Potential biological and environmental influences on the *Octopus vulgaris* population of the Gulf of Gabès (south-eastern Tunisian coast)

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Abstract

Octopus fishing is abundant along the Tunisian coasts especially in the Gulf of Gabès, which accounts for 83% of the national landings. In spite of the Tunisian regulation controlling the octopus fishing, the catch is variable. The potential causes of such variability are presented and qualitatively discussed.

1. Introduction

The most exploited cephalopod species along the Tunisian coast are the common cuttlefish (*Sepia officinalis*), the musky octopus (*Eledone moschata*), the broadtail squid (*Illex coindetii*) and the common octopus (*Octopus vulgaris*). Of these, the common octopus is the most important target species, especially in the Gulf of Gabès (Figure 1), where the landings represent 83% of the national production destined for local consumption and mainly for exportation. Actually, the Gulf of Gabès presents the best environmental conditions for the expansion of the octopus stock and the use of static and traditional gears which ensure the selective capture of octopus. The artisanal fishing provides 90% of the octopus landings in this region. The increase in fishing effort on the southern octopus stock raised the coastal landings from 2,600 tons in 1975 to 12,000 tons in 1988; nevertheless, production underwent many fluctuations between 1975 and 2000.

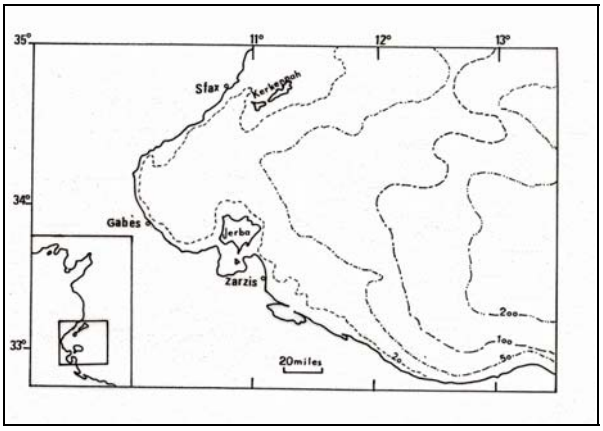

Figure 1. Geographic situation of the Gulf of Gabès

Octopus vulgaris fishery regulations were established in 1987 and were amended in 1992 and in 1994. These regulations provide that fishing any octopus weighing less than 1 kg is forbidden from 16 May to 15 October, but allow the possibility of delaying or advancing,

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respectively, the opening or the closing dates. The decision was taken on the basis of the results of biological sampling both before the opening campaign and during the fishing season for the closing time. These regulations concern both trawling and artisanal fishing. However, in spite of this legal control, the annual production has undergone annual fluctuations, with a falling trend since 1990 (Figure 2).

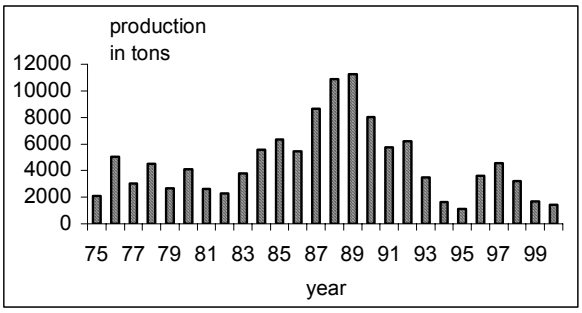

Figure 2. *Octopus vulgaris*: coastal landings in the Gulf of Gabès (from 1977 to 2000)

Fluctuations in landings might reflect modifications in the pattern of fishing (e.g. changes in the distribution of fishing in time and space, dispersion or concentration, and variation in the effectiveness of a unit of fishing effort) and in the interactions between the octopus and the bio-ecological and environmental factors, in addition to the effects of human activities. Since all these factors posed a problem in the rational management of the stock, we have tried to review here the different factors that might explain the variation in the landings and prevent an accurate stock assessment.

2. Materials and methods

The data used in the present work were from biological and dynamic studies of octopus in the Gulf of Gabès and from surveys conducted in the region. Data from the literature dealing with the physical and chemical characteristics of the central Mediterranean were also considered here.

For each factor, whether it was inherent in the biological parameters of the octopus or linked to the environmental conditions, we tried to draw up an evaluation sheet of the potential effects to explain the octopus catch variability. Three parameters were considered particularly as factors affecting the octopus fishing:

- the bio-ecological characteristics
- the behaviour of the octopus with respect to the environment
- the environmental effects, excluding the specifically oriented effects of human activities (i.e. those not directly linked to the fishery for the species investigated).

3. Results

3.1 Bio-ecological effects

The octopus has a biological predisposition to govern its own stock. The reaction of the stock to biological variability is fast and depends on the fishing method. These changes affect a number of biological parameters which are discussed in the present paper.

Growth and life-span

In the Gulf of Gabès, the octopus grows quickly and at a nearly constant rate, particularly during the first months of its life. In fact, according to the results of Zguidi (2002), there are two cohorts in the octopus population of the Gulf: one from the spring spawning, characterized by a high growth rate and a short life-span; the second is from the summer spawning, distinguished by a lower growth rate and a longer life-span. However, the global formula established for octopus growth, with respect to the stock in the Gulf of Gabes, is an exponential equation:

$$Lt= 29.6*[1–exp(–0.560*t+0.225)]$$

where Lt is mantle length in centimetres; t is in years.

Like most cephalopods, the octopus of the Gulf of Gabès has a very short life-span, estimated between 13 and 20 months, depending on the laying period, and rarely exceeds 2 years. Thus, the biggest animals sampled in Tunisian waters (weighting 10 kg) were not necessarily older than 3 years, but they likely found adequate food supplies which contributed to their rapid growth (Ezzeddine-Najaï 1992).

Short life-span and high growth rate afford the common octopus stock a high turnover rate and therefore ensure a potentially rapid renewal of the stock. This rate is estimated at 16% of the mean biomass, according to a stock assessment of the species in the Gulf of Gabès which revealed an overexploited stock (Zguidi 2002). Besides, on account of the same biological effects, the stock is sometimes subject to large variation with the possibility of a population explosion or collapse. These fluctuations are often difficult to forecast, because it is difficult to monitor changes in stock size over a very short life-span (1.5 years). Such an event was recorded for the octopus stock in the Gulf of Gabès between 1977 and 2000 (Figure 2) and elsewhere in the coastal water of the Gambia and of neighbouring Senegal between 1986 and 1990 (Caverivière 1994).

Reproduction

In the female, fertilization of the eggs is internal; the introduction of the male's hectocotyle into the female's mantle cavity ensures that the fertilization takes place inside the glands of the oviduct where the spermatozoa are stocked (Mangold and Boletzky 1973). In the Gulf of Gabès, 50% of the female population reaches sexual maturity during the second year of life when the mean size of the mantle length reaches 14.5 cm. The first year of their life is devoted to increasing the body weight, hence the stock weight. Moreover, this method of reproduction constitutes a biological protection of the stock against environmental risks.

Spawning and fecundity

Sexual maturity is reached at an average weight of 1200–1450 g (Ezzeddine-Najaï 1992; Zguidi 2002). These results agree with those reported for the species inhabiting other geographical areas (Mangold-Wirz 1963; Guerra 1979; Hatanaka 1979; Caverivière 1990).

In the Gulf of Gabès, females of the common octopus have a prolonged spawning season (from February to September) with a peak between March and July, whereas the males are mature all the year round. The breeding is preceded by an inshore migration in autumn, the males preceding the females (Ezzeddine-Najaï 1992). This migration has a genetic and probably a trophic origin. Along the coasts, the animals find enough light and feeding (crabs, shrimps and shellfishes) for gonad growth. In early spring, a large number of adult females isolate themselves in shelters for spawning.

The potential fecundity expressed as the number of ova in one ovary is equally important; the values estimated for Tunisian species are between 127,607 and 1,326,597, but the number is not related to the size of the animal (Zguidi 2002). These results agree with those obtained for other Mediterranean populations, such as those in the Catalan sea, where the number of eggs laid by a female varies from 100,000 to roughly 500,000 (Mangold 1983). The large number of eggs emphasizes the importance of fertility in the common octopus compared to other octopus species.

The above-mentioned biological characters (extended spawning season, method of reproduction, spawning migration, high fertility) ensure a high yearly recruitment to the stock. On the other hand, when the octopus moves inshore, a large number of maturing animals are subject, before breeding and spawning, to precocious capture by trawlers which cut off their way inshore.

3.2 Behavioural effects

The natural behaviour of this species was observed and described in the laboratory and in the field.

Egg care

The female always attaches its egg strings to the substrate on rocky shores, in a hole or any sheltered place generally inaccessible to trawl nets. During the incubation period, the female ventilates and protects the eggs until they hatch, starves and usually becomes senile and dies. However, in spite of the high level of maternal care, several eggs are often eaten by predators inhabiting the same areas as the octopus. These losses have a negative effect on stock recruitment.

Planktonic stage

Hatchlings live for some time in the plankton (Figure 3) and then sink to the bottom. During the planktonic phase, they are transported by the water currents which ensure them a large distribution throughout the sea. Nevertheless, the juveniles are very vulnerable to environmental risks and the mortality rate is significant during this phase. In rearing experiments, the survival rate, from hatching to settling, was only 9% (Itami and al. 1963); but in natural conditions, this rate probably exceeds 90% (Mangold 1983).

Figure 3. Newly hatched 24-h-old *O. vulgaris* (INSTM Museum, Salammbô)

Way of life

Other very particular behavioural characteristics allow the species to protect itself from environmental dangers.

According to the aggregation indices of the spatial distribution of the species (Guerra 1981), the octopus is normally solitary and territorial, especially in the spawning season. It digs into soft substrata to rest quietly during the daytime. Juveniles and females bury themselves in sandy and muddy sediment to shelter against predator attack (Boletzky 1996). The bottom of the Gulf of Gabès is muddy or sandy, covered over a large area by seagrass and inhabited by several species, among which, the common octopus finds its favourite prey: crustacea (Decapod sub-orders Macrura, Brachiura, Anomura), molluscs (classes Gasteropoda, Cephalopoda) and fishes (order Teleostei) (Ezzeddine-Najaï 1992; Zguidi 2002) (Figure 4).

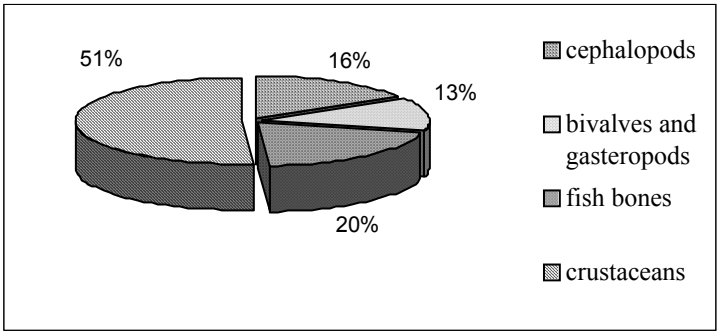

Figure 4. *O. vulgaris*: frequency of occurrence of various prey items in the diet

Unfortunately, the recent degradation of the bottom in the Gulf of Gabès, due to excessive bottom trawling, has affected the environment and contributed to a decrease in the extent of the octopus population and consequently to a drop in the catches in the Gulf.

General behaviour

The common octopus changes its appearance in response to some environmental and physiological events (ejecting, hunting, reacting to disturbance etc.) described by Packard and Sanders (1971) and Mather and Mather (1994). In addition to anti-predator behaviour (modification of skin colour and texture), the octopus is able to hide itself behind a cloud of ink ejected from the funnel.

These highly developed kinds of instinctive behaviour (burying, mimesis, maternal instinct) help to protect the octopus from drastic overfishing. In contrast, the interspecific interactions between the octopus and others species inhabiting the same biotope remain a continual danger for the common octopus. Among these competitive species, we especially mention the grouper, the sea bream and the moray.

3.3. Environmental effects

Biotic and abiotic effects

Several factors characterize the Gulf of Gabès and influence the life of the octopus. Among these factors, we note the large area of the continental shelf, which is especially marked by a gradual slope and by the many channels around the Kerkennah Islands. Thus, the line of the 50-m isobath to the north of Gabès is 110 km from the coast, and the 100-m and 200-m isobaths are 175 km and 250 km from the shore, respectively. The tides here have the biggest amplitude in the Mediterranean, with a maximum of 2.4 m. The Atlantic water flows through the Strait of Sicily and then turns southwards. The seasonal variability of this cyclonic circulation affects the water circulation in the Gulf of Gabès (Poizat 1970). The distribution of the octopus in this area would be related to the fluctuations in this cyclonic water circulation which is rich in suspended sediments (Brahim *et al*. 1994), in addition to the hydrographic parameters (high temperature and salinity). The biodiversity is equally rich and characterized by Neptune grass (*Posidonia oceanica*) and seaweed beds covering a large area. All these characteristics of the Gulf of Gabès favour the expansion of the octopus, but also the use of specific fixed fishing gears to capture the species.

Effects of human activities

The geomorphological and hydrographical features of the Gulf of Gabès have favoured the development of a traditional activity based on the use of "static" gears, such as pots, traps and bored stones, to catch the octopus (Najaï 1981). In the same way, a very important industrial fishery, mainly based on bottom trawling, has been developed. Excessive fishing pressure is exerted on the octopus stock, not only during fishing season but also clandestinely outside it, in spite of the restriction measures. A large number of juveniles have been captured in recent years off-season, inducing a quantitative and qualitative decrease in the octopus landings.

In other words, human activities in the Gulf of Gabès have contributed to the variability of the coastal biodiversity, affecting the flora and fauna and then ecosystem stability. The loss of

the seaweed beds has altered sedimentation, with an important impact on the nature of the sea bed. This alteration could have induced a temporary predominance of some animal species that would in turn be reduced. So, in 1980, the overfishing of species of grouper and sea bream caused a drop in the landings in the Gulf of Gabès. Their reduction would have permitted the temporary proliferation of their preferred prey, the octopus, which, having a high turnover rate, would have resisted aggression initially. Subsequently, becoming in turn vulnerable to the destabilization of the ecosystem, the octopus landings would have decreased after 1988, as is illustrated in Figure 2.

4. Discussions and conclusions

The stock of *Octopus vulgaris* is affected by several factors which are related to biological parameters and environmental conditions, including human activities and which make it difficult to forecast the stock level.

A study of *Octopus vulgaris* along the north-western coast of Africa (Demarcq and Faure 2000), indicated that a demographic explosion occurs when the environmental conditions, particularly upwelling, help larval survival. Similarly, Faure *et al*. (2000) noted the importance of retention by the upwelling, as an environmental index, in areas of *O. vulgaris* recruitment over the Arguin Bank off Mauritania.

In the Gulf of Gabès, there is no upwelling to have comparable effects on the interannual variability in the catches. However, the incoming water from the Atlantic is divided into two currents in the western Mediterranean; one moves northwards and the other flows towards the eastern Mediterranean and reaches the Gulf of Gabès, feeding a cyclonic current within the Gulf (Brahim *et al.* 1994). This eastern stream has a pronounced seasonal variability which, in turn, affects the water circulation in the Gulf of Gabès. The permanent cyclonic circulation in the Gulf could have an effect on the variability of the recruitment of the octopus and eventually on the biomass, depending on the importance of the flow, which would partially explain the fluctuations in the catches. To verify the accuracy of these effects, we need a regular series of annual data which would allow study of the relationship between the recruitment to the octopus stock and the hydrographic parameters of the Gulf (wind, tides, water circulation, sediment flux, particulates dynamics etc.). Such data series should include those from remote-sensing satellites. Meanwhile, annual monitoring surveys are conducted in Tunisia in order to preserve the stock, although the need to determine the independence of the octopus stock in the southern part of the Gulf remains. To meet this need, we propose a tagging project in collaboration with the bordering countries.

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