On the presence of basking shark (*Cetorhinus maximus*) in the Mediterranean Sea

by

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ABSTRACT. - The presence of basking shark *Cetorhinus maximus* Gunnerus, 1765 throughout the Mediterranean Sea was investigated using data stored in the "Large Elasmobranch Monitoring" programme database (Italy), with new records coming from the French area and also including the first data from the eastern sector of the Mediterranean basin. More than 500 records of information on basking sharks were included in the database, with older records coming from the 19th century, but also including the most recent literature. Data revealed the presence of specimens of quite different sizes that ranged from very young (about 2 m TL) to large adults (8-9 m TL) encompassing large part of the body length range known for this shark at global scale. Most of the occurrences of the species in Mediterranean are reported off the coastal areas of the western central sectors of the Mediterranean basin, where it is often caught incidentally by trammel nets in spring. The numerous records registered in the last two decades may be related rather to an increasing scientific and public interest on the species than to an actual abundance trend of the Mediterranean population. The knowledge on the distribution and population structure of basking shark in the Mediterranean basin plays an important role in the implementation of conservation measures of such protected species.

RÉSUMÉ. - Sur la présence du requin-pèlerin (*Cetorhinus maximus*) en Méditerranée.

La présence du requin-pèlerin, *Cetorhinus maximus* Gunnerus, 1765 en Méditerranée est analysée à partir de la base de données du programme "Surveillance des grands Élasmobranches" (Italie) et de nouvelles observations concernant les côtes méditerranéennes françaises et la région occidentale du bassin méditerranéen. La base de données ainsi constituée compte plus de 500 observations de requins-pèlerins, les plus anciennes datant du XIXe siècle. Des individus de toutes les tailles sont enregistrés, depuis de très jeunes individus (environ 2 m LT) jusqu'à de grands adultes (8-9 m LT) recouvrant une grande partie de la distribution des longueurs connues pour ce requin. La plupart des observations de l'espèce en Méditerranée ont été effectuées au large des côtes de la région occidentale centrale, où les requins-pèlerins sont souvent capturés au printemps par des filets tramails. Les nombreux signalements enregistrés au cours des deux dernières décennies sont plus liés à l'intérêt croissant des scientifiques et du public pour cette espèce qu'à une augmentation de l'abondance de l'espèce en Méditerranée. La connaissance de la distribution des requins-pèlerins et de la structure de la population méditerranéenne est importante pour rendre effectives les mesures conservatrices de cette espèce protégée.

Key words. - Cetorhinidae - *Cetorhinus maximus* - Basking shark - MED - Occurrence - Database.

Basking shark (*Cetorhinus maximus*) is not a target for Mediterranean fishery, although this has happened in colder marine regions, in which this species was widely exploited for a long time (UK, Western Ireland and Norway: Kunzlik, 1988; Bonfil, 1994). In addition to few sightings made in the open sea, the presence of this shark is mainly recorded by incidental catches in trammel nets or in other fishing gears, which are frequently used in coastal waters of different countries (Lien and Fawcett, 1986; Serena and Vacchi, 1996; Francis and Duffy, 2002). The presence of this species in the Mediterranean (especially in the northwestern part) can be considered frequent, but mainly in spring (Serena *et al*., 2000).

It seems that some basking sharks are philopatric, as many other large sharks, and some individuals show the tendency to return every year to the same coastal summer feeding locations. Sims *et al*. (2003) report that one basking shark tagged off Plymouth returned to the English Channel in winter, after spending most of the intervening time at the Bay of Biscay shelf edge. Despite their geographical wide range, basking sharks may be effectively part of local stocks that are particularly vulnerable to depletion by fisheries

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activity (Fowler, in press). Studies involving satellite tagging and photo-identification of basking sharks have shown that this species forages selectively on specific zooplankton assemblages along thermal front systems in shallow coastal regions of the north-east Atlantic from May to August (Sims *et al*., 1997; Sims and Merrett, 1997; Sims and Quayle, 1998). Basking sharks probably locate and remain within temporally discrete "hot-spots" of productivity occurring seasonally along large-scale frontal features at much greater spatial scales (100 to 1000 km) (Sims *et al*., 2003).

The species is widely distributed in temperate waters, but a large number of specimens tend to be concentrated in a few favoured coastal areas, where feeding and, possibly, breeding activity takes place at, or near, the surface. Sims *et al*. (2000) identify ecologically important thermal-front regions off southwest England as key aggregative features for social behaviour of this protected shark species. Annual variations in sightings and catch records may be strongly influenced by the weather conditions, water temperature and cyclical fluctuations in the distribution and abundance of zooplankton (Sims and Reid, 2002). This species has among the lowest natural mortality and productivity yet calculated for a commercially fished marine species (Smith *et al*., 1998).

C. maximus is one of the species that most requires measures of protection, because of its reproductive strategy. In the northeast Atlantic, this species is listed as endangered in the IUCN Red List of Threatened Species (Hilton-Taylor, 2000). The global status of the basking shark is assessed as vulnerable (A1a,d, A2d) in the 2002 IUCN Red List proposal (Fowler *et al*., in press; www.redlist.org). Compagno (1984) considers the basking shark "to be extremely vulnerable to overfishing, perhaps more so than most sharks… ascribed to its slow growth rate, lengthy maturation time, long gestation period, probably low fecundity and probable small size of existing populations". In fact, this species has been included in the Annex II (Endangered or Threatened Species) of the Barcelona Convention for the Protection of the Mediterranean Sea (1976), in the Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean. Moreover, the basking shark Mediterranean population was added to Appendix II (strictly protected species) of the Bern Convention on the conservation of European Wildlife and Natural Habitats in December 1997. In 2000, basking shark has been also included in Appendix II of the Washington Convention (CITES) (CITES, 2002).

The present study aims to compile data on the presence, distribution, seasonal changes in number, length frequency and sex ratio of basking sharks in the Mediterranean. A summary of the fishing gears, which capture sharks is also presented here. Although data are often scarce to perform statistical analyses, we think it could be important to show them because of the lack of information on *C. maximus* in the Mediterranean.

MATERIAL AND METHODS

The occurrence of *C. maximus* in the Mediterranean Sea was analysed from data collected during the "Large Elasmobranchs Monitoring (LEM) Program" and from the literature (Belloc, 1948; Ben-Tuvia, 1971, Boero and Carli, 1979; Quéro *et al*., 1991; Barrull and Mate, 1999; Lipej *et al*., 2000; Soldo and Jardas, 2002; Kideys, 1997). LEM represents a survey on the presence of large elasmobranches. It started in 1985 in the Italian waters (Serena and Vacchi, 1997) and now is enlarging to other Mediterranean countries on a framework with a common protocol (called MEDLEM-Subproject basking shark) proposed during the 3rd section of GFCM/SAC Sub-Committee on Marine Environments and Ecosystems (Barcelona, 6-9 May 2002). This program has allowed the acquisition of valuable miscellaneous information, including anecdotical information of catches starting from 1795. A major contribution was provided thanks to the collaboration with military authorities, with professional and recreational fishermen and from different research institutes. Other important source of data derives from the recent collaboration with the Algerian and Tunisian colleagues and from the national basking shark sightings recording scheme carried out in France by APECS (Association pour l'étude et la conservation des sélaciens) since 1998.

All data acquired have been stored in a database, in which information available on the data, place, sex, length, weight and other morphometric characteristics of the specimens were recorded. ArcView 3.2 software (ESRI, 1996) enabled plotting of georeferenced information on catches and observations on a map, constituting a useful complement of the database. In the data analysis, especially from the literature, total length (TL) and sex data could not be included for all specimens because of their omission in the original sources. A biogeographic analysis was carried out in which the whole Mediterranean basin was divided into four "regions" corresponding to the main Mediterranean subbasins (Fig. 1):

Balearic (B), limited by the Gibraltar straits in the most western part and by the conjunction between Punta Muchillina (Corse Island, France) - St. Tropez (France), Punta Falcone (Sardinia Island, Italy) - Punta di Sprono (Corsica Island, France) and Capo Serrat (Tunisia) - Capo Boi (Sardinia Island, Italy) in the eastern part;

Tyrrhenic (T), limited by the conjunction Punta Muchillina (Corse Island, France) - St. Tropez (France) in the northern part; Marsala (Sicily Island, Italy) - Capo Bianco (Tunisia), Capo Serrat (Tunisia) - Capo Boi (Sardinia Island, Italy) and Punta del Faro (Sicily Island, Italy) - Scilla (Calabrian, Italy) in the southern part, Punta Falcone (Sardinia Island, Italy) - Punta di Sprono (Corsica Island, France) in the western part;

Adriatic (A), limited in its southern part by the imaginary

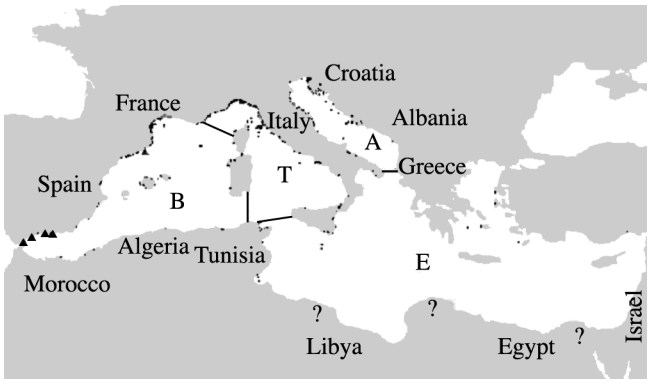

Figure 1. - Geographical allocation of observations and captures of *Cetorhinus maximus* in the Mediterranean Sea. B = Balearic region; T = Tyrrherian region; A = Adriatic region; E = Eastern Mediterranean; ▲ = Imprecise geographical position; ? = Lacking of data. *[Localisation des observations et des captures de* Cetorhinus maximus *en Méditerranée.]*

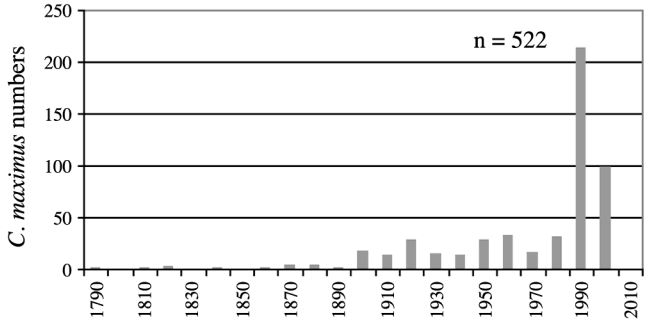

Figure 2. - Frequency of incidental catches of *C. maximus* by year in the Mediterranean. *[Fréquence annuelle des captures acciden - telles de* C. maximus *en Méditerranée.]*

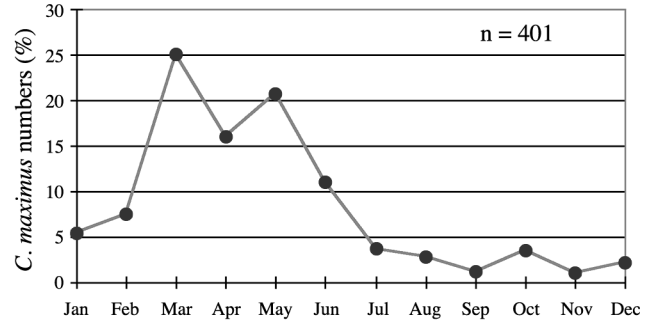

Figure 3. - Frequency of incidental catches of *C. maximus* by month in the Mediterranean. *[Fréquence mensuelle des captures accidentelles de* C. maximus *en Méditerranée.]*

conjunction between Capo d'Otranto (Apulia, Italy) and Capo Linguetta (Albania);

Eastern Mediterranean (E) limited by the conjunction Marsala (Sicily Island, Italy) - Capo Bianco (Tunisia), Punta del Faro (Sicily Island, Italy) - Scilla (Calabrian, Italy) and Capo d'Otranto (Apulia, Italy) and Capo Linguetta (Albania).

For each region, a length frequency distribution (LFD) of *C. maximus* was reconstructed based on available records.

RESULTS

From 1795 to 2002, 535 records of basking shark were collected in the Mediterranean area (Fig. 1). Of these, about 40% were represented by sightings and 45% by accidental catches. Only 15% of the records were related to other causes of death (for example strandings). Many of these records were lacking of ancillary information as, for example, size, sex and weight. In the Mediterranean basin the species appears confined in the Western and Central sectors (about 1.3 million km^2). The largest number of observations is concentrated along the coastal areas characterised by a narrow continental shelf, as in the Liguro-Provençal area (northernmost sector of Mediterranean western basin), and could be linked to the upwelling phenomena that are more likely to occur in these zones (Serena *et al*., 2000). The highest record number in Italian waters coincide with the boundaries of the International Cetacean Sanctuary (L. 11/10/2001 no 391) of the Mediterranean ranging about 96,000 km^2, although no specific regulations are available for this species within these protected areas.

The frequency of incidental catches and sightings of *C. maximus* was analysed on 522 specimens (Fig. 2). The three observed peaks probably coincide with the increased scientific interest in this species since 1990. For 401 records information regarding month of capture or observation was available (Fig. 3). Catches and sightings of basking shark were higher in spring and winter, with a maximum in March (25%). A great number of specimens were recorded, especially in the western part of the basin (Fig. 4). Using "pop-up" archival transmitting (PAT) tags, Sims *et al*. (2003) found that basking sharks spend less time near the surface during winter than in summer. Therefore, in winter, individuals are much less likely to be observed, and this probably explains why for so long this species was thought to disappear into the depths during cold months.

The length frequency distribution of 349 basking sharks, for which total size was available, shows a maximum for 6 m TL (Fig. 5). The sex was only specified for 138 individuals. Among them, 57% (n = 78) were represented by males and 43% (n = 60) by females, with a sex ratio of 0.43 (number of females/total number). Among these, both information about sex and TL was available for 125 specimens (Fig. 6).

The LFD analysed for 292 records during the four seasons showed a maximum of young individuals (i.e., less than 3.5 m TL) in autumn (50%) and of adult specimens (about 7 m TL) in winter (Fig. 7). The length frequency composition

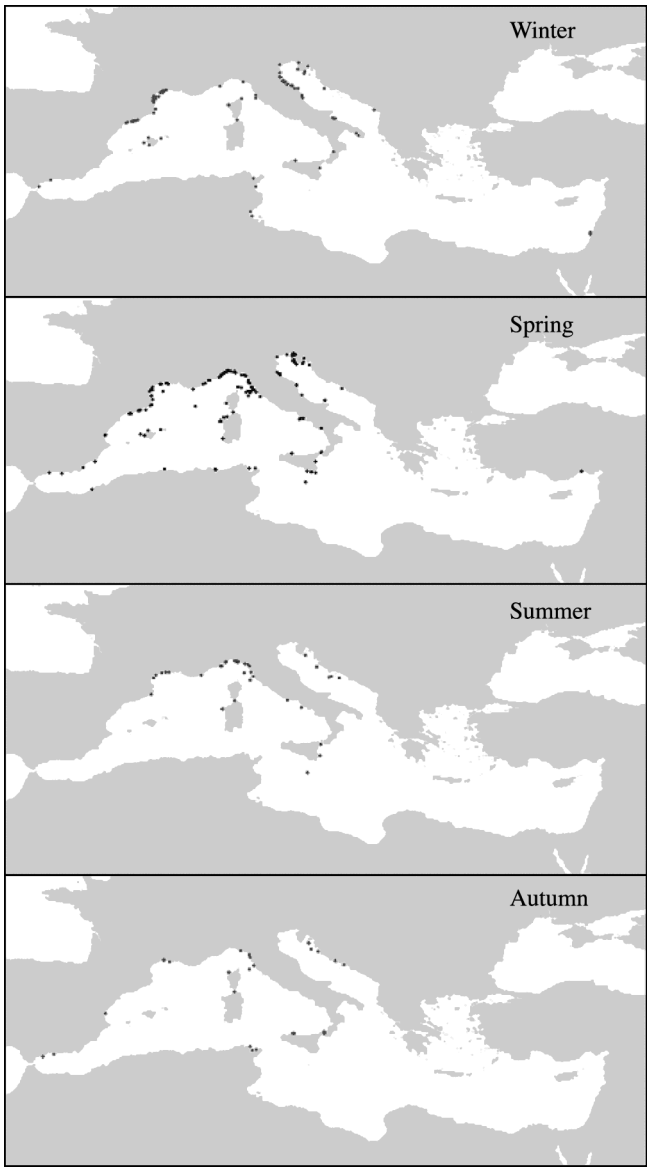

Figure 4. - Geographical allocation of findings of *C. maximus* per season in Mediterranean Sea. *[Localisations saisonnières des observations de* C. maximus *en Méditerranée.]*

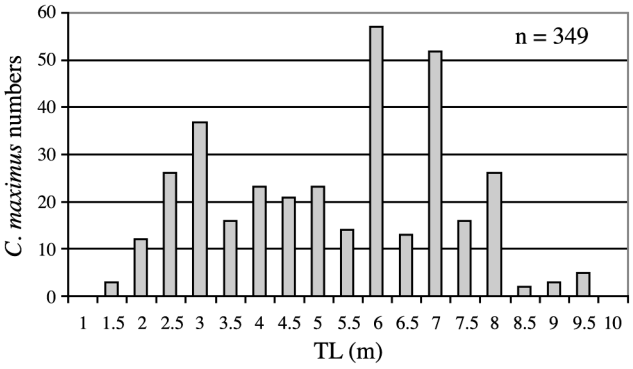

Figure 5. - Length frequency distribution of *Cetorhinus maximus*. *[Distribution des tailles de* C. maximus.*]*

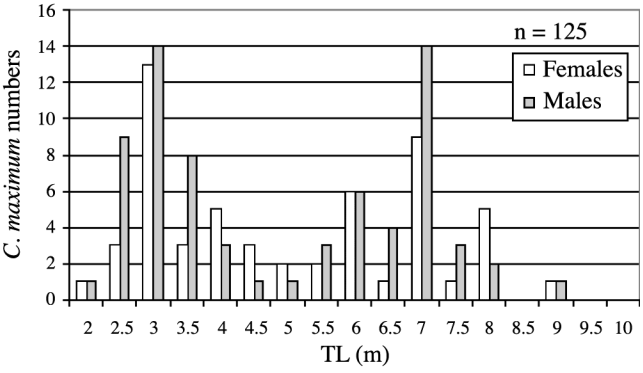

Figure 6. - Length frequency distribution of *Cetorhinus maximus* per sex. *[Distribution des tailles de* C. maximus *en fonction du sexe.]*

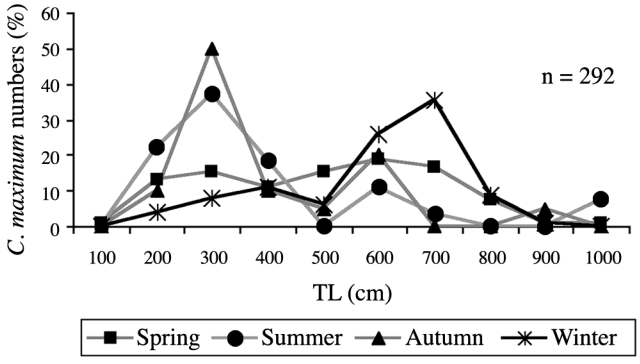

Figure 7. - Length frequency distribution of *Cetorhinus maximus* per season. *[Distribution des tailles de* C. maximus *en fonction de la saison.]*

in summer is similar to the autumn one, but with less specimens. The size composition in spring shows a more even distribution for all the length sizes (between 10 and 20%).

Only 346 records contain information on size and place where the sharks were caught or seen (Fig. 8). Many records (n = 150) come from the Tyrrhenian area, with almost all size classes represented. Between 4 and 9 m TL, subadult and adult specimens occurred predominantly (respectively 67%, 76% and 51%) for A, B and T regions. In the E region, on the contrary, there are 65% of juvenile specimens (TL < 4 m).

Today, the only information about *C. maximus* in Mediterranean basin comes from occasional sightings (42%) and incidental catches with trammel nets (15% of the total 323 records analysed). For the most part, fishing gear was not specified. Among the 323 records, the total length was recorded only for 122 specimens (Fig. 9). The length frequency distribution was available only for the specimens (about 6 m in TL) caught with trammel net.

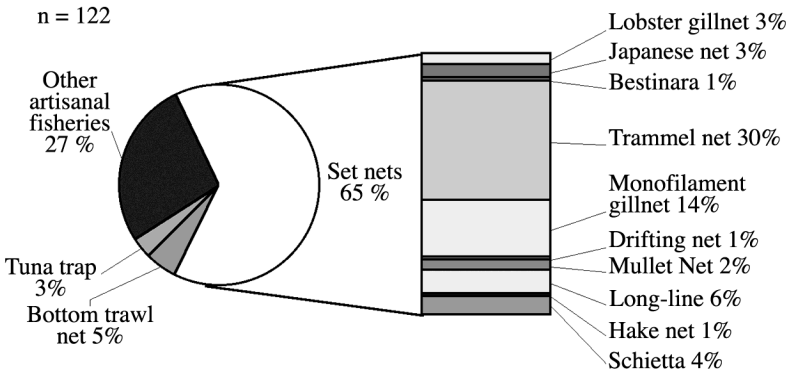

Figure 8. - Incidental catches of *Cetorhinus maximus* split by fishing gear (only for the specimens for which TL was specified). Others: anchovy larsen trawl (n = 1); lamparo net (n = 2); seine net (n = 2); rifle (n = 1); not specified caught (n = 27). *[Captures accidentelles de* C. maximus *en fonction de l'engin de pêche (seulement pour les spécimens pour lesquels la longueur totale était connue).]*

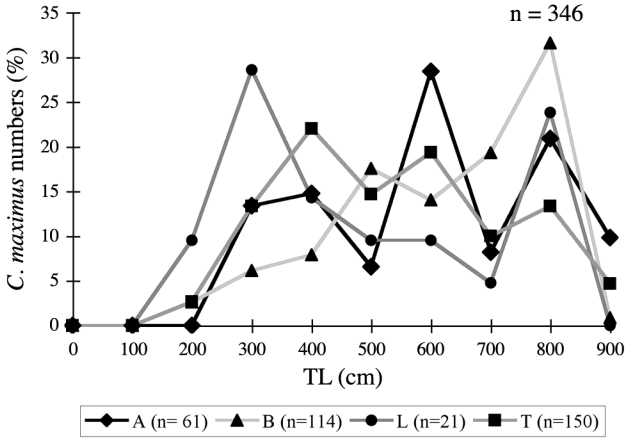

Figure 9. - Length frequency distribution of *C. maximus* per region. B = Balearic region; T = Tyrrhenian region; A : Adriatic region; E = Eastern Mediterranean. *[Distribution des tailles de* C. maximus *suivant les régions.]*

DISCUSSION

The aim of the work was to compile all available data reporting the presence of basking shark in the Mediterranean region. Therefore, we do not document species abundance, because the observation effort was not homogeneous in space and time. Observations differ in various Mediterranean sectors because they depended on the scientific interest of the observers, even if their presence in an area is also often linked to meteorological conditions.

It seems that a potential aggregation site correspond to the Cetacean Sanctuary in the Ligurian Sea (Northern Tyrrhenian), and in the Balearic region, where the total body length was around 6-7 m for all the observed specimens; no data are available concerning sex identification. It is worth noting the abnormal presence of numerous basking sharks in the Adriatic Sea during 2001 summer, which contrasted with the general paucity of this species in this Mediterranean sector. Almost all the individuals were subadults with a small number of juveniles.

The Mediterranean distribution of the basking shark could be related to many oceanographic and climatic factors as surface water temperature, wind speed, surface current and average chlorophyll concentration data. Identifying frontal regions from satellite-derived ocean-colour data of phytoplankton abundance, for example in using OCEAN Project data (2000), may help indirectly in studies of zooplankton and fish distribution (Sims and Quayle, 1998). The seasonal chlorophyll concentration distribution by season in the Mediterranean area is shown in figure 10. Quantitative data could be useful to test the relationship between the chlorophyll concentration and the high presence of basking sharks in some specific areas of the Mediterranean (Lion Gulf, Genoa Gulf, north Adriatic Sea) during the year. It is generally assumed that the come back of basking sharks to coastal waters during spring is associated with periods of high biological production, when supplies of their planktonic prey are high (Sims and Quayle, 1998). Basking sharks exhibit a typical behaviour in response to specific zooplankton densities and characteristics (Sims and Merret, 1997): they follow and move between tidally transported patches in fronts, as selective foragers on zooplankton assemblages. This behaviour was previously unknown (Priede, 1984; Sims and Quayle, 1998).

To date, a quantitative estimate of basking shark population in the Mediterranean Sea is not possible because available information is insufficient, linked to the absence of specific basking shark projects and targeted fisheries (Serena *et al*., 2000).

The lack of data about factors explaining basking shark presence in the Eastern Mediterranean area could be related to the biological, chemical and physical characteristics of this area: high water temperatures and low chlorophyll concentration through the year. The only few records in this area correspond to small coastal zones, where the chlorophyll concentration was a little bit higher (Israel, Turkey, Tunisia).

The data available for catch location are insufficient to propose new findings. The number of vessels and the frequency of utilization of different gears might be better investigated to find correlation with potential aggregation sites of *C. maximus*.

The poor information on incidental captures and sightings of basking shark in the Eastern Mediterranean region can be explained by the lack of a dedicated specific scientific monitoring in this area. This stressed the necessity of creat-

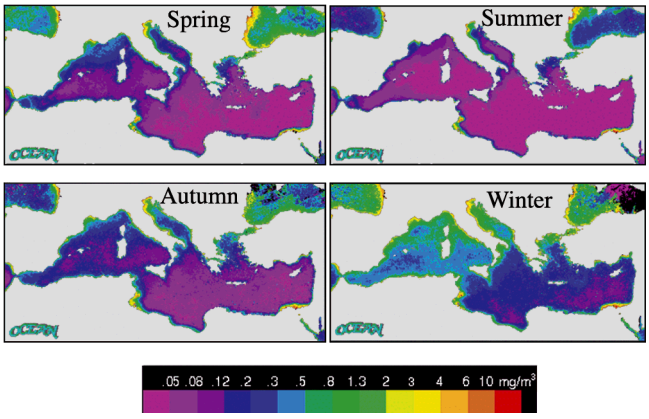

Figure 10. - Mediterranean average concentration of chlorophyll-like pigment (mg/m^3) for season (Satellite imagery: © OCEAN Project, 2000). [*Concentration saisonnière moyenne des pigments de chlorophylle (mg/m^3) en Méditerranée.]*

ing a Mediterranean researcher group interested in collecting information on basking sharks. During the 3rd section of GFCM/SAC Sub-Committee on Marine Environments and Ecosystems (Barcelona, 6-9 May 2002), it has been proposed a common protocol, called MEDLEM-Subproject basking shark, to be adopted by Mediterranean countries. The aim of this program is to collect field data and to monitor basking shark in the Mediterranean Sea. This activity, started along the Italian coasts since 1985, is now enlarged to other Mediterranean countries such as France, Spain, Algeria, Tunisia, Turkey, Slovenia and Greece. Biological and ecological studies (growth, histomorphology, genetics, parasitology, etc.) are carried out in the frame of a Mediterranean cooperation.

In order to obtain a more homogeneous and realistic description on the presence and distribution of basking shark into the whole Mediterranean basin, future data might include information for each individual: date and location of capture, gear used, individual size, sex and weight.

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