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Recent findings of *Ommastrephes bartramii* (Cephalopoda: Ommastrephidae) in the eastern Mediterranean and the implication on its range expansion

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Abstract

The neon flying squid Ommastrephes bartramii is found circumglobally in subtropical, temperate waters and sustains important fisheries in the North Pacific, but it is rarely encountered in the Mediterranean Sea. During the last decade, and particularly since 2004, the frequency of its presence in the Aegean Sea and nearby regions has increased, raising a question about a change in the species distribution and abundance in this area. In this study, we reviewed the literature on O. bartramii findings in the Mediterranean Sea and present new data describing body and beak morphometry, diet and the maturity of specimens recently collected from the easternmost basins. According to data from the entire Mediterranean Sea, collected individuals reached 66 cm in mantle length (ML), wherein only females were larger than 32 cm in ML. An isometric growth in body weight (BW) was shown, whereas the growth of the lower beak rostral length (LRL) was allometrically positive in relation to the ML. Occasional catches by jigs during experimental cruises provided most of the individuals recorded in the period from 1982-1992. In contrast, the most recent records are primarily comprised of mature females collected on or near the shore in the eastern basin and of predominantly smaller individuals from the western basin caught by professional jigging fisheries. The distribution of the specimen recorded from the Aegean Sea indicates an association between the species distribution and the circulation of the warm Levantine Intermediate Water. The more frequent observations of moribund spawning females at the periphery of the Cretan Sea are indicative of a spawning ground at this area. The suspected recent increase of O. bartramii abundance in both the northeastern and northwestern basins might be due to the warming of upper sea layers, which has been observed since the mid-1980s and is considered to be the main factor driving the northward expansion of the warm-water species' range within the Mediterranean Sea.

Keywords: Cephalopods; *Ommastrephes bartramii;* Distribution; Mediterranean Sea; Spawning grounds; Climatic effect.

Introduction

The neon flying squid Ommastrephes bartramii Lesueur 1821 has been recognised as a unique species of the genus Ommastrephes after a series of investigations, which confirmed the proposals of PFEFFER (1912) and CLARKE (1966) who stated that O. bartramii and O. caroli represented respectively younger and older individuals of the same species (ZUEV et al., 1975). According to the latest revision of the distinct characteristics of the six genera in the Ommastrephinae subfamily by YOUNG & VECCHIONE (2008, in ROPER et al., 2010), Ommastrephes is the only among them that lacks large subcutaneous or visceral photophores.

Ommastrephes bartramii is a true oceanic species that is typically encountered throughout all ontogenetic stages at the surface, subsurface and bathypelagic layers up to 1500 m in the high seas and is generally avoiding areas with a bottom depth less than 200 m and seamounts (ROPER *et al.* 2010).

This species is widely distributed in the subtropical and temperate zones of worldwide oceans, predominantly residing at sea surface temperatures between 10° and 25°C (ROPER et al., 2010). The highest population densities associated with the warm Kuroshio current have been encountered in the northwestern Pacific Ocean, where the species has been targeted by international jigging and driftnet fisheries, the latter of which has ceased activities since the end of 1992 (BOWER & ICHII, 2005). In the Atlantic Ocean, the foraging O. bartramii are concentrated seawards from the subtropical anticyclonic gyres and into the waters of the North Atlantic Current and the Mediterranean Sea (ZUEV et al., 1976). The species has been more abundant in the southeastern part, up to 19° N of the North Atlantic Ocean, where seasonal changes in its distribution correlated with seasonal changes in the 22-23°C surface layer temperatures (ZUEV & NIGMATULIN, 1977). Best exploratory jigging yields in the south-western Atlantic were also correlated with surface temperatures of 22-24°C (BRUNETTI & IVANOVIC, 2004). The results of exploratory surveys performed in various regions of the Atlantic Ocean revealed that *O. bartramii* may be a potential candidate for a directed jigging fishery, concomitant with further research to understand the species ecology (LETA, 1989; VECCHIONE & GAL-BRAITH, 2001; BRUNETTI & IVANOVIC, 2004).

Similar to most cephalopod species in the Mediterranean Sea. O. bartramii is considered to be a temperate, subtropical species that entered from the Eastern Atlantic after the Messinian salinity crisis and the opening of the Strait of Gibraltar 5.33 million years ago (MANGOLD & BOLETZKY, 1988, NESIS 2003). From a review of data collected during Russian research cruises in the Atlantic Ocean and the Mediterranean from 1952-1974, as well as data from published literature between 1835 and 1973, ZUEV et al. (1976) concluded that this squid is common in the Mediterranean and in the Aegean Sea on the Peloponnesus meridian. BELCARI (1999), from a review of the O. bartramii records in Italian waters from 1977 to 1990, noted that the squid is rarely caught in small numbers, yet it is practically absent from the fish markets. More recently, POTOSCHI & LONGO (2009) reported that, though infrequently, O. bartramii is captured by jigs targeting Todarodes sagittatus off the Aeolian islands in the southern Tyrrhenian Sea.

This paper aimed to review all available data on *O. bartramii* specimens from the Mediterranean Sea, including new data on body and beak morphometry, diet and the maturity of specimens recently collected from the eastern Mediterranean. The mantle length (ML)–body weight (BW) and lower beak rostral length (LRL)-mantle length (ML) regression equations, based on available data from the Mediterranean Sea, are provided. Finally, the temporal range of the species distribution in this area is discussed in relation to the circulation of the water masses and the recent changes in oceanographic regimes due to climate effects.

Materials and Methods

Since 2003, nineteen *O. bartramii* specimens have been recorded in the Aegean Sea and adjacent regions (Fig. 1, Table I). Five were brought to the laboratories at the Hellenic Centre for Marine Research in Crete and Athens, the Biology Department of the University in Thessaloniki or the Department of Hydrobiology of the Ege University in Ismir. Basic measurements, characteristic appendices (beaks, sucker rings) and photographs of the remaining specimens were taken and examined by direct observers at the original location.

The species identification and its distinction from the most abundant large Ommastrephid in the Mediterranean, *Todarodes sagittatus*, was based primarily on the following characteristics:

- The length of the *Ommastrephes bartramii* tentacular club is shorter than that of the *Todarodes sagittatus*, which extends almost up to the base of the tentacles; this characteristic is easily visible, even in photographs.
- The fixing apparatus at the carpus of the tentacular club, on which 4 to 6 small suckers are located proximal to the first smooth knob (Fig. 2a)
- The presence of side pockets by the funnel pit (Fig. 2b).
- The dentition in the rings of larger manus

suckers in the tentacular clubs, where the teeth are enlarged in each quadrant (Fig. 2c).

• A more prominent ridge on the internal side of the upper beak in *O. bartramii* than in *Todarodes sagittatus* (Fig. 2d).

All of the specimens examined in the laboratory were in good condition. They were measured and dissected while they were still fresh or soon after being defrosted, except for the specimen stranded in Chalkidiki, for which more detailed morphometric measurements were taken after its fixation in a formalin solution.

Dorsal mantle length (DML), total length (TL), mantle circumference (MC), fin length (FL), fin width (FW), head length (HL), arm length (AL-x), tentacle length (TL-x) and tentacle club length (TCL-x) were measured to the nearest millimetre, whereas body weight (BW) was approximated to 10 g.

The standard dimensions of the beaks according to CLARKE (1962) (rostral length: RL, hood length: HL, crest length: CL, wing length: WL, distance between jaw angles: JAd of both upper: U and lower: L mandibles, amplitude of the lateral wall: LWa in the upper beak and length of base line: BL in the lower beak), as well as the sucker diameters (maximum arm sucker diameter: ASDmax, maximum tentacle sucker diameter: TCSDmax) were measured to the nearest 0.1 mm using callipers.

In addition, information on the gonad maturity, mating signs and stomach content were recorded.

For reviewing the species records in the Mediterranean Sea, the synonyms for *Ommastrephes bartramii*, including *Ommastrephes caroli* and *Stenoteuthis bartramii*, were also considered. The records are listed in chronological order, displaying information about the date/year, location and method of collection, along with data for the mantle

									- 1
Record	Date / Year	Loootion		Number of	Siz	ie ie	0,000	Defense	
No	of finding	Location	Collection way	specimens	ML (mm)	BW (g)	Sex	kelerence	
1	< 1905	Gulf of Lions	stranded	1				Lozano-Rey, 1905	
		(Banyuls-Sur-Mer)							
5	24/3/1910	NE Adriatic Sea		1	165			Gamulin-Brida and	
		(off Vodice)						Ilijanić, 1965	
ю	10/1/1967	Gulf of Taranto	fished at 70-100m	1	108			Torchio, 1967	
		(off Galipoli)							
4	6/2/1967	Gulf of Taranto	stranded	1	540	~ 6000		Torchio, 1967	
		(Porto Cesareo)							
5	1/3/1982	N. Tyrrhenian Sea	purse-seine at 70m	1	009	10900		Biagi, 1990	
		(off Capraia Isl.)							
9	March 1986	NW Adriatic Sea	pelagic trawl	1	560		Ц	Guescini and	
		(off Falconara)						Manfrin,1986	
7	April 1988	S. Tyrrhenian Sea	drifting pelagic net	1	613	9412	Ĺ	Ragonese and Jereb, 1990	
		(off Ustica Isl.)							
8	summer 1989	S. Tyrrhenian Sea	trammel net	1	137	185		Ragonese et al., 1992	
6	1988-1993	Ligurian Sea	Isaac Kid Midwater	1				Orsi-Relini et al., 1994	
			Trawl						
10	14/8/1989	Ligurian Sea	jigging	5	110-175			Orsi-Relini, 1990	
		(43°49' N, 9°07' E)							
11	9/12/1989	Ligurian Sea	jigging	ю	195-213		Σ	Orsi-Relini, 1990	
		(43°43' N, 9°09' E)							
12	9/12/1989	Ligurian Sea	jigging	1	255		Ĺ	Orsi-Relini, 1990	
		(43°43' N, 9°09' E)							

Table 1Records of Ommastrephes bartramii in the Mediterranean Sea.

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D.£	Kelerence	Orsi-Relini, 1990		Ragonese et al., 1992	Ragonese et al., 1992	Katağan <i>et al.</i> , 1992		Akyol and Sen, 2004																	
2	Xac	ц		Ĺ	Ц	ĹŢ		ſц		Ĺ		ſц		М		Ĺ		ĹŢ		ĹŢ		ĹŢ		Ĺ	
ze	BW (g)	5		7540	5260	8500		56		300-500		550-600		1050		1680		710		130		510-700		0029	
Si	ML (mm)	27		597	525	560		157		210-260		275		320		370		268		160		195-260		550	
Number of	specimens	1		1	1	1		1		9		2		1		1		1		1		3		1	
	сопесноп мау	jigging		drifting pelagic net	jigging	jigging		floating near shore																	
T	Location	Ligurian Sea	(44°08' N, 9°07' E)	S. Tyrrhenian Sea	S. Tyrrhenian Sea	SE Aegean Sea	(36°10' N, 26°01' E)	SE Aegean Sea	(36°46' N, 26°32' E)	SE Aegean Sea	(35°54' N, 26°32' E)	NW Levantine Sea	(36°46' N, 28°01' E)	NW Levantine Sea	(36°46' N, 28°01' E)	NW Levantine Sea	(36°39' N, 28°45' E)	NW Levantine Sea	(36°39' N, 28°45' E)	SE Aegean Sea	(36°46' N, 26°32' E)	NW Levantine Sea	(36°39' N, 28°45' E)	NE Aegean Sea	(Ismir Bay)
Date / Year	of finding	5/2/1990		11/3/1990	17 /3/1990	17/5/1990		18/9/1990		19/9/1990		19/9/1990		19/9/1990		11/12/1990		9/3/1991		10/12/1991		11/12/1991		20/11/2002	
Record	No	13		14	15	16		17		18		19		20		21		22		23		24		25	

(continued)

	Table 1 (Conti	inued)				
5	Collootion way	Number of	Siz	se	Cov	
	COLLECTION WAY	specimens	ML (mm)	BW (g)	VOC	
ı Sea	jigging	91	135-285			
antine Sea off Cvprus)	jigging	1	165	159		
ikos Gulf	stranded		608	7200	ſı	

te / Yea	5	T anation	Collootion wow	Number of	Siz	ie ie	Cov	Dofononoo
finding Location	LUCALIUI		сопесноп мау	specimens	ML (mm)	BW (g)	Yac	
t. 2002, Ligurian S	Ligurian S	Ìea	jigging	91	135-285			Relini and Garibaldi, 2005
pt. 2003								
/10/2003 NE Leval	NE Levai	ntine Sea	jigging	1	165	159		present report
(north of	(north of	f Cyprus)						
/3/2004 Thermaik	Thermaik	tos Gulf	stranded	1	608	7200	Ц	Vafidis et al., 2008
(N. Potid	(N. Potid	ca)						
rch 2004 NE Aege	NE Aege	an Sea	floating near shore	1	660	~ 9000	Ĺ	present report
(north of	(north of	Tenedos Isl.)						
oril 2004 Eastern A	Eastern A	vegean Sea	floating near shore	1	610	~ 10000	Ĺ	present report
(İzmir Ba	(İzmir Ba	y, off Karaburun)						
ne 2004 SE Aeges	SE Aegea	ın Sea	floating near shore	1	520	~ 7000	Ц	present report
(Kusadas	(Kusadas	i bay)						
/2/2005 SE Aege:	SE Aege	un Sea		1		8000		present report
(off Bodr	(off Bodr	um)						
ay 2006 Thyrrenia	Thyrrenia	n Sea	trawl	1	562	6269	Ĺ	Cuccu et al., 2009
(39°05' N	(39°05' N	, 9°18'E)						
//9/2006 Gulf of T	Gulf of T	aranto	dip-net	4	150-230			Bello, 2007
/3/2007 SE Aege:	SE Aege:	an Sea	stranded	1	552	5900	Ц	present report
(Crete Is	(Crete Is	l., Karteros)						
)/2007- S. Tyrrhe	S. Tyrrhe	enian Sea	jigging	379				Potoschi and Longo, 2009
2 2008 (off Aeo	(off Aeo	lian islands)						
/1/2008 SW Aege	SW Aege	ean Sea	hake long-line at 550-620 m					present report
(Myrtoar	(Myrtoar	ı Sea)						

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Table 1

j. j. d	Kelerence	present report		present report		present report		present report		present report		present report		present report		present report		present report		present report		present report	
U st	Nac					Ц		Ч				Ц											
se	BW (g)	7000		4200								5830						8100				~ 12000	
Siz	ML (mm)					533		580		470		535											
Number of	specimens	1		1		1		1		1		1		1		1		1		1		1	
Caller 24 and 200	Collection way	floating near shore		floating near shore		stranded		floating near shore		swordfish drifting	long-line	stranded		floating near shore		drifting near shore				trawl		sport fishery	
T	госацон	SW Aegean Sea	(off Apollonia Milos Isl.)	SW Aegean Sea	(off Chania, Crete Isl.)	SE Aegean Sea	(off Amoydara, Crete Isl.)	SE Aegean Sea	(Crete Isl., Karteros)	NW Levantine Sea	(off Kastelorizo Isl.)	SE Ionian Sea	(Spiatza, Peloponnesos)	SE Aegean Sea	(off Goyrnes, Crete Isl.)	Argolikos Gulf	(Karathonas bay)	SW Aegean Sea	(off Chania, Crete Isl.)	NW Aegean Sea	(off Skyros Isl.)	SE Mediterranean	(off Ierapetra, south Crete Isl.)
Date / Year	of finding	14/1/2008		15/1/2008		4/3/2008		2/6/2008		8/4/2008		2/3/2009		17/3/2009		12/1/2010		9/3/2010		11/10/2010		16/3/2011	
Record	No	38		39		40		41		42		43		44		45		46		47		48	



Fig. 1: Distribution of recent *Ommastrephes bartramii* records from the Aegean Sea and neighbouring areas of the Eastern Mediterranean. Records of stranded or drifting individuals collected from shallow waters are marked by diamonds (\blacklozenge), whereas those caught by fishing gear over deep waters are denoted by circles (\bullet).

length range, body weight and sex of collected specimens.

The regression equation for the DML-BW relationship was derived based on data available from the entire Mediterranean, whereas the equation for the DML-LRL relationship was computed only with specimens sampled from the eastern Mediterranean. The best fitted model for each regression was selected according to the best adjusted R^2 of standard curves tested by the statistical software STATGRAPHICS 4.0.

Results

Recorded sightings of the neon flying squid, *O. bartramii*, in the Mediterranean

Sea through March 2011 are presented in Table 1. Four males and 32 females are included, with ML ranges of 19.5-32 cm and 25.7-66 cm, respectively. The majority of individuals reported in the western Mediterranean were caught during professional and experimental jigging off the western Italian coasts (ORSI-RELINI & GARIBAL-DI, 2005; POTOSCHI & LONGO, 2009) during the last decade. There was a scarcity of species records from the Ionian and Adriatic Seas, which primarily described single, stranded specimens, with the exception of one female caught by pelagic trawl in the NW Adriatic (GUESCINI & MANFRIN, 1986). The catch of a few individuals by drifting long-lines targeting swordfish since the mid-1970s in the South



Fig. 2: Ommastrephes bartramii - (a) a carpus of the tentacular club with adhesive suckers and knobs, (b) a funnel pit with side pockets, (c) tentacular sucker rings with four longer teeth forming a cross and (d) a ridge formed at the internal side of the upper beak rostrum

Adriatic was mentioned by BELLO (1990) without any further details. Information on the specimens from the eastern Mediterranean until 2000 has been based on experimental jigging catches during the Turkish seasonal acoustic surveys of 1990-1991 in the SE Aegean and NW Levantine Seas. The most recent records primarily describe females collected individually on or near the shore.

The exact locations of the species sightings in the eastern Mediterranean are shown in Figure 1. Data on the body morphometry, including the maturity and diet information for individuals examined in the laboratory, are shown in Table 2, whereas data on the dimensions of the available beaks are presented in Table 3.

All of the large individuals from the Aegean and Ionian Seas examined in the laboratory were fully mature or partly spent females, and spermatophores were observed in the buccal membrane of some of them.

The regression of the body weight (BW)

Table 2

Record No	28	34	40	41	43
DML	608	552	533	580	535
TL		1300			1410
MC	465*				415
FL	295*		249		265
FW	455*	422.5	448		425
ALI	283*	235	352	363	315
ALII	347*	244	375	355	
ALIII	350*	310	375	333	368
ALIV	345*	290	282		367
TCL	640*	728	835	742	765
ASDmax		7			13
TCSDmax		10			12
Maturity	fully mature	fully mature	partly spent	fully mature	partly spent
Prey type	cephalopod, fish,	cephalopod, fish	cephalopod, fish	empty	empty
	Mysidacea				

Body dimensions (in mm), maturity and prey type of examined *Ommastrephes bartramii* females from the Eastern Mediterranean during the period of 2004-2009.

 Table 3

 Beak measurements (in mm) of Ommastrephes bartramii specimens from the Eastern Mediterranean Sea.

Record No	21	23	27	28	29	31	35	40	41	42	43
DML	370	160	165	608	660	520	552	533	580	470	535
URL	8.3	5.3	4.5	20	15.4	13.9	14.5	14.6	13.1	11.5	14.5
UHL	24	14.1	13.5	47.2	50.8	42.8	39.7	46.2	40.1	31.4	42.7
UCL	35.4	17.2		60.7	60.8	54.1	53.0	52.1	45.3	41.7	53.4
UWL	13.9	7.3		18.8	21.2	19.5	14.2	14.0	11.9	10.7	14.7
ULWa				31.7			22.5	23.5	23.3	19.8	23.3
UJA				13			11.0	11.1	9.8	8.7	11.1
LRL	8.1	4.8	3.8	12.3	14.3	13.1	13.4	13.5	12.0	10.4	14.0
LHL	8.8	5.0	5.5	14.9	14.6	12.8	9.9	12.3	11.0	9.6	11.3
LCL	19.9	9.2	9.5	30.7	31.5	29.8	24.3	25.5	23.2	20.6	27.7
LWL	13.2	5.9	5.8	28.6	24.5	22.1	20.9	23.6	18.4	16.6	21.7
LBL	22.5	10.0	11.1	38.4	42.2	33.5	31.5	29.2	28.0	24.3	27.5
LJA			16.5	16.9			11.1	10.2	10.1	9.8	11.5

(in g) to the dorsal mantle (DML) (in mm) was best fitted by the following exponential equation:

 $BW=49.2456 + \exp(0.0089 \times DML),$ $R^2 = 0.97 (N=30)$ The relationship of the lower rostral length (LRL) (in mm) compared to the DML (in mm) was best described by the following multiplicative model:

 $ML = 36.2613 \times LRL^{1.069}, R^2 = 0.95 (N=11)$

Discussion

Geographic distribution and association to water mass circulation

Studies in the North Pacific have shown that the O. bartramii distribution and abundance strongly correlated with the water temperature. Specifically, spawning grounds correlated with a sea surface temperature (SST) range of 21-25°C, whereas the feeding grounds and migrating routes, where jigging and driftnet fisheries perform catches, were observed in the 6-15°C range at a 200 m depth (BOW-ER & ICHII, 2005), and the optimum SST varied from 10 to 22°C according to the season (CHEN et al., 2007). In addition, the zooplankton abundance has been attributed to promoting suitable biological conditions for the formation of neon flying squid fishing grounds (CHEN et al., 2007). Changes in environmental conditions, driven by Kuroshio current bending, were observed to play an important role in the inter-annual variation of CPUE, influencing both squid recruitment and aggregation at the spawning and feeding grounds, respectively (CAO et al., 2009).

Most of the *O. bartramii* records in the eastern Mediterranean are distributed along the eastern Aegean and the periphery of the Cretan Sea (Fig. 1). This pattern of distribution correlates with the circulation of the warm Levantine Intermediate Water (LIW), which enters into the Aegean through the eastern straits of the Cretan Arc, moves northward along the Turkish coast and spreads into Cretan Sea, predominantly occupying the subsurface layer up to 200 m deep (STER- GIOU et al., 1997), where dense O. bartramii schools have been observed (KATAĞAN et al., 1992). During the winter when the circulation pattern is generally cyclonic and strong convective mixing occurs in the Cretan Sea, waters with LIW characteristics extend from the surface down to 750-1000 m. However, during the summer, the influence of the Asia Minor Current (AMC) that drives the LIW into the Aegean is less pronounced (THEOCHARIS et al., 1993). A temporal variation in O. bartramii abundance, which is at a maximum in autumn, decreases from the winter to the spring and is completely absent during the summer, was demonstrated by seasonal recordings of O. bartramii concentrations by echosounders in the SE Aegean-NW Levantine (KATAĞAN et al., 1992). This variation seems to correlate with the seasonal presence of the LIW. The seasonal variation observed in the most recent findings from the South Aegean, with a higher frequency in the winter and early spring, is consistent with previous observations.

Spatio-temporal distribution and biological characteristics of recorded specimens

All squids, either found stranded or drifting in shallow waters, dissected in this study were spawning females, which is likely similar to the stranded or moribund individuals collected from different areas (Table 1) and is indicative of the reduction in their capability for active locomotion due to spawning and the rising of their buoyant bodies towards the surface, as observed in several cephalopod species (BOYLE & ROD-HOUSE, 2005). Because large females appear to be sighted more frequently along the north coast of the island of Crete, the deep basin of the Cretan Sea may be an *O. bartramii* spawning area.

Conversely, the capture of relatively

smaller individuals during jigging off of western Italian coasts (ORSI-RELINI, 1990; PO-TOSCHI & LONGO, 2009) may indicate the existence of important feeding grounds in the Ligurian and the Thyrrenian Seas, characterised by permanent cyclonic gyres and colder waters (LONGHURST, 1995; CORDERO et al., 1999). Younger individuals (ML<143 mm) have been mainly caught in August-September (POTOSCHI, personal communication), whereas largest ones (ML: 560-660 mm) have been caught from April to June, during which a significant warming of the Tyrrhenian Sea surface waters was observed in 1985-2006 (NYKJAER, 2009). Older records of large females in the southern Tyrrhenian (RAGONESE & JEREB 1990; RAGONESE et al., 1992; CUCCU et al., 2009) have also been reported during the spring (Table 1), which may indicate a seasonal species migration to the southernmost areas for spawning. However, there is a paucity of available data, thus a more systematic collection of information describing O. bartramii catches is needed to determine its definitive distribution and seasonal variation.

Vertical distribution and availability to fishing gear

ROPER & YOUNG (1975) revealed that open sea Ommastrephids, like *O. bartramii*, occur primarily in the upper few hundred meters during both the day and the night. However, some individuals are observed at great depths, which are in agreement with the presence of this species' remains in the stomach content of a *Centrocymnus coelolepis* specimen caught at 2220-2240 m in the western Mediterranean (VIL-LANUEVA, 1992). According to Japanese investigations, individuals smaller than 20 cm ML mainly inhabit surface waters, whereas, as shown by biotelemetry, adult squids are distributed from 0-100 m during the night but migrate to depths of 150-350 m near the Sub-arctic Frontal Zone and below 400 m in more oligotrophic southern areas of the Pacific Ocean during the day (BOWER & ICHII, 2005). Although the eastern Mediterranean is considered to be one of the most oligotrophic marine areas, echosounder records have shown that *O. bartramii* form dense schools at 200-250 m depths during the day and at bottom depths of 800-2200 m at night, moving up to 40 m depths only when the vessel lights are switched on (KA-TAĞAN *et al.*, 1992).

The scarcity of O. bartramii records in the Mediterranean could be attributed to the mesopelagic distribution of the species and the lack of either professional or experimental systematic mid-water fishing in the open sea. Fishing gears that have captured predominantly smaller specimens include jigs (ORSI-RELINI, 1990; KATA-GAN et al., 1992; ORSI-RELINI & GARIBALDI, 2005; POTOSCHI & LON-GO, 2009), drifting long-lines (BELLO, 1990; specimen No 42 in Table 1 of the present study), drift nets (RAGONESE & JEREB, 1990), purse seines (BIAGI, 1990) and pelagic trawls (GUESCINI & MAN-FRIN, 1986; ORSI-RELINI et al., 1994) as well as three records of bottom trawling (SÁNCHEZ et al., 1998; CUCCU et al., 2009; specimen No 47 in Table 1 of the present study) and a single individual caught by a bottom long-line used for hake in the SW Aegean (Table 1).

The pelagic habitat of this species may also be supported by the presence of its remains in the stomach contents of large pelagic fishes and dolphins (BELLO, 1991; SAL-MAN, 2004; ÖZTÜRK *et al.*, 2007; ORSI-RELINI & GARIBALDI, 2005; PEDÀ *et al.*, 2009; SALMAN & KARAKULAK, 2009).

Climatic effect and perspectives on the fisheries

Since 2007, the repeated recurrent sightings of individuals stranded or floating in near shore waters of the Aegean Sea have become a popular subject of public discussion, which may be attributed to the increase in fisherman attention to rarely caught species due to the recent invasion of venomous alien species (Lefkaditou *et al.*, 2010). However, this attention may also be indicative of a recent increase in *O. bartramii* abundance in the Eastern Mediterranean, favoured by the more pronounced warming of upper sea layers observed in this area since 1994 (RAITSOS *et al.*, 2010).

The geographical spread of species with affinities to warm water, similar to most species that enter from the Atlantic into the Mediterranean, has been observed in the Mediterranean region since the 1980s and correlates with direct and indirect recent global warming effects (BIANCHI, 2007)

Because of the "meridionalisation" of the Mediterranean Sea, more intensive efforts should be devoted to the monitoring of the northward expansion of indigenous and allochthonous thermophilic species. Additionally, a parallel study of the evolution in water mass circulation may be undertaken to detect biodiversity changes, particularly in the top mid-water predators. Currently, O. bartramii represents a small part (<3%) of Ommastrephids targeted by jigging fisheries off of the Aeolian islands (PO-TOSCHI & LONGO, 2009). Developing directed jigging fisheries for O. bartramii and the association of this species with the water mass circulation in the southern Aegean, Ligurian and Thyrrenian Seas should be a priority for further investigations.

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References

- AKYOL, O. & SEN, H., 2004. A new large pelagic squid record for the Northern Aegean Sea of Turkey; Neon Flying Squid, Ommastrephes bartramii (LeSueur, 1821) (Cephalopoda: Ommastrephidae). Turkish Journal of Fisheries & Aquatic Sciences, 4: 111-113.
- BELCARI, P., 1999. Ommastrephes bartramii. In: Synthesis of the Knowledge on Bottom Fishery Resources in Central Mediterranean (Italy and Corsica), G. Relini, J. Bertrand & A. Zamboni (Eds). Biologia Marina Mediterranea, 6 (Suppl.1): 721-724.
- BELLO, G., 1990. The Cephalopod fauna of the Adriatic. *Acta Adriatica*, 31(1-2): 275-291.
- BELLO G., 1991. Role of cephalopods in the diet of the swordfish, Xiphias gladius, from the eastern Mediterranean Sea. *Bulletin of Marine Science*, 49 (1-2): 312-324.
- BELLO, G., 2007. *Ommastrephes bartramii* (Cephalopoda, Teuthida, Ommastrephidae) in the Gulf of Taranto, eastern Mediterranean Sea. *Basteria*, 71 (4-6): 97-100.
- BIAGI, V., 1990. Cattura di un grande esemplare di *Ommastrephes bartramii* (Lesueur) (Cephalopoda, Teuthoidea) nel canale di Corsica. *Conchiglie*, 26: 125-130.
- BIANCHI, C.N., 2007. Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiologia*, 580: 7-21.
- BOWER, J.R. & ICHII, T., 2005. The red flying squid (*Ommastrephes bartramii*): A review of recent research and the fishery in Japan. *Fisheries Research*, 76 (1): 39-55.
- BOYLE, P. & RODHOUSE, P., 2005.

Cephalopods ecology and fisheries. Blackwell Science, Oxford, 452 pp.

- BRUNETTI, N.E. & IVANOVIC, M.L., 2004. *Ommastrephes bartramii*: a potential target for the squid fishery in the Southwest Atlantic. *Revista de investigacion y desarrollo pesquero*, 16: 51-66.
- CAO J., CHEN, X. & CHEN, Y., 2009. Influence of surface oceanographic variability on abundance of the western winter-spring cohort of neon flying squid *Ommastrephes bartramii* in the NW Pacific Ocean. *Marine Ecology Progress Series*, 381: 119-127.
- CHEN, X.J., ZHAO, X.H. & CHEN, Y., 2007. El Niño/La Niña Influence on the Western Winter-Spring Cohort of Neon Flying Squid (*Ommastrephes bartarmii*) in the northwestern Pacific Ocean. *ICES Journal of Marine Science*, 64: 1152-1160.
- CLARKE, M.R., 1962. The identification of cephalopod "beaks" and the relationship between beak size and total body weight. *Bulletin of the British Museum (Natural History), Zoology*, 8 (10): 441-480.
- CLARKE, M.R., 1966. A review of the systematics and ecology of oceanic squids. *Advances in Marine Biology*, 4: 91-300.
- CORDERO, S.G., 1999. The use of thermal satellite data in dense water formation studies in the Mediterranean Sea. *Journal of Marine Systems*, 20 (1): 175-186.
- CUCCU, D., MEREU, M., MASALA, P., CAU, A. & JEREB, P., 2009. Chiroteuthis veranyi and Ommastrephes bartrami (Cephalopoda: Teuthida) in the Sardinian waters. p.316-317. In: Proceedings of the 40th Congress of the Italian Society of Marine Biology, May 26-29, Livorno, Italy.
- GAMULIN-BRIDA, H. & ILIJANIĆ, V., 1965. Notes sur quelques espèces de Céphalopodes, rares en Adriatique, deposes dans la Musée de zoologie de Za-

greb. *Rapports et Procès-Verbaux des Réunions de la Commision International pour l' Exploration de la Mer Méditerranée*, 18 (2): 207-210.

- GUESCINI, A. & MANFRIN, G., 1986. Rinvenimento di Cefalopodi rari in Adriatico: *Abralia veranyi* (Ruppell, 1844) e *Ommastrephes caroli* (Furtado, 1887). *Nova Thalassia*, 8 (Suppl. 3): 519-521.
- KATAĞAN, T., SALMAN, A. & BENLI, H.A., 1992. Nouvelles observations sur Ommastrephes bartramii (Lesueur, 1821) (Cephalopoda, Ommastrephidae) dans le bassin Mediterraneen Oriental. Rapports de la Commision International pour l' Exploration de la Mer Méditerranée, 33: 298.
- LEFKADITOU, E., VASSILOPOULOU, V., PETRAKIS, G., PERISTERAKI, P., KAVADAS, S., POLITOU C.-Y., KAPANTAGAKIS, A., MACHIAS A. & PAPACONSTANTINOU, C., 2010. The effect of Lessepsian immigrants to the Hellenic Fisheries. p.60-73. Working Document in: Sub-Regional Technical meeting on the Lessepsian migration and its impact on Eastern Mediterranean fishery, Nicosia, Cyprus, 7-9 December 2010. FAO-EastMed Scientific and Institutional Cooperation to Support Responsible Fisheries in the Eastern Mediterranean, GCP/INT/041/EC-GRE-ITA/TD-04. (Available at http://www.faoeastmed. org/html/publications.html)
- LETA, H.R., 1989. Exploratory and experimental jigging for red squid (*Ommastrephes bartramii*) and short finned squid (*Illex argentinus*) in the Uruguayan sector of the Argentine-Uruguayan common fishing zone (winter 1986.). *Frente maritime (Montevideo)*, 5: 29-37.
- LONGHURST, A., 1995. Seasonal cycles of pelagic production and consumption. *Progress in Oceanogaphy*, 36 (2): 77-167.
- LOZANO-REY, L., 1905. Los Cefalopodos

de Cataluña y Baleares. *Revista de la Real Academia de Ciencias Exactas, F£sicas y Naturales de Madrid*, 3 (2): 159-221.

- MANGOLD, K. & BOLETZKY, S.V., 1988. Mediterranean Cephalopod Fauna. p.315-330. In: *The Mollusca. Vol. 12. Paleontology and Neontology of Cephalopods*, M.R. Clarke & E.R. Trueman (Eds). Academic Press, San Diego.
- NESIS, K.N., 2003. Distribution of recent Cephalopoda and implications for Plio-Pleistocene events. p.199-224. In: *Coleoid cephalopods through time*. Warnkle, K., Keupp, H. & S.v. Boletzky (Eds). Berliner Paläobiologische Abhandlungen.
- NIKJAER, L., 2009. Mediterranean Sea surface warming 1985-2006. *Climate Research*, 39 (1): 11-17.
- ORSI-RELINI, L., 1990. Field observations of young *Ommastrephes bartramii* in offshore waters in the Ligurian Sea. *Rapports et procès-verbaux des réunions de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée*, 32 (1): 243.
- ORSI-RELINI, L. & GARIBALDI, F., 2005. Mesopelagic cephalopods biodiversity in the cetacean sanctuary as a result of direct sampling and observations on the diet of the Cuvier's beaked whale, *Ziphius cavirostris. Biologia Marina Mediterranea*, 12 (1): 106-115.
- ORSI-RELINI, L., GARIBALDI, F., PA-LANDRI, G. & CIMA, C., 1994. La comunità mesopelagica e i predatori "di superficie". *Biologia Marina Mediterranea*, 1 (1): 105-112.
- ÖZTÜRK, B., SALMAN, A., ÖZTÜRK, A. & TONAY, A., 2007. Cephalopod remains in the diet of striped dolphins (*Stenella coeruleoalba*) and Risso's dolphins (*Grampus griseus*) in the eastern Mediterranean Sea. *Vie et Milieu*, 57 (1-2): 57-63.

- PEDà, C., MALARA, D., BATTAGLIA, P., PERZIA, P., ANDALORO, F. & ROMEO, T., 2009. Cephalopods in large pelagic fish stomach contents: beaks identification and creation of a photographic archive. *Biologia Marina Mediterranea*, 16 (1): 354-355.
- PFEFFER, G., 1912. Die Cephalopoden der Plankton Expedition. Zugleich eine monographische Übrersicht der oegopsiden Cephalopoden. Ergebnisse der Plankton Expedition der Humboldt-Stiftung, Vol. 2. Lipsius & Tischer, Kiel, 815 pp.
- POTOSCHI, A. & LONGO, F., 2009. Cephalopoda Teuthoidea Mollusca fishery description in the Aeolian islands. *Biologia Marina Mediterranea*, 16 (1): 356-357.
- RAGONESE, S. & JEREB, P., 1990. A large specimen of *Ommastrephes bartramii* (Lesueur, 1821) caught in the southern Tyrrhenian Sea. *Oebalia*, 16 (2): 741-744.
- RAGONESE, S., RIVAS, G. & JEREB P., 1992. New records of large neon flying squid (Ommastrephes bartramii Lesueur, 1821) in the southern Tyrrhenian Sea. Rapports de la Commision International pour l' Exploration de la Mer Méditerranée, 33: 308.
- RAITSOS, D.E., BEAUGRAND, G., GE-ORGOPOULOS, D., ZENETOS, A., PANCUCCI-PAPADOPOULOU, M.A., THEOCHARIS, A. & PAPATHA-NASSIOU, E., 2010. Global climate change amplifies the entry of tropical species into the Mediterranean Sea. *Limnology & Oceanography*, 55 (4): 1478-1484.
- ROPER, C.F.E. & YOUNG, R.E., 1975. Vertical Distribution of Pelagic Cephalopods. *Smithsonian Contribution to Zoology*, No. 209, 51 pp.
- ROPER, C.F.E., NIGMATULLIN, C. & JEREB, P., 2010. Family Ommastrephidae. p.269-347. In *Cephalopods of*

the world. An annotated and illustrated catalogue of species known to date. Volume 2. Myopsid and Oegopsid Squids. P. Jereb & C.F.E. Roper (Eds). FAO Species Catalogue for Fishery Purposes. Rome, FAO.

- SALMAN, A., 2004. The role of cephalopods in the diet of swordfish (*Xiphias gladius* Linaeus, 1758) in the Aegean Sea (Eastern Mediterranean). *Bulletin of Marine Science*, 74 (1): 21-29.
- SALMAN, A. & KARAKULAK, S., 2009. Cephalopods in the diet of albacore, *Thunnus alalunga*, from the eastern Mediterranean. *Journal of Marine Biology Association U.K.*, 89 (3): 635-640.
- SÁNCHEZ, P., BELCARI, P. & SARTOR, P., 1998. Composition and spatial distribution of cephalopods in two north-western Mediterranean areas. *South African Journal of Marine Science*, 20: 17-24.
- STERGIOU, K.I., CHRISTOU, E.D., GE-ORGOPOULOS, D., ZENETOS, A. & SOUVERMEZOGLOU, C., 1997.
 The Hellenic Seas: physics, chemistry, biology and fisheries. p.415-538. In: Oceanography and Marine Biology: an Annual Review (1997). Vol. 35. A.D. Ansell, R.N. Gibson & M. Barnes (Eds). UCL Press.
- THEOCHARIS, A., GEORGOPOULOS D., LASCARATOS A. & NITTIS K., 1993. Water masses and circulation in the central region of the Eastern Mediterranean: Eastern Ionian, South Aegean and Northwest Levantine, 1986-1987. *Deep-Sea Research II*, 40 (6): 1121-1142.
- THEOCHARIS, A., KLEIN, B., NITTIS, K. & ROETHER, W., 2002. Evolution and status of the Eastern Mediterranean Transient (1997-1999). *Journal of Marine Systems*, 33-34: 91-116.
- TORCHIO, M., 1967. Reperti di Histioteuthis bonelliana (Férussac) e di Om-

mastrephes bartrami (Lesueur) in aque neritiche del Golgo di Taranto. (Cephalopoda, Dibranchiata). *Thalassia Salentina*, 2: 1-7.

- VAFIDIS D., KOUTSOUBAS D., CHAR-TOSIA, N. & KOUKOURAS, A., 2008. The Teuthoidea (Cephalopoda, Mollusca) fauna of the Aegean Sea: comparison with the neighboring seas and notes on their diet composition. *Journal of Biological Research-Thessaloniki*, 10: 191-205.
- VECCHIONE, M. & GALBRAITH, J., 2001. Cephalopod species collected by deepwater exploratory fishing off New England. *Fisheries Research*, 51 (2-3): 385-391.
- VILLANUEVA, R., 1992. Deep-sea cephalopods of the north-western Mediterranean: indications of up-slope ontogenetic migration in two bathybenthic species. *Journal of Zoology, London*, 227: 267-276.
- ZUEV, G.V., NESIS, K.N. & NIGMAT-ULLIN, CH.M., 1975. Systematics and evolution of the squid genera *Ommastrephes* and *Symplectoteuthis* (Cephalopoda, Ommastrephidae). *Zoologischesky Zhurnal*, 54 (10): 1468-1479.
- ZUEV, G.V., NESIS, K.N. & NIGMA-TULLIN, CH.M., 1976. Distribution of the genera Ommastrephes D' Orbigny, 1835, Sthenoteuthis Verrill, 1880 and Todarodes Steenstrup, 1880 (Cephalopoda, Oegopsida) in the Atlantic Ocean. Moskovskoe Obsestvo Ispytatelej Prirody, Bulletin. Otdel Geologiceskij, 81 (4): 53-63.
- ZUEV, G.V. & NIGMATULLIN, CH.M., 1974. Distribution of the North Atlantic squid Ommastrephes bartramii (Lesueur, 1821.). In: Fisheries and Marine Service Translation. Series, No 3898. Newfoundland Biological Station, Canada.