hampered, mean sand grain size is reduced, oxygen concentration in the water column and oxygen penetration in the sediment are much lower. The sediments contain more organic matter because the organic-laden freshwater runoff concentrates in

these small artificial gulfs as mixing and renewing of the water is prevented by the groins.

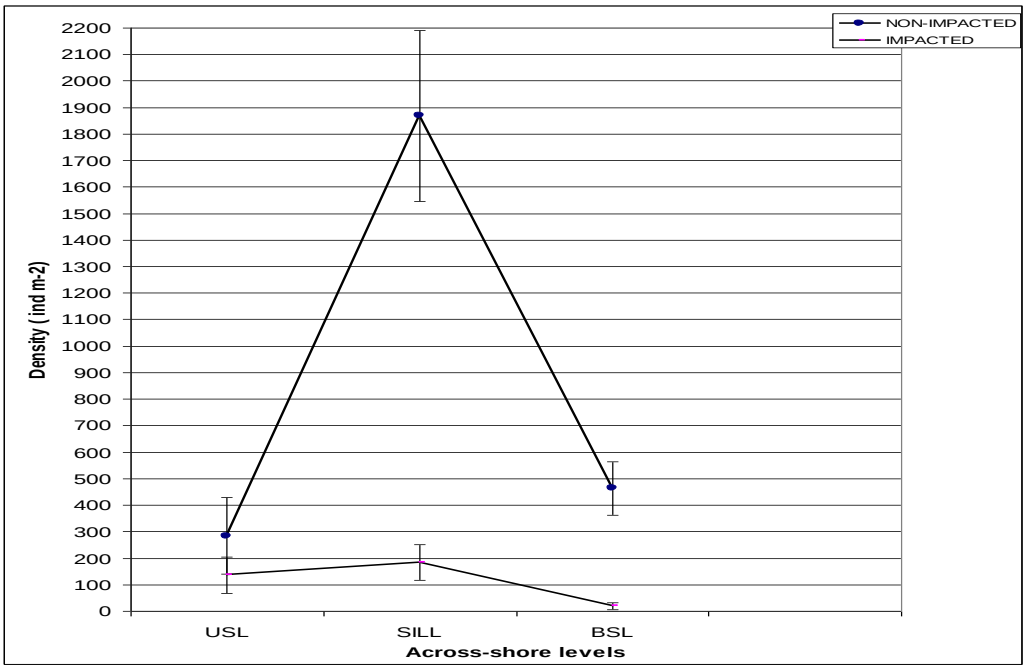

Fig. 4 - Plot of average densities (mean ± standard error) at USL, SILL and BSL on non-impacted (Cazemata, Roxy, La Stuf) vs. impacted (Marina Sud, Golf I, Golf II) transects

The negative impact of "hard" beach protection solutions on the survival of this rare and endangered species becomes obvious if we compare the average densities attained by *Donacilla cornea* at the three sampling levels on transects not impacted by beach protection groins (Cazemata, Roxy, La Stuf) with those from impacted transects (Marina Sud, Golf I, Golf II).

The mean lengths, averaged over all transects, were of 8.68 mm at USL, 10.68 mm at the sill and 11.93 mm of at BSL.

A two-factor ANOVA of the mean lengths of *Donacilla* calculated for each sampling point showed that they do not significantly differ ($P > 0.05$, $F < 2.996$) between transects along the beach, but they are significantly different ($P < 0.05$, $F > 3.88$) between the across-shore levels.

The smaller, younger wedgeclams concentrate at the higher across-shore levels, while the larger, older ones preffer the lower levels. The largest individuals, over 18mm long, were foundonly at the sill and at BSL. Depth segregation, a phenomenon previously observed in *Mesodesma mactroides*

(DEFEO & RUEDAueda, 2002) and *Donax trunculus* (GASPAR *et al.*, 2002) seems to be also present in *Donacilla cornea* from the Romanian Black Sea.

Table 2

Two-factor ANOVA of *Donacilla cornea* mean lengths between transects and across-shore levels

Source of variation	SS	df	MS	F	P-value	F crit
Across-shore levels	212.4057	2	106.2028	6.707477	0.01108	3.885294
Transects	86.41293	6	14.40215	0.9096	0.519826	2.99612
Error	190.002	12	15.8335			
Total	488.8206	20				

The Von Bertalanffy growth function for *Donacilla cornea* based on the length-frequency distribution of 1020 individuals collected in June, July and August 2005 has the parameters L_{∞}=24.15mm and K=0.67, yielding a φ'_{LFA}=2.592.

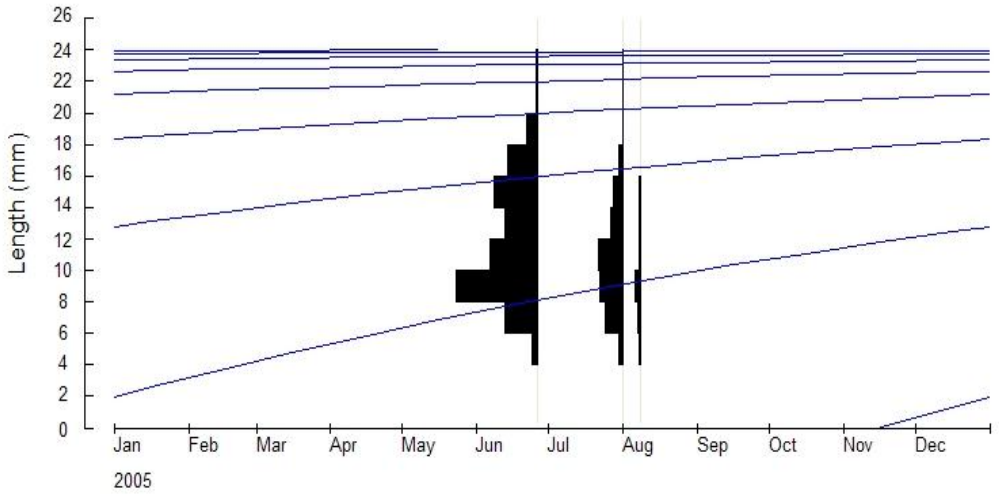

Fig. 5 - Von Bertalanffy growth function and length-frequency plot for *Donacilla cornea*

The Von Bertalanffy growth function for *Donacilla cornea* based on length-at-age established through reading of external shell growth rings (80 size-at-age data pairs) has the parameters L_{∞}=24.76mm and K=0.20, yielding a φ'_{LAA}=2.089.

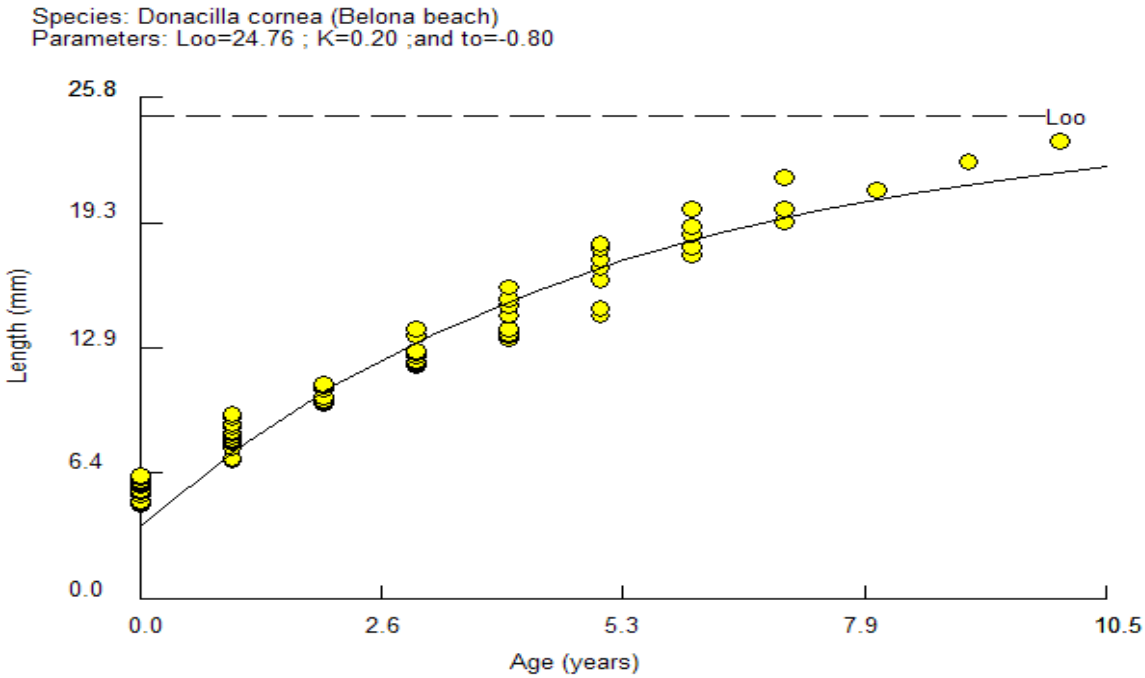

Fig. 6 – Von Bertalanffy growth function for *Donacilla cornea* based on length-at-age

The difference between φ'_{LFA} and φ'_{LAA} is too large, indicating that the growth functions fitted separately to length-frequency data from the sampled population and to length-at-age data from external growth rings of the shell do not agree well. This does not support the hypothesis that external growth ring readings can provide a quick and accurate estimation of the age in *Donacilla cornea*.

The maximum length recorded by us from the samples (24.0 mm) is closely matched by the predicted maximal length Lmax=24.23 mm. It exceeds the maximum length of 22.1 mm given by Grossu (1962) and is identical with that of 24.0 given by Gomoiu (1976).

The predicted maximum length of 24.23 mm for *Donacilla cornea* from the Romanian Black Sea represents 97% of the maximum length of 25 mm given for Mediterranean populations (Poutiers, 1987). The performance capacity is sufficiently close to its maximum, suggesting that *Donacilla cornea* is far from its limit of physiological tolerance at the study site.

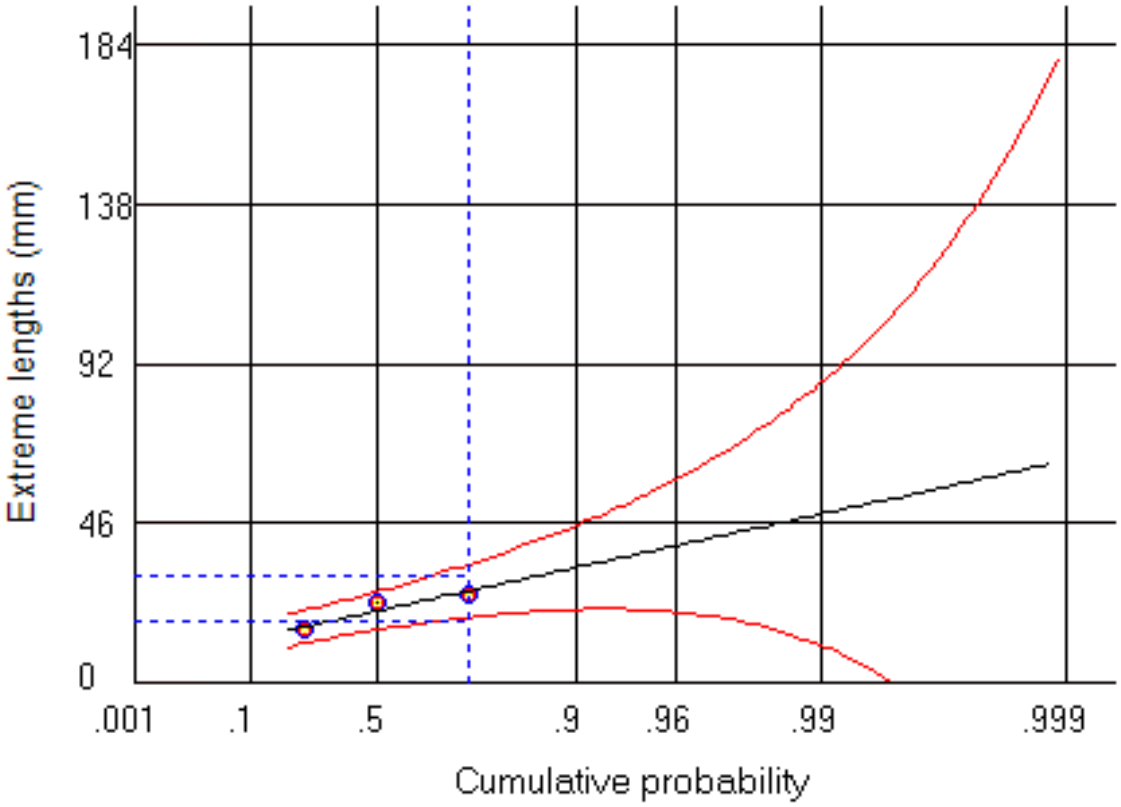

Fig. 7 – Prediction of the maximal length

CONCLUSIONS

1. Of the 109 valid mollusk species (Polyplacophora 2, Gastropoda 66, Bivalvia 41) of the Romanian Black Sea (MICU, 2004), 30 gastropod and 25 bivalve species have been recorded alive since 2000. Among them, this finding gives us hope/confidence that, with the advent of more intense scientific attention and the use of appropriate methods for marine biodiversity research, rarer mollusk species will be recorded again, as we already did in a few other cases: *Donax trunculus*, *Pholas dactylus*, *Tricolia pullus*, *Chrysallida fenestrata*, *Ebala pointeli*.

2. This species lacks a planktonic larval stage, thus rendering impossible long-range dispersal and repopulation of Romanian beaches by propagules coming from neighboring Bulgarian and Ukrainian waters. Therefore, the *Donacilla cornea* population that we found in Eforie bay is living proof that, contrary to what has been widely believed until now, the species has never truly disappeared from the Romanian Black Sea. Thus, the midlittoral coarse sands biocenosis still exists in the Romanian Black Sea. It is possible that in the future the polychaete *Ophelia bicornis*, who does have a planktonic larval stage, will reappear.

3. Although the *Donacilla* population from Eforie bay is healthy, it is the only one that survived all along our coasts. A reevaluation of the IUCN status of *Donacilla cornea* in the Romanian Black Sea against the IUCN Red List Categories and Criteria: Version 3.1 (2001) and Guidelines for Application of IUCN Red List Criteria at Regional Levels: Version 3.0 (2003) has yielded the new regional status of Critically Endangered CR.

4. The densities of *Donacilla cornea* are significantly different between the three across-shore levels sampled along the beach. Wedgeclams seem to have a predilection for the sill, concentrating here all along the beach. The densities recorded by us are within normal limits for a healthy, stable population, but do not raise yet to the maximum levels from the reference period (1960s).

5. The negative impact of "hard" beach protection solutions (groins, dikes) on the survival of this rare and endangered species was revealed. The lowest densities were attained by *Donacilla* on transects impacted by such structures, which alter natural beach dynamics and deteriorate the ecological quality of sandy beaches.

6. The distribution of the mean lengths across the sampled depths indicates that *Donacilla cornea* manifests depth segregation in the Romanian Black Sea. The mean lengths of *Donacilla* are significantly different between the across-shore levels, with the smaller, younger wedgeclams concentrated at the highest across-shore level, and the larger, older ones prefferring the lower levels.

7. The growth functions fitted separately to length-frequency data from the sampled population and to length-at-age data from external growth rings of the shell yielded different values for the parameters L_{∞}, K and φ'. This does not support the hypothesis that external growth ring readings can provide a quick and accurate estimation of the age in *Donacilla cornea*.

8. The predicted maximum length L_{max}=24.23mm, closely matched by the maximum length of 24.0 mm recorded by us from the samples represents 97% of the performance capacity of Mediterranean populations, suggesting

that *Donacilla cornea* is far from its limit of physiological tolerance at the study site.

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