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INCIDENTAL CATCH OF THE LOGGERHEAD TURTLE, *CARETTA CARETTA* (LINNAEUS, 1758), IN THE NORTHERN TYRRHENIAN SEA

CATTURE ACCIDENTALI DI TARTARUGA MARINA COMUNE, CARETTA CARETTA *(LINNEO, 1758), NEL MAR TIRRENO SETTENTRIONALE*

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Abstract. *Since 1993, the Acquarium of Grosseto municipality, detached section of the Maremma Natural History Museum, has been engaged in the activity of rescue, recovery and release of sea turtles in the northern Tyrrhenian Sea. During this period, a total of 144 specimens of loggerhead sea turtle,* Caretta caretta *(Linnaeus, 1758), has been recovered: 40 specimens have been found dead, 7 died during the rehabilitation phases, 97 have been released. Due to the prevalence of trawl fishery in the northern Tyrrhenian Sea, the major part of the specimens of loggerhead sea turtle recovered have been provided by trawl vessels: a total of 107 specimens has been caught by trawling. The time series of turtle catches showed an oscillating behaviour, with two main peaks in 2003 (17 specimens) and in 2008 (22 specimens). It was attempted to relate the accidental catches of loggerhead sea turtle to the time series of mean monthly data of some explanatory variables, such as the sea surface temperature, the wind speed, and the North Atlantic Oscillation (NAO) index. The time series of* C. caretta *catches resulted significantly related to the sea surface temperature ($r = -0.66$, $p < 0.05$) and to the wind speed ($r = 0.31$, $p < 0.05$). These results suggest that during the coldest months the catches of loggerhead sea turtle are higher.*

Riassunto. *Dal 1993, l'Acquario Comunale di Grosseto, sede distaccata del Museo di Storia Naturale della Maremma, si occupa di attività di recupero, riabilitazione e rilascio di tartarughe marine nel Mar Tirreno Settentrionale. Durante il periodo di attività, un totale di 144 individui appartenenti alla specie* Caretta caretta *(Linneo, 1758) è stato recuperato: 40 esemplari sono stati trovati morti, 7 sono morti durante la permanenza all'Acquario, durante le fasi di riabilitazione, e 97 sono stati liberati in mare. Tra i sistemi di pesca utilizzati nel Mar Tirreno Settentrionale, la pesca a strascico è quella che riveste la maggiore importanza; di conseguenza, la maggior parte degli individui di tartaruga marina recuperati dall'Acquario Comunale (un totale di 107 esemplari) sono stati catturati proprio con questo sistema di pesca. La serie storica ottenuta con i dati di cattura delle tartarughe ha mostrato un andamento fluttuante, dal 2000 al 2008, con due picchi di abbondanza nel 2003 (17 individui) e nel 2008 (22 individui). È stato tentato di correlare le catture di tartarughe marine con le serie temporali di alcuni fattori ambientali, come la temperatura superficiale, la velocità del vento e l'indice NAO (North Atlantic Oscillation). La serie temporale di catture di* C. caretta *è risultata significativamente correlata alla temperatura superficiale ($r = -0,66$, $p < 0.05$) ed alla velocità del vento ($r = 0,31$, $p < 0.05$). Questi risultati suggeriscono che durante i mesi freddi le catture accidentali di tartarughe marine sono più frequenti.*

Introduction

Sea turtles are threatened worldwide by many human activities, from direct exploitation to climate change. Fishing-induced mortality (incidental catch by fishing

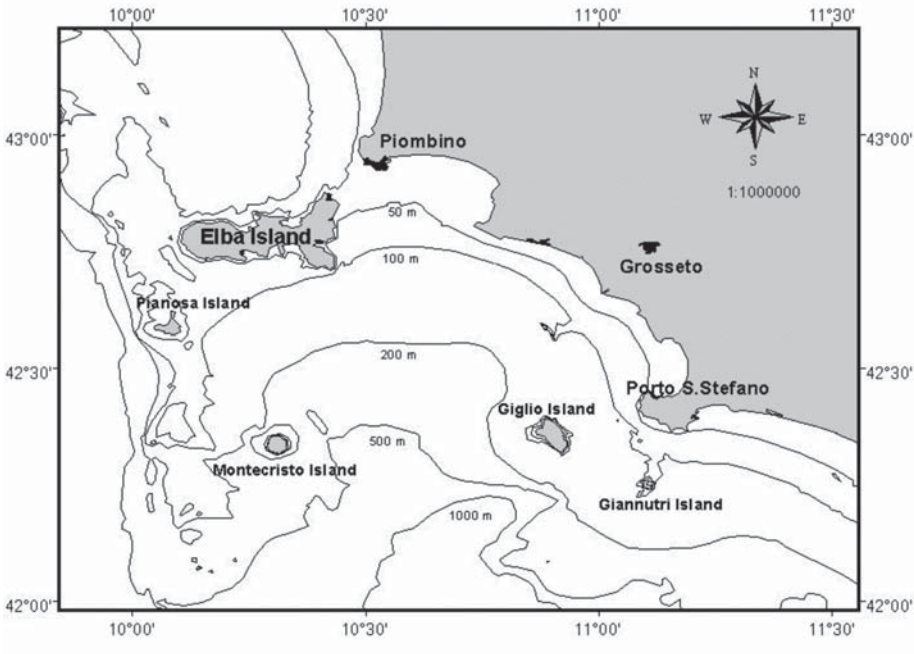

Fig. 1 – Northern Tyrrhenian Sea.

gear or bycatch) is considered a major threat to sea turtle populations worldwide, and trawling is one of the methods with the highest impact (Casale et al. 2007).

Also in the Mediterranean Sea, interaction with fisheries represents the most important threat to sea turtle populations, both from mortality directly caused by the fishing gear and, in some cases, also from the intentional killing of captured turtles, mainly for consumption.

Pelagic longline is the fishing gear responsible for the highest number of turtle captures: probably several tens of thousands per year (Casale et al. 2007). Some technical modifications have been proposed to reduce catch rate, such as using different hooks and fishing at greater depths (Gilman et al. 2006). Also bottom trawlers catch a significant number of turtles, with a wide range of mortality rates (Casale et al. 2004). When captured by a trawl net, turtles may drown, becoming first comatose and eventually dying. In fact, the routine dive time of turtles is shorter than usual tow times, and tolerance is further reduced during a forced apnoea (Henwood & Stuntz 1987). Comatose turtles can not swim and may therefore be unable to surface to breath if released into the sea in this condition.

Even though several technical modifications of the trawl gear have been proposed to reduce this mortality due to forced apnoea (Lucchetti et al. 2008), some authors believe that the TEDs (Turtle Exclusion Devices) available at present are probably not a realistic solution for reducing turtle bycatch in the Mediterranean (Casale et al. 2004).

Since 1993, the Acquarium of Grosseto municipality, detached section of the Maremma Natural History Museum, has been engaged in the activity of rescue, recovery and release of sea turtles in the northern Tyrrhenian Sea. More than one hundred specimens belonging to the species *Caretta caretta* (Linnaeus, 1758), the so called loggerhead sea turtle, have been recovered and released by its staff. The loggerhead

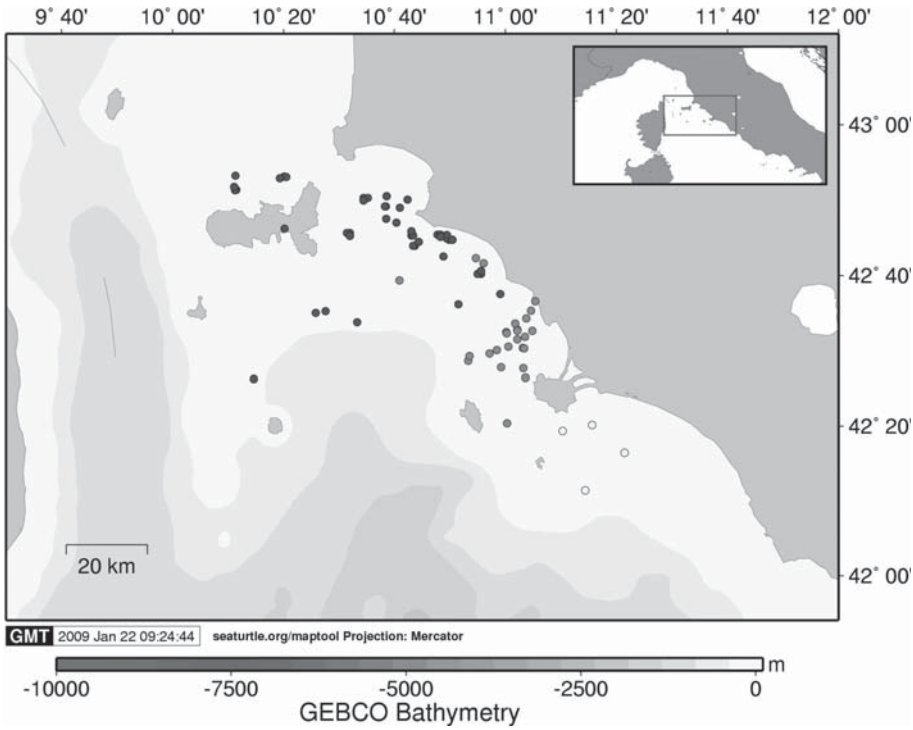

Fig. 2 – The sites of capture of the 100 specimens caught by trawlers from 2000 to 2008 are shown by the dots. Black dots: turtle caught by Castiglione della Pescaia trawlers; gray dots: Porto Santo Stefano trawlers; white dots: Porto Ercole trawlers (SEATURTLE.ORG Maptool. 2002. SEATURTLE.ORG, http://www.seaturtle.org/maptool).

sea turtle is one of the eight surviving sea turtle species; it is distributed widely in warm-temperate and subtropical oceans. It is found throughout the Mediterranean, where it constitutes the most common sea turtle. Nesting in the Mediterranean appears mainly confined to the eastern basin: Greece, Turkey, Cyprus and Libya (Bentivegna 2002). The loggerhead sea turtle is listed as Endangered in the IUCN Red List of Threatened Species.

The present study aims to analyze the time series of the incidental catch data of *C. caretta* in the northern Tyrrhenian Sea (NW Mediterranean) from 2000 to 2008. In addition, it was intended to relate the temporal evolution of the bycatch of *C. caretta* to some environmental features. As a matter of fact, biological time series, used together with abiotic (environmental variables, human activity indices, etc.) data, are essential tools to track the long-term properties of marine systems, detect meaningful shifts and assess whether are attributable to human impact or other causes.

Materials and Methods

The study has been carried out in the northern Tyrrhenian Sea (fig. 1). A traditional trawl fishery targeting several important demersal species, such as the European hake, the red mullet, the horned octopus, the deep-water rose shrimp, the Norway lobster, etc. is already established in the northern Tyrrhenian Sea. The area is mainly

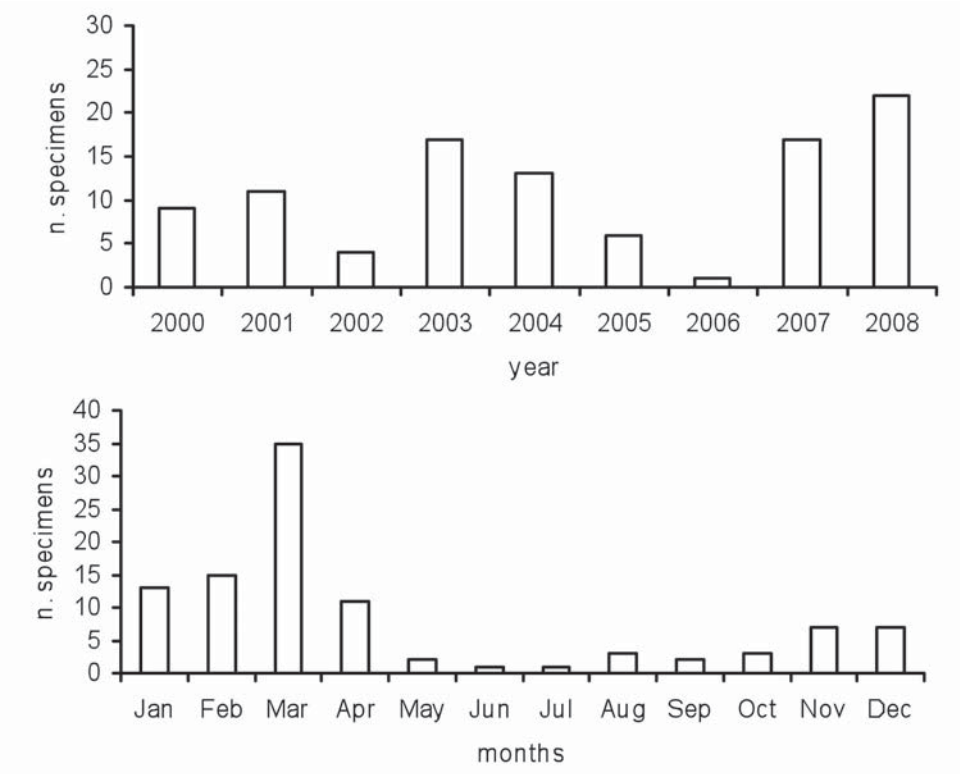

Fig. 3 – Number of loggerhead sea turtles caught per year (a) and per month (b).

exploited by the bottom trawlers of Porto S. Stefano, Porto Ercole and Castiglione della Pescaia fleets. The small scale fishery is represented by a huge number of small vessels working close to the coastline with trammel nets, gill nets and traps; only few vessels are targeting swordfish using pelagic long-lines (Sbrana et al. 2007).

The analyses presented here were performed on the loggerhead sea turtle specimens caught by trawl fishing between 2000 and 2008. Information on the site of capture (duration of the haul, depth, geographical coordinates) has been obtained through direct interview with fishermen.

To investigate the effect of hydrological conditions on the catches of loggerhead sea turtle by trawling, a suite of environmental factors was selected. Time series of mean monthly values of remote sensing data of sea surface temperature (SST, °C), wind speed (W, m/s), measured in the northern Tyrrhenian Sea, and the NAO (North Atlantic Oscillation) index were used; these data were obtained from the web site of the Physical Oceanography Distributed Active Archive Centre (PO.DAAC: http://podaac.jpl.nasa.gov/index.html) and the Pacific Fisheries Environmental Laboratory (PFEL: http://www.pfeg.noaa.gov/).

The sea surface temperature and the wind speed are frequently implicated as factors affecting abundances and have been used by several authors as explanatory variable (Zuur et al. 2003; Bartolino et al. 2008). The North Atlantic Oscillation is a large-scale fluctuation in atmospheric pressure between the subtropical high pressure system located near the Azores in the Atlantic Ocean and the sub-polar low pressure system near Iceland and is quantified in the NAO Index. The surface pressure drives

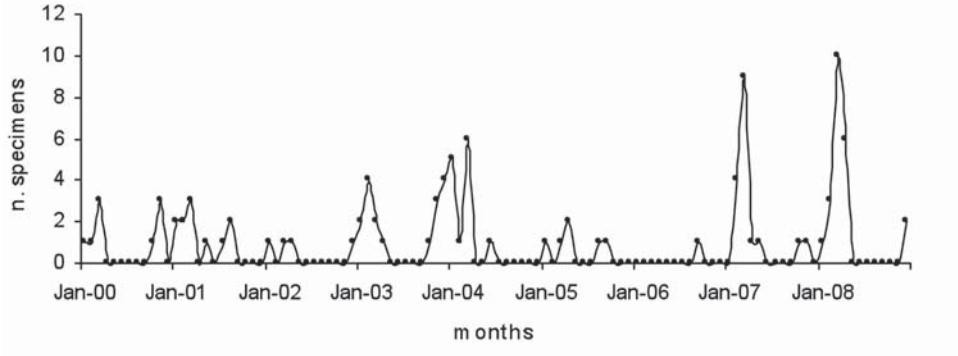

Fig. 4 – Monthly plot of the captures of loggerhead sea turtle.

surface winds and wintertime storms from west to east across the North Atlantic, affecting climate from New England to western Europe as far as eastward central Siberia and eastern Mediterranean and southward West Africa. When the NAO index is positive, the North Sea has an increase in storms and northern Europe has warmer temperatures and increased precipitation. When the NAO index is negative, the northern Europe is drier, and the Mediterranean countries have increased precipitation.

The analyses were carried out by means of the cross-correlation function performed by the software package Brodgar 2.5.1 (www.brodgar.com). The cross-correlation function gives an indication of the association between two variables (time series) X_t and Y_t (Zuur et al. 2003; Zuur & Pierce 2004; Erzini 2005; Erzini et al. 2005). The significance level of the cross-correlation is obtained from $\pm 2/\sqrt{n}$, where n is the length of the time series.

Results

Since 1993, a total of 144 loggerhead sea turtles has been recovered by our staff: 40 specimens have been found dead, 7 died during the rehabilitation phases, 97 have been released. The major amount of the loggerhead sea turtles recovered (107 specimens) has been caught by trawl nets. The mean size (straight carapace length, SCL) of the specimens caught was 42.7 (±11.3) cm: this size is typical of a sub-adult cohort.

As shown by fig. 2, the specimens recovered from 2000 to 2008 (100) have been accidentally caught by trawling on the continental shelf. The time series of turtle catches showed an oscillating behaviour, with two main peaks in 2003 (17 specimens

	N
SST	**-0.66**
W	**0.31**
NAO	0.16

Tab. 1 – Cross-correlations. Response variable: N = number of specimens caught per month; explanatory variables: SST = sea surface temperature (°C), W = wind speed (m/s), NAO = NAO index. Significance level for correlations ± 0.19. Significant correlations are highlighted in bold.

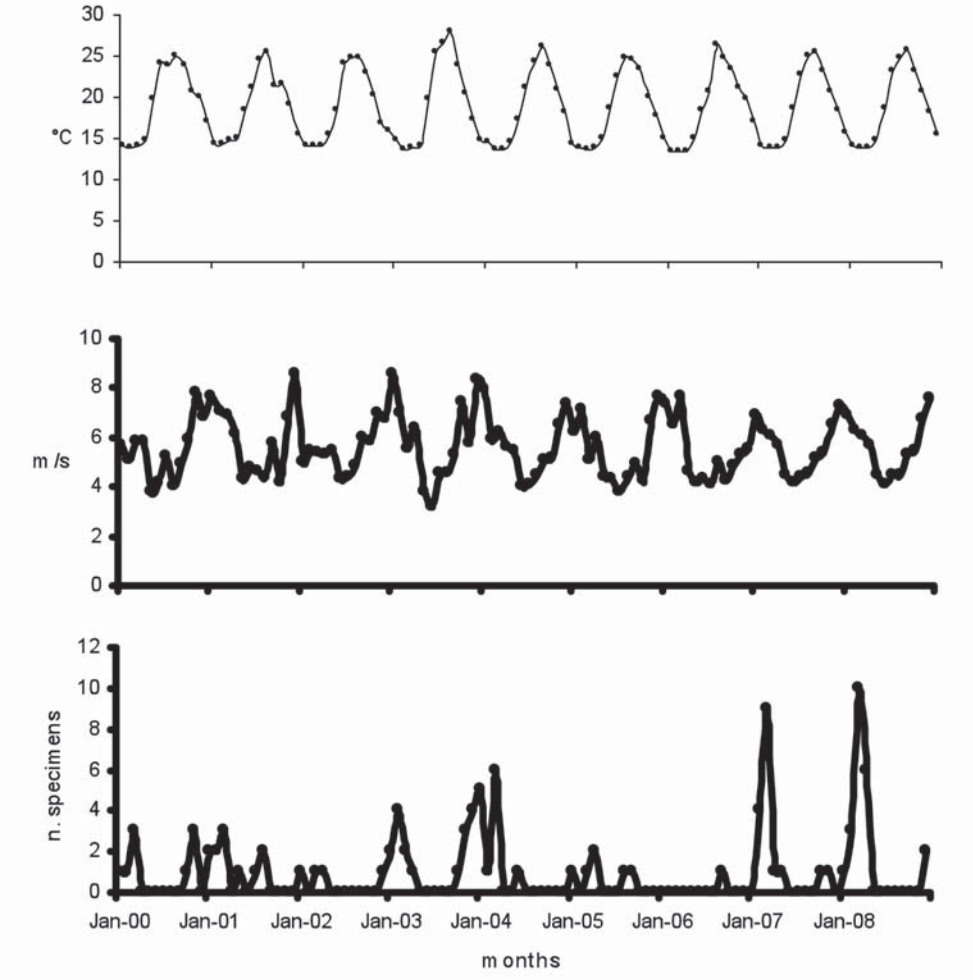

Fig. 5 – Monthly time series plots of sea surface temperature (°C), wind speed (m/s), and NAO index.

recovered) and in 2008 (22 specimens) (fig. 3a). The most amount of catch was in March: a total of 35 specimens caught (fig. 3b). More than the 65% of the specimens have been caught from January to April. The plot showing the time series of the catch per month of loggerhead sea turtle is summarised in fig. 4, while fig. 5 shows the time series of monthly data of the environmental factors. The sea turtle capture time series showed a clear oscillating behaviour, characterized by the presence of peaks in correspondence of the colder months. Also the time series of the sea surface temperature and of the wind speed were characterized by an oscillating behaviour, with a evident seasonality effect. Less clear is the pattern followed by the NAO index.

The time series of *C. caretta* catches resulted significantly cross-correlated to the sea surface temperature ($r = -0.66$, $p < 0.05$) and to the wind speed ($r = 0.31$, $p < 0.05$) time series (tab. 1). No significant correlation was obtained between the time series of sea turtle captures per month and the NAO index. These results suggest that

the captures of loggerhead sea turtle in the northern Tyrrhenian Sea are concentrated in the periods of the year characterized by low temperature and high wind speed, mainly corresponding to the winter months.

Discussion

A central challenge in ecology is to understand why species abundance changes over time (Ciannelli et al. 2008). Human activities are considered to be among the main factors determining marine species dynamics. Nevertheless, both abiotic (climate and hydrodynamics) and biotic (trophic resources and predators) variables could cause oscillations at the intra- as well as the inter-annual level. Although significant progress has been made during the last decade, we are currently only beginning to understand how anthropogenic activities affect life in the sea: the lack of understanding arises partly because the effects on marine ecosystems are far more difficult to observe and quantify than effects of man's activities on land (Gislason et al. 2000; Alverson 2002).

The time series of data on incidental catches of loggerhead sea turtle in the northern Tyrrhenian Sea showed a general increasing trend. Anyway, this increase could be biased by the higher awareness of the fishermen on the problem linked to the conservation of sea turtles and to the scientific research. This can be considered the most important result of the activities of the Acquarium of Grosseto municipality.

However, common questions in biological and environmental time series studies not only concerned general patterns over time in the measured variables, but also interactions between the measured variables (Zuur et al. 2003). The aim of the present study was not to estimate the general pattern of the time series of the incidental catch of loggerhead sea turtle, but to analyse the possible influence of environmental factors on the vulnerability of sea turtle by trawling.

The time series of *C. caretta* catches resulted negatively related to the sea surface temperature, and positively to the wind speed. As a matter of fact, more than the 65% of the specimens were caught from January to April. The peak of catch was in March: a total of 45 specimens was caught. Similar results were reported by Lazar & Tvrtkovic (2001) from the Adriatic Sea.

These results suggest that during the coldest months, characterized by low temperature and strong wind, the catches of loggerhead sea turtle are higher than in the rest of the year. Nevertheless, the available data and information are not sufficient to discriminate among several hypotheses. The high incidental catch of specimens in winter and earl spring could be directly linked to the abundance of loggerhead sea turtle in the northern Tyrrhenian Sea: this area could represent a foraging site, where sub-adults spend the winter, before starting the migration to the southern areas of the Mediterranean. Thus, the high catch rate could reflect the actual high abundance of loggerhead sea turtle in the area.

The high incidental catch rate could be also related to the distribution of the fishing effort. In winter, the trawl vessels usually work closer to the coast due to the bad weather conditions (Colloca & Sartor unpubl. data). In summer and autumn, when the trawlers exploit the Norway lobster (*Nephrops norvegicus*) fishing grounds, the accidental catches of *C. caretta* are lower. Since turtles in demersal phase prefer shallow waters, catch rates are likely to be higher in shallow than in deep waters (Epperly et al. 1995).

The last hypothesis deals with the dormant winter submergence behaviour (overwintering). Bentivegna et al. (2003) and Hochscheid et al. (2005) observed longer dive duration of loggerhead turtles in response to low temperatures, both in the wild and in captivity, and defined this behaviour as "dormant winter submergence".

The increase in dive duration with decreasing water temperature probably resulted directly from reduced oxygen consumption, and thus inducing lower metabolic

rate, activity and food intake. These behavioural and physiological adjustments reflect an acclimatisation to periods when energy resources are scarce, and thus need to be saved (Bentivegna et al. 2003). This behaviour could increase the vulnerability of sea turtles to trawl nets which are towed on the sea bottom (Musick et al. 1992), determining the high catch rate observed in the colder months of the year.

It is well known that the western Mediterranean is an important feeding ground for juvenile loggerhead turtles (Cardona et al. 2005). As a matter of fact, the mean size of the specimens caught in the northern Tyrrhenian Sea is typical of a sub-adult population.

However, further investigations are strongly requested to deepen those aspects dealing with the spatial-temporal distribution and density of the population of loggerhead sea turtle in the northern Tyrrhenian Sea. For this purpose, the study of the migratory patterns of *C. caretta* in the Mediterranean basin by means of satellite telemetry should provide fundamental data. The lack of information on the migrations of loggerhead sea turtles in the Mediterranean basin raised concerns about the conservation and management of this species: data on the migratory pattern of the species are essential in order to devise effective conservation strategies (Bentivegna 2002). In addition, there is an increasing array of behavioural data that can be relayed via satellite and sometimes these parameters might be used to indicate the behavioural changes by the turtles (e.g. dive profiles variations, overwintering behaviour, etc.) (Hochscheid et al. 2005).

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