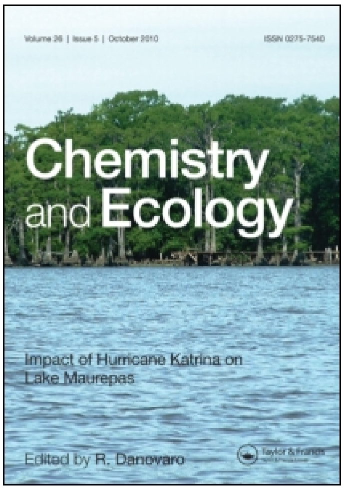

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Dystrophy effects on the *LIZA RAMADA* (Risso, 1826) (Pisces, Mugilidae) population in the Cabras lagoon (Central-Western Sardinia)

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DYSTROPHY EFFECTS ON THE *LIZA RAMADA* (RISSO, 1826) (PISCES, MUGILIDAE) POPULATION IN THE CABRAS LAGOON (CENTRAL-WESTERN SARDINIA)

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Fish samples were collected between 1999 and 2002 in the Cabras lagoon, the largest brackish area in Sardinia and one of the most important areas for the artisanal lagoon fishery in the Mediterranean area. Because of its natural connection with both the Oristano Gulf and the 'Mare e Foghe' river, in which pollution problems are frequent, this area suffers from dystrophic crises linked to phytoplanktonic or macrophytes blooms. The effect of the 1999 dystrophy on the fish population was studied by analysing the commercial landings variations and the modification of the demographic structure of the most important species, *Liza ramada.* Because of the dystrophy, the yields have decreased by about 90% since 1998. These effects are most likely attributable to the reduction in recruitment as the VPA analysis on *L. ramada* suggests. The calculated growth parameters of Thinlip mullet, which are the first reported for a Sardinia lagoon, are useful for fishery management of these areas. The study leads us to conclude that the trophic conditions probably changed, causing the reduction in the natural lagoon's 'call-effect' of recruits from the sea.

Keywords: *Liza ramada*; Coastal lagoon; Ecosystem disturbance; Fishery management; Sardinia; Mediterranean Sea

1 INTRODUCTION

Coastal waters are the ultimate recipients for pollutants from land via rivers (De Casabianca, 1996). Where lagoons are present, because of their interface with both the coastal area and rivers, pollution problems are frequent. Coastal lagoons appear to be the areas where most damage is concentrated (De Casabianca, 1996). Most aquatic pollution in lagoons originates from land-based sources (agriculture, urban development; Sly, 1991; Dukhuis *et al.*, 1992; Dounas *et al.*, 1998). Aquatic pollution, even at low levels, influences fish production in both the short and long-term (Clark, 1992).

The polluted inputs from rivers have caused frequent anoxic crises linked to phytoplanktonic or macrophytes blooms, often resulting in fish mortality (Ardizzone, 1984; Izzo and Hull, 1991; Viaroli *et al.*, 1995; De Casabianca and Kepel, 1999). Species may be disadvantaged by chronic effects such as tissue damage, impaired reproduction or abnormal larval development

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(Larsson, 1986; Arkoosh and Kaattari, 1987; Rice and Weeks, 1989; Thuvander, 1989). Therefore, the long-term effects of aquatic pollution on fish should not be underestimated.

Problems relating to lagoon pollution and dystrophy are well known in Sardinia (Central Mediterranean Sea; Sechi, 1982, 1983; Capone *et al.*, 1983). In particular, the Cabras lagoon, located in the western coast of the island, has historically been affected by such anthrophic impacts (Cataudella *et al.*, 1995).

The Cabras lagoon represents 28% of all the productive lagoons of the island. This highly productive ecosystem with rich fishery resources (Cottiglia, 1970; Cannas *et al.*, 1997) is also the largest winter refuge in Sardinia for migratory waterfowl. Because of its rich biodiversity, especially waterfowl, the area (3575 ha; 39° 57′ N 008° 29′ E) was designated by the Government of Italy as a Ramsar Site in 1979 under the Convention of Wetlands of International Importance. Cabras represents 6% of all the Ramsar Italian designated sites.

The Cabras lagoon has undergone major ecological changes in the last several years, mostly due to the salinity changes caused by the changes made to the morphology of the outer channel by the Regional Government Authority in 1970 (AA.VV., 1981). Moreover, in June 1999, a dystrophy occurred with fish production damaged and serious socio-economic and environmental consequences as a result. Therefore, a monitoring programme was initiated to manage the problem. In this programme, which is part of an interdisciplinary plan for the investigation of the present ecological status of the Cabras lagoon, the University of Cagliari (Department of Animal Biology and Ecology) studied the fish population. The aim was to provide a biological description of the main fish stock and to gain greater knowledge for managing the environment.

In this paper, the fishery economy and fishery resource management of the Cabras lagoon are discussed, with focus on the dynamic population of the Thinlip mullet, *Liza ramada*, one of the most important fish species.

2 MATERIALS AND METHODS

2.1 Study Area

The Cabras Lagoon is situated on the west coast of Sardinia (central Mediterranean). It is the largest brackish water lagoon with an estuarine nature and sprawls along the west coast (Fig. 1). The L-shaped lagoon is about 8 km long, with a width varying from 2 to 5.7 km. The waterspread area of Cabras is about 22 km^2. The watershed covers an area of over 458 km^2 (Franco *et al.*, 1987), including about 22 km^2 of the lagoon itself. It is supplied mainly by the ‘Rio Mare e Foghe’ river, together with runoff from adjacent agricultural land.

The lagoon is connected to the outer channel by three channels with several shoals restricting the flow and head loss. The 1-km-long and 500-m-wide, narrow, outer channel (Sa Mardini) connects the lagoon to the Bay of Oristano, near the village of Torre Grande. A small tourist port is located at the mouth of the channel.

The Cabras lagoon can be broadly divided into four natural sectors based on salinity and depth: southern zone, central zone, northern zone and outer channel (Franco *et al.*, 1987). The major part of the lagoon has a depth of less than 60 cm, while the maximum depth of 2.5–3 m is in the central sector and outer channel. The average depth is about 1.2 m (Cataudella *et al.*, 1995).

Generally gillnet, fyke nets, traps and V-shaped fishing equipment called ‘lavoriero’ are used for fishing. The lavoriero is old fishing equipment, always set up in the canals connecting the lagoons with the sea (De Angelis, 1959; Tesch, 1977). The ‘catching power’ of this

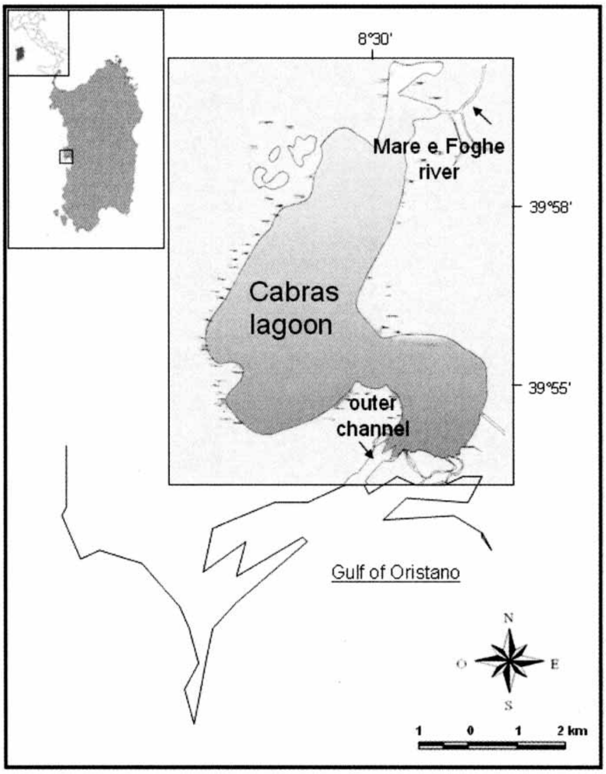

FIGURE 1 Study areas.

equipment is derived from the 'call-effect' of incoming seawater flowing down into the lagoon and the tendency of the catadromous fish to migrate at sea when sexual maturation starts (De Angelis, 1960).

2.2 Sampling Strategy and Biological Analyses

To assess fishing efforts, commercial fish landings were regularly monitored. The daily accounting records of fish landings compiled by fishermen between March 1994 and December 2002 were used for this purpose. A check of catch quantities reported by fishermen was carried out twice per month from June 1999 by an author (M.M.) directly on the landing ports, and a census of the total active fleet present in the lagoon was also carried out.

To obtain information about specific composition, demography and abundance of the lagoon's fish populations, a monthly experimental survey was also conducted between June 1999 and December 2002. A random sampling design for haul allocation was adopted. On average, four hauls were carried out on each trip. A total of 269 hauls were carried out over 56 fishing days. The same fishing equipment used by fishermen (gillnet) was used for sampling activities. This net (a mesh net) is made from fine cotton thread, with a mesh size of 10 × 10 cm, height of 1.2 m and a length of 60 m. The mesh net was lowered during daylight using two boats each equipped with a 180-m-long net.

A set of biometrical measurements was undertaken on the fish samples. All the fished species were identified and weighed. The total length (TL) and weight were measured, respectively, to the lower half centimetre and the lower gram. For mullets, the classification was done by checking the pyloric caeca under a stereomicroscope (De Angelis, 1967). Sex was determined by direct inspection of the gonads.

Landings were used to obtain a general trend by fish group and to identify the most important species in terms of weight. From this, further investigations on biological parameters and a virtual population analysis (VPA) were carried out.

Von Bertalanffy growth parameters (von Bertalanffy, 1934) were calculated for sexes combined. The growth parameters L_∞ (theoretical maximum individual size), K (annual growth rate) and t_0 (the fish age at length zero) were calculated by modal progression in the time series of monthly size-frequency distribution (MPA). A cohort analysis was performed using the Bhattacharya (1967) method, the FISAT–FAO ICLARM Stock Assessment Tools (Gayanilo *et al.*, 1996), and the Expectation-Maximization (EM) algorithms from Dempster *et al.* (1977), implemented in Multimix (Murray and Hunt, 1999), which had been successfully used by Sabatini *et al.* (2002). To obtain the growth parameters, results from the cohort resolution were used for the 'Linking of means' procedure (FISAT).

The catch composition of the annual thinlip mullet was extrapolated by age group by applying the proportions of the age groups, found in the catches of the experimental random sample, to the total number of thinlip mullet landed. The total number of catches was calculated relating length size histogram and yields by length class. This process was obtained, using the length–weight relationship obtained experimentally from samples. The size–weight relationship was calculated according to the power equation $y = ax^b$, where a is a constant, x is the size (TL; cm), y is the weight (g) and b is the allometric coefficient (or slope).

The age structure of the catch was used as input for the VPA carried out, solving algorithms backwards in time, to obtain an estimate of the value of the recruitment to the first age class (R_1; Pope, 1972).

3 RESULTS

The total annual catch in the Cabras lagoon varied annually between 80 and 850 t from 1994 to 2002. Fishes represent, on average, about 99% of commercial catches, of which mullets are the most abundant species (82.3%). The fish composition includes thinlip mullet (*L. ramada*, Risso), which is the most abundant species, and other species with a high market value such as the European eel (*Anguilla anguilla* L.), the gilthead seabream (*Sparus aurata* L.) and the seabass (*Dicentrarchus labrax* L.; Tab. I).

The effect of the dystrophic crisis that occurred in June 1999 can be seen when analysing the trend of total production (t yr^{-1}). The total number of catches dropped from 850 t (in 1988) to 354 t (1999), and during the last years of the period, a gradual decline in

TABLE 1 Percentage fish composition of commercial catches in the cabras lagoon (average of total annual weight over the period 1994–2002).

Commercial fish species	*Catches (%)*
Liza ramada	68.2
Other mugilidae	14.1
Anguilla anguilla	14.0
Dicentrarchus labrax	0.5
Sparus aurata	0.4
Other species	2.8

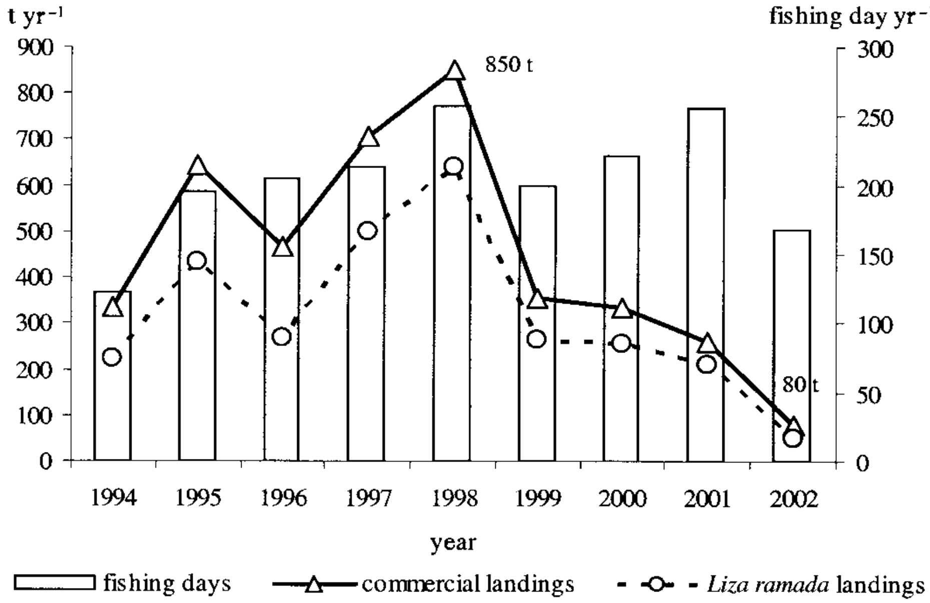

FIGURE 2 Commercial fish landings (tonnes yr^{-1}) and fishing effort (d yr^{-1}) in the Cabras lagoon over the period studied.

the fishery yield was also observed, with total catches falling below the limit of 80 t in 2002. It is interesting to note that there is apparently no correlation between effort, expressed as the number of fish day per year, and the decrease in catches (Fig. 2).

Because of the abundance and the economic importance of *L. ramada*, which accounts for most mullet species, its population structure was analysed in detail to consider the eutrophication effects.

During the experimental survey carried out monthly between June 1999 and December 2002, TL) data (nearest cm) were collected for a total of about 5700 thinlip mullet specimens. The length distribution of *L. ramada* showed a wide range (33 cm). The minimum and maximum observed length was about 8.5 cm (67 g) and 40 cm (670 g), respectively. The length structure shows three modal classes (mode at 24 cm). With regard to the size structure over the years, a progressive reduction in small (19 cm) and large (29 cm) fish components was observed (Fig. 3).

The size distribution for sexes combined was used to perform an MPA. Von Bertalanffy's growth parameters obtained from Bhattacharya's (1967) method and the EM algorithms are reported in Table II. These parameters are similar to those found by Farrugio (1975) in a Tunisian lagoon and are used as a reference parameter for this species (see Froese and Pauly, 2002) as the $\o'$ calculation suggests.

The number of mullets per age group in the catch was then determined (Gulland, 1966) by taking the proportions of age groups obtained from the experimental samples and applying these to the total catch (landings). The total biomass by age group was converted to numbers using the results of the previous analysis (demographic structure, MPA) and using the *a* and *b* coefficients of length–weight allometric regression (0.0049 and 3.18, respectively). The composition of the annual catch by age group per year is shown in Figure. 4.

A gradual decline in the 4^+ age class is evident in the last years of the period. It is likely that the difficult environmental conditions caused by the dystrophy made the fish stock more vulnerable to the fishing pressure, and this age class disappeared rapidly. Consequently, the

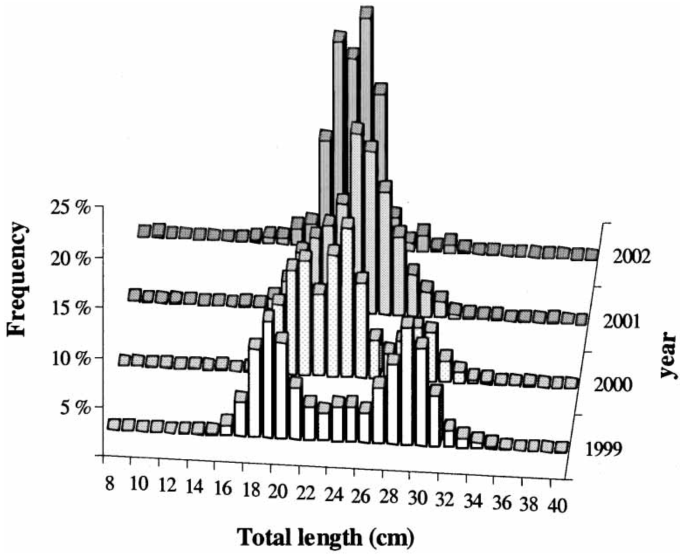

FIGURE 3 Length-size histogram of the *Liza ramada* population in the Cabras lagoon over the period 1999–2002.

TABLE II Parameters of the growth equation according to Von Bertalanffy's model applied to *liza ramada* in the cabras lagoon.

Author technique	*Present work* Bhattacharya	*EM*	*Farrugio Bhattacharya*
L_∞	47.76	51.17	40.5
K	0.21	0.19	0.31
t_0	−0.152	−0.1	−0.121
ϕ'	2.680	2.697	2.706

reduction in the 4^+ age fraction forced fishermen to catch younger animals (2^+ and 3^+ age class).

To evaluate the fish-stock status, the VPA was performed using the landings data and its age-group composition. The analysis represented in Figure 5 shows that after the fish-plague

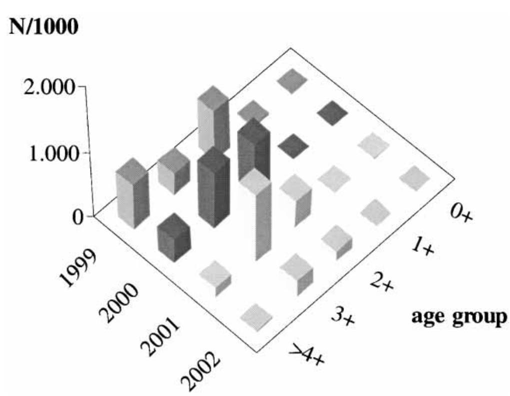

FIGURE 4 Evolution of catch composition ($N/1000$) of *Liza ramada* by age group.

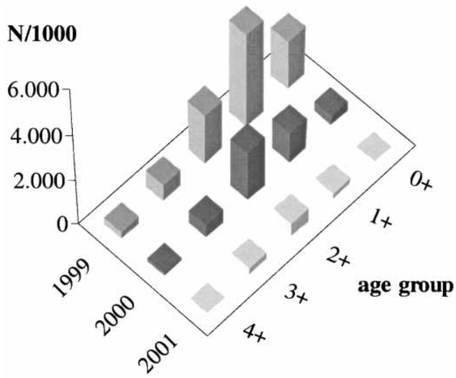

FIGURE 5 Virtual population analysis of *Liza ramada* by age group and year.

period (1999), there was a decrease in all age groups. The great reduction in recruits (0^+) explains the collapse of the *L. ramada* population.

4 DISCUSSION

In the Cabras lagoon, the trend of the total commercial catches highlights a drop in the fish population after 1998. This fall is attributable to the 1999 dystrophy, which had both short- and long-term effects. In the Cabras lagoon, the 1999 yields were about 60% lower as a result of the fish plague caused by the dystrophy. Thereafter, a progressive decline took place. The yields have decreased by about 90% since 1998, yet the numbers of fishing days (effort) have not been reduced.

These effects are most likely attributable to the reduction in recruitment. As the VPA analysis on *L. ramada* suggests, the differences observed in the annual catch mainly depend on the poor recruitment. Since the 1999 dystrophy, a general decrease in numbers in all the age groups, and in particular a reduction in the 0^+ age class, has been observed. In addition, fishing activity of *L. ramada* in the 4^+ age class and younger specimens (3^+) has increased over the years. This leads us to conclude that the trophic conditions probably changed, causing the reduction in the natural lagoon's 'call-effect' of recruits from the sea.

The effects of human impacts (eutrophication following pollution, poor water and land management, etc.) are well known in some Mediterranean lagoons (Izzo, 1987; Bucci *et al.*, 1988; De Casabianca, 1989, 1996; Izzo *et al.*, 1990; Izzo and Hull, 1991; Dukhuis *et al.*, 1992; Viaroli *et al.*, 1995; Dounas *et al.*, 1998; De Casabianca and Kepel, 1999; Koutsoubas *et al.*, 2000).

Lagoon 'fish stock' are usually compromized by the deterioration in the quality of the habitat. This situation may also cause socio-economic problems. Scientists are being asked to provide urgent solutions to resolve these crises.

As in other polluted lagoons, an increase in the production in the Cabras waters can be achieved by active management and quality control of the environment. The management of these should focus on obtaining an improvement in the quality of the water and the rational handling of the fish population (Rossi and Papas, 1979; Quignard, 1984; Rossi and Cannas, 1992). At present, an improvement in water quality in Cabras could be an initial intervention. Having improved the quality of the water, a better thought-out management of fish resources is needed.

The management of the fish populations in brackish lagoon waters is easier than that in open-sea environments (Carrada, 1988). This is because it is possible to quantify fishing efforts and, by means of a 'lavoriero' in the outer channel, to control recruitment and adult fish migration. In a stabilized environment, with a balanced fishing effort and equipment use, artificial fry-stocking could be the lever to increase the fish stock (Corsetti *et al.*, 1998; Cataudella *et al.*, 1999; Corsetti, 2001).

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