VII.9. RESEARCH ON CEPHALOPOD RESOURCES IN HELLAS

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INTRODUCTION

Several cephalopod species are considered commercially important in Hellas (Chapter II.4) and, as coastal finfish stocks undergo depletion in heavily exploited fishing grounds, the interest in the exploitation of cephalopod resources is steadily increasing.

Fisheries research conducted during the last seventeen years includes the study of the biology, ecology, fisheries and rearing conditions of Cephalopods, aiming at the conservation of wild Cephalopod populations and the development of aquaculture.

Available information on Cephalopods' resources, resulting from the analyses of fisheries' statistical data and the investigation based on experimental surveys, visual census, cephalopod fisheries' monitoring and laboratory rearing is compiled in this document. Among our aims is (a) to summarize research conclusions related to management measures, and (b) to identify in this context gaps in knowledge and priorities for future research.

STUDIES ON SPECIES' LIFE HISTORY

Demographic analysis and estimation of the basic biological parameters of selected Cephalopod species has been included in national and international research projects concerning the assessment of commercially important stocks in various areas of the Hellenic Seas and based on trawl surveys, since 1990.

Analyses of seasonal size and maturity stages' composition, performed for *Illex coindetii, Eledone cirrhosa, Eledone moschata, Sepia elegans, Sepia orbignyana Sepietta oweniana* and *Alloteuthis media* sampled with trawl nets in the Aegean Sea, have shown prolonged spawning and recruitment periods for all species, with one or more seasonal peaks (Table 1). Considerable variation has been observed in species' abundance between seasons or different years, related to their short life-span, rapid population turnover, reproductive behaviour and recruitment seasonality (PAPACONSTANTINOU *et al*., 1993, 1994, 1998).

The data collected during trawl surveys were insufficient for life cycle studies of neritic commercially important species such as *Sepia officinalis, Loligo vulgaris* and *Octopus vulgaris*. Biological studies of the latter two species have been carried out, however, in the framework of two PhD studies based on respectively, a) *Octopus vulgaris* on monthly visual census at several coastal sites (0-30 m depth) of the southern Aegean and Ionian Seas (KATSANEVAKIS, 2004), and b) *Loligo vulgaris* on monthly sampling of commercial catches by beach-seiners and trawlers in the Thracian Sea (LEFKADITOU, 2006). Moreover, monthly progress of maturation and length-weight relationships were studied for *Illex coindetii, Loligo vulgaris* and *Sepia officinalis* in different areas of the Hellenic seas, based on monthly sampling of commercial catches carried out in the framework of the European research projects CEPHVAR (Environmental, Genetic and Biological Variation of Cephalopods in European Waters. 1997-2000) and CEPHASSES (ARVANITIDIS *et al.,* 2001, 2002; MORENO *et al*., 2002).

Two main benthic settlement (recruitment) peaks were found for *Octopus vulgaris,* indicating respective spawning peaks (Table 1), which were more pronounced and shorter in duration when seasonal temperature increased (KATSANEVAKIS & VERRIOPOULOS, 2006a). A similar effect of temperature has been observed during the spawning period of *Loligo vulgaris* which was found to last from late winter to early autumn in the Thracian Sea, reaching a peak in spring (LEFKADITOU, 2006).

Density of both species in the coastal zone was also found to be associated with temperature. Adult octopuses (>200 g) tended to dwell deeper during the period of intense thermocline than during the no-thermocline period (KATSANEVAKIS & VERRIOPOULOS, 2004), whereas, *Loligo vulgaris,* as supposed by beach-seine CPUE variations, migrated extensively to inshore fishing grounds after a considerable decrease of temperature in late November (LEFKADITOU *et al*., 1998).

Octopus life-span and growth rate (Table 1) were estimated by a time-variant, stage-classified, matrix population model based on monthly density measurements of 4 size stages (1:<50g, 2: 50-200g, 3: 200-500g, 4: >500g) (Figure 1) which were recorded during scuba diving (KATSANEVAKIS & VERRIOPOULOS, 2006b).

Table I. Life cycle features and parameters of commercially important and most abundant cephalopod species in Hellenic Seas (compiled from LEFKADITOU & PAPACONSTANTINOU, 1995; ANONYMOUS, 2000; ARVANITIDIS *et al.*, 2001; 2002; MORENO *et al.*, 2002; ANONYMOUS, 2005; KATSANEVAKIS & VERRIOPOULOS, 2006; LEFKADITOU, 2006)

Species	ML_{max} (cm)	ML_{50} (cm)	Spawning period (peak season)	Recruitment period (peak season)	Length-weight relationship	Life span (months)	DGR range (g/day)	Relative Fecundity (No oocytes/ g BW)	Food items (rank order)
Alloteuthis media	♀ 10.4 ♂ 8.1		All year	All year (autumn-winter)	$BW=0.0012ML^{2.06}$ $BW=0.0022ML^{1.89}$				
Eledone cirrhosa	♀ 15.5 ♂ 12.0		early summer-mid autumn	All year (autumn-winter)	$BW=0.0026ML^{2.51}$ $BW=0.0034ML^{2.43}$				
Eledone moschata	♀ 18.4 ♂ 18.2		March –September (early summer)	All year (autumn)	$BW=0.0004ML^{2.87}$				
Illex coindetii	♀ 24.0 ♂ 18.0	14.6-18.1 11.3-13.8	All year (summer)	All year (autumn-winter)	$BW=7x10^{-5}ML^{2.83}$ $BW=1x10^{-5}ML^{3.25}$	13.5 14.5	0.06-1.17 0.06-1.09	506 (±101)	Fish Cephalopod Crustacean
Loligo vulgaris	♀ 29.5 ♂ 46.5	13.9-18.9 13.5-15.5	November-June (mid spring)	All year (summer)	$BW=0.0001ML^{2.81}$ $BW=0.0002ML^{2.59}$	12 13.5	0,13-10,39 0,12-8,93	44(±11)	Fish Cephalopod
Octopus vulgaris	♀ 21.5 ♂ 20.0		(late winter-spring & late summer-early autumn)	All year (late spring-summer & late autumn)	$BW=0.0034ML^{2.60}$	12-15	1.74-3.89*		
Sepia elegans	♀ 7.6 ♂ 5.7		All year (spring)	summer-winter (autumn)	$BW=0.0007ML^{2.51}$ $BW=0.0009ML^{2.44}$				
Sepia officinalis	♀ 26.4 ♂ 32.0			All year (summer)	$BW=0.0064ML^{2.18}$ $BW=0.0025ML^{2.37}$				
Sepia orbignyana	♀ 9.1 ♂ 8.4		All year	All year (autumn)	$BW=0.0017ML^{2.36}$ $BW=0.0019ML^{2.3}$				
Sepietta oweniana	♀ 3.6 ♂ 3.4	1.8 - 2.4 1.4 - 1.8	All year (spring)	All year (autumn)	$BW=0.0069ML^{2.12}$ $BW=0.0107ML^{1.97}$			16 (±4)	Crustacean Fish Cephalopod

* estimation for octopods 50-500g based on analysis of monthly population density of 4 size classes, which was measured through visual census.

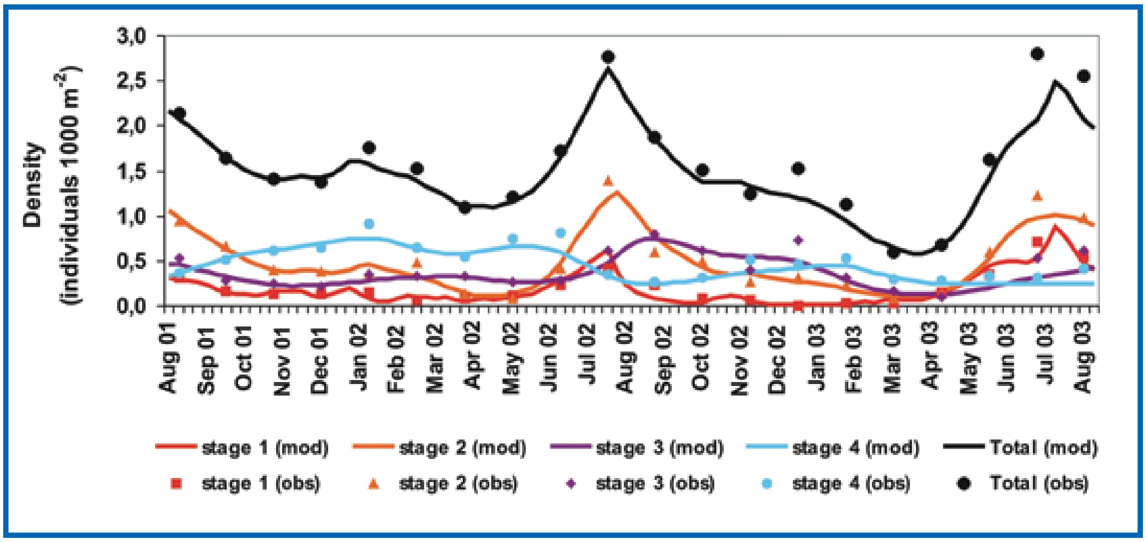

Figure 1: Model predictions, starting from an initial density vector n_1 equal to the observed vector at that time, vs. observed densities. Lines represent model a estimations and markers represent observed data. Source: KATSANEVAKIS & VERRIOPOULOS, 2006.

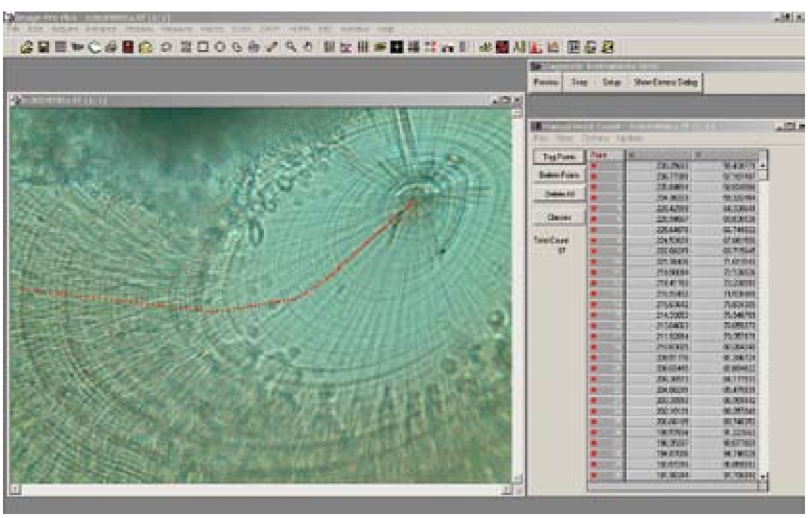

Figure 2: Manual tagging of growth increments on a digital image from *Illex coindetii* statoliths and recording of tag coordinates through the routines of IMAGE-PRO-PLUS programme.

Estimates of *Illex coindetii* life-span by modal analyses of seasonal length frequency through indirect methods calculating the Von Bertalanfy growth equation parameters, were considered overestimates when compared to direct age estimates from statoliths (PAPACONSTANTINOU *et al.*, 1993, 1994). The daily nature of growth increments exposed on ground squid statoliths has been verified by chemical marking for several squid species since the mid 1980s, whereas direct ageing resulting from increment counts in cuttlefish statoliths and octopus beaks has not been validated yet. In Hellas the reading of statoliths started in 1992 in the framework of a PhD thesis (LEFKADITOU, 2006) including, among other issues, the ageing of *Illex coindetii* and *Loligo vulgaris*. The development of the ageing methodology using squid statoliths was greatly facilitated by the use of an Image Analysis System obtained by HCMR in 1996, as well as, by its further updates concerning the routines of the IMAGE-PRO-PLUS programme (Figure 2), the frame grabber and the rest of the hardware used.

In respect to the diet composition of cephalopod species, the existing information originating from examination of material collected in various areas of the Aegean Sea, indicates that Fish, Crustacean and Cephalopods compose the preferential prey categories, their dominance order depending on the species and the fishing ground, while other groups such as Polychaeta Annelida, Tunicata and Cnidaria Hydrozoa participate with very low percentages (KOUKOURAS *et al.*, 2001; LEFKADITOU, 2006).

MONITORING OF CEPHALOPOD FISHERIES IN THE THRACIAN SEA

According to analyses of National Staticis data on cephalopod catches by fishing region and fishing gear for the period 1998-2002, small-scale fishery (beach seine and other gears) contributes half or more of the cephalopod catches in most fishing areas (Figure 3), whereas the major part of the

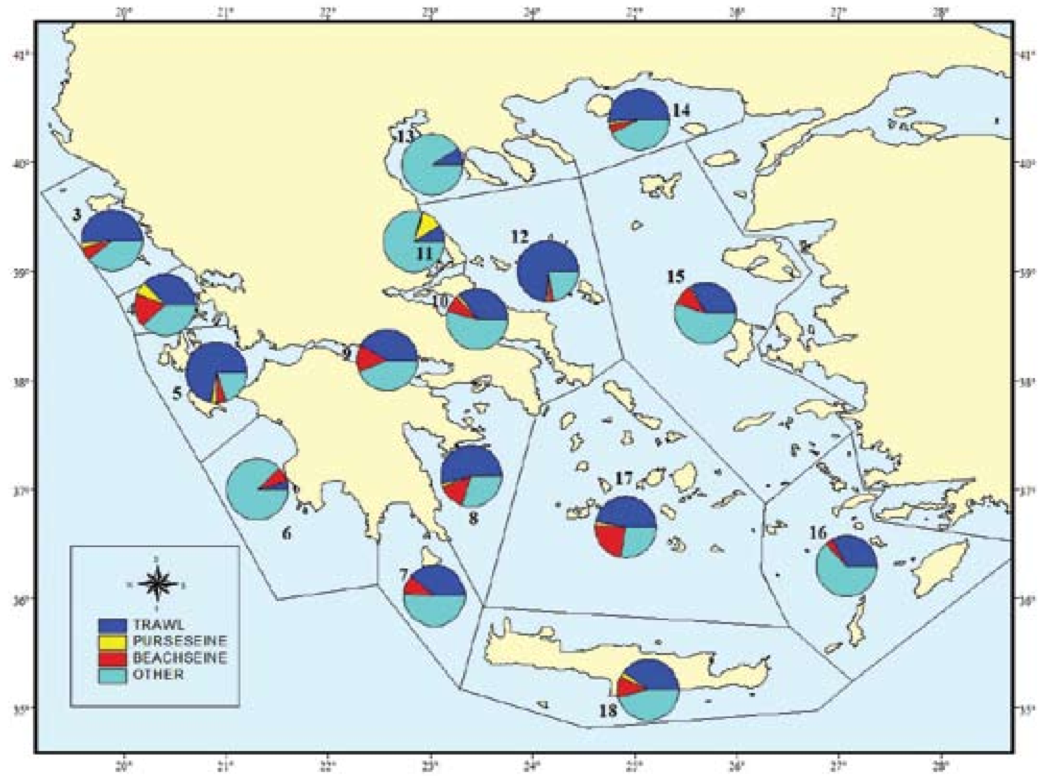

Figure 3: Percentage contribution of different fishing gear categories in cephalopod catches by fishing area, during the period 1998-2002.

cephalopod catches is exploited in the Thermaikos Gulf (Region 13) and Thracian Sea (Region 14), where *Sepia officinalis* and *Octopus vulgaris* dominate the continuously increasing catches (LEFKADITOU *et al*., 2002).

Since 1994 four research projects that have been undertaken by FRI and HCMR (Table 2), aimed at the investigation of exploitation patterns for *Loligo vulgaris, Sepia officinalis, Octopus vulgaris, Eledone moschata* and *Eledone cirrhosa* in the Thracian Sea, where apart from the traditional gears fishing Cephalopods, new profitable fishing techniques (fyke-nets, plastic pots) for common octopus have been developed since the early 1990s.

Multi-species gears, such as trawl and beach-seine, were observed to undertake in some cases specific hauls targeting commercially important species like *Octopus vulgaris, Sepia officinalis* and *Loligo vulgaris*. During the fishing period October 1998-May 1999, Cephalopods constituted 27% of the trawler landings at the port of Kavala and 19% of their total sales. *O. vulgaris* was the most important species among Cephalopods in terms of landings and sales (49%), followed by *S. officinalis* (23%). The average contribution of *Loligo vulgaris* in Cephalopod sales (17%) was quite higher than in landings (6%), due to its higher price in the market. Eledonids had the lowest prices among Cephalopods and contributed the lowest proportion (*E. moschata*: 6%, *E. cirrhosa*: 2%) in cephalopod sales (LEFKADITOU *et al.,* 2001). The contribution of Cephalopods to the total sales of beach-seiners (36%) was higher than for their landings (17%). This was due to the dominance of low-price species such as *Sardina pilchardus* in their landings (LEFKADITOU & ADAMIDOU, 1997), particularly in winter, whereas, the highly priced *Loligo vulgaris* represented 49% of the cephalopod landings accounting for 74% of the total cephalopod sales. Average annual catches of common squid per vessel for beach seiners has been shown to be threefold that of trawlers operating in the Thracian Sea (LEFKADITOU & PAPACONSTANTINOU, 1999), thus proving the importance of beach seine gear for the exploitation of this coastal resource. Considering the likely implications of Fisheries Regulations which might stop beach seine operation in Hellenic waters, an experimental hand operated jigging machine with light attraction was tested as potentially alternative fishing gear for the coastal exploitation of *L. vulgaris*, which however, has been proved

Table 2. Research projects undertaken by FRI and HCMR, concerning cephalopod fisheries' monitoring in the Thracian Sea. List of studied species, fishing gears (BS: Beach-seine, PS: Purse-seine, TR: Trawl, FN: Fyke-nets, TN: Trammel-nets, STN: Sepia-trammel-nets, P: Pots) and LPUE data collection period.

Title of Study	Fishing gears	Species	Data collection period
Experimental squid jigging with light attraction (Studies/ EU DG XIV, Contract No: MED93/19).	Beach-seine Purse-seine Trawl	*Loligo vulgaris*	Oct. 1994 – May 1995 (daily)
Stock assessment of some coastal species (COASTAL) (Studies/ EU DG XIV, Contract No: 96/054).	Fyke-nets Trammel-nets	*Octopus vulgaris* *Sepia officinalis*	Sep. 97- Sep 99 (fortnightly)
Analysis and evaluation of the fisheries of the most commercially important cephalopod species in the Mediterranean Sea. (Studies/ EU DG XIV, Contract No: 97/054)	Beach-seine	*Eledone moschata* *Loligo vulgaris* *Octopus vulgaris* *Sepia officinalis*	Oct. 99 – May 99 (fortnightly)
	Fyke-nets	*Octopus vulgaris*	Oct. 99– June 99 (fortnightly)
	Sepia-trammel-nets	*Sepia officinalis*	Feb. 99 – May 99 (fortnightly)
	Trawl	*Eledone moschata* *Eledone cirrhosa* *Loligo vulgaris* *Octopus vulgaris* *Sepia officinalis*	Oct. 99 – May 99 (fortnightly)
Cephalopod Stocks in European Waters: Review, Analysis, Assessment and Sustainable Management (CEPHSTOCK) (Concerted Action/ EU DG XII, Contract No: Q5CA-2002-00962)	Trammel nets Pots	*Sepia officinalis* *Octopus vulgaris* *Octopus vulgaris*	April 1998 - Dec. 2003 (daily)*
	Pots	*Octopus vulgaris*	Oct. 2003 – June 2005 (daily)*

* Data provided by the Fishermens' Cooperative "EVROS" of artisanal vessels operating in the eastern Thracian Sea.

inefficient (LEFKADITOU *et al.,* 1997).
Fyke nets, used for fishing octopus since 1982 on bottoms covered by sea grass, composed 6% of small-scale fishing gears recorded in the whole area but 56% of gears used around Thassos island (KALLIANIOTIS & KOUTRAKIS, 1999). PVC/plastic pots (Chapter III.4) targeting octopus on sandy or muddy bottoms since 1992 and traditional Sepia-trammel nets, contributed 90-98% of annual cephalopod quantities landed in the years 1998-2003 by the small-scale fishing vessels of the Fishermens' Cooperative "EVROS" operating in the eastern Thracian Sea (LEFKADITOU *et al.*, 2004). Various types of hand jigs targeting *O. vulgaris* and *L. vulgaris* were considered of minor importance since they are mainly used by sport-fishermen.

Analyses of LPUE monthly variation (Figure 4) have shown seasonal peaks related to pre-spawning and spawning aggregation of neritic species on trawl and inshore fishing grounds respectively, as it is observed for *L. vulgaris* during early autumn-winter, for *S. officinalis* during late winter – spring and for *O. vulgaris* during late spring-early summer. On the other hand, Landings per Unit Effort (LPUE) variation may also reflect local fishery legislation and the strategy of the fishing fleet, as indicated, for example, by the inverse trend of the two eledonid species LPUE in autumn 1998, which is decreasing for *E. cirrhosa* and increasing for the neritic *E. moschata* in November, when fishing grounds closer to the coast were opening for trawling activity. The evident decline of *L. vulgaris* LPUE from winter to early spring, for both trawl and beach-seine fisher-

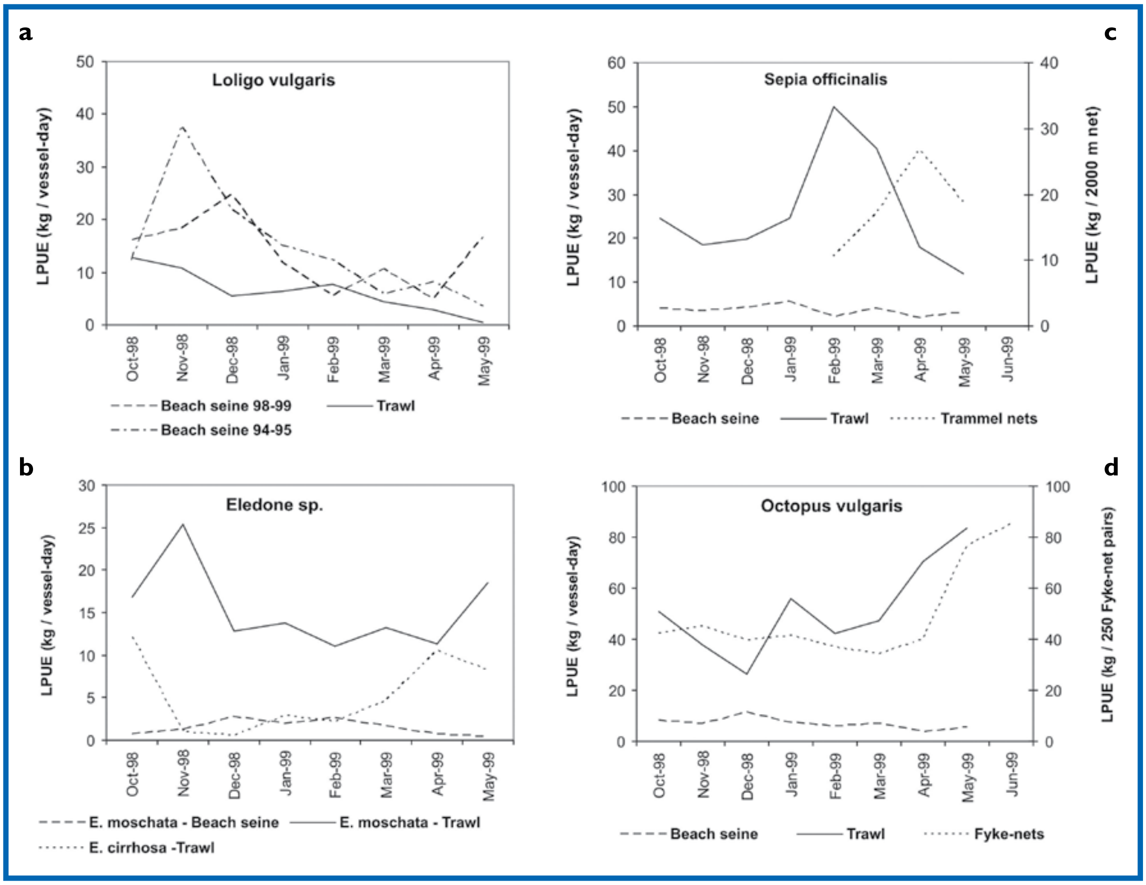

Figure 4: Monthly evolution of *L. vulgaris* (a), *E. moschata* & *E. cirrhosa* (b), *S. officinalis* (c) and *O. vulgaris* (d) LPUE by different fishing gears in the Thracian Sea.

ies, provided some scope for the use of depletion models to estimate population size (TSANGRIDIS *et al,* 1998). However, the fact that the period of decreasing LPUE coincides with the spawning period of *L. vulgaris* (Table I) has to be taken into account, which means that the effects of fishing are not easy to distinguish from the consequences of high post-spawning mortality.

Length composition analyses for the monthly catches of *O. vulgaris* and *S. officinalis* by the various types of fishing gears have shown that, in general, trawlers exploit smaller specimens which have not reached maturity, whereas, selective artisanal gears operating in the coastal zone of the Thracian Sea (fyke-nets, pots, Sepia-trammel-nets) affect spawners mainly (KALLIANIOTIS *et al*, 2001; BELCARI *et al*, 2002; TSANGRIDIS *et al*, 2002; ADAMIDOU & KALLIANIOTIS, 2005).

MODELLING TEMPORAL AND SPATIAL VARIATION OF CEPHALOPOD CATCHES

A few attempts were made to model temporal variation of cephalopod landings in relation to temperature variations (STERGIOU, 1987; GEORGAKARAKOS *et al.*, 2002, 2006) or to simplistic estimations of fishing effort in number of vessels or vessel's total horsepower (STERGIOU, 1989). During the pre-war period (1928-1939) of low fishing pressure, significant positive correlations of total cephalopod, squid, cuttlefish and octopod catches with the mean annual, February and March air temperature have been encountered, whereas squid and octopod catches were shown to be significantly correlated also with the 3-year running means of the mean December air temperature (STERGIOU 1987). GEORGAKARAKOS *et al.* (2002) have also found positive correlations of common squid landings with SST during February and March of 1988, 1993 and 1995 in the Thermaikos Gulf (NW Aegean Sea). The second period (September-October) with high cross-correlations between SST and landings of both common squid and flying squid, noted by GEORGAKARAKOS *et al.* (2002), should however, be reconsidered by taking into account the opening of trawl and beach-seine fisheries in October, since these fishing gears exploit the above-mentioned species

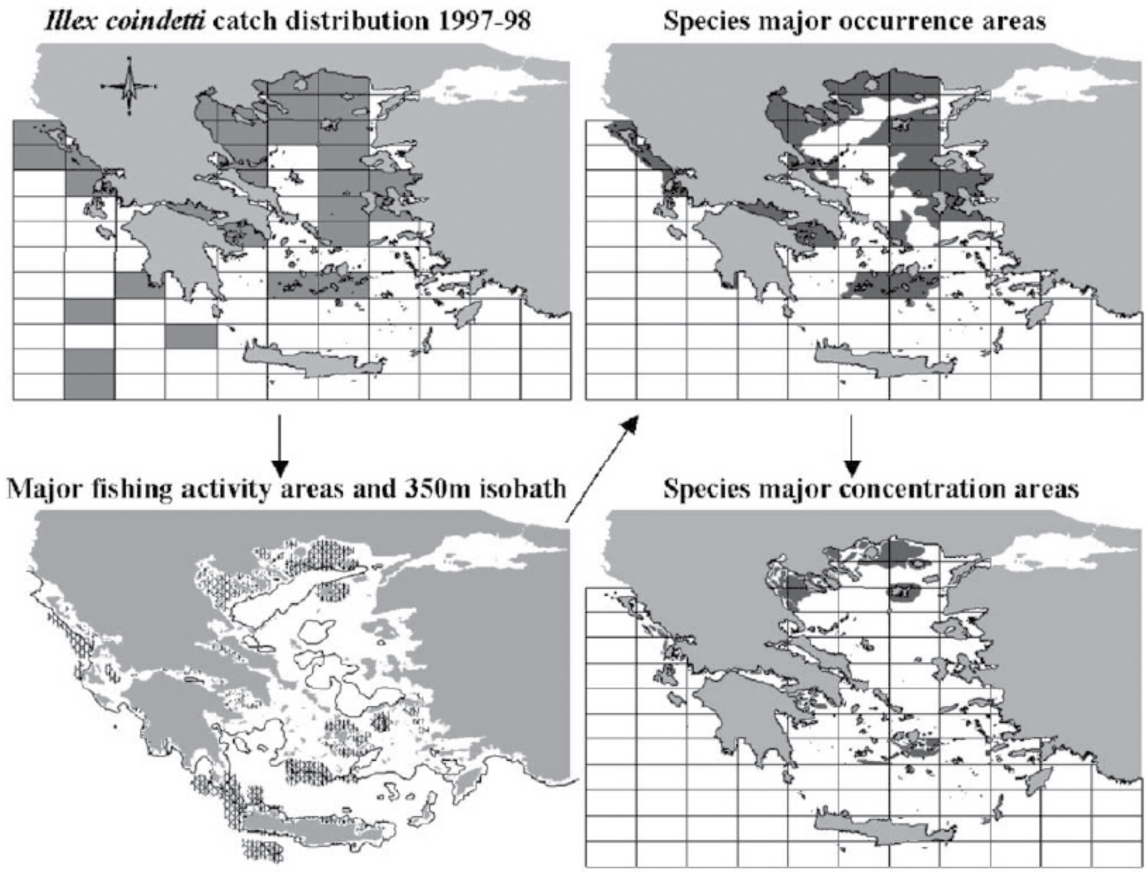

Figure 5: Spatial integrations among georeferenced fishery data for *Illex coindetii*, by the GIS tool: 'Marine Information System for Cephalopod Fisheries in the Greek Seas'. Catch distribution (top left) is integrated with bathymetry (bottom left) to reveal species major occurrence areas (top right), which in turn, is integrated with fishing fleet major activity areas (bottom left) to reveal species major concentration areas (bottom right). (Compiled from VALAVANIS *et al.,* 2004).

almost exclusively. STERGIOU (1989) analysing cephalopod catches during 1964-1981 suggested that fishing played rather the most important role in the decreasing trend of Catch per Unit Effort (CPUE), noting however, that the simplistic models used might overlook other important natural or economic reasons.

The use of more sophisticated models (Artificial Neural Networks and Bayesian Dynamic System Analysis) seemed to enable prediction of annual landings of the neritic common squid in the north Aegean Sea based on Sea Surface Temperature (SST) descriptors but not of those of the flying squids, which inhabit deeper waters where SST could not express adequately the environmental conditions (GEORGAKARAKOS *et al.*, 2006).

A GIS tool for mapping seasonal distribution patterns of commercially important cephalopod species (VALAVANIS *et al.*, 2002) has been developed by ex Institute of Marine Biology of Crete (IMBC), in the framework of the EU research projects CEPHVAR and CEPHSTOCK. The tool features a menu-driven user-interface and a comprehensive database of commonly geo-referenced biological and environmental datasets. The innovative aspect of this marine geographic system is the integration of species' life history data in GIS analysis (Figure 5). Species' preferences for certain spawning conditions, migration habits, and depth ranges are used as constraints in GIS analysis and integration. VALAVANIS *et al.* (2004) using catch and effort data collected per statistical rectangle of NPFDC along with SST and chlorophyll concentration (CHL) and Sea Surface Salinity distribution (SSS) in the Hellenic Seas, has found a significant overlap of monitored distribution of *Loligo vulgaris* and *Illex coindetii* CPUE with the spatial extent of marine productivity hotspots in the north Aegean, the Kyklades Plateau and the Ionian Sea fishing grounds.

Table 3. Relationships between common octopus body weight (W, g) and specific growth rate (SGR, $\%day^{-1}$), absolute growth rate (AGR, g day^{-1}), absolute feeding rate (AFR, g day^{-1}), feed efficiency (FE, %), protein retention efficiency (PRE, %), energy retention efficiency (ERE, %), oxygen consumption rate (R, mg h^{-1}) or ammonia excretion rate (U, μmol h^{-1}) at different temperatures (T) (compiled from KATSANEVAKIS *et al.*, 2005; MILIOU *et al.*, 2005)

T (°C)	Regression equation	n	R^2
15	LnSGR=-2.0342+0.3936lnW	16	0.89
20	LnSGR=1.5091-0.3106lnW	17	0.92
25	LnSGR=2.9832-0.5842lnW	17	0.98
15	LnAGR=-6.6206+1.3880lnW	16	0.99
20	LnAGR=-3.1116+0.6912lnW	17	0.98
25	LnAGR=-1.6626+0.4219lnW	17	0.95
15	LnAFR=-3.5493+0.9662lnW	16	0.97
20	LnAFR=-3.0741+0.8955lnW	17	0.97
25	LnAFR=-3.2478+0.9229lnW	17	0.98
15	LnFE=1.3911+0.4618lnW	16	0.90
20	LnFE=4.6212-0.2020lnW	17	0.58
25	LnFE=6.1824-0.4897lnW	17	0.94
15	LnPRE=1.4248+0.4622lnW	16	0.89
20	LnPRE=4.6789-0.2051lnW	17	0.58
25	LnPRE=6.1936-0.4837lnW	17	0.93
15	LnERE=1.2986+0.4638lnW	16	0.89
20	LnERE=4.5462-0.2028lnW	17	0.57
25	LnERE=5.9837-0.4673lnW	17	0.93
13	LnR=-2.66+0.893lnW	9	0.97
15.5	LnR=-2.33+0.907lnW	20	0.91
20	LnR=-1.99+0.951lnW	22	0.96
25	LnR=-1.53+0.886lnW	27	0.97
26	LnR=-1.18+0.858lnW	18	0.95
28	LnR=-0.92+0.829lnW	12	0.96
15.5	LnU=-1.87+1.177lnW	9	0.95
20	LnU=-0.16+0.937lnW	19	0.92
25	LnU=0.27+0.877lnW	26	0.91
26	LnU=1.16+0.768lnW	14	0.88

LABORATORY STUDIES ON SPECIES PRESENTING AQUACULTURE POTENTIAL

Octopus vulgaris, a commercial cephalopod species that is easy to rear under captivity conditions, at least from the benthic juvenile stage to the adult stage, has been identified as an important potential candidate for mariculture, due to its rapid growth and high food conversion. Experiments with common octopus rearing have been conducted at the Department of Zoology-Marine Biology of the University of Athens since 2000. Combined effects of temperature (T) and body mass (M) on octopus growth, feed efficiency, metabolic rates, biochemical composition and protein retention efficiency were studied (Table 3), whereas, experiments related to the reproduction, hatching and paralarvae rearing of octopus have been also carried out (TZITZINAKIS *et al.,* 2001).

Specific growth rates (SGR) estimated for *O. vulgaris* (114 - 662 g) feeding on anchovy at a constant temperature of 20 °C ranged from 0.43 to 0.95 $\%day^{-1}$ and were similar to those reported for other high-lipid diets (bogue, sardine) and lower than SGR values found for low-lipid, high-protein diets (squid, crab) (PETZA *et al.*, 2006) The estimated assimilation efficiency (AE) values (80.9-90.7%) were lower than the AE values estimated for other cephalopod species with different diets of lower lipid content such as crabs or mussels. The atomic oxygen-to nitrogen (O/N) ratio values found were low (5.5 – 15.6), indicating a protein-dominated metabolism for *O. vulgaris*, with no significant dependence on body mass or temperature in the range of 15.5-26 °C (KATSANEVAKIS *et al.* 2005a, PETZA *et al.* 2006). However, O/N value depends on the type of food and different O/N ratios might arise under different feeding conditions (KATSANEVAKIS *et al*., 2005a).

The energetic cost of octopus feeding was not found to differ for temperatures examined (20-28°C) and the SDA (Specific Dynamic Action, reflecting the energy requirements of the behavioural, physiological and biochemical processes that constitute feeding) response was proved to be relatively fast in relation to the response in other temperate species, indicating the ability of the species to digest and assimilate food rapidly and efficiently (KATSANEVAKIS *et al*., 2005b).

The temperature for maximum growth rate and feed efficiency decreased with increasing octopus size. Furthermore, proximate composition and the protein/energy ratio were not affected by temperature or body weight, whereas, protein utilization was more efficient at maximum growth rate temperature; in smaller (50-150 g) individuals protein retention was better at 25 °C, while in larger ones (200-600g) at 15 °C (MILIOU *et al*., 2005). Fatty acid composition of *O. vulgaris* was influenced by temperature and body weight, but with an n-3/n-6 ratio of more than 3 and a docosahexaenoic/eicosapentaenoic (DHA/EPA) ratio of more than 1.5. Thus to optimise the economic viability of rearing, temperature should be adjusted according to the body weight of octopus, being higher for small individuals and gradually reduced for larger animals (MILIOU *et al*., 2005; 2006). *O. vulgaris* has been also shown as an excellent potential source of arachidonic acid, containing sufficient n-3 Highly Unsaturated Fatty Acids (HUFA) levels in warm temperatures for small individuals and in low temperatures for large ones, i.e. at temperatures that promote growth in relation to the body weight of octopuses (MILIOU *et al*., 2006).

GAPS IN KNOWLEDGE-PRIORITIES FOR FUTURE RESEARCH

Despite the importance of Cephalopods for Hellenic fisheries, there are still major gaps in the biological knowledge of even the commonest and most widespread species (Table I). Moreover, due to the general characteristics of their life cycle, i.e. the short life-span, the plastic growth of neritic species in particular, the extended periods of spawning and recruitment, the rapid generation turnover and the weak stock-recruitment relationships, Cephalopods dynamics is inherently difficult to model.

Growth parameters and their spatio-temporal variation in the Hellenic Seas, should be estimated for all commercially important cephalopod species, presupposing the development of direct ageing techniques for cuttlefishes and octopods. The use of indirect methods not based on the Von-Bertalanfy equation for the estimation of growth parameters could be an alternative for some cephalopod species, provided that monthly or even better fortnightly sampling of size composition of the population including early life stages could be ensured. Tagging experiments, as well as, targeted sampling of cephalopod paralarvae should be attempted also, as a complementary approach to understand cephalopod species dynamics.

Regarding the use of recorded cephalopod landings for monitoring cephalopod fisheries and resource assessment, species recorded under the same common name should be distinguished in fisheries' statistics, at least in case where the component species are exploited in important quantities and can be easily identified, as in the case of the 2 eledonid species. A further distinction is also necessary in the category of the artisanal fishing gears and particularly the consideration of the specified fishing methods targeting cuttlefish and common octopus as separate "métiers" during routine fisheries' data collection, in order to quantify their contribution, given that they have been shown to contribute the major part of the targeting species catches in the NE Aegean Sea and they are expected to expand more due to the increasing market demand for these species and the heavy exploitation of coastal fish resources. In order to produce a framework for implementation of management measures for cephalopod resources, a long-term monitoring of the traditional and the newly developed small-scale fisheries targeting Cephalopods, as well as, of trawl fisheries is required. Pilot monitoring of Cephalopod fisheries is proposed to be established according to priority in the Thracian Sea and the Thermaikos Gulf (North Aegean Sea), where more intensive exploitation of Cephalopods does occur.

The GIS tools and the advanced modelling methodology seem to be promising for the study of the spatio-temporal variations in the catches of cephalopod species that are sensitive under certain environmental conditions demonstrating, however, the need for integrated monitoring of fishing effort directed to Cephalopods and of marine environment changes, as well as for a thorough knowledge of target species' life history. Further development of GIS tools enabling the mapping of meso-scale thermal fronts and fine-scale environmental variability in particular, will greatly enhance the spatial component of cephalopod fisheries' assessment and management.

Concerning the potential of octopus aquaculture, although considerable progress has been made recently, in order to be considered self-sustainable further investigation on the development of suitable artificial feeds, as well as on eco-physiological and nutritional requirements of paralarvae, which are still impossible to rear at successful survival rates, is needed.

REFERENCES

ADAMIDOU, A. & KALLIANIOTIS, A., 2005. Monthly distribution and comparison of length frequencies of *Penaeus (Melicertus) kerathurus* and *Sepia officinalis* in the catches from open sera and artisanal fisheries in the Thracian Sea. *Proceedings of 12th National Congress of Ichthyologists. Drama 13-16 October 2005*, pp. 44-47 (in Hellenic, abstract in English).

ANONYMOUS, 2000. Analysis and evaluation of the fisheries of the most commercially important cephalopod species in the Mediterranean sea. *Final Report (Contract No: 97/0054).*

ANONYMOUS, 2005. Cephalopod Stocks in European Waters: Review, Analysis, Assessment and Sustainable Management (CEPHSTOCK). *Final Report (Contract No: Q5CA-2002-00962).*

ARVANITIDIS, C., KOUTSOUBAS, D., PANAGIOTAKIS, G., BARBOUNI, M., KAPATAGAKIS, A., DOUNAS, C. & VALAVANIS, V., 2001. Biological parameters of the Cephalopod species *Illex coindetii* Vérany, 1839 and *Sepia officinalis* Linnaeus, 1758, from the Cretan Sea (October 2000 – May 2001). *Proceedings of 10th National Congress of Ichthyologists, Chania 18-20 October 2001*, pp. 5-8. (in Hellenic, abstract in English).

ARVANITIDIS, C., KOUTSOUBAS, D., ROBIN, J.-P., PEREIRA, J., MORENO, A., CUNHA, M.M., VALAVANIS, V. & ELEFTHERIOU, A., 2002. A comparison of the fishery biology of three *Illex coindetii* (Vérany 1839) (Cephalopoda: Ommastrephidae) populations from the European Atlantic and Mediterranean waters. *Bulletin of Marine Science*, 71 (1): 129-146.

BELCARI, P., SARTOR, P., SANCHEZ, P., DEMESTRE, M., TSANGRIDIS, A., LEONDARAKIS, P., LEFKADITOU, E. & PAPACONSTANTINOU, C., 2002. Exploitation patterns of the cuttlefish, *Sepia officinalis* (Sepioidea: Sepiidae), in the Mediterranean Sea. *Bulletin of Marine Science*, 71: 187-196.

GEORGAKARAKOS, S., HARALABOUS, J., VALAVANIS, V., ARVANITIDIS, CH., KOUTSOUBAS D. & KAPANTAGAKIS, A., 2002. Loliginid and ommastrephid stock prediction in Greek waters using time series analysis techniques. *Bulletin of Marine Science*, 71: 867-882.

GEORGAKARAKOS, S., KOUTSOUBAS, D., & VALAVANIS, V., 2006. Time series analysis and forecasting techniques applied on loliginid and ommastrephid landings in Greek waters. *Fisheries Research*, 78(1): 55-71.

KALLIANIOTIS, A. & KOUTRAKIS, E., 1999. Structure of coastal fisheries in the Thracian Sea. Meeting of the Geotechnical Chamber of Greece - Branch of Thrace on "Fish stock management in the Thracian Sea", May 1999, *Proceedings volume*: 4-12 (in Hellenic).

KALLIANIOTIS, A., VIDORIS, P. & KOKKINAKIS, A., 2001. Common octopus (*Octopus vulgaris*, Cuvier, 1797) coastal fishery, during the peak of species reproduction. *Rapports Commision International Mer Méditerranée*, 36: 279.

KATSANEVAKIS, S., 2004. *Ecology of Octopus vulgaris. PhD Thesis*, National and Kapodistrian University of Athens, 100 pp (in Hellenic, abstract in English).

KATSANEVAKIS, S. & VERRIOPOULOS, G., 2004. Abundance of *Octopus vulgaris* on soft sediment. *Scientia Marina*, 68 (4): 553-560.

KATSANEVAKIS, S., STEPHANOPOULOU, S., MILIOU, H., MORAITOU-APOSTOLOPOULOU, M. & VERRIOPOULOS, G., 2005a. Oxygen consumption and ammonia excretion of *Octopus vulgaris* Cuvier (Cephalopoda) in relation to body mass and temperature. *Marine Biology*, 146: 725-732.

KATSANEVAKIS, S., PROTOPAPAS, N., MILIOU, H. & VERRIOPOULOS, G., 2005b. Effects of temperature on specific action in the common octopus *Octopus vulgaris* (Cephalopoda). *Marine Biology*, 146: 733-738.

KATSANEVAKIS, S. & VERRIOPOULOS, G., 2006a. Modelling the effect of temperature on hatching and settlement patterns of meroplanktonic organisms: the case of octopus. *Scientia Marina*.

KATSANEVAKIS, S. & VERRIOPOULOS, G., 2006b. Seasonal population dynamics of *Octopus vulgaris* in eastern Mediterranean. *ICES Journal of Marine Science,* 63: 151-160.

KOUKOURAS, A., CHARTOSIA, N., VAFIDIS, D., KOUTSOUBAS, D. & LYTRA, E., 2001. Observations on cephalopod feeding habits in the Aegean Sea. 23th Panhellenic Conference of Hellenic Society for Biological Sciences, Chios, May 2001, Book of Abstracts, pp: 85 (in Hellenic).

LEFKADITOU, E., 2006. *Taxonomy and biology of Cephalopods in the North Aegean Sea. PhD Thesis*, University of Patras, 298 pp + Annexes (in Hellenic, abstrtact in English).

LEFKADITOU, E. & PAPACONSTANTINOU, C., 1995. Distribution, growth and maturity of *Eledone cirrhosa* (Cephalopoda: Octopoda) in the Thracian Sea (Eastern Mediterranean). *Rapports Commision International Mer Méditerranée*, 34: 247.

LEFKADITOU, E. & PAPACONSTANTINOU, C., 1999. Cephalopod distribution and fisheries in the Thracian Sea. Meeting of the Geotechnical Chamber of Greece - Branch of Thrace on "Fish stock management in the Thracian Sea", May 1999, Proceedings volume: 15-32.

LEFKADITOU, E. & ADAMIDOU, A., 1997. Beach-Seine Fisheries in the Thracian Sea. Preliminary results. *Proceedings of the 5th Panhellenic Symposium of Oceanography and Fisheries,* Kavala, Greece, 1997- Vol. II : 21-24 (in Hellenic, abstract in English).

LEFKADITOU, E., ADAMIDOU, A., TSANGRIDIS, A. & SANCHEZ, P., 1997. Examination of the effectiveness of an experimental jigging gear and the fishing gears in use, for the exploitation of the squid *Loligo vulgaris*. *Proceedings of the 8th Panhellenic Ichthyological Congress*, Thessaloniki, September 1997, Doc.07: 7pp (in Hellenic, abstract in English).

LEFKADITOU, E., SANCHEZ, P., TSANGRIDIS, A. & ADAMIDOU, A., 1998. A preliminary investigation on how meteorological changes may affect beach-seine catches of *Loligo vulgaris* in the Thracian Sea (Eastern Mediterranean). *South African Journal of Marine Science*, 20 : 453-461.

LEFKADITOU, E., PAPACONSTANTINOU, C., TSANGRIDIS, A. & LEONDARAKIS, P., 2001. Contribution of Cephalopods to the artisanal and trawl fisheries in the Thracian Sea. *Proceedings of the 10th Panhellenic Ichthyological Congress,* Chania, Greece, October 18-20, pp. 45-48 (in Hellenic, abstract in English).

LEFKADITOU, E., KAVADAS, S. & PAPACONSTANTINOU, C., 2002. Cephalopod fisheries statistics in Greek waters (NE Mediterranean). *ICES Living Resources Committee, ICES CM 1999*/G: 4, Working Group on Cephalopod Fisheries and Life History, Lisbon, Portugal, 4-6 December 2002, 6pp.

LEFKADITOU, E., HARALABOUS, J., SARIKAS, D., KARAMELIDOU, S. & KAVADAS, S., 2004. The Cephalopods in the small-scale fishery in the eastern Thracian Sea (NE Mediterranean). *ICES CM 2004*/ CC: 19, 12pp.

MILIOU, H., FINTIKAKI, M., KOUNTOURIS, T. & VERRIOPOULOS, G., 2005. Combined effects of temperature and body weight on growth and protein utilization of the common octopus, *Octopus vulgaris*. *Aquaculture,* 249 (1-4): 245-256.

MILIOU, H., FINTIKAKI, M., TZITZINAKIS, M. & VERRIOPOULOS, G., 2006. Fatty acid of the common *Octopus vulgaris*, in relation to temperature and body weight. *Aquaculture*, 256: 311-322.

MORENO, A., PEREIRA, J., ARVANITIDIS, C., ROBIN, J.-P., KOUTSOUBAS, D., PERALES-RAYA, C., CUNHA, M.M., BALGUERIAS, E. & DENIS, V., 2002. Biological variation of *Loligo vulgaris* (Cephalopoda: Loliginidae) in the eastern Atlantic and Mediterranean. *Bulletin of Marine Science*, 71(1): 515-534.

PAPACONSTANTINOU, C., CARAGITSOU, E., VASSILOPOULOU, V., PETRAKIS, G., MYTILINEOU, CH., FOURTOUNI, A., TURSI, A., POLITOU, C-Y, GIAGNISI, M., D' ONGHIA, G., SIAPATIS, A., MATARRESE, A., ECONOMOU, A. & PAPAGEORGIOU, E., 1993. Investigation of the abundance and distribution of the demersal stocks of primary importance to the Greek fishery in the North Aegean Sea. *Final Report*, 342pp.

PAPACONSTANTINOU, C., POLITOU, C-Y, CARAGITSOU, E., STERGIOU, K., MYTILINEOU, CH., VASSILOPOULOU, V., FOURTOUNI, A., KARKANI, M., KAVADAS, S., PETRAKIS, G., SIAPATIS, A., LEFKADITOU, E., CHATZINIKOLAOU, P. & GIAGNISI, M., 1994. Stock assessment of the demersal populations with commercial importance in the Thermaikos Gulf and the Thracian Sea. *NCMR Final Report*, 356 pp. (in Hellenic).

PAPACONSTANTINOU , C., PETRAKIS, G., KARAGITSOU, E., LABROPOULOU, M., KARKANI, M., VASILOPOULOU, V., MYTILINEOU, CH., LEFKADITOU, E., SIAPATIS, A., KAVVADAS, S., CHATZINIKOLAOU, P., ANASTASOPOULOU, C., KAPIRIS C., TERRATS, A., DOGRAMMATZI, C., BEKAS, P., CHRISTIDIS ,G. & FOURTOUNI, A., 1998. Greek Fisheries Development. Assessement of demersal fish stocks commercially important at the Southern Aegean Sea. *Final Report of NCMR*, 301 pp. (in Hellenic).

PETZA, D., KATSANEVAKIS, S. & VERRIOPOULOS, G., 2006. Experimental evaluation of the energy balance in *Octopus vulgaris*, fed *ad libitum* on a high-lipid diet. *Marine Biology,* 148: 827-832.

STERGIOU, K.I., 1987. Cephalopod abundance in Greek waters in relation to environmental fluctuations. *Biologia Gallo-Hellenica*, 13: 25-34.

STERGIOU, K.I., 1989. Assessment of the state and management of the cephalopod trawl fisheries resources in Greek waters. *Toxicological and environmental Chemistry*, 20/21: 233-239.

TSANGRIDIS, A., LEFKADITOU, E. & ADAMIDOU, A., 1998. Analysis of catch and effort data of *Loligo vulgaris* in the W. Thracian Sea (NE Mediterranean, Greece) using a depletion model. *Rapports Commision International Mer Méditerranée*, 35: 494-495.

TSANGRIDIS, A., SÁNCHEZ, P. & IOANNIDOU, D., 2002. Exploitation patterns of *Octopus vulgaris* in two Mediterranean areas. *Scientia Marina*, 66:59-68.

TZITZINAKIS, M., KATSANEVAKIS, S. & VERRIOPOULOS, G., 2001. Research findings on the reproduction of the common octopus (*Octopus vulgaris*) in laboratory conditions. *Proceedings of 10th National Congress of Ichthyologists*. Chania 18-20 October 2001, pp. 145-148. (in Hellenic, abstract in English).

VALAVANIS, V. D., GEORGAKARAKOS, S., KOUTSOUBAS, D., ARVANITIDIS, CH. & HARALABOUS, J., 2002. Development of a marine information system for cephalopod fisheries in Eastern Mediterranean. *Bulletin of Marine Science*, 71: 867-882.

VALAVANIS, V.D., GEORGAKARAKOS, S., KAPANTAGAKIS, A., PALIALEXIS, A. & KATARA, I., 2004. A GIS Environmental Modelling Approach to Essential Fish Habitat Designation. *Ecological Modelling,* 178 (3-4): 417-427.