Assessment of the effect of the climate variations of coastal surface water and study of Sepia officinalis *spawing*

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Abruzzo,
Adriatic Sea,
Climate change,
Cuttlefish,
Sepia officinalis,
Sustainable fisheries,
Water temperature.

Summary
The aim of this study was to establish whether climate change affected migratory behaviour of *Sepia officinalis* (Linnaeus, 1758), which is an important resource for small-scale fishermen of Abruzzo region (Italy). Starting at the beginning of March until the end of April, the cuttlefish in this area migrates from deep cold water towards warmer coastal waters, where they spawn. Small-scale fishing of cuttlefish is permitted in costal waters from March to September. During the study period, between March and September 2008, both cuttlefish traps and trammel nets were used in 5 sampling areas along the Abruzzo coast to test their relative efficiency in catching cuttlefish. Trapped specimens were counted, weighed and measured, their gender and sexual maturity were also determined. The data obtained from the sampling were correlated to surface water temperature to assess possible changes in migration behaviours. The obtained data show that during the first months of migration (March and April), a greater percentage of large males was caught, while females and smaller males predominated later in the year. The study also showed that surface water temperature did not reveal any significant shifts from the trend over the last 10 years. As for the efficiency of the fishing methods, traps were found to be more effective than trammel nets.

Valutazione dell'incidenza delle variazioni climatiche nelle acque costiere e studio della produttività di Sepia officinalis *in Abruzzo, Italia*

Parole chiave
Abruzzo,
Mare Adriatico,
Cambiamenti climatici,
Seppia,
Sepia officinalis,
Pesca sostenibile,
Temperatura dell'acqua.

Riassunto
La seppia (*Sepia officinalis* Linnaeus, 1758) costituisce una delle più importanti risorse per gli operatori della "piccola pesca" della regione Abruzzo, Italia. Lo studio ha avuto come obiettivo la valutazione della consistenza della popolazione di seppia nell'anno 2008 lungo la costa abruzzese (Mare Adriatico) e la verifica di eventuali alterazioni nei comportamenti migratori derivanti dai cambiamenti climatici. Annualmente nel Mare Adriatico, nei mesi di marzo-aprile, la seppia migra dalle fredde acque profonde verso le acque costiere più calde dove si riproduce. In Abruzzo, la cattura della seppia è consentita da marzo a settembre. Lo studio effettuato si è svolto in questi stessi mesi del 2008, in 5 zone di campionamento, impiegando come attrezzi da pesca la nassa e il tramaglio, testando di questi ultimi anche l'efficienza. Gli esemplari pescati sono stati contati, pesati e misurati, determinando il sesso e lo stadio di maturazione sessuale. La nassa è risultata più efficace nelle catture rispetto al tramaglio. Durante i primi mesi di migrazione (marzo-aprile) è stata catturata una percentuale superiore di maschi di grandi dimensioni, seguita da catture di femmine e maschi di dimensioni ridotte nei mesi successivi. La nassa si è rivelata uno strumento di campionamento valido. L'elaborazione dei dati relativi alla temperatura superficiale dell'acqua negli ultimi 10 anni non ha mostrato scostamenti significativi dalla norma .

Introduction

Sepia officinalis belongs to the class of Cephalopoda (Linnaeus, 1758), it is a bentho-nectonic neritic species which can be found either in costal areas with sandy and muddy beds or in areas covered by algae and spermatophyte (Lucchetti 2004). This cuttlefish is widespread throughout the Mediterranean and West Atlantic areas; within the Mediterranean basin, it can be found in the Aegean Sea, Sea of Marmora and in the Sea of the East, whereas in the Atlantic Ocean its presence has been reported from the coastal water of Shetland Islands and Southern Norway to the 16° N, at the boundaries of Mauritania and Senegal (Pierce *et al.* 2008, Wolfram *et al.* 2006).

Sepia officinalis is one of the most important resources for the local fishing activities[1,2], particularly in the early spring, when the species' reproductive season begins. Thanks to its swimming skills, it can easily face migrations. In fact, within the 2 year span of their life (Adamo *et al.* 2000, Dunn 1999, Wang *et al.* 2003), individuals of this species migrate often times from coastal to deep water depending on the season and in relation to their reproductive cycle (Denis *et al.* 2001, Mangold-Wirz 1963, Mangold 1989).

Like all cephalopods, cuttlefishes have distinct sexes and reproduce only once in their lifetime. Eggs are usually laid at water temperatures between 13°C and 15°C. The cuttlefish life cycle is 12-24 months, varying according to the environmental conditions. Growth is quite fast, the individuals born in summer from eggs laid in spring, usually spawn in the autumn of the following year, while those born in the autumn clutch spawn in the spring of their second year of life (Jereb and Roper 2005).

During the early spring, *S. officinalis* leaves the seabed which it inhabits during the winter and moves toward the coastal waters where it begins its reproductive process (Wang *et al.* 2003). It should be noted that not all the specimens migrate in the same manner: the first individuals to leave the seabed are the bigger ones, usually these are male specimens which can begin to migrate up to a week before the females (Jereb and Roper 2005). In the Southern part of the Adriatic see, the bigger individuals start to move toward coastal waters between February and March, while smaller specimens migrate during the summer. The inverse migration path, from coastal water to seabed, can be observed with the approaching of the autumn when the temperature decreases. The migration process may depend on the water temperature, its salinity, the nature of the seabed and the marine current. Among these, however, the temperature of the coastal water is deemed to be the main factor affecting the migration behaviour of this species.This study aimed to correlate cuttlefish migration behaviour with surface water temperature. This hypotesis, if proved, would imply an early starting of the fishing season and a deployment of trammel nets and traps.

[1] Legge 13 marzo 1958, n. 250. Previdenze a favore dei pescatori della piccola pesca marittima e delle acque. *Off J*, **83**, 5.4.1958.

[2] European Community (EC). 1999. Council Regulation (EC) No 2792/1999 of 17 December 1999 laying down the detailed rules and arrangements regarding Community structural assistance in the fisheries sector. *Off J*, **L** 337, 30.12.1999, 10-28. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:337:0010:0010:EN:PDF.

Materials and methods

Surface seawater temperatures

Surface seawater temperatures were measured using data collected *in situ* and data stored in the digital archive of the Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise 'G. Caporale' (IZSAM) for the period 1989-2007. Data were recorded at 500 m, 1,000 m, 2,000 m and 3,000 m from the outlet to the sea of the rivers Alento, Arielli, Cerrano, Feltrino, Foro, Moro, Pescara, Piomba, Saline, Salinello, Sangro, Sinello, Tordino, Trigno, Tronto, Vibrata e Vomano (Giansante 1998, Giansante 2001, Giansante 2008).

Surface temperatures around the Abruzzo coast between 1992 and 2008 were measured via satellite every 8 days within an area between 14° and 15°E and 42° and 43°N (Figure 1). Data from 1992 to 2007, originated from the SST (Sea Surface Temperatures) Pathfinder version 5 (developed by the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS) and the National Oceanic and Atmospheric Administration (NOAA) - National Oceanographic Data Center (NODC), United States Department of Commerce) were recorded by NOAA AVHRR (National Oceanic and Atmospheric Administration - Advanced Very-High-Resolution Radiometer; for the year 2008 (AVHRR data were not

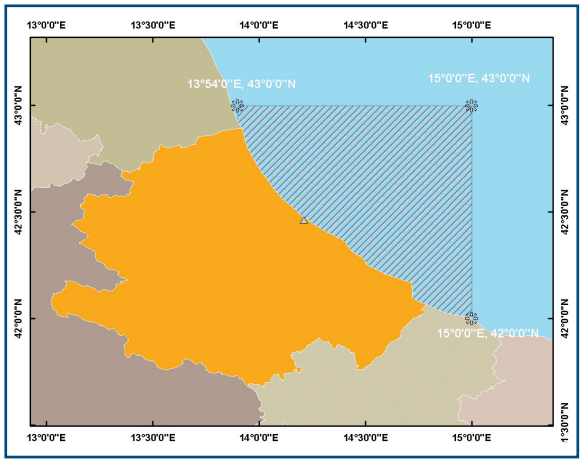


Figure 1. *Selected sea area of the Abruzzo coast (Italy) for temperature monitoring by satellite.*

available), values were taken from the MODIS/Aqua (Moderate Resolution Imaging Spectroradiometer)[3] developed by OCEAN ESIP (Ocean Earth Science Information Partners)[4].

Gaps in the satellite data were overcome using surface temperature values recorded by the Institute for Environmental Protection and Research (ISPRA) Marigraphic Service's Ortona data buoy (42° 21´ 21" N, 014° 24´ 53" E). Measurements were taken at one-hour intervals every day from January 1998 to October 2008.

Scientific sampling of *Sepia officinalis*

A sampling campaign was carried out from February 15 2008 to September 29 2008 in the areas around Martinsicuro, Giulianova, Montesilvano, Francavilla and Ortona, for a total of 55 sets of samples. Sampling was carried out using a 500 m long, 2 m high trammel net with a 40 mm mesh and 40 cuttlefish traps (*nasse o bertovelli*). Water and air temperatures were measured during each collection with a certified field thermometer (model THM912, Oregon Scientific, Portland, Oregon, USA). Trapped specimens were counted, transported to the laboratory under refrigeration for the determination of morphometric parameters, gender and maturity (Lipinski 1979, Mangold 1989, Mangold-Wirz 1963, Richard 1971, Richard *et al.* 1979). Specimens caught in the trammel net and any surplus animals caught in the traps were also measured (mantle length-ML) from the anterior dorsal edge to the back and weighed in-field. Biometric measurements were made using a moulded fish ruler (Scubla Aquaculture, Udine, Italy) and a dynamometer (model PHS3000, MPIM, Chieti, Italy).

Statistical analysis

The annual means of the surface seawater temperatures logged in the database of the IZSAM have been calculated. Monthly and annual means have also been calculated for data collected by the buoy. The significance of the regression line with a 95% confidence interval has been evaluated on the annual means. Finally, monthly means have been calculated for the data obtained from satellite measurements.

Results

Surface temperatures

Surface seawater temperatures measured by the IZSAM during the monitoring campaign carried out from 1989 to 2007 were extracted and processed (Figure 2).

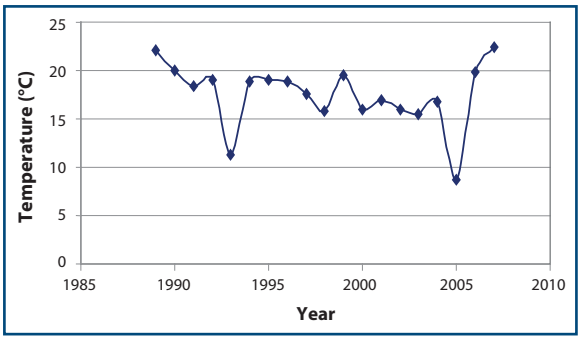


Figure 2. *Annual mean surface seawater temperature of the Abruzzo coast for the years 1989-2007.*

The mean daily temperatures were calculated, followed by the average monthly temperature, obtaining 120 temperature values. A standard decomposition analysis of the time series was conducted to identify the trend, seasonality and residue using the 'decompose' function of the Stats software package R 2.9.2™. The function first determines the trend of the time series using the rolling average of 13 values and weights (wi) of:

$$wi = \begin{cases} 1/24, & i=\{1;13\} \\ 1/12, & i=\{2:12\} \end{cases}$$

The seasonal component of the detrended series is calculated as the mean of the values assumed for the same month in each year and the residual component is obtained on the basis of the selected model (in this case additive) by removing trend and seasonality from the original time series. The adequacy of the model is evaluated by analysis of the residues, testing the mean (t-test) and studying the distribution (Figure 3, Table I). The t-test demonstrated that the mean of the residues is not significantly different from 0. The trend analysis did not reveal any significant trends with respect to temperature rises or drops (slope: $t = 0.748$; $p = 0.456$).

Satellite data showed frequent gaps, especially near the coast, probably due to cloud cover and signal noise causing sensor disorders. For this reason, it was not always possible to obtain temperature means representative of the entire area in question, and so no time series analysis was carried out. However, the monthly means for surface water temperature near the Abruzzo coast were analysed to show possible trend. The temperature value is averaged each month over the entire area taken into consideration.

Figures 4a and 4b depict the surface temperature trend (monthly means) for 1992-2008 and show a sinusoidal trend over the seasons. With respect to the general temperature trend, there is a slight increase in the minimum temperature in 2007. Figure 5

[3] http://gcmd.nasa.gov/records/GCMD_OBPG_MODIS_AQUA_L3_M4D_SST.html.

[4] http://noaasis.noaa.gov/NOAASIS/ml/avhrr.html.

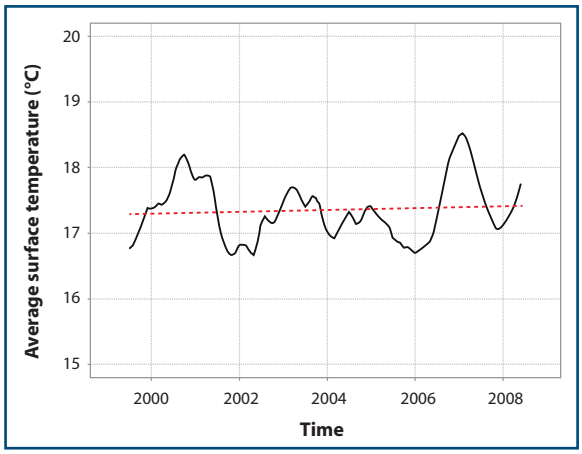


Figure 3. *Fitting of a linear trend to the time series trend component.*

Table I. *Regression analysis of trend to evaluate the adequacy of the model by analysis of the residues, testing the mean (by t-test) and studying the distribution.*

Slope	Estimate	Std. Error	t value	p value
	0.001056	0.001411	0.748	0.456

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
-2.289	-0.574	0.0134	-0.000827	0.680	2.161

t-test for mean <>0: t = -0.009241469; p = 0.5036782.

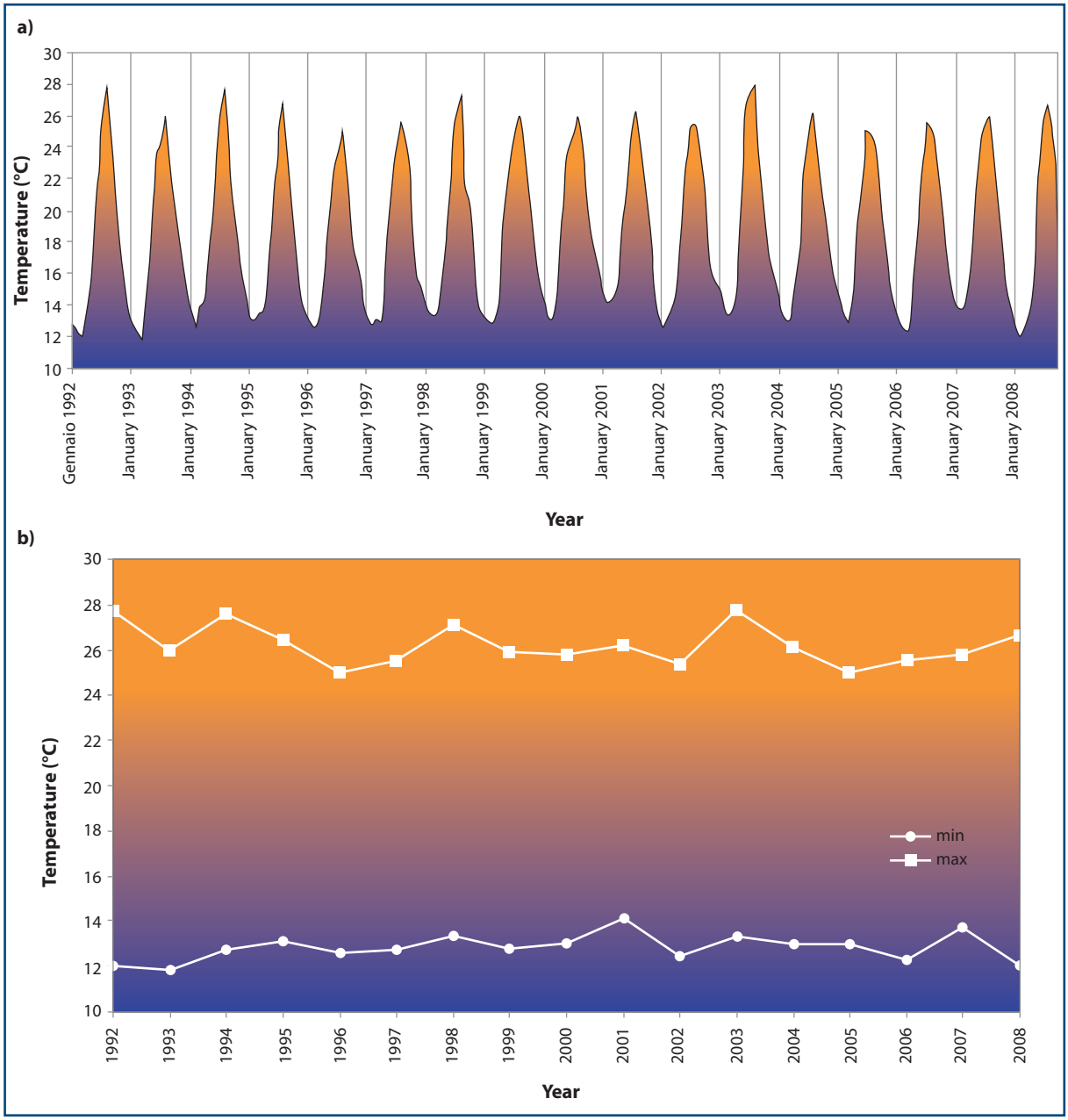


Figure 4. *Sea surface temperature trends of the Abruzzo coast for the years 1992-2007 (a); maximums and minimums (b).*

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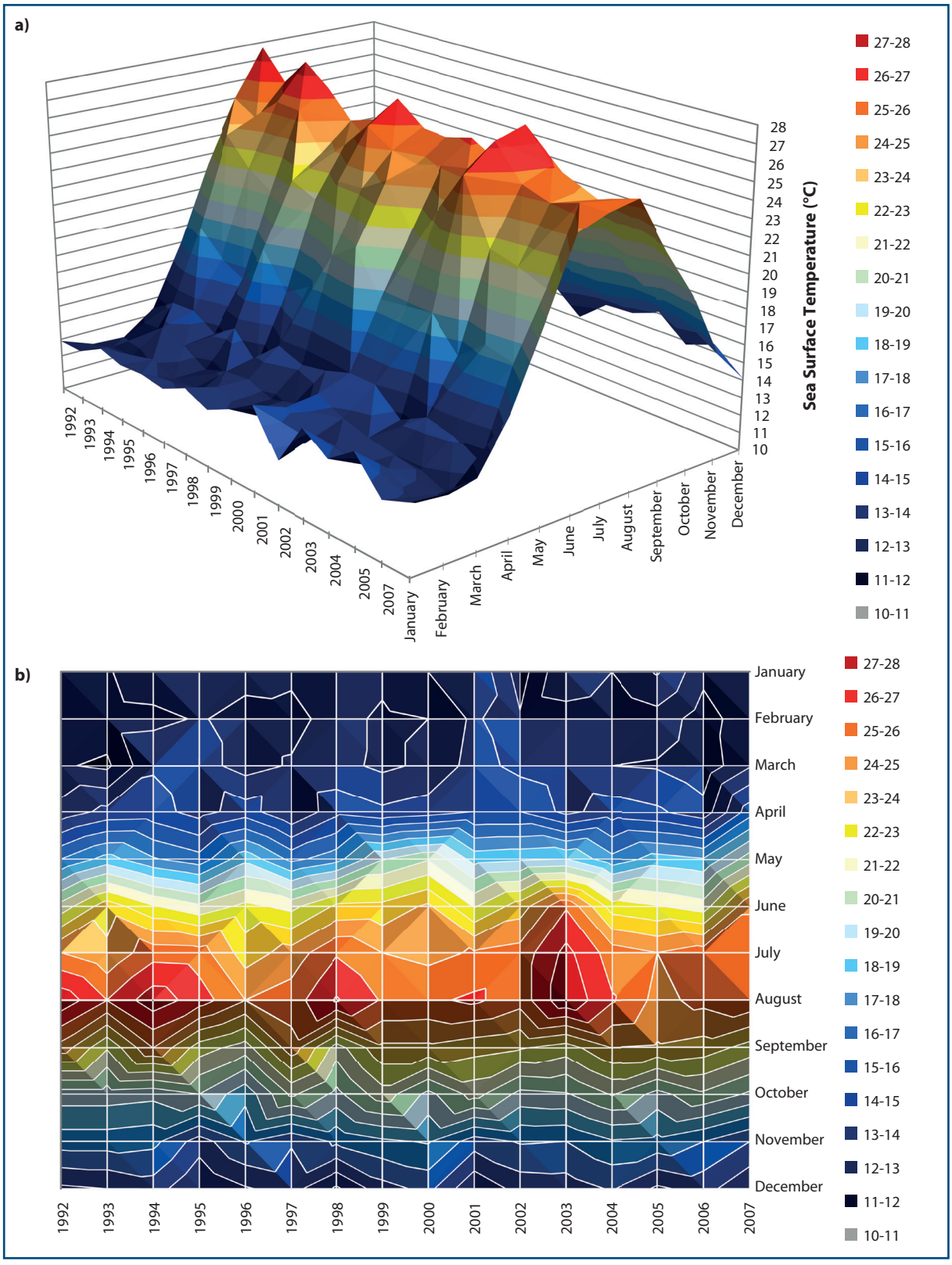


Figure 5. *(a) and (b) SST (Sea Surface Temperature) gradient of the Abruzzo coast for 1992-2008.*

shows that the highest temperatures were recorded in August, whereas the lowest temperatures were observed in February-March. It is noteworthy that, starting in 2002, the temperatures recorded for July and August are increasingly similar. At the same time, in 2007, data show an early increasing of the temperature in April and May, which is quite odd when compared with data concerning both, the previous and the subsequent year, when the temperature did not go above 15°C.

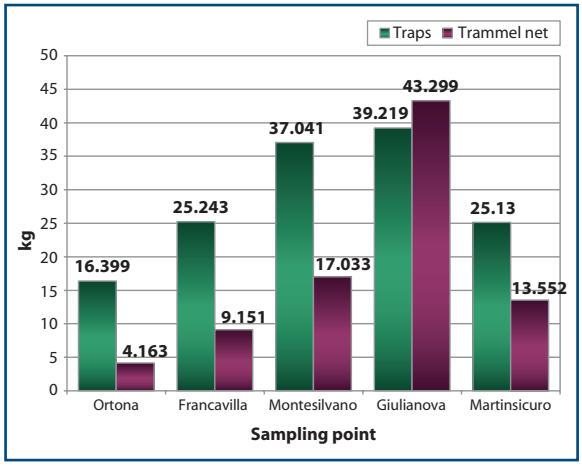


Figure 6. *Total biomass of* Sepia officinalis *caught during monitoring runs by sampling point and tackle used.*

Scientific sampling of *Sepia officinalis*

Nine hundred ninty-two specimens were caught during the scientific sampling campaign: 720 were captured using traps, 272 using trammel nets. The total biomass was 230.23 kg, 143.032 kg in traps and 87.198 kg in trammel nets. The number of specimens caught, and consequently the biomass, was greater in April, May and June at all 5 sampling sites. Catches were poor in July, August and September (no more than 5 specimens captured with 40 traps), with the exeption of Ortona, where 12 cuttlefish were caught on August 20 and 7 on September 3 2008. Similar results were obtained using trammel nets: the most successful captures occurred in April, May and June, whereas in the following months only 2 individuals per run were caught with this tackle (Ortona sampling point).

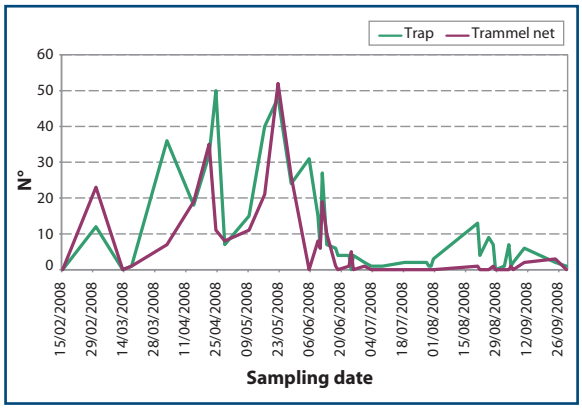


Figure 7. *Total number of* Sepia officinalis *caught in traps and trammel net at all sampling points.*

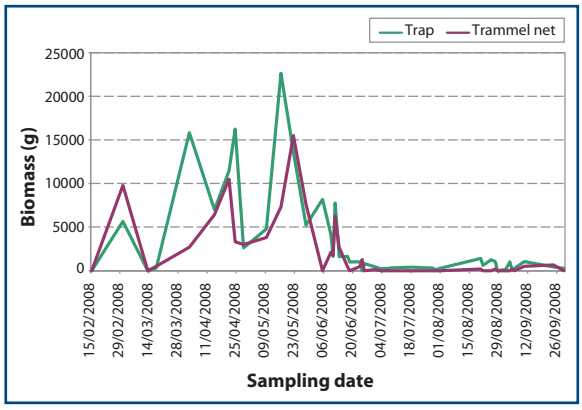


Figure 8. *Total biomass of* Sepia officinalis *caught in traps and trammel net at all sampling points.*

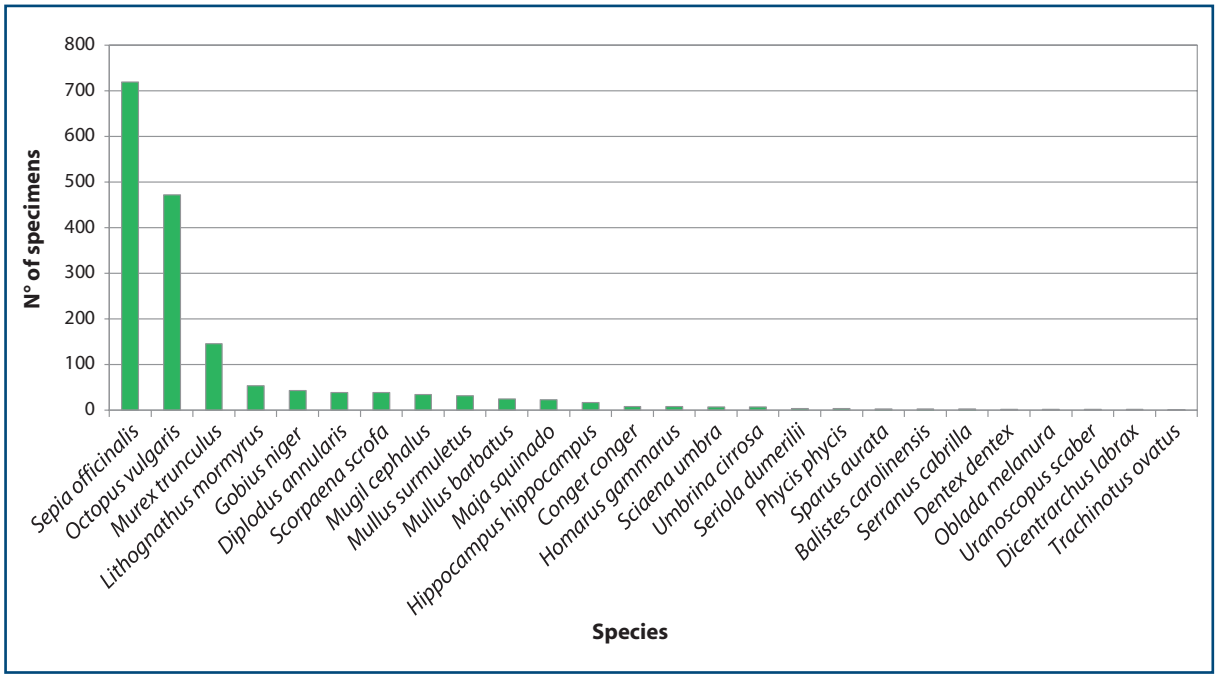


Figure 9. *Number of specimens caught in traps over all sampling points on the Abruzzo coast between March and September 2008.*

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With reference to the total biomass of cuttlefish caught at each sampling point, the data showed that the best catches occurred in Giulianova, probably due to various factors including greater skill of the fisherman in positioning the tools, greater number of cuttlefish in the area, and/or weather and sea conditions. The data concerning the Giulianova site showed an inverse trend: the cuttlefish biomass caught in the trammel nets was greater than that caught in the traps. Also in this case the results might have depended on greater skill of the fisherman in positioning the tools, greater number of cuttlefish in the area, and/or weather and sea conditions.

Figure 6 reports the data about the biomass originating from each type of tackle (traps and trammel nets) used at each monitoring point. Figures 7 and 8 compare the number and biomass of cuttlefishes caught in the traps and those caught in the trammel nets. The Mann-Whitney test identified a statistically significant difference with respect to both, number of specimens ($U = 2048$, $p<0.01$) and biomass ($U = 1979.5$, $p<0.01$). Both, the number of specimens and their biomass were significantly greater when using the traps.

The traps also caught 472 octopuses (*Octopus vulgaris*), not normally caught in trammel nets or using other fishing methods. The low number of other species caught by the traps confirms their high selectivity (Figure 9) .

Results showed that the first specimens to approach coastal water are males, as it was recorded during the first 2 observations carried out for each sampling point. Until April, males were generally more numerous than females, however in May and June the male/famale ratio was inverted.

Of all the speciments collected during the study, 300 out of 596 individuals were males, while 296 were female. Almost all the male specimens, 272 out of 300, were in the IV stage of gonad maturation, whereas 21 individuals were in the II or III stage and only 7 specimens had a completely vacant spermatophore capsule indicating that the reproductive phase was concluded.

Almost all females, 291 out of 296, were in the III phase of the gonad maturation, which preceeds the reproduction stage; 4 specimens were in stage IV, while only 1 individual showed to have already layed its eggs. Most of the specimens were caught with a surface seawater temperature between 14.4° and 21.5°C.

Figures 10, 11, 12, 13, 14 the dashed lines indicate the opening of the fishing season according to current legislation, i.e. 15 March for traps, and 1 April for trammel nets.

The data analysed in this study showed that:

- on February 15, the starting date of the scientific sampling in Montesilvano, no specimen was captured and the seawater temperature was 7.5°C;
- on March 1, in Giulianova during the second sampling, 12 individuals were captured with

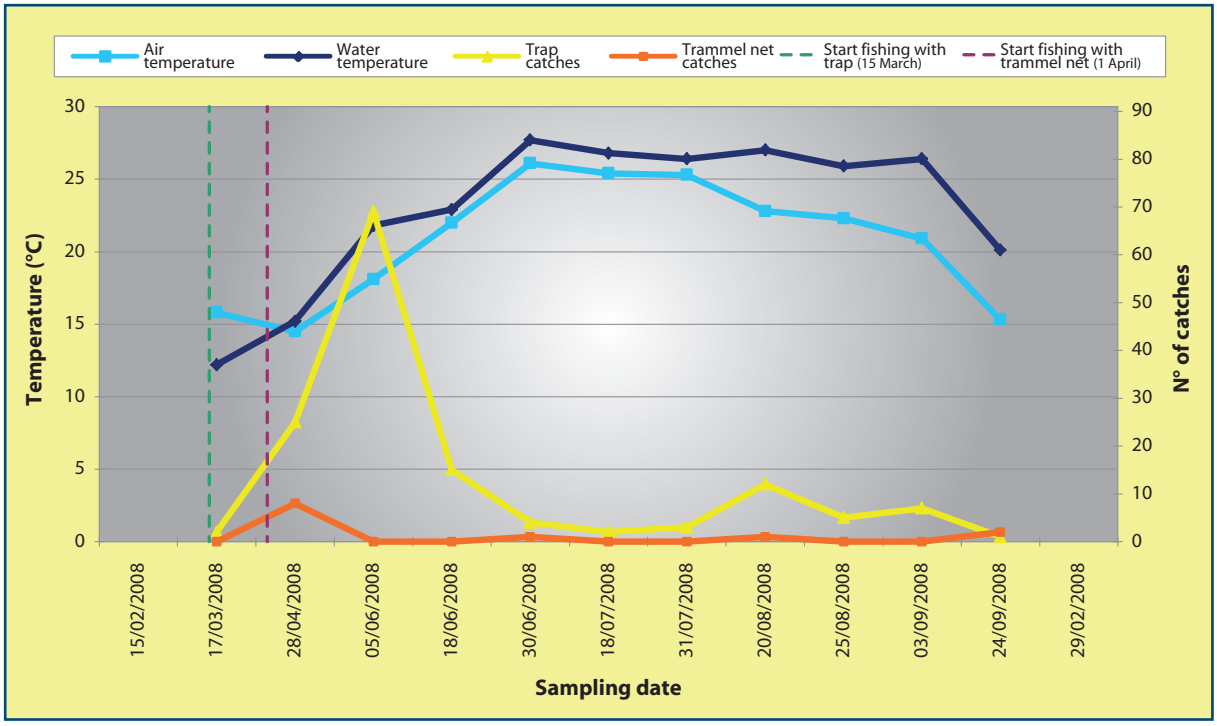


Figure 10. *Ortona: specimens of* Sepia officinalis *caught by tackle type in relation to air temperature and surface seawater temperature.*

traps and 23 using trammel nets, the seawater temperature was 10.4°C;

- on March 13, in Martinsicuro, during the third sampling, no specimen was captured and the seawater temperature was 10.0°C;
- on March 17, in Ortona during the fourth sampling, 1 specimen was captured using traps and 1 using trammel nets. The sea water temperature was 10.6°C;
- on April 2, in Francavilla, during the fifth sampling, 36 individual were captured with traps and 7 with trammel nets, the water temperature was 12.2°C.

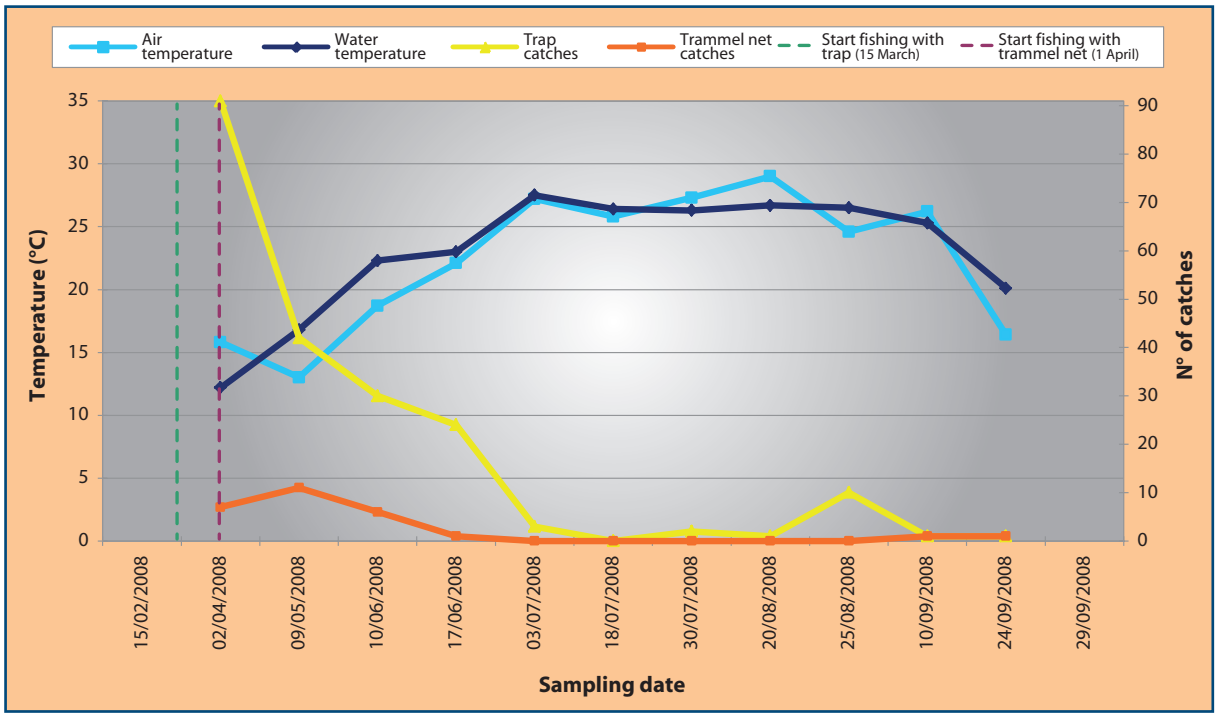


Figure 11. *Francavilla: specimens of* Sepia officinalis *caught by tackle type in relation to air temperature and surface seawater temperature.*

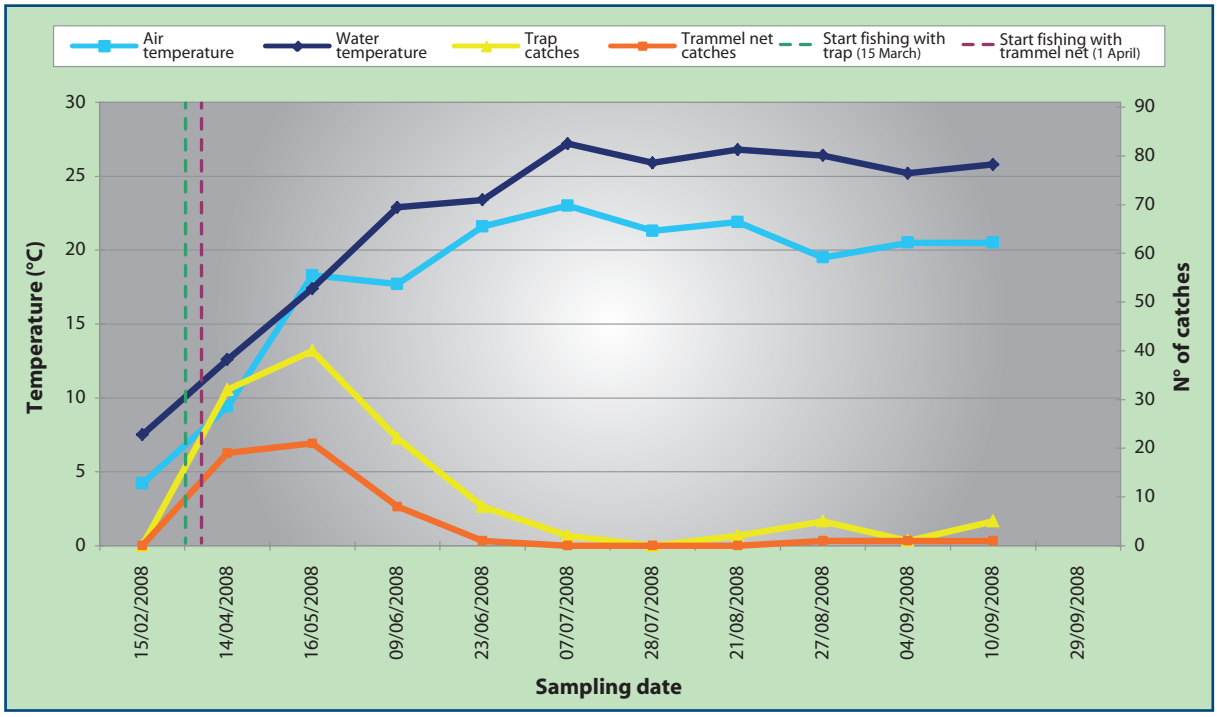


Figure 12. *Montesilvano: specimens of* Sepia officinalis *caught by tackle type in relation to air temperature and surface seawater temperature.*

Figures 15 and 16 show the linear regression of mantle length variations of the individuals caught during the sampling period. The length of the specimens variated over time and such variation was more evident in males than in females. Males captured during the first phase of the sampling could be up to 21 cm long.

The linear regression highlighted an important negative relationship between the sampling dates and the length of the specimens, with a significantly negative angular coefficient, especially in males (Table II).

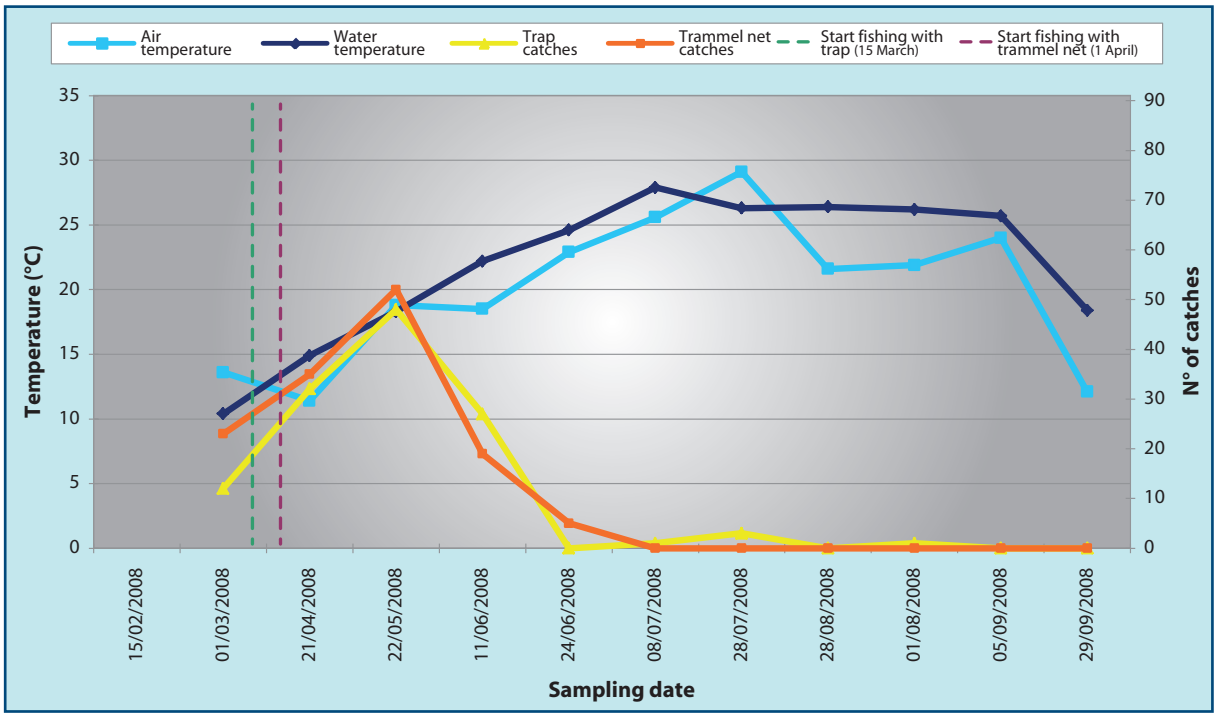


Figure 13. *Giulianova: specimens of* Sepia officinalis *caught by tackle type in relation to air temperature and surface seawater temperature.*

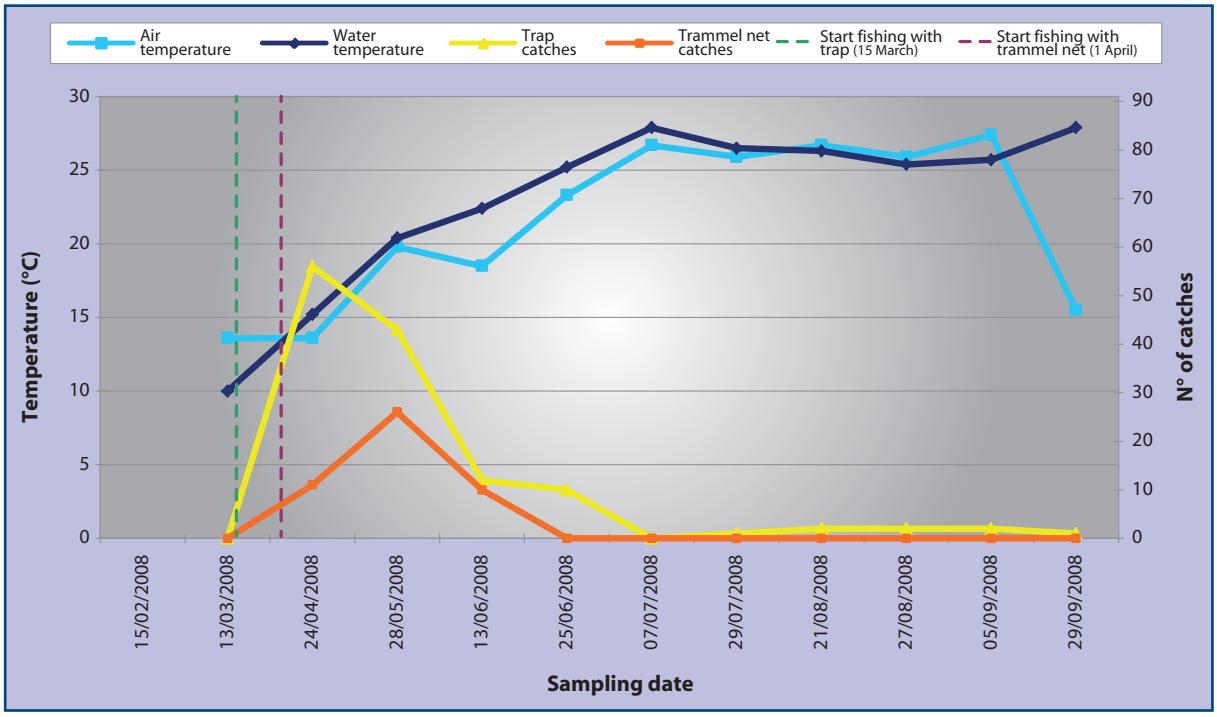


Figure 14. *Martinsicuro: specimens of* Sepia officinalis *caught by tackle type in relation to air temperature and surface seawater temperature.*

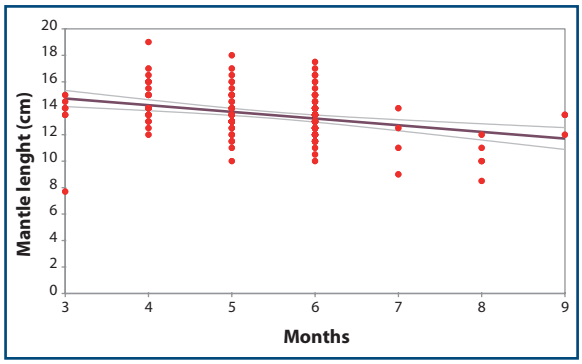


Figure 15. *Regression analysis of mantle length and month of sampling (*Sepia officinalis *females).*

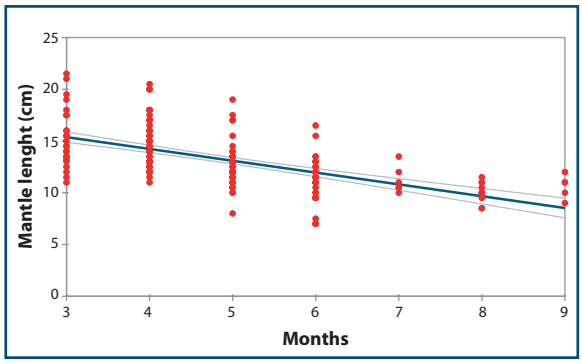


Figure 16. *Regression analysis of mantle length and month of sampling (*Sepia officinalis *males).*

Table II. *Regression analysis of mantle length variations in males and females* Sepia officinalis *caught during the sampling period.*

Group	Parameter	Coefficient	Standard error	t value	Significance	95% confidence interval for coefficient	
						Lower limit	Upper limit
Females	Constant	16.248	0.637	25.523	<0.0001	14.992	17.505
	Time (months)	-0.504	0.114	-4.436	<0.0001	-0.729	-0.28
Males	Constant	18.805	0.558	33.712	<0.0001	17.705	19.905
	Time (months)	-1.142	0.11	-10.371	<0.0001	-1.359	-0.925

Discussion

Data collected by the data buoy (1999-2008) did not show any significative trend concerning the increasing or decreasing of surface seawater, whereas satellite data concerning the same period showed an early increase of the seawater temperature occurring in April-May 2007. On the basis of these data it can be argued that during the last 10 years no significative variation of the surface seawater temperature has been recorded.

Data collected via the scientific sampling highlighted that surface seawater temperature is likely to be a determining factor in the migration behaviour of the cuttlefish, which moves toward the coast only when the surface temparature is above 10 °C.

The first evidence of the presence of *S. officinalis* in coastal water was obtained during the first days of March. During the following days it is likely that, given the worstening of the weather conditions, the cuttlefish returned offshore.

Temperature seems to be the main factor limiting the presence of cuttlefish in the coastal area. Sudden drops in temperature resulted in cooler water and instigated cuttlefish to move away temporarily, as occurred in the first sampling at both, Giulianova (01.03.2008: 35 specimens caught, seawater temperature 10.4 °C) and Martinsicuro (13.03.2008: no specimens caught, seawater temperature 10.0°C). It is worthwhile stressing that rain and snow had fallen between the 2 samplings causing a decreasing of the surface seawater temperature.

The length of caught specimens diminished from March to September and were consistent with the findings reported in literature (Mangold 1989).

An analysis of the gonad maturation confirmed that the reproductive period corresponds to the most proficous period for the small fishery activities, stressing therefore the need to choose fishing tools and methods which woud have the least possible impact on the resource and on its reproductive cycle. Cuttlefish traps showed to be the most efficient tool to capture cuttlefish as well as other species such as octopus. Furthermore, cuttlefish would use the traps for egg deposition, so if the these tools are left in the sea until September, as it is currenly required by the existing regulations, they will foster the natural increasing of the resource. Hence, the number of traps that can be deployed by each fisherman (which is regulated by the local authority, Capitaneria di Porto) should be determined keeping in mind the presence of the resource in the area.

Conclusions

On the basis of the data considered there were no significant shifts in surface water temperature with respect to the trend over the last 15 years.

Trammel nets showed to be a less efficient tool for the capture of cuttlefish when compared to traps and, although there are not limitations set for their deployment, this tool has a high negative impact on several species (e.g. cetaceans and turtles, protected species).

We conclude that trammel nets should not be used for capturing cuttlefish; furthermore, in order to preserve this resource, traps should be the only tool allowed for the capture of this species and the opening of the fishing season should not be anticipated earlier.

References

Adamo S.A., Brown W.M., King A.J., Mather J., Mather L., Shoemaker K.L. & Wood J.B. 2000. Agonistic and reproductive behaviours of the cuttlefish *Sepia officinalis* in a semi-natural environment. *J Mollus Stud*, **66**, 417-419.

Denis V. & Robin J.P. 2001. Present status of the French Atlantic fisheries for cuttlefish (*Sepia officinalis*). *Fisheries Research*, **52**, 11-22.

Dunn M.R. 1999. Aspects of the stock dynamics and exploitation of cuttlefish, *Sepia officinalis* (Linnaeus, 1758), in the English Channel. *Fisheries Research*, **40**, 277-293.

Giansante C. 1998. Programma di Ricerca e Sperimentazione Mare Adriatico (PRISMA Fase 1) anni 1995-1997. Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise 'G. Caporale'- Regione Abruzzo, Teramo.

Giansante C. 2001. Programma di monitoraggio delle acque marine costiere anni 1989-2000. Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise 'G. Caporale' - Regione Abruzzo, Teramo.

Giansante C. 2008. Programma di monitoraggio delle acque marine per la molluschicoltura anni 1996-2007. Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise 'G. Caporale' - Regione Abruzzo, Teramo.

Jereb P. & Roper C.F.E. 2005. Cephalopods of the world. An annotated and illustrated catalogue of cephalopod species known to date. Volume 1. Chambered nautiluses and sepioids (Nautilidae, Sepiidae, Sepiolidae, Sepiadariidae, Idiosepiidae and Spirulidae). FAO Species Catalogue for Fishery Purposes. 4, 1, Rome, FAO.

Lipinski M. 1979. Universal maturity scale for the commercially important squids. The results of maturity classification of the *Illex illecebrosus* (Lesueur, 1821) population for years 1973-1977. ICNAF Res. Doc. 79/11/38, Serial No. 5364, 40.

Lucchetti A. 2004. La seppia comune. Biologia, pesca e consumo delle più importanti specie commerciali – *Sepia officinalis* (Linneo, 1758). *Il Pesce*, **2**, 93-95.

Mangold K. 1989. Reproduction, croissance et durée de vie. *In* Céphalopodes. Traité de zoologie. Anatomie, Systématique, Biologie. Grassé P.P., Masson, Paris, **5** (4), 493-552.

Mangold-Wirz K. 1963. Biologie des céphalopodes benthiques et nectoniques de la Mer Catalane. *Vie Milieu Paris*, **13** (Suppl.), 285 pp.

Pierce G.J., Valavanis V.D., Guerra A., Jereb P., Orsi-Relini L., Bellido J.M., Katara I., Piatkowski U., Pereira J., Balguerias E., Sobrino I., Lefkaditou E., Wang J., Santurtun M., Boyle P.R., Hastie L.C., MacLeod C.D., Smith J.M., Viana M., Gonzalez A.F. & Zuur A.F. 2008. A review of cephalopod-environment interactions in European Seas. *Hydrobiologia*, **612**, 49-70.

Richard A. 1971. Contribution à l'étude expérimentale de la croissance et de la maturation sexuelle de *Sepia officinalis* L. (mollusque cephalopode). PhD Natural Sciences. Université de Lille, Lille, 264 pp.

Richard A., Van den Branden C. & Decleir W. 1979. The cycle of activity in the accessory nidamental glands from Cephalopods. Naylor E. & Hartno R.G., 2nd ed., 173-180.

Wang J., Pierce G.J., Boyle P.R., Deni, V., Robin J.-P. & Bellido-Millan, J.M. 2003. Spatial and temporal patterns of cuttlefish (*Sepia officinalis*) abundance and environmental influences - a case study using trawl fishery data in French Atlantic coastal, English Channel and adjacent waters. *ICES J Mar Sci*, **60**, 1149-1158.

Wolfram K., Mark F.C., John U., Lucassen M. & Pörtner H.O. 2006. Microsatellite DNA variation indicates low levels of genetic differentiation among cuttlefish (*Sepia officinalis* L.) populations in the English Channel and the Bay of Biscay. *Comp Biochem Physiol Part D Genomics Proteomics*, **1**(3), 375-383.