Stock evaluation of the sea urchin *Paracentrotus lividus* in a lagoonal environment

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**ABSTRACT:** *Paracentrotus lividus* stock was estimated in the coastal lagoon of Urbinu (Corsica, France) in 1990, 1994, and 1996 based on sea urchin densities obtained by stratified sampling and thematic maps of the lagoon. The population decreased from approximately 6 million individuals to 3 million individuals, a population decline of 54% between 1990 and 1994, and then subsequently increased between 1994 and 1996. This decrease is linked to the exceptional rainfall that occurred in the autumn of 1993 and which caused a major salinity decrease in the lagoon. The stock decrease observed was relatively small for a stenohaline marine invertebrate and remains within the population's resilience capacity.

**KEY WORDS:** *Paracentrotus lividus*, Coastal lagoon, Stock estimation, Mortality, Salinity.

1 INTRODUCTION

*Paracentrotus lividus* populations may play a deciding role in the organization and function of benthic communities in the Mediterranean (Verlaque, 1987), notably in determining levels of primary production and the distribution of macrophytes (Lawrence and Sammarco, 1982). This species is also intensively fished for commercial purposes in several countries (Le Direac’h et al., 1987a). For this reason, there have been a considerable number of studies on its biology and ecology (i.e. Byrne, 1990, Turon et al., 1995). Conversely, there has been little research on stock evaluation, and the few studies that have been carried out have examined open sea populations. In coastal lagoons, environmental parameters (temperature, salinity, oxygen) can vary considerably and invertebrate populations are usually adapted to survive these variations (Kjerfve, 1994). Exceedingly high variations in environmental parameters can occur, however, and these events result in mass mortalities. The aim of this study was to quantify the stocks of the sea urchin *Paracentrotus lividus* in a lagoonal environment over a relatively long period (1990, 1994, 1996). This kind of study is important if we want to increase our understanding of these particular ecosystems and this key species.

2 MATERIALS AND METHODS

The study was carried out in the coastal lagoon of Urbinu situated in Corsica (Mediterranean, France) on the East coast of the island (42° 03' N; 9° 28' E). This lagoon is characterized by the homogeneity of its water mass (with the exception of the river mouth and the communicating channel with the sea) and does not present a high level of confinement (Frisoni et al. 1983). This lagoon exhibits five different benthic communities or bottom types (strata): (1) clear sand bottoms, (2) pebble bottoms, (3) *Cymodocea nodosa* (Ucria) Ascherson (Magnoliophyte) meadows (4) silt bottoms between -2 and -8m and (5) silt bottoms at more than 8m in depth. The first three strata are situated between 0 and - 5 m. *Paracentrotus lividus* is present only in the first four strata. The surface area occupied by the different strata was estimated by generating thematic maps of the lagoon based on aerial photographs and computer image processing using MULTISCOPE software (version 2.2 of Matra Cap System company®) (Pasqualini et al., 1995). The estimation of sea urchin numbers was carried out in June 1990, 1994 and 1996. Population densities were evaluated based on stratified sampling with optimal allocation (Scherrer 1983). Sea urchin population counts for each stratum were carried out according to a simple random sampling with a 1 m² surface area as a sampling unit. The total surface area examined varied between 56 and 322 m² depending on the strata and the year. All sea urchins
greater than 8mm were counted by scuba divers. Regardless of the precautions taken, individuals below this size threshold (diameter without the spines) are generally missed using this method (Azzolina, 1988). Previous studies and field observations, however, have shown that the small-sized individuals are mostly found in the pebble areas, intermediate sized sea urchins are localized on sand or silt bottoms and the larger individuals are found within the seagrass beds (Fernandez et al., 2001). The density confidence limits were estimated following logarithmic transformation \((y = \log (x + 1))\); Elliot, 1977). The confidence interval was applied to the original arithmetic mean and the back transformed limits generated the final confidence interval (Elliot, 1977). This transformation has already been used in stock evaluation studies of *Paracentrotus lividus* (Le Direac’h et al., 1987b, Azzolina, 1988, Palacin et al., 1998).

### 3 RESULTS

The total surface area of the lagoon is approximately 690 ha, excluding the salt marshes. The statistical analysis performed by the computer image processing shows that *Cymodocea nodosa* beds occupied a smaller surface area in 1994 than in 1990. This same trend can be observed for the sand bottoms (Figure 1). Conversely, silt bottoms increased over this same time period. In 1996 the biotope surface areas are similar to those observed in 1990.

<table>
<thead>
<tr>
<th>Year</th>
<th>Pebble</th>
<th>Seagrass</th>
<th>Sand</th>
<th>Silt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>31.90</td>
<td>0.71</td>
<td>0.12</td>
<td>0.11</td>
</tr>
<tr>
<td>1994</td>
<td>17.71</td>
<td>0.54</td>
<td>0.09</td>
<td>0.08</td>
</tr>
<tr>
<td>1996</td>
<td>30.06</td>
<td>0.71</td>
<td>0.16</td>
<td>0.14</td>
</tr>
</tbody>
</table>

The comparison between years reveals that mean population densities decreased significantly in all biotopes between 1990 and 1994 (Mann-Witney test, \(p<0.05\)). The drops in numbers were, on average, 33% for the sand biotope, 44% for the pebble bottom, 66% for the silt bottom and 23% for the seagrass beds. This represents a total decrease of 54% for the lagoon. In total, sea urchin numbers dropped from approximately 6 millions individuals to approximately 3 millions (Figure 2). In 1996, data reveals that population density increased significantly in all biotopes (Mann-Witney test, \(p<0.05\)). In the entire lagoon, total sea urchin numbers increased from 3 million individuals in 1994 to 5 million in 1996 (Figure 2).

The multiple comparisons test reveals the existence of an area rich in sea urchins (pebble stratum) and an urchin-poor area (the area made up of the other three remaining strata) \(p<0.05\). The pebble stratum, despite its small surface area (approximately 10 ha), contains more than half of the lagoon's sea urchin population, and this for all of the sampling periods.

### 4 DISCUSSION AND CONCLUSIONS

The *Paracentrotus lividus* population in Urbinu lagoon is distributed in two areas whose densities are very different. Pebble bottoms shelter more than half of the individuals living in this lagoon while the surface area occupied by this bottom type is small (approximately 2% of total bottoms). Most individuals living in the pebble stratum are small-sized individuals (less than 24 mm) and this area is in fact the recruitment area of the lagoon (Fernandez et al.,

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**Table 1:** Mean density and limit of the confidence intervals (95%) of *Paracentrotus lividus* in the four biotopes studied.

**Figure 1:** Surface area (ha) estimates for each community and bottom type in 1990, 1994 and 1996, at 0 to 8 m depths.

**Figure 2.** Total number of *Paracentrotus lividus* \((x \times 10^6)\) in the sampled biotopes.
Between 1990 and 1994, an important decrease in the sea urchin population was observed. Stock estimations were performed during similar periods (June) by using an identical sampling procedure. The decrease observed is therefore not attributable to the methodology. It can equally not be attributed to the decrease in meadow and sand areas. Indeed, these last areas seem to have been replaced by silt and sea urchin densities in these last three strata are quite similar.

Interannual variations in sea urchin numbers have already been recorded for several populations. Such variations have been attributed to both biotic or abiotic factors. These factors are principally fluctuations in recruitment (Guillou and Michel 1993) or in predation pressures (Boudouresque et al. 1989; San Martin 1995), disease (Bak et al. 1984; Azzolina 1988; Lessios 1988), migration (Azzolina, 1988) or for abiotic factors: increases in pollution (Delmas; 1992), temperature variations (Lawrence, 1996) but also siltation (Delmas, 1995) or salinity variations (Lawrence, 1996).

Over the study period, one of the abiotic factors was observed to fluctuate substantially in Urbinu lagoon. Indeed, on October 31 and November 01 1993, exceptional rainfalls followed by flooding occurred in Corsica. The average rainfall in the lagoon and watershed area was in the order of 450 mm in 48h (average annual precipitation in this sector is between 500 to 706 mm/year). During this fresh water input, the lagoon salinity fell drastically: water pockets at 7‰ were observed for over a three day period descending to depths of at least 1.2 m (pers. obs.). One month after the rainfall, the lagoon salinity was still at 33‰ instead of 39‰, this latter value being generally observed during this period of the year (unpublished data IFREMER).

What evidence exists to link the decrease in Paracentrotus lividus stock to the exceptionally low salinity rather than to other causes? (1) As early as the first few days of November 1993, many tests of dead Paracentrotus lividus were washed up on the beaches of the lagoon and dead sea urchins were observed by scuba divers. (2) In an experimental rearing pen of Paracentrotus lividus situated at the edge of the lagoon, 72% of individuals died during the two weeks that followed the rainfall. (3) Monthly dives were carried out from June 1990 to June 1993 in the pebble area and average sea urchin densities remained at 20 to 30 individuals/m² throughout the period. (4) From June 1990 to June 1994, the annual variation of other abiotic factors (e.g. temperature, oxygen) presented normal values (unpublished data IFREMER).

The above information suggests that the saline crisis of October and November 1993 may have been responsible for the 50% decline in Paracentrotus lividus numbers.

Urchins are generally considered to be stenohaline (Roller and Stickle 1993). Massive mortalities due to drops in salinity have already been observed elsewhere for Lytechinus variegatus (Goodbody 1961; Lawrence 1975) or Strongylocentrotus purpuratus (Lawrence, 1996). This kind of massive mortality due to low salinity is generally the result of river discharge or heavy rainfall (Lawrence, 1996). For Paracentrotus lividus, the effect of salinity variations have been studied in laboratory by Le Gall et al. (1989). These authors show that, at low salinity and when variations in salinity are brutal, mortality occurs rapidly (100% mortality after 200 hours at 17‰ or after 1 hour at 5‰). In the present study, the saline shock was important with a significant drop in salinity (as low as 7‰). A massive mortality was therefore observed in at least part of the population. The decrease in sea urchin numbers was more important in the silt and pebble areas (where the population is the densest) than in the seagrass or sand areas. The pebble biotope is in fact located near the river mouths which spill into the lagoon. The sea urchins present in this biotope must therefore have been the most strongly affected by the salinity drop. Moreover, most of the sea urchins present on the pebble bottom are small (<24 mm) and would be approximately 2 year old (Fernandez et al., 2001). These young sea urchins are found in shallow waters (<1 m in depth), which renders them more vulnerable to salinity decreases. Indeed, Himmelman et al. (1983) noted that, in the estuary of the St Lawrence (Canada), small Strongylocentrotus droebachiensis are very sensitive to low salinity (much more than adult individuals). The density decrease was also very important on the silt bottoms. These areas, which are deeper and thus less sensitive to variations in salinity, were the site of an important sedimentation of suspended matter brought to the lagoon by runoff following the exceptional rainfall recorded (increase in the surface area occupied by the bottoms between 1990 and 1994). Echinoderms, and Paracentrotus lividus in particular, are very sensitive to siltation (Delmas, 1992, Lawrence 1996). The sea urchins present on these strata would have been affected by this phenomenon.
Sea urchin populations living in lagoons are subject to environmental fluctuations of a greater magnitude than those experienced in the open sea. High mortality levels can occur if these fluctuations reach extreme levels. The small maximal sizes observed for Paracentrotus lividus in lagoon environments (Kempf 1962; Fernandez and Caltagirone 1990) may be due to an earlier mortality as the result of sporadic events such as the one described here, and not to genetic dwarfism. It has been suggested that such early mortalities are characteristic of sea urchin populations living in an unstable environment (Lumingas 1994; Turon et al. 1995).

Finally, after only two years, the sea urchin population increased again (x 1.7) in all biotopes. This result demonstrates that the Paracentrotus lividus population possesses a great ability to recolonize, by recruitment or immigration, the different areas of the lagoon. This lagoonal population is therefore largely within its resilience capacity (disturbance level high enough to generate a response but for which there is progressive return to anterior values when the disturbance has ceased).

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