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AUTOECOLOGY AND PRODUCTION OF *ZOSTERA MARINA* IN VENICE LAGOON

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The presence of the three seagrasses *Zostera marina* L., *Zostera noltii* (Hornem.) and *Cymodocea nodosa* (Ucria) Aschers. plays an important role in Venice lagoon ecosystem for trophic balancement, for reducing erosion, improving water clarity, trapping suspended material, producing accumulation of organic and inorganic material. The whole area of the lagoon can be divided into three different hydrological basins with three inlets connecting the lagoon to the Adriatic Sea. The entire lagoon averages about one meter in depth. There are tidal flats which drain almost completely at low tide, islets covered with halophylous vegetation and flooded by the high tide and shallow and deeper canals (ranging from few centimeters to 4-5 m). In the southern basins *Zostera marina* is the most widespread species.

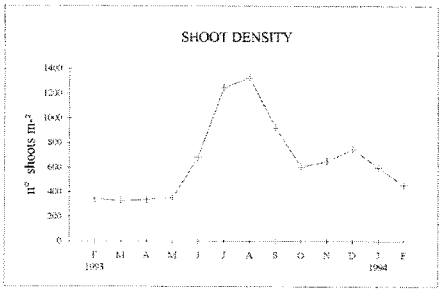
Previous studies concerning autoecology and phenology of *Cymodocea nodosa* in Venice lagoon pointed out the importance of the belowground compartment of the plant and the high values of belowground biomass (rhizoms and roots), in comparison with other mediterranean sites. For this reason a similar research was carried out for *Zostera marina*, considering the importance of this species and its very restricted distribution in Mediterranean Sea. It is also important that, due to pollution and other factors, *Zostera marina* is confined to some areas of the lagoon, with clean water and high current velocities, but in general the lagoon *Zostera marina* beds are not in a satisfactory condition and for this reason this is generally considered an endangered species (DEN HARTOG *et al.*, in press).

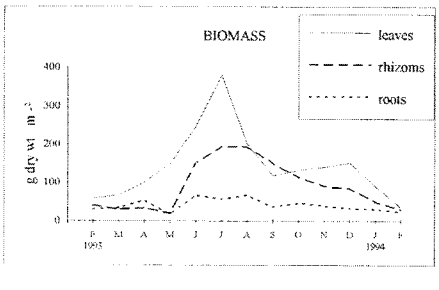
Sampling was carried out monthly from February '93 to February '94, in a pure homogeneous *Zostera marina* stand, close to the central inlet of Malamocco (central lagoon). Shoot density samples were collected by using 40 cm quadrats. Biomass was measured by coring, with a dedicated circular device 25 cm large and 30 cm deep. Following Zieman's method, all the shoots in three quadrats were monthly punched. Plastocronic interval (PI) was also calculated.

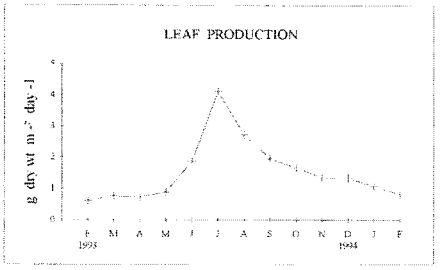
Density values reached a 1,328 shoots.m^{-2} maximum in August and a 330 shoots.m^{-2} minimum in winter time. Total biomass followed a regular trend during the observation year, ranging from February (89 g(d.w.).m^{-2}) to July (630 g(d.w.).m^{-2}. Belowground fraction represented, during almost the whole year, the dominant compartment, reaching always over 50% of the total biomass. Leaf density results positively correlated with LAI (leaf area index), ranging from 0.5 (winter) to summer value between 5 and 7 (7.7. in July). Highest production values were collected in July, with a high 4.1 g(d.w.).m^{-2}.d^{-1}, while in winter time no values under 0.6 g(d.w.).m^{-2}.d^{-1} were collected. The annual set of data showed a regular increasing trend until July and a similar decrease until winter time.

During same period observations, *Zostera marina* did not showed so high density and total biomass values as for *Cymodocea nodosa*. Belowground biomass represents only 40-50 % of the total, while for *Cymodocea nodosa* this datum ranges from 55 to 90%, pointing out the importance of the root apparatus for this species in compacting sediment and preventing erosion. Leaf production is lower for *Zostera marina* than for *Cymodocea nodosa*, but it presents a more regular trend during the year.

Some *Zostera marina* beds in Venice lagoon, far from urban outputs and critic light transmission sites are expanding (SCARTON *et al.*, in press). An estimate of leaf annual production for *Zostera marina*, is 5,500 kg (d.w.) per ha, and 20,000 tons(d.w.) for the entire lagoon.







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AUTOTOMY AND INDUCED FRAGMENTATION IN THE RED CORAL (*CORALLIUM RUBRUM* L.)

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The red skeletal axis of the mediterranean sea-fan *Corallium rubrum* has been used to make jewellery since prehistoric times, and throughout the centuries, increasingly efficient methods have been devised to harvest natural banks. Today, colonies sufficiently large for jewellery manufacture have become rare and this led to study as how best to manage this marine resource, also taking into account the biology and ecology of the species. Much of our knowledge about the reproductive biology of the red-coral comes from a study conducted over 100 years ago (LACAZE-DUTHIERS, 1864), which describes the classical life cycle of colonial Anthozoans : vegetative growth of the colony branches by asexual replication of polyps, and formation of new colonies from sexually produced larvae. A much more recent study, albeit 20 years old, showed that the red coral has gonochoric larvae and colonies, and a gonadic cycle that is annual for male and biennial for female colonies. During attempts to rear the red-coral in the laboratory (RUSSO *et al.*, 1993), we became aware of a new type of reproductive process, which seems to implicate a reconsideration of the life cycle of the species: the production of new colonies by asexual reproduction and the formation of daughter colonies through the fragmentation of parent colonies by autotomy of branch ends or by deliberate breakage. Records of asexual reproduction of colonies are very rare in Octocorallia. In the sea-fan *Plexaura* sp., localised constrictions in branches facilitates fragmentation by external disturbances (LASKER, 1984). Moreover, endogenous processes of fragmentation are known only for some soft-corals (Alcyonacea) (TURSCH & TURSCH, 1982) and for two species of fan-corals : fragmentation after stolonization in *Briareum asbestinum* (LASKER, 1983), and autotomy of branch ends in *Junceella fragilis*, whereby the coenenchyme is resorbed and the thin, not-living axial core is mechanically broken-off (WALKER & BULL, 1983).

In *Corallium rubrum* the autotomy of branch ends seems to occur with the complete resorption of tissues including the calcareous central axes. The process implies a particular dynamics of calcification which might explain the recently reported higher absorption of Ca in the apical stem (1 cm maximum from the tip) with respect to the remaining part of the colony (ALLEMAND & BENAZET, 1992). Such a specialized mechanism of asexual reproduction as autotomy is the evidence that fragmentation in red-coral is not an accidental consequence of external disturbances, but the result of natural selection with an adaptive meaning. In red-coral colonies, autotomy, occurred after removal from their natural environment to the laboratory and after drastic changes in water temperature and salinity. This indicates that, like in soft-corals (TURSCH & TURSCH, 1982), this asexual process was stress-induced. That is, under adverse conditions, the colonies asexually produce a sufficient number of propagules to ensure population survival. However, the marine environments colonized by red-coral are very stable and are not subject to such drastic changes. Therefore, reproduction by autotomy of branches seems to have a wider ecological meaning than supposed from data obtained in soft-coral. Fragmentation gives rise to colonies that are physiologically distinct but genetically identical ("genets") (HUGES *et al.*, 1992). This is in line with the low genetic variability recently found in *Corallium rubrum* (ABBIATI *et al.*, 1992, 1993). Furthermore, population spreading by short-living planulae and by passive benthonic dispersal of fragments probably enhances philopatry (short-distance dispersal). This kind of life cycle leads to considerable inbreeding, which is promoted by sexual reproduction, and to a high degree of genetic relatedness, which is promoted by fragmentation . Sexual reproduction within inbred lines is the reproductive strategy that best duplicates genotypes over many generations; this is because asexual reproduction faithfully replicates mutants which progressively build up in frequency over time (JACKSON & COATES, 1986). This model predicts that genetic relatedness and intensive inbreeding are extremely favourable for long-living organisms in stable environments, which is likely the case of red-coral. Production of new colonies by mechanical fragmentation, on the other hand, has been reported for many stony-corals (Esacorallia, Scleractiniaria) and seems to be an important mode of reproduction and population stabilization among the main tropical reef- building species. Fragmentation seems to play a major role in the recovery of reefs from recurrent disturbances produced by hurricanes (HIGHSMITH, 1980). Dredging activity for harbour construction, which promotes mechanical fragmentation, also "appears to have no major or lasting effect on the coral diversity and cover" (SHEPPARD, 1980).

Our observations confirm for the red coral what is already well documented for reef building scleractinians: survival and growth of fragments are integral parts of the life cycle of the species and, therefore, are much more than an occasional event. This new reproductive feature should be further studied in order to elucidate a number of biological implications as well as to revaluate the effects of harvesting methods on natural banks. Dredging for red-coral is illegal in most Mediterranean countries because it is considered highly destructive for the bottom communities and scarcely efficient for the harvesting activity. However, because dredging, in which many coral fragments are left on the sea bottom, enhances fragmentation, it could play a not secondary role in the recovery of natural red-coral populations. Red-coral harvesting by scuba divers, on the other hand, is permitted because it is believed to be more efficient and less destructive than dredging (MATÈ, 1984). However, modern diving techniques are so sophisticated as to allow harvesting over almost the entire depth range of the species and, unlike dredging, in cavities. The selective harvesting by divers has a low degree of disturbance for the overall bottom community but, avoiding breakage and loss of commercially valuable parts, could reduce the role of fragmentation in the recovery of red coral population. It is certainly true that the present situation of overexploitation is mostly the effect of an excessive collecting effort in the time, but the attitude of divers to collect all the material available and to avoid leftovers is an aspect of the problem that should not be longer overlooked. An 18th-century Italian prince, believing that red coral colonies were 'zoo-phytes', and thus capable of vegetative reproduction, ordered coral fragments to be scattered over the sea bottom to repopulate the natural banks. Our observations give the first evidence of the effective occurrence of a vegetative reproduction in red coral colonies and therefore the conceptual basis of that early experiment is surprisingly modern.

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