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I. Introduction

The striped venus clam *Chamelea gallina* is a bivalve, lamellibranch, filter feeder belonging to the Veneridae family; it lives in high beds density hosting the "biocenosis of fine well-sorted sands" (SFBC) as described by Peres & Picard (1964), at depths between 1 and 15 m. It is particularly present in the wild, mainly on the central and northern Adriatic, where the sea water is rich in mineral salts and organic matter, due to inputs of rivers like Po and others. The target species is gonocorist with a spawning season approximately comprised between April and October with 1-2 peak(s) (FROGLIA, 1975 a, b; CASALI, 1984; VALLI *et al.*, 1985; KELLER *et al.,* 2002). The earliest mature individuals are 13-15 mm (MARANO *et al.,* 1982; CORDISCO *et al.,* 2003), though full maturity is reached when clams are 20-25 mm and about two years old.

In Adriatic area the clams reach a size of 15-20 mm at the beginning of the first year of life, approximately 25 mm a year later, and 32-34 mm in the third year (POGGIANI *et al*., 1973; FROGLIA, 1975a; MARANO *et al*., 1982; ARNERI *et al*., 1995). However, some studies (NOJIMA & RUSSO, 1989; MASSÈ, 1971) have shown that the growth rate of individuals can differ among sites, and age classes may have a slightly different range. Nevertheless, according to the Council Regulation (EC) No 1967/2006, 25 mm is the minimum commercial size allowed.

Studies on the ecology and physiology of *Chamelea gallina* are scarce, but some information on environmental factors influencing its abundance may be gained from several studies carried out since the mid-1970s in the northern Adriatic in response to phenomena such as "red tides", as well as "marine snow" which could negatively impact both human health and tourism (ROMANELLI *et al*., 2009).

It is known that the growth of bivalves is primarily dependent on food availability, water temperature and salinity, and sediment characteristics (BROOKS *et al*., 1991; ORBAN *et al*., 2002; ORBAN *et al*., 2004).

Chamelea gallina feeds on phytoplankton and other suspended material; for its growth the dissolved nutrients amount and the nitrogen and phosphorus ratio are also relevant.

Water temperature has a dominant role in growth rates: values below 10 °C strongly slow or avoid growth (FROGLIA, 2000), while very high temperatures measured on the sea bottom (28 ° C) during summer have detrimental effects, reducing energy absorption and above all increasing energy expenditure via respiration (RAMÓN & RICHARDSON,1992; MOSCHINO & MARIN, 2006).

Dissolved oxygen is a further abiotic factor influencing bivalves growth: hypoxia, anoxia and high temperatures during summer seasons can lead to increased ammonia concentrations which may contribute to negative growth values in exposed animals, as demonstrated in *R. decussatus* by SOBRAL & WIDDOWS (1997).

An additional source of stress for *C. gallina* is reproduction, which starts from spring and continues until late summer, with a reproductive peak in July (NOJIMA & RUSSO, 1989). *C. gallina*, similarly to many other bivalve species, shows increased respiration rates during the reproductive period (WIDDOWS, 1978; IGLESIAS & NAVARRO, 1991; URRUTIA *et al*., 1999).

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In the 1970s the development of clam fishery based on hydraulic dredges led to an over-exploitation of the resource with a dramatic decrease in density of clams populations and an increase in mortality events from the 90s onwards (Ministry of Agriculture, 1998). In the late 1970s the fishery yielded 80,000-100,000 metric tons while actually it doesn't exceed 20,000 metric tons.

At the beginning of the 80s, general rules were defined for limiting fishing licenses and establishing the maximum catches allowed in order to minimize the resource depletion.

In recent years, clam fishery management has been entrusted directly to fishermen' associations who plan fishing activity on the basis of available resources, set fishing days per week, work's daily hours, periods of catch suspension and daily catch amounts.

In the Italian region of Molise it exists a unique association named Co.Ge.Vo. and established in 1995, with ten clam vessels.This association, authorized by the Ministry of Agriculture and Forestry to manage the resource *Chamelea gallina*, has as main objective the enhancement, protection and safeguard of clam populations through the establishment of planting and restocking areas, the monitoring of catches effort, and the arrangement of periodic alternation between work and rest among fishermen.

The present study evaluates populations of *Chamelea gallina* along Molise's coastline in terms of biomass and size distribution, recruiment abundance, in order to provide useful informations for better resource management and efficient production planning by clams associations.

II. Materials and Methods

a) Study area

The Molise region is located in the center-southern area of Italy and is washed by Middle-Southern Adriatic waters. The study area extends for about 35 km of coastline and has uniform characteristics, without important inlets, except for the port of Termoli city (Molise, Italy). The sea bed is sandy and, near the major rivers' estuaries, muddy. It gently slopes up to 6-8 meters of depth, at a distance of approx. 0.3 nautical miles from the coastline. In addition, artificial reefs and breakwaters are placed along extended coastline parts at short distance from the shore.

There are four rilevant streams: Trigno, Sinarca, Biferno and Saccione (listed as located from north to the south of coastlines) and secondary streams (Tecchio, Mergolo and Rio vivo). The fluvial apports influence physical and chemical parameters of sea water: in fact rilevant changes of salinity and suspended matter are recorded near freshwater inflows. The salinity values vary on average between 22‰ and39 ‰, while those of the suspended matter between 3 mg/l and 56 mg/l. The water temperature values show seasonal fluctuations and are generally comprised between 8°C (winter) and 28 °C (summer).

b) Sampling and analyses

Clam samples were dredged along the Molise's coastline, comprised between Trigno and Saccione rivers, in 2003-2012 years at regular time intervals. Seasonal samplings were conducted according to monitoring plans approved by the Molise region and weather and sea water conditions permitting.

The survey area was divided into four zones: Trigno, Sinarca, Rio vivo e Saccione.

Sampling was carried out in collaboration with fishermen's cooperative.

The catches were performed by hydraulic dredges with 11 mm grid, along transects perpendicular to the coast at a distance of 250-500 m from coastline, dredging 200-300 m long stretches. All sampling points were located with GPS positioning system.

For each catch, all sampled material collected into the dredge was weighted and a subsample, rapresentative of total individuals, was prelevated, placed in net bags and labelled. After collection, animals were transported within about an hour to the laboratory in a cool box.

In laboratory, at first, organisms with open or damaged shell were discarded. The antero-posterior lenght (L) of the shells was measured using a 0.1 mm precision calliper, and it was defined size distribution on the basis of lenght measurements.

Popolutation distribution was assessed in respect to clams' size and age, considering three specific dimensional groups:

- 12-24 mm: group 1+, specimens of two;
- 25-35 mm: group 2+, specimens of three;
- >35 mm: group 3+, specimens over three.

In this study, the size distribution analysis was affected by the selectivity of used dredges so it was impossible to evaluate specimens in the first year of age (class 0 +). It was then recorded the weight of commercial (≥ 25 mm) and sub-commercial (<25 mm) clams and finally estimated the resource's abundance. The catches values were calculated according to the following formula: catch (Kg/1000 sqm) = clams weight (kg) * 1000 / (length of dredged stretch (m) * dredge's width (m)).

III. Results and Discussion

a) Chamelea gallina stocks evaluation

National clams production data reported by the Italian Ministry of Agriculture and Forestry (Irepa sources) for 1996-2009 years show a positive long-term trend, although the bivalves production after introduction of hydraulic dredges showed highly variable phases of expansion and contraction. During the period between 1996 and 2009, a steady decline in fishing effort

determined a production reduction and a substantial stability of the catch per unit effort (CPUE). In 2005–2009 years, the values of annual production in the compartment of Termoli varied between 129,295 and 374,733 kg (Irepa sources).

In the present study, during 2003-2012 years, fishable biomass ranged in average between 3.3 and 60.9 kilogram/1000sqm in Trigno zone (Fig. 1), between 1.6 and 21.2 kilogram/1000sqm m in Sinarca zone (Fig. 2), between 6.9 and 58.3 kilogram/1000sqm in Rio vivo zone (Fig. 3), between 0.1 and 32.6 kilogram/1000sqm in Saccione zone (Fig. 4).

In all areas, biomass values of not-commercial clams are always lower than those of fishable biomass, with mean values between 1.5 and 25.8 kilogram/1000sqm m in Trigno area (Fig. 1), between 2.7 and 13.3 kilogram/1000sqm m in Sinarca area (Fig. 2), between 4 and 39.6 m kilogram/1000sqm in Rio vivo area (Fig. 3), between 0.04 to 9.8 kilogram/1000sqm in Saccione area (Fig. 4).

From 2008, it was evidenced a marked increase in commercial and juveniles clams' biomass values, even with large seasonal fluctuations, in all areas, except for Sinarca.

In addition to temporal variations of *Chamelea gallina* biomass, also changes in the populated surface area constitute an indication of the resource's exploitation state.

Considering the natural beds' distribution along the Molise coastline in 2003-2012 years (unpublished data), we show marked variations in the clams' areas extension, in particular a clear decrease in the southern area of Termoli. This observation emphasizes the importance of knowledge in terms of both spatial and temporal variations for the proper planning of *Chamelea gallina* management.

Data reported in this study seem to indicate that the fishing effort has been unevenly deployed over the last decade along Molise coast, but nevertheless, in most considered areas, with compatible time frame for stocks natural balance.

Considering limit value for the fishery economic sustainability as 5 kilogram/1000 sqm, analysis of the last decade data shows that Saccione area, unlike all the others, is a poorly productive area, in fact in the most sampling observations were found values close to that limit. From comparison of the biomass values recorded in different zones during last decade, it is clear that areas with greater fishable biomass are those near Trigno and Rio vivo, especially in 2010-2012 years.

Based on these evidences, we evaluated seasonal biomass trends during 2010-2012 years in the two areas mentioned above.

In Trigno zone, the highest values of fishable biomass were found in summer and autumn of 2010 and in spring of 2011 (Fig. 5). These data can be explained considering the growth of sub-commercial individuals recorded in large amounts in the spring of 2010 (Fig. 6). The importance of recruitment is also evident in terms of abundance. In fact, considering the biomass and abundance graphs in Trigno area (Fig. 5, 6, 7 and 8), these show similar seasonal trends, with the exception of spring 2012, when low biomass values corrisponding to high juveniles density. This result is explained considering the high abundance values of organisms with 20-21 mm size.

In Rio vivo area, the highest values of fishable biomass were recorded in autumn 2011 (Fig. 9). The biomass and abundance graphs showed the same seasonal trends during 2010-2012 years (Fig. 9, 10, 11 and 12).

The clams biomass and density amounts show strong seasonal and annual variations in both areas, with no detectable similar trends in several years. This data is in agreement with findings reported by Italian Ministry of Agriculture and Forestry (Irepa sources) in terms of trends in catch per unit of effort and clams' production for Molise region during period 1996-2009. These fluctuations could be due to natural resource's variations or fishery activities. During 2010-2012 years, data collected in Trigno zone, the most productive fishing area along Molise' s coastline, seem to indicate that fishing effort has been limited and has not altered the biomass availability.

b) Chamelea gallina population structure

Outcome of population analysis are given only for Trigno and Rio vivo areas because, on the basis of biomass values recorded in all zones, these areas are the most representative of Molise clams stocks.

Considering collected data during 2010-2012 period in the Trigno area, abundance values, in terms of percentage of organisms with 12-24 mm size, show large annual variations (Fig. 13), with maximum in winter 2010 (84%) and minimum in summer 2011 (26%). These trends may be due to fishing activities and also stressed that the abundance of specimens belongig to 1 + group can be a useful tool for fishery planning in next year.

On the contrary, considering abundance values in terms of percentage of organisms with 12-24 mm size in the Rio vivo area during 2010-2012 period (Fig. 14), there are no clear seasonal patterns or evident annual variations.

Comparing two areas, it is evident that in Rio vivo zone population consists of organisms with lower percentage sub-commercial size than those resident in Trigno area. Moreover Rio vivo clam population is characterized by lower variability in terms of abundance percentage and, consequently, by greater stability of community structure.

Clams' growth is influenced by several abiotic and biotic factors as well as population density. In fact, in presence of density above500 individuals/m2

(overcrowding), phenomena as natural mortality increasing have been highlighted, especially in summer when hypoxic events, lower growth rates and reduced recruitment are more frequent (BACHELET et al., 1992).

In this study, concentrations of sub-commercial size individuals suggesting crowded conditions were never detected. In conditions of not-overcrowding and in presence of high densities, to lower values of average size Correspond higher recruitment rates.

In order to assess stocks recruitment, clams size and density mean values were compared.

In Trigno area, an opposite pattern for the two indicators of recruitment importance is evident: in presence of higher densities we have smaller sizes. In contrast, in the Rio vivo area, the comparison between size and density annual average values shows no correspondence, presumably due to lower abundance values.

In Trigno area, during 2010-2012 years, average size values are comprised between 21.34 and 26.47 mm, while in Rio vivo area between 24 and 26.04 mm; these data seem to indicate a low recruitment rate in both areas.

Considering size-abundance diagrams relative to 2010 in both areas, a uniform shift towards bigger size classes at seasons following is detected (Fig. 15 and 16): this trend reflects clams natural growth. The values of modal size increase progressively from 21 mm (in fall) to 26 mm (in autumn) in Trigno area and from 23 to 25 mm in Rio vivo area.

On the contrary, in both areas, a clear seasonal pattern relative to 2011 is not detected (Fig 17 and 18). Finally, in 2012, size-abundance diagrams show same trends in all seasons with values of modal size between 24 and 25 mm in Trigno area and between 25 and 26 mm in Rio vivo area (Fig. 19 and 20).

These results show widely variable trends from year to year and indicate that populations of *Chamelea gallina* consist mainly of organisms with close to commercial size (25 mm). In fact, even considering seasonal mean values of Bodies length in both areas, in 2010-2012, these are close to commercial size (25 mm).

In addition, considering only commercial fraction, bodies average length values range between 25.9 and 27.7 mm in Trigno area and 26.3 and 27.9 mm in Rio vivo area.

Data analysis evidence that fishery activity is based almost exclusively on one age class (group 2+: 25-35 mm): specimens that have just reached minimum commercial size. In fact, clams over 35 mm are very scarce.

This finding is in agreement with previous studies showing disappearance of great size organisms compared to the past (ROMANELLI *et al*., 2009). Finally, in both areas, there is a progressive increase in commercial Organisms size. So it is supposable, despite recruitment low rate, a positive trend for population growth.

IV. Conclusions

Reported results show biomass and abundance fluctuations in several years and at different investigated areas, stressing the importance of temporal and spatial scale observations. This need is due to the high variability of coastal environment and of considered specie.

Considering temporal and spatial trends of *Chamelea gallina* in the study's initial period, a clear exploitation of natural beds with a drastic populations' decrease in some areas is highlighted.

In contrast, it is evidenced that althought during 2003-2012 years the most exploited fishing area was the Trigno zone, the applied fishing effort seemed sustainable, presumably due to management measures implemented by association (e.g. suspension of fishing activity, amounts of daily clams catch).

Total community is, however, subjected to large fluctuations in terms of abundance percentage and close to commercial size organisms are predominant. This finding emphasizes the importance of continuous monitoring plans.

In fact, although study's results point out not relevant phenomena of reduced growth or increased natural mortality, local fishing communities reported some death events during the examined period.

Considering that monitored population doesn't seem subjected to particular suffering conditions, clams beds investigation are facilitated and support subsequent comparisons in case of future anthropogenic disturbance or environmental phenomena.

It is also advisable to improve sampling and population analysis techniques through advanced tools, until now rarely used for this species in Adriatic Sea. Finally these kind of studies could be more exhaustive if implemented by outline informations.

Continual and so defined research activities are valid tools for maintaining close relationships between scientists and fisherman and for stimulating an awareness of resource conservation by fishing associations.

Monitoring plans targeted and closely related to fishermen are useful to provide real-time informations for the planning of resource management in time and space by clams sector associations. Previous research has in fact allowed Chamela gallina stocks enjoy a good stability degree on national scale in recent years, which is determined by sufficient recruitment, strong attenuation in frequency of high mortality events and adoption of more careful management practices.

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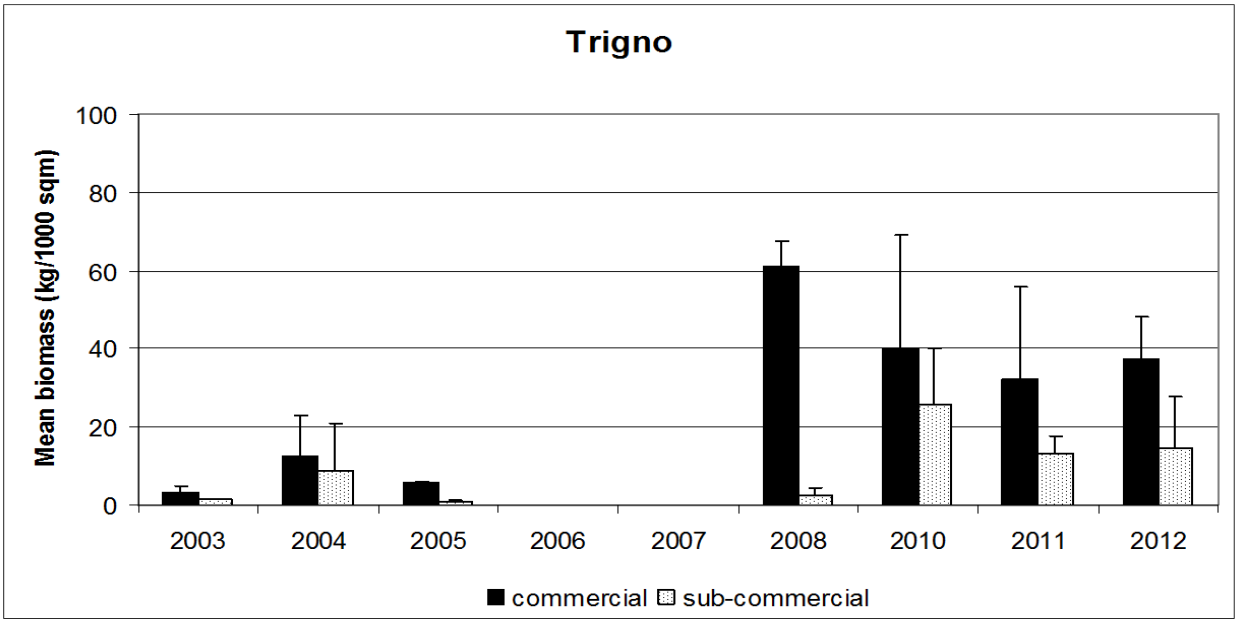

Figure 1 : Clam biomass annual variations in Trigno area during 2003-2012.

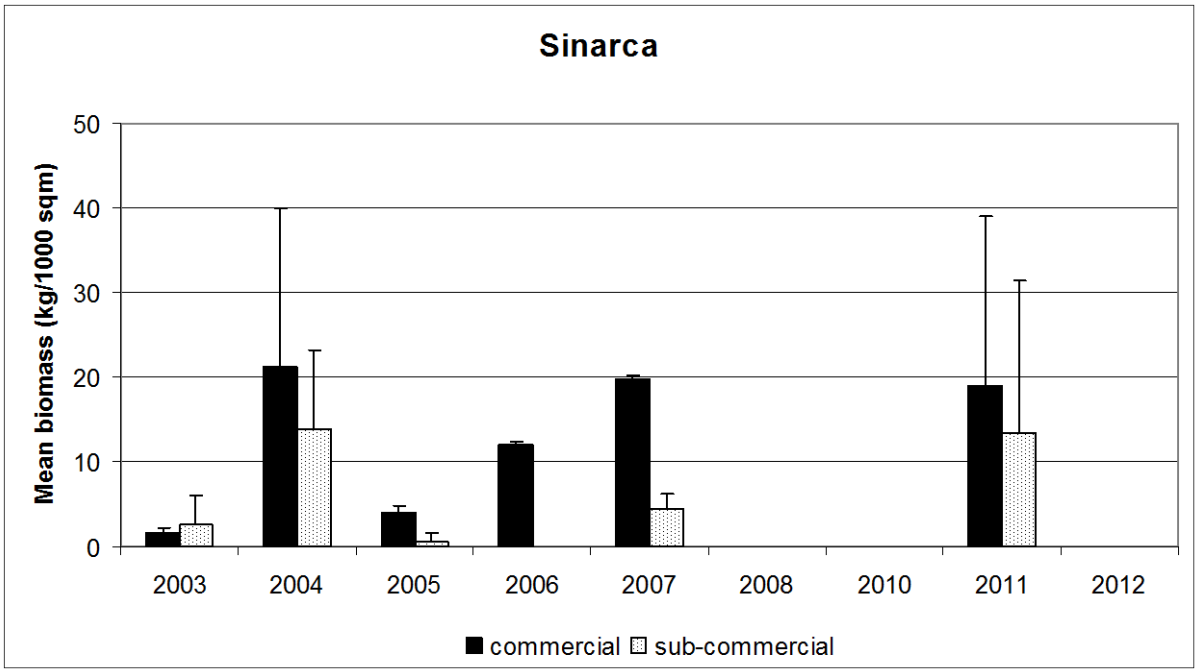

Figure 2 : Clam biomass annual variations in Sinarca area during 2003-2012.

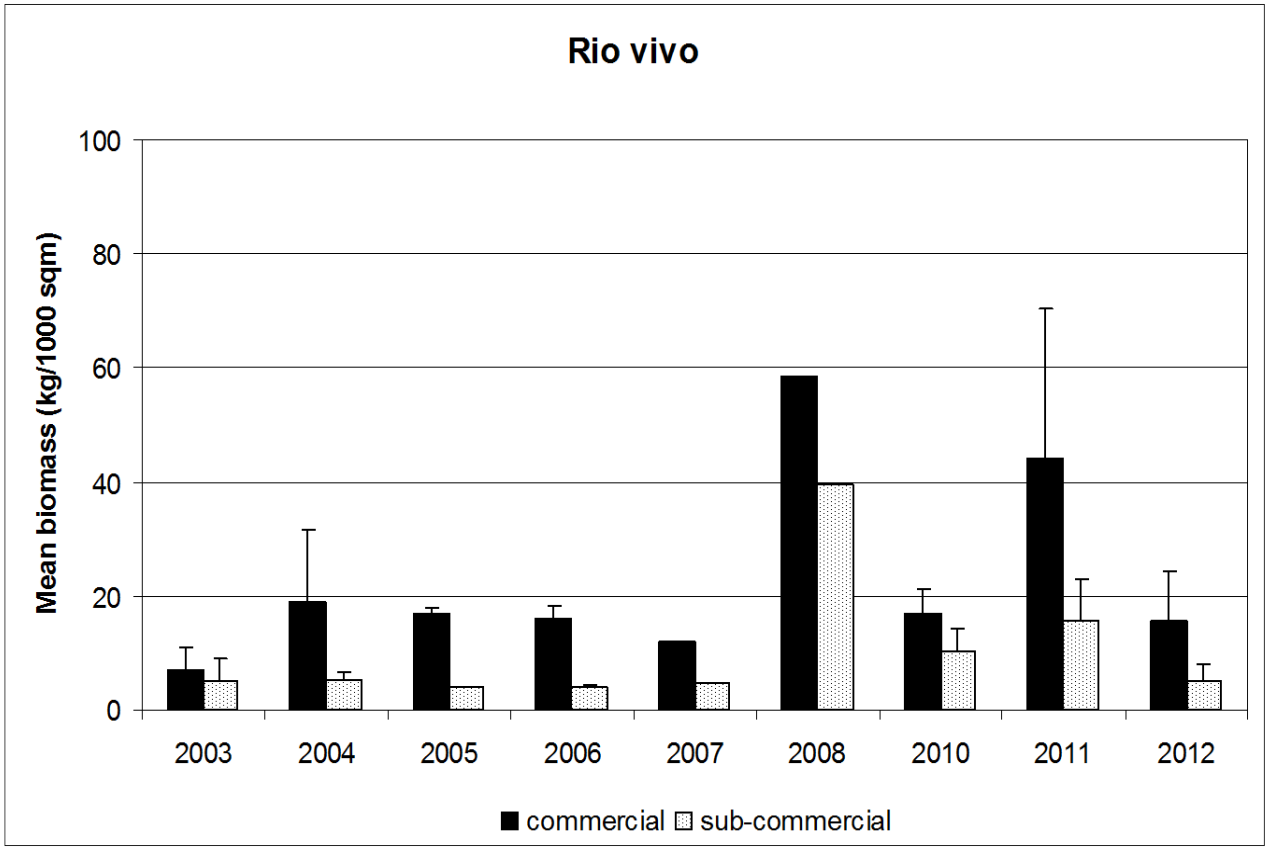

Figure 3 : Clam biomass annual variations in Rio vivo area during 2003-2012.

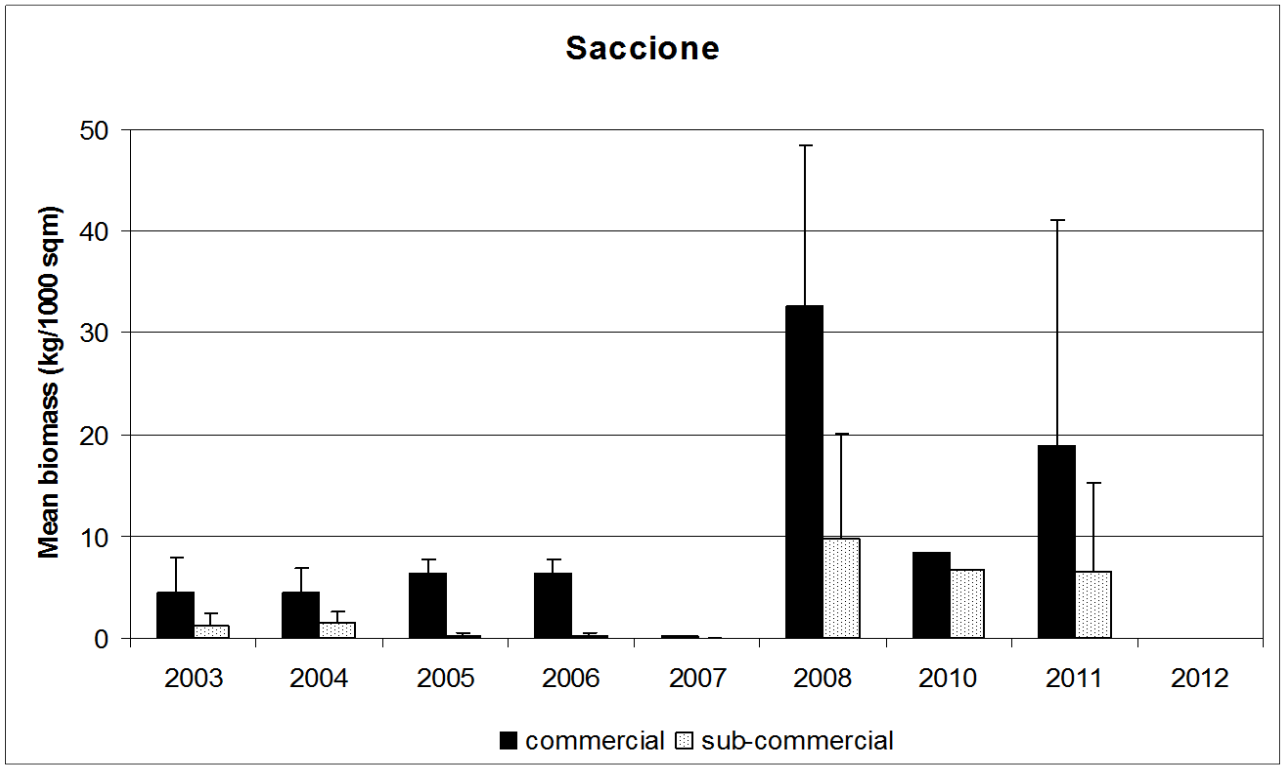

Figure 4 : Clam biomass annual variations in Saccione area during 2003-2012.

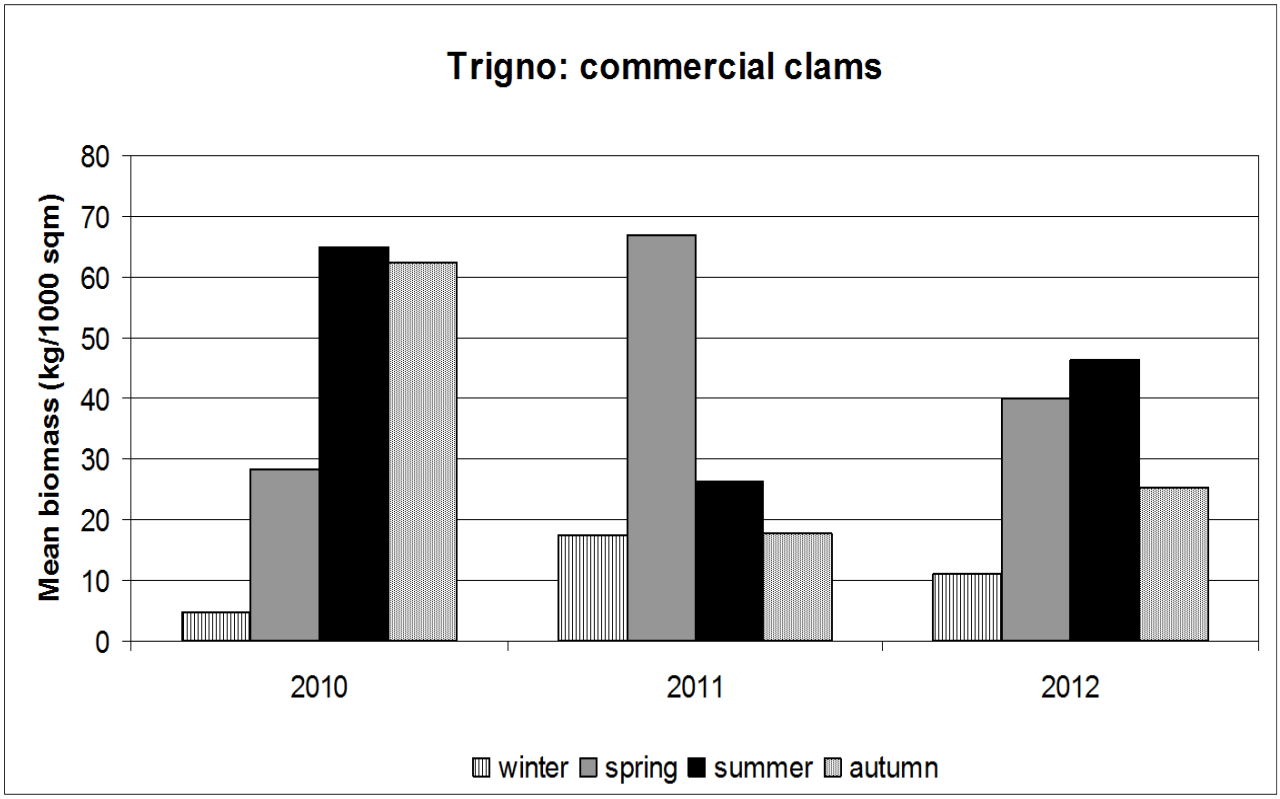

Figure 5 : Seasonal variations of commercial clams biomass in Trigno area during 2010-2012.

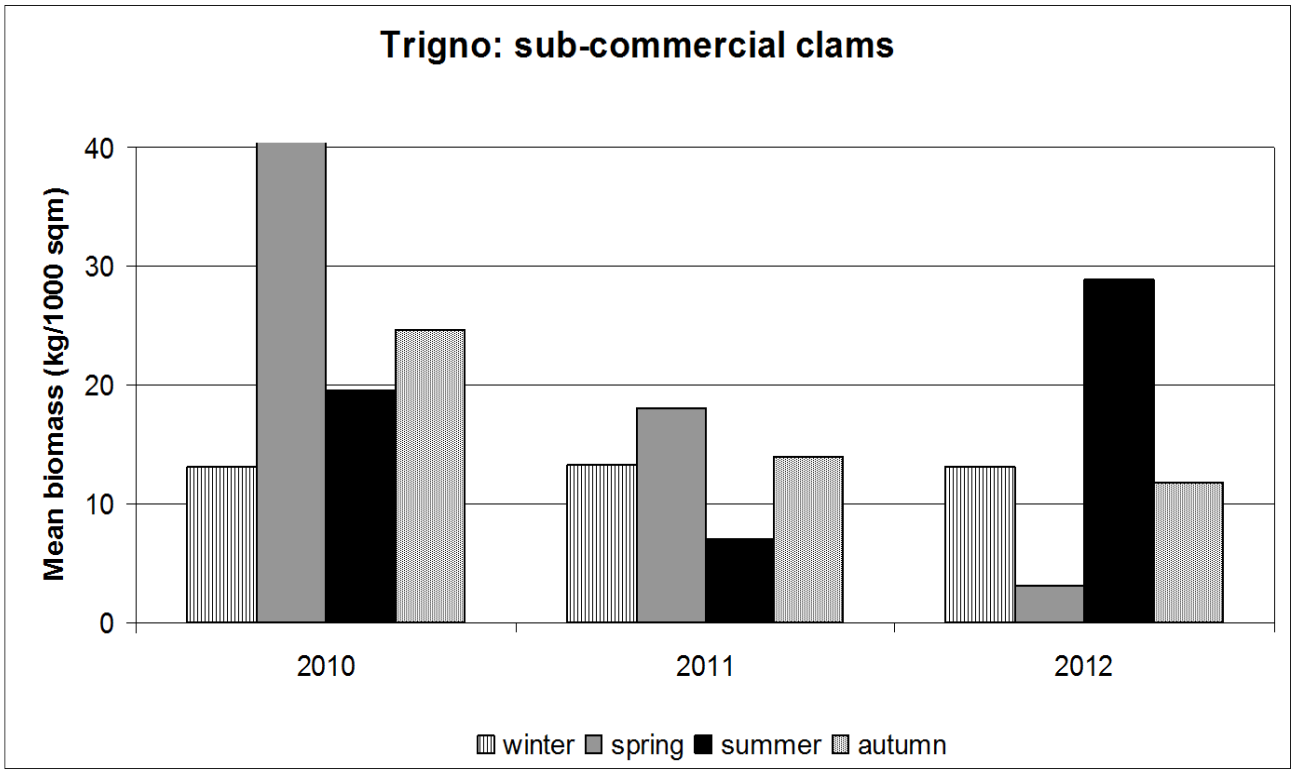

Figure 6 : Seasonal variations of not-commercial clams biomass in Trigno area during 2010-2012.

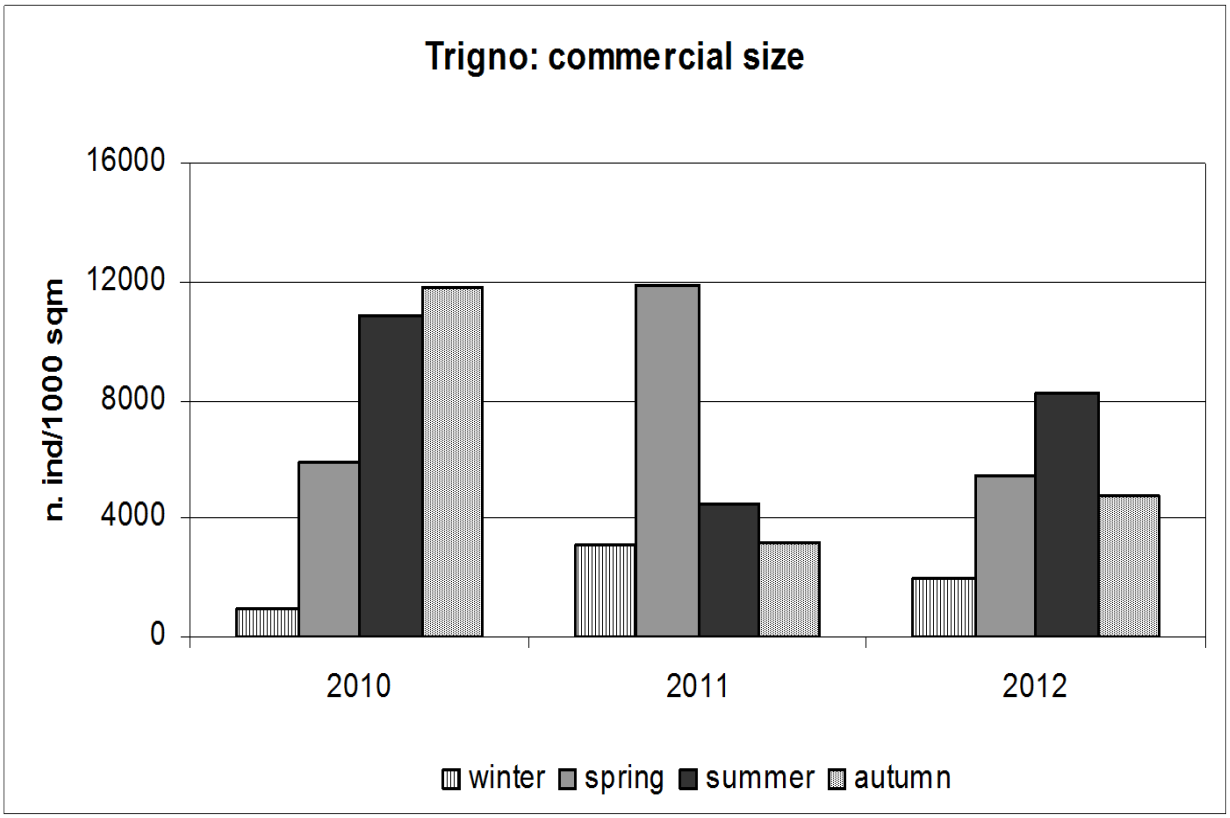

Figure 7 : Seasonal variations of commercial clams density in Trigno area during 2010-2012.

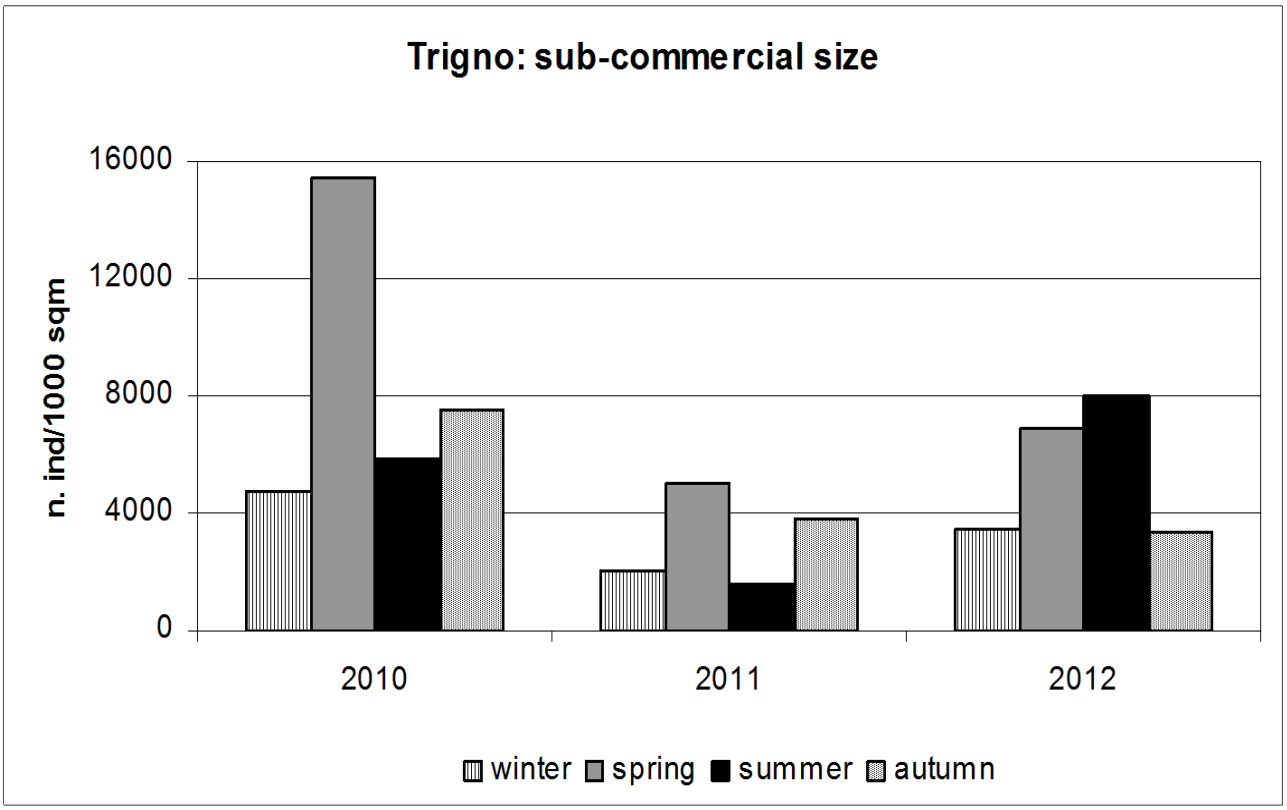

Figure 8 : Seasonal variations of not-commercial clams density in Trigno area during 2010-2012.

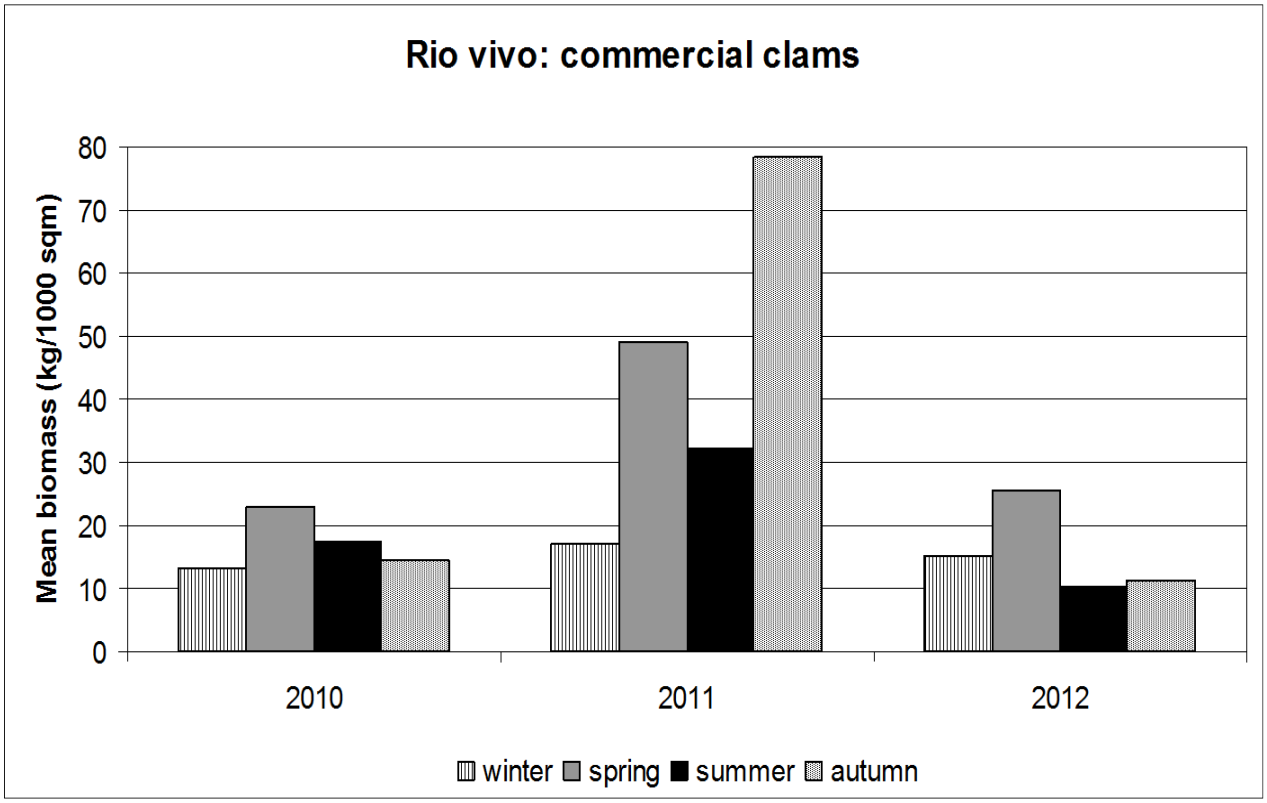

Figure 9 : Seasonal variations of commercial clams biomass in Rio vivo area during 2010-2012.

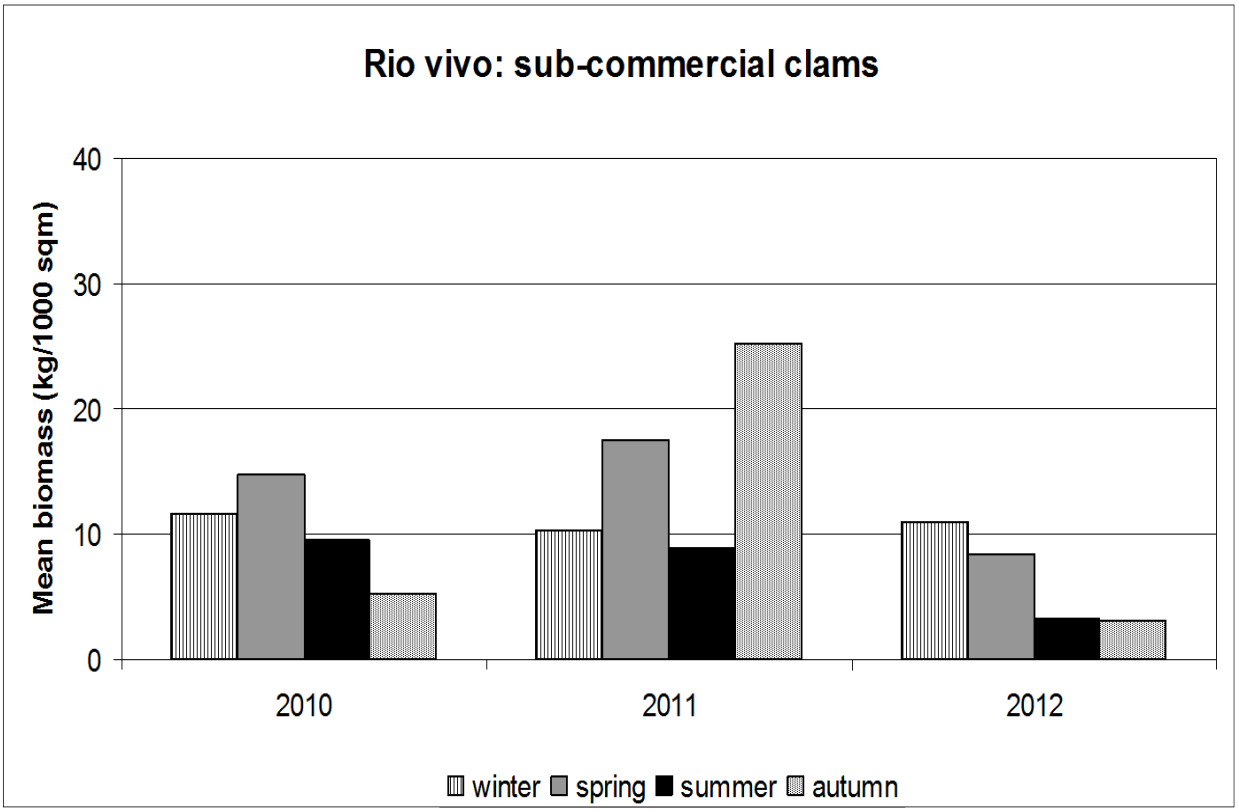

Figure 10 : Seasonal variations of not-commercial clams biomass in Rio vivo area during 2010-2012.

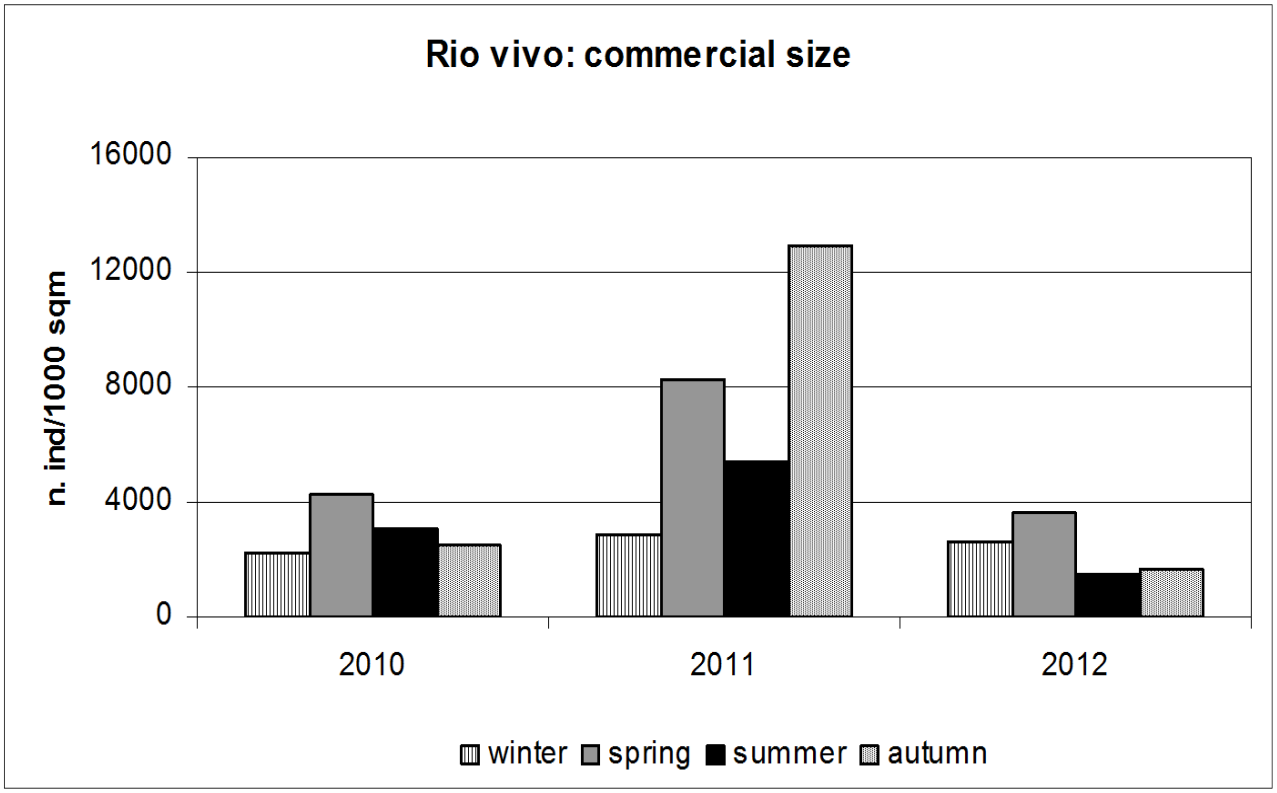

Figure 11 : Seasonal variations of commercial clams density in Rio vivo area during 2010-2012.

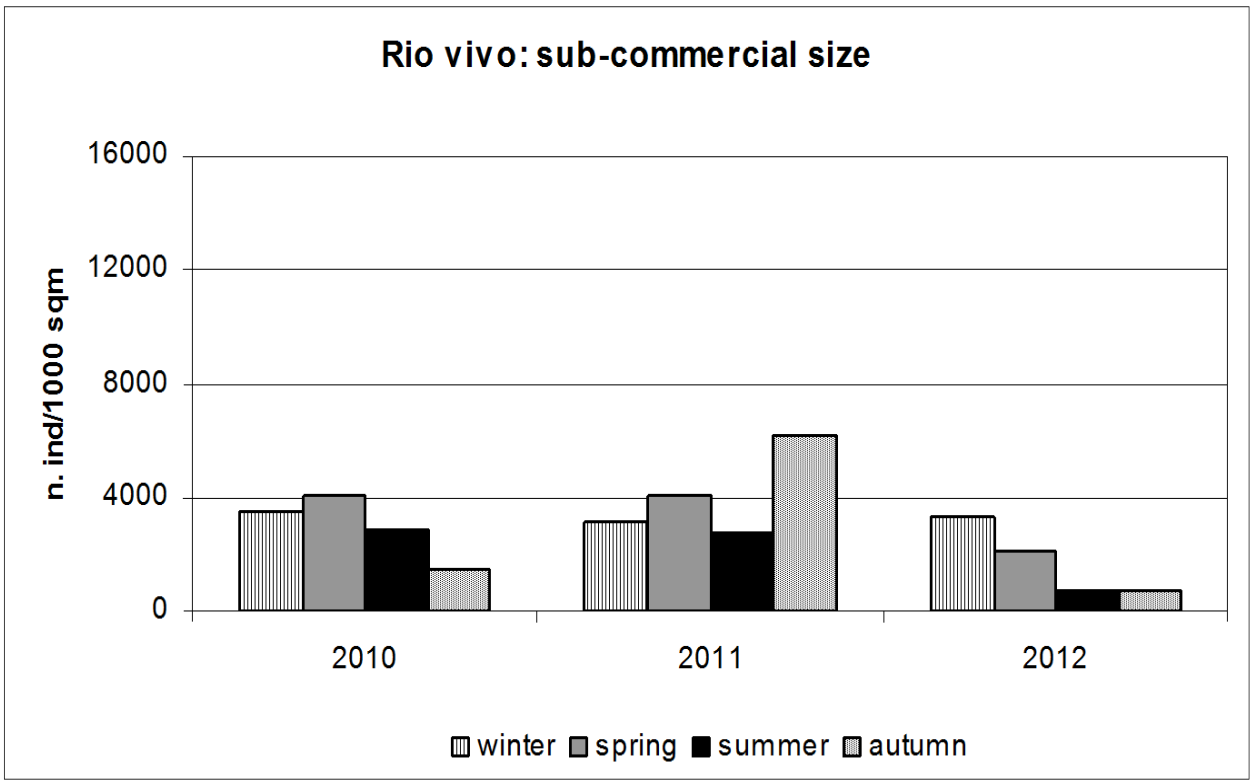

Figure 12 : Seasonal variations of not-commercial clams density in Rio vivo area during 2010-2012..

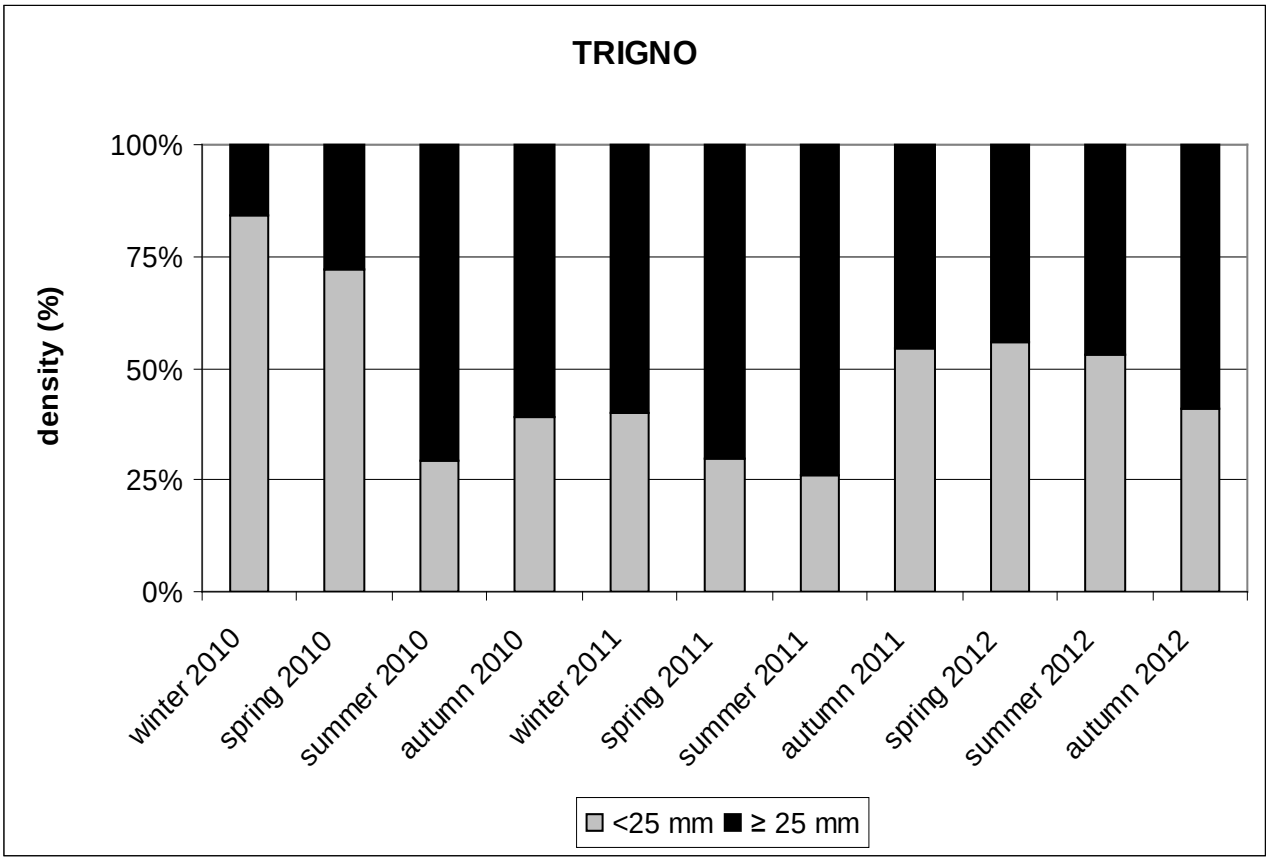

Figure 13 : Seasonal variations of commercial clams abundance percentage in Trigno area during 2010-2012.

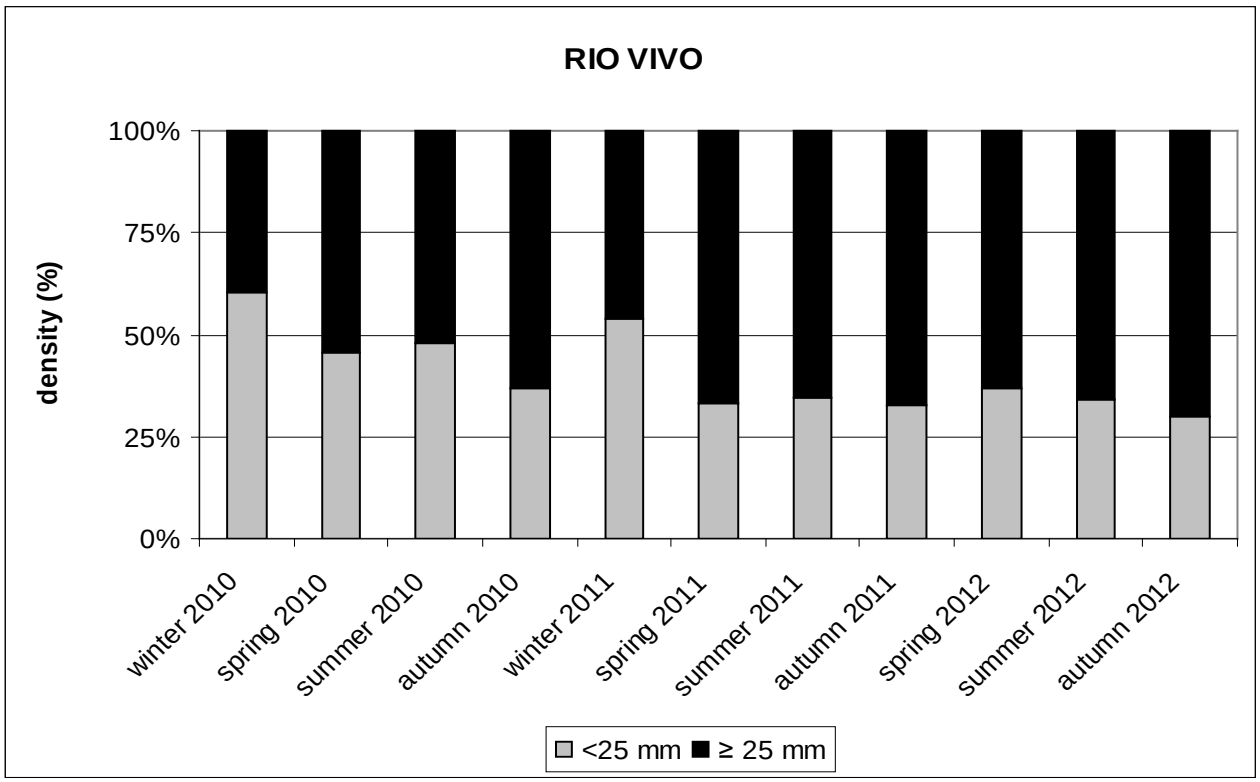

Figure 14 : Seasonal variations of commercial clams abundance percentage in Rio vivo area during 2010-2012.

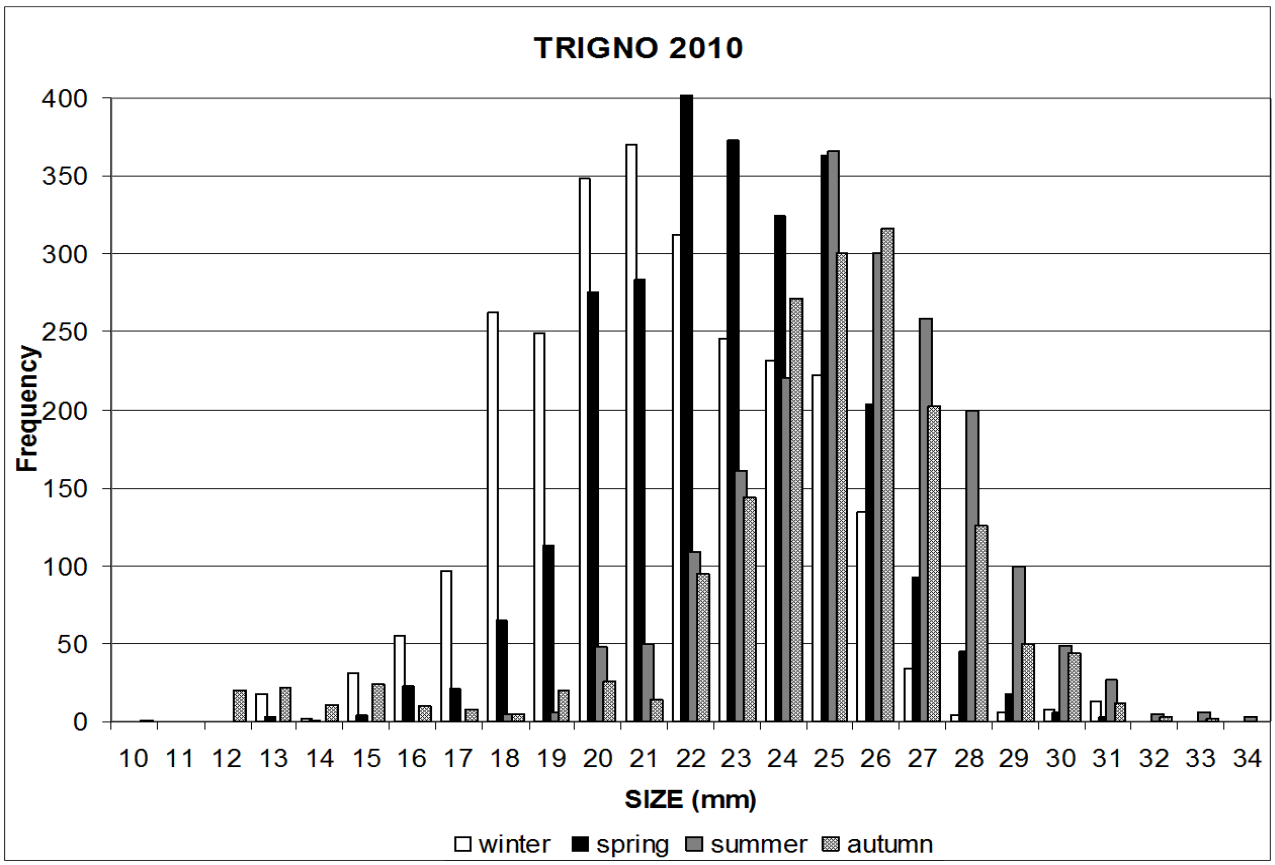

Figure 15 : Size-distribution of *Chamelea gall*ina population in Trigno area during 2010.

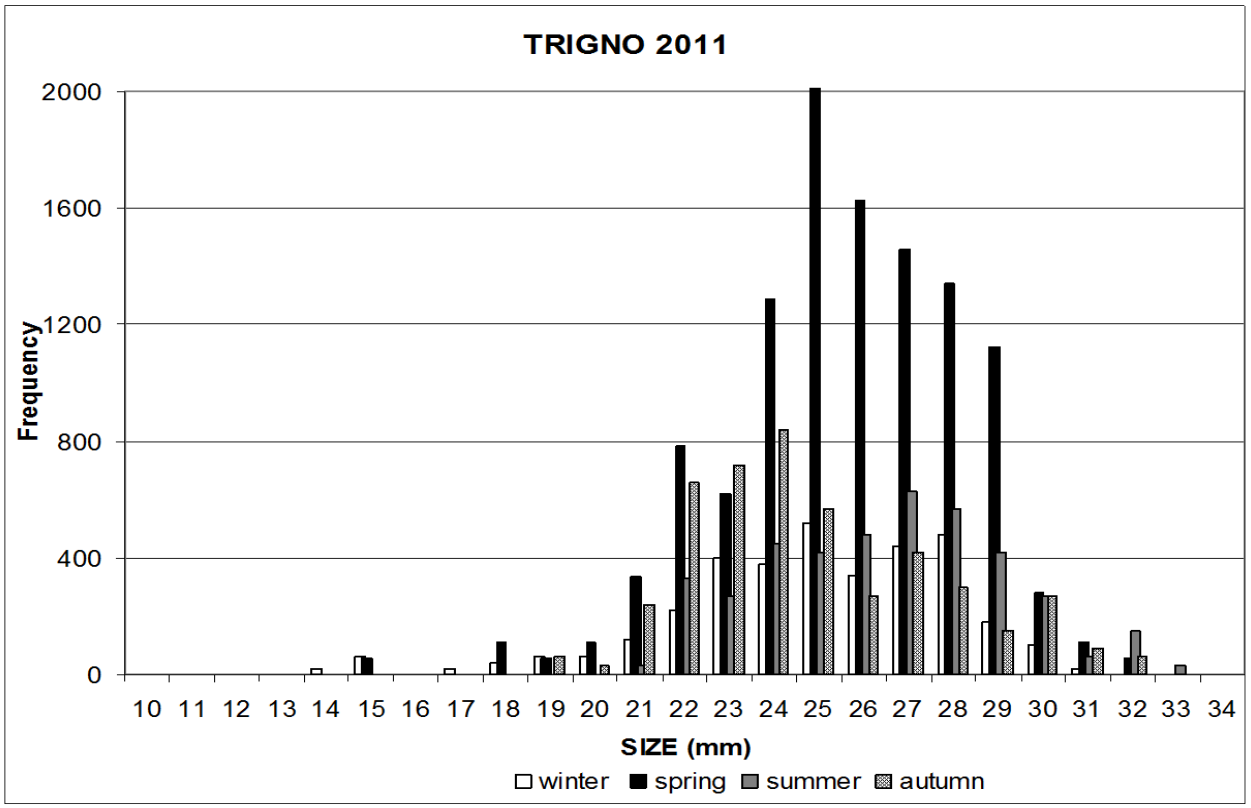

Figure 16 : Size-distribution of *Chamelea gallina* population in Rio vivo area during 2010.

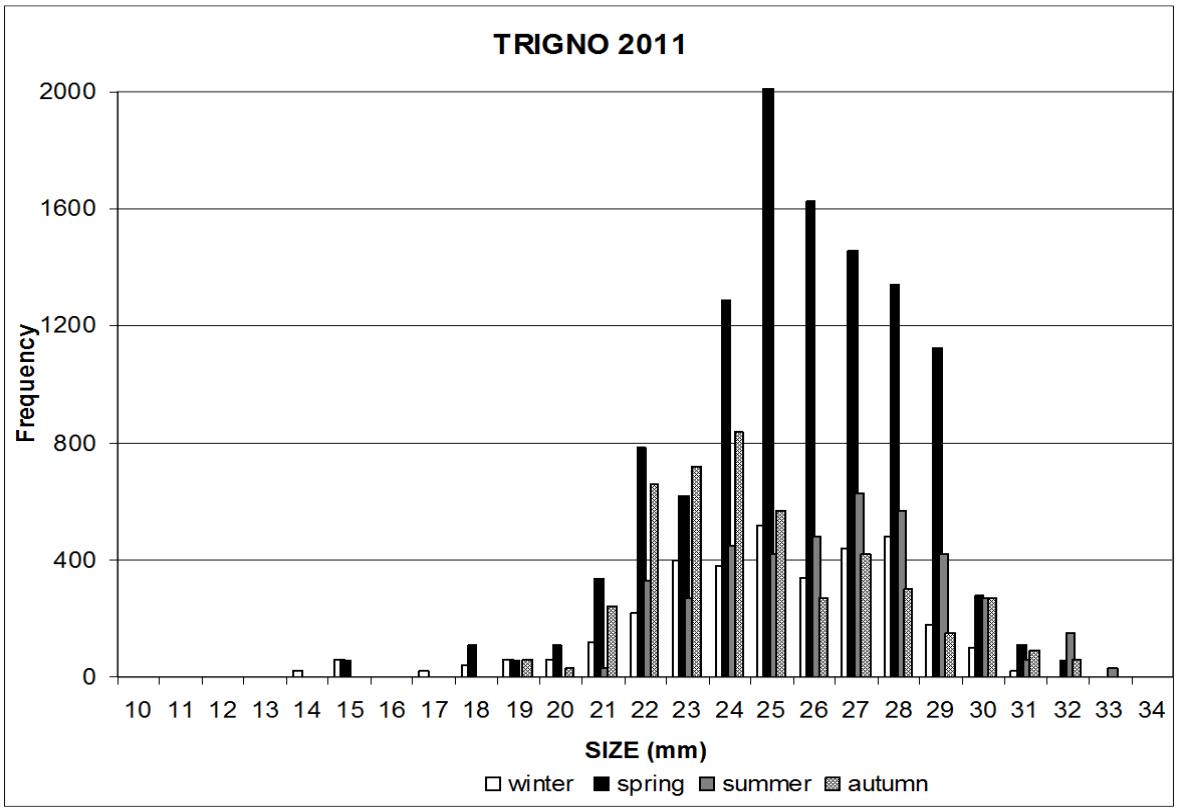

Figure 17 : Size-distribution of *Chamelea gal*lina population in Trigno area during 2011.

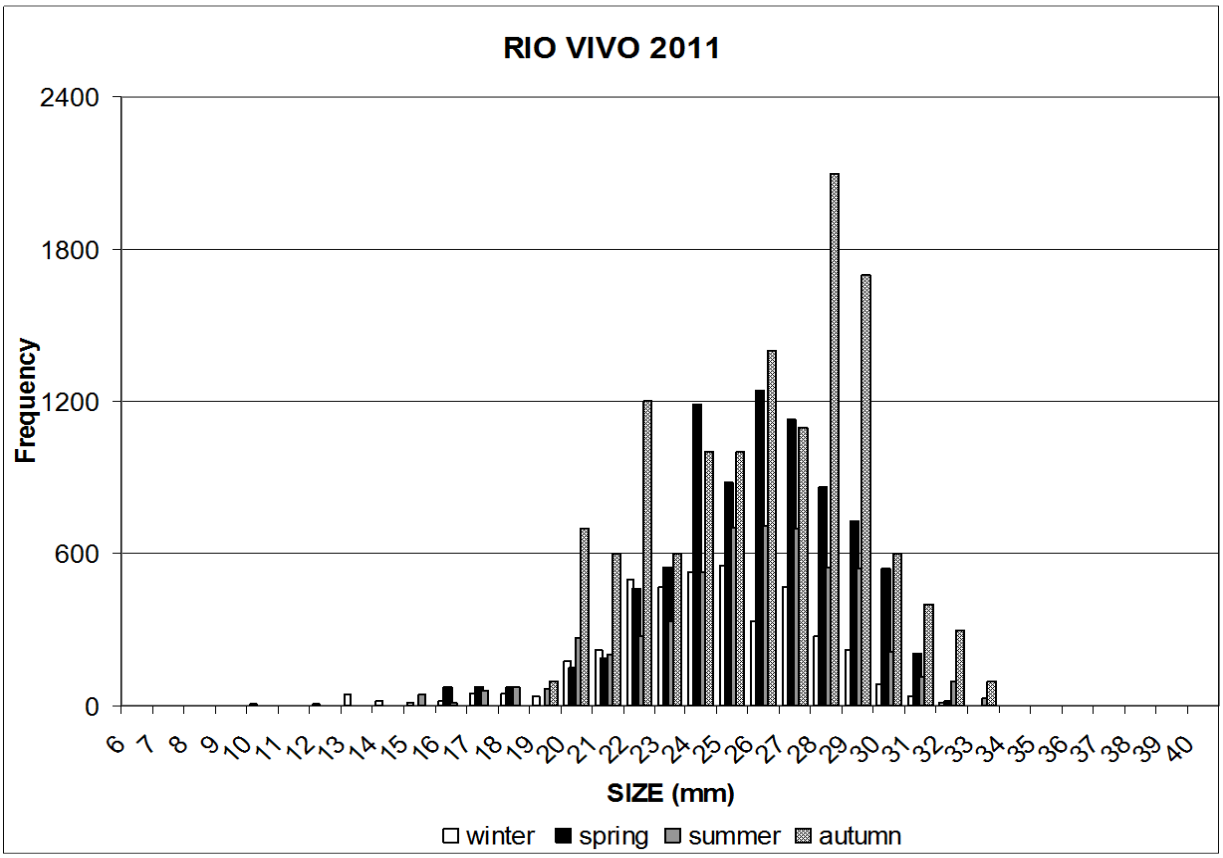

Figure 18 : Size-distribution of *Chamelea gallina* population in Rio vivo area during 2011.

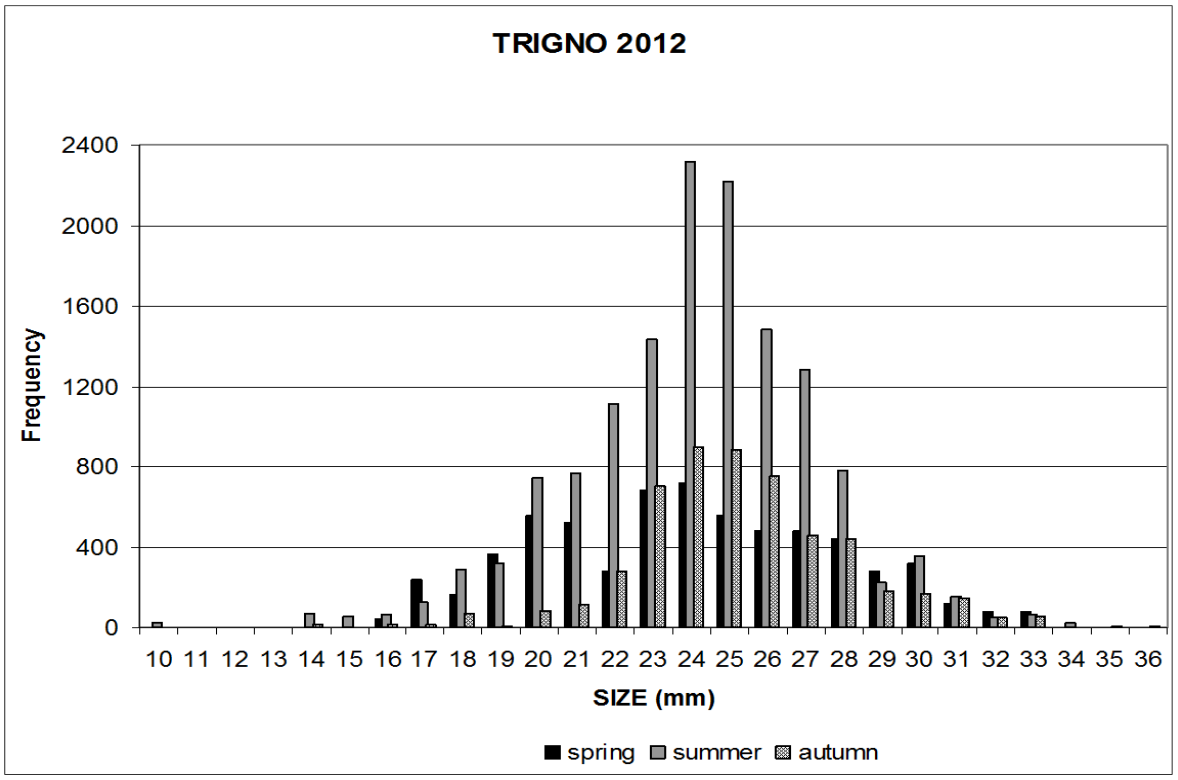

Figure 19 : Size-distribution of *Chamelea gallina* population in Trigno area during 2012.

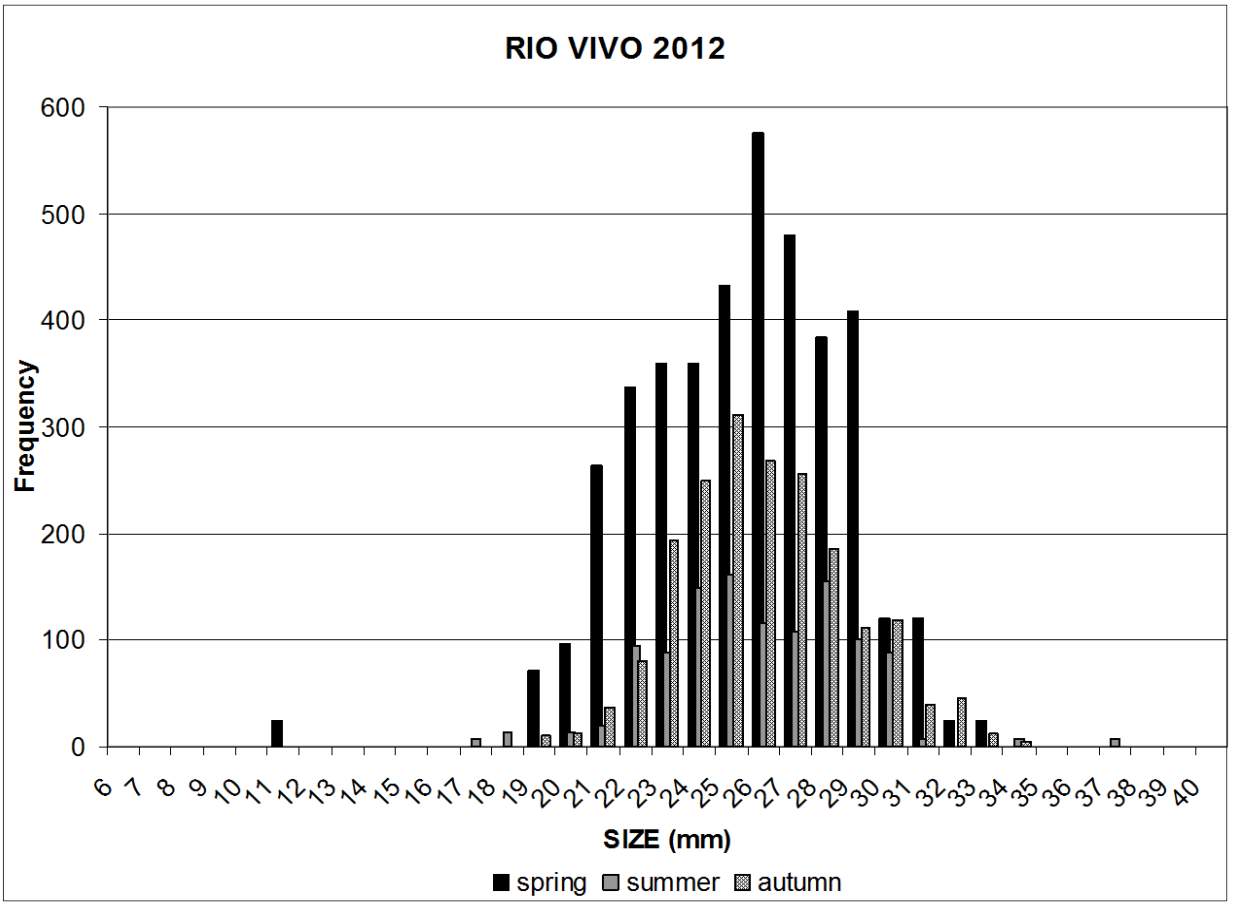

Figure 20 : Size-distribution of *Chamelea gallina* population in Rio vivo area during 2012.

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