Journal of the Marine Biological Association of the United Kingdom, 2009, 89(3), 635–640.
doi:10.1017/S0025315408002555 Printed in the United Kingdom

Cephalopods in the diet of albacore, *Thunnus alalunga*, from the eastern Mediterranean

ALP SALMAN[1] AND F. SAADET KARAKULAK[2]

[1]Ege University Faculty of Fisheries, Department of Hydrobiology, 35100 Bornova, İzmir, Turkey, [2]Istanbul University, Faculty of Fisheries, Ordu cad. No.200, 34470 Laleli, Istanbul, Turkey

In this study, the stomach contents of 116 albacore specimens, Thunnus alalunga *were examined from the eastern Mediterranean Sea. Fifty-five of the 116 stomachs examined were empty. The occurrence of major prey categories in stomachs were 95.1% cephalopods, 47.5% teleosts and 39.3% crustaceans with a total of 633 individuals belonging to 14 species identified.* Heteroteuthis dispar *from the order Sepiolida constituted 56.40% of the main cephalopod prey followed by* Onychoteuthis banksii *from the order Teuthida.*

Keywords: stomach content, *Thunnus alalunga*, cephalopods, eastern Mediterranean

Submitted 10 January 2008; accepted 27 June 2008; first published online 19 September 2008

INTRODUCTION

Albacore, *Thunnus alalunga* (Bonnaterre, 1788), is a highly migratory species found in both subtropical and temperate waters of three oceans. In the Atlantic, three stocks are commonly recognized by ICCAT (The International Commission for the Conservation of Atlantic Tunas): the northern and southern stocks separated by latitude 5°N, and the Mediterranean stock (ICCAT, 2006). The northern stock is considered to be independent of the Mediterranean stock based on the existence of an independent spawning zone in the Mediterranean (Dicenta, 1975), different morphometrics (Bard, 1981), different growth rates (Megalofonou, 2000) and ages of first maturity (Arena *et al.*, 1980), and distinct larval distribution (FAO, 1994). Tagging data are also concordant with this hypothesis, although some interstock migrations have been observed (Arrizabalaga *et al.*, 2004).

Albacore are top level carnivores and they opportunistically prey on schooling sardine, anchovy, mackerel and squid. Other authors have found that in the north-east Atlantic, the albacore diet is mainly composed of fish, primarily *Trachurus trachurus* (Ortiz de Zárate, 1987), and to a lesser extent, crustaceans (Hassani *et al.*, 1997); Bello (1999) reported the major diet in the Adriatic Sea to be cephalopods.

Albacore is not caught as a target species in the Turkish waters; rather it is a by-catch in bluefin tuna purse seine fishery and swordfish longline fishery. The catch quantity of albacore has not been recorded in the recent past before 2004, with a total catch of 27 MT (TUIK, 2004). Due to the decrease in the stocks of small pelagic species (anchovy and sardine), which are important for Turkish fishery, Turkish fishermen have changed their fishing areas and their target species in recent years. Albacore was caught as a target species in the Levantine Sea by driftnet between May and July in 2006 (Karakulak *et al.*, 2007), after which time driftnet fishery was prohibited in the Turkish waters by the Turkish Ministry of Agriculture and Rural Affairs in September 2006 (Anonymous, 2006).

MATERIALS AND METHODS

The size of the albacore analysed ranged from 64 to 91 cm fork length (FL) (mean 73.9 ± 4.9 cm), and they weighed between 4.8 and 12.7 kg (mean 6.9 ± 1.4 kg); 116 stomachs were examined. The albacore were caught in Antalya Bay (Levantine Sea) by long line, set at the surface late in the afternoon and retrieved early in the morning, from May to July 2007, with the fishing ground depth ranging from 150 to 2300 m (Figure 1). The total length (FL) of the fish was measured to the nearest 0.1 cm and weight was recorded to the nearest 0.1 g.

Stomachs were removed immediately after capture of the fish and kept frozen waiting for processing in the laboratory. The beaks of cephalopods were separated for this study and stored in 70% ethanol. Identification of the cephalopod lower beak in the stomach contents was carried out according to Clarke (1962, 1986), Mangold & Fioroni (1966) and Lu & Ickeringill (2002). All beaks were then compared to beaks from the personal collection of one of the authors (A.S.). For the species belonging to orders Sepiolida and Teuthida, the lower rostral length (LRL) was measured, while for the species of the order Octopoda, the hood length (HL) was measured. The systematic order of the species was determined according to Sweeney & Roper (1998). During specimen identification and measurement, a stereomicroscope (Olympus model SZ-60) with a micrometric ocular was used.

RESULTS

Fifty-five of the 116 stomachs examined were empty (~47%). In the remaining 61 full stomachs, most of the remnants of

Corresponding author:
A. Salman
Email: alp.salman@ege.edu.tr

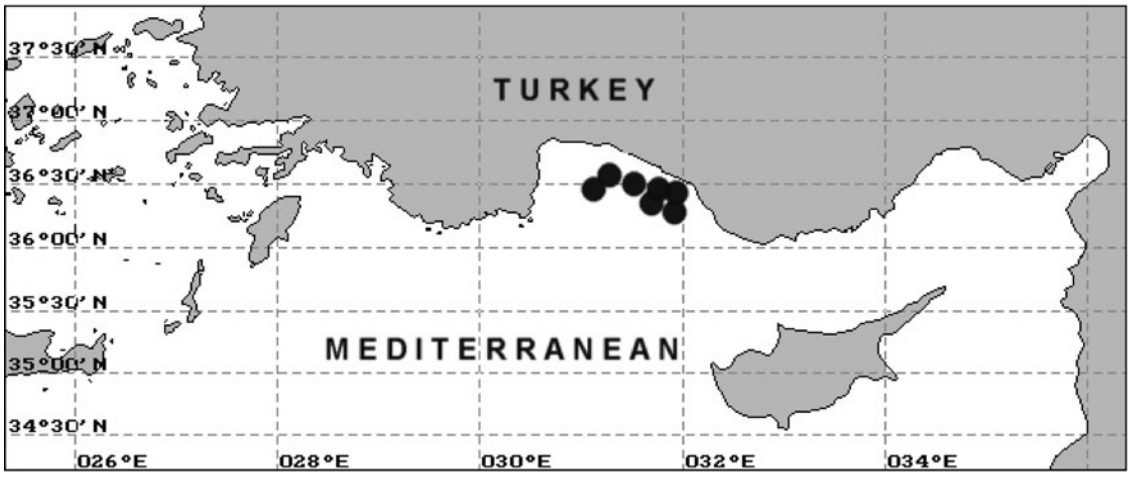

Fig. 1. Sampling area.

fish and crustaceans were digested to an unidentifiable condition; however, 633 lower beaks from cephalopods were identified.

Overall, cephalopod remains were present in 95.1% of the stomach contents in the albacore followed by teleosts at 47.5% and crustaceans at 39.3%. In addition, some plastic remains were present in the stomach contents (Table 1).

In this study, 633 lower beaks of cephalopod specimens belonging to 14 species were found. The identified species are generally pelagic species and among them, *Heteroteuthis dispar* was the most abundant species (56%), followed by *Onychoteuthis banksii* (12%) and *Chiroteuthis veranyi* (8.6%). The percentage of frequency in the stomach was 50.8% for *O. banksii* and 49.1% for *H. dispar*, followed by *C. veranyi* (36%) and *Todarodes sagittatus* (27.2%) (Table 2). The pelagic species, *Tremoctopus violaceus* and *Argonauta argo*, constituted 9.5% of the content, and when counted together, the pelagic species were the third most-abundant species.

One of the most frequently found species inside the stomach of *H. dispar*, is a short pelagic Sepiolid that migrates to the surface at night (Roper, 1974). Three hundred and fifty-seven lower beaks from this species were counted inside 30 of the stomachs and the length was estimated from the lower rostral length using the equation $ML = 13.759\ LRL^{1.574}$ (Relini, 1995). The range of the lower rostral length was LRL 0.6–1.5 mm and the mantle lengths estimated from this equation are given in Figure 2. From the estimated length values, the specimens were considered to be sub adult and adult individuals.

Table 1. Frequency of the general food groups in stomach contents of *Thunnus alalunga* (NS, number of occurrences in stomach contents; %FO, percentage frequency of occurrence).

Groups	NS	%FO
Teleost	29	47.5
Crustacean	24	39.3
Cephalopods	58	95.1
Plastics	6	9.8
Empty stomach	55	47
Total	116	

Onychoteuthis banksii is a mid-sized, muscular squid; 78 specimens of this species were found inside 31 stomachs, making it the most frequently found species (50.8%) inside the examined stomachs (Table 2). The range of the LRL was between 0.4–2.3 mm, from which we estimated the mantle length using the equation $ML = 2.31 + 32.75_{LRL}$ given by Lu & Ickeringil (2002). We found these to be generally sub-adult specimens (Figure 3).

Todarodes sagittatus is a large muscular squid; 42 specimens of this species were found inside 17 stomachs and the range of the LRL was between 0.5–3.0 mm. The mantle lengths of the individuals were estimated using the equation $l = -11.3 + 41.36r$ given by Clarke (1986) and from these estimates, all individuals were considered to be immature specimens, according to Quetglas *et al.* (1998) (Figure 4).

Chiroteuthis veranyi is a luminous and gelatinous squid that lives in mesopelagic and bathypelagic zones. Knowledge

Table 2. Percentage distributions and frequency of occurrence of cephalopods found in stomach contents of *Thunnus alalunga* (NS, number of stomachs; NI, number of individuals; %N, percentage composition by number; %FO, percentage frequency of occurrence).

	NS	NI	%FO	%N
SEPIOLIDA				
Heteroteuthis dispar (Rüppell, 1844)	30	357	49.1	56.40
Sepietta sp.	1	2	1.63	0.32
TEUTHIDA				
Pyroteuthis margaritifera (Rüppell, 1844)	1	1	1.63	0.16
Pterygioteuthis giardi Fischer, 1896	1	1	1.63	0.16
Octopoteuthis sicula Rüppell, 1848	7	15	11.47	2.37
Onychoteuthis banksii Leach, 1817	31	78	50.81	12.32
Ancistroteuthis lichtensteini (Orbigny, 1839)	3	5	4.91	0.79
Histioteuthis reversa Verrill, 1880	1	13	1.63	2.05
Todarodes sagittatus (Lamarck, 1798)	17	42	27.8	6.64
Ommastrephes bartramii (Le Sueur, 1821)	3	4	4.91	0.63
Chiroteuthis veranyi (Férussac, 1835)	22	55	36.06	8.69
OCTOPODIDA				
Scaeurgus unicirrhus (D'Orbigny, 1840)	1	1	1.63	0.16
Eledone cirrhosa (Lamarck, 1798)	1	1	1.63	0.16
Tremoctopus violaceus Della Chiaje, 1829	13	47	21.31	7.42
Argonauta argo Linnaeus, 1758	8	11	13.11	2.37
TOTAL		633		100

https://doi.org/10.1017/S0025315408002555 Published online by Cambridge University Press

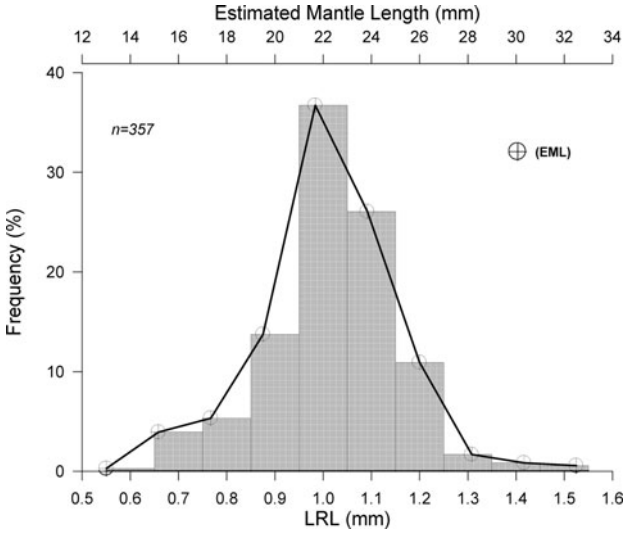

Fig. 2. Relative distribution of estimated mantle lengths based on lower rostral length of the beaks of *Heteroteuthis dispar* found in the stomach of albacore, *Thunnus alalunga*.

about several *Chiroteuthis* species is still incomplete (Clarke, 1986), but the distribution of *C. veranyi* in the Mediterranean Sea is well-known (Mangold & Boletzky, 1987). Fifty-five lower beaks from this species were counted inside 22 stomachs and the range of the LRL was between 0.5–3.5 mm. The estimated mantle lengths of the individuals, using the equation $l = 11.4 + 24.46r$ from Clarke (1986) are summarized in Figure 5.

Fifty-five specimens of the pelagic octopodan cephalopod, *T. violaceus* were found inside 13 stomachs and the range of the hood length of the lower beaks was between 0.4–1.1 mm. These beaks were of similar length to the 7–12 mm ML juvenile individual beaks, found in the *Thunnus thynnus* stomachs (unpublished data). Through comparison with this data, all specimens found in the stomach of *T. alalunga* were estimated to be juvenile individuals; the hood lengths of the specimens are presented in Figure 6.

DISCUSSION

In this study, cephalopods were found in 95% of the stomach contents of the albacore *Thunnus alalunga* in the eastern Mediterranean (Table 1). Six hundred and thirty-three cephalopod specimens from 14 species were found in the examined stomach contents (Table 2) and were generally found to be small and slow swimmers.

The ubiquitous species of the Mediterranean, *Heteroteuthis dispar*, as Bello (1999) reported, was also found to be the most abundant species (56.4%) in this study, followed by *Onychoteuthis banksii* (12.32%), *Chiroteuthis veranyi* (8.59%) and *Todarodes sagittatus* (6.64%) from the order Teuthida (Table 2). All of the sepiolid specimens (*Heteroteuthis dispar*) and nearly 75% of the specimens belonging to the Teuthida (*Onychoteuthis banksii* and *Chiroteuthis veranyi*) that were used as prey represent luminous species carrying photophores. Fourteen species were found in the stomach contents of albacore in the eastern Mediterranean, which is a high number when compared to the 4 species reported by Bello (1999) from the Adriatic Sea.

The benthic cephalopod specimens identified, *Eledone moschata* and *Scaeurgus unicirrhus*, were probably used as bait in long-line fishing.

The pelagic cephalopods (*Argonauta argo* and *Tremoctopus violaceus*) found in the stomach contents of *T. alalunga* in the eastern Mediterranean, were not reported by Bello (1999) in the Adriatic Sea. These two geographical areas also gave the same

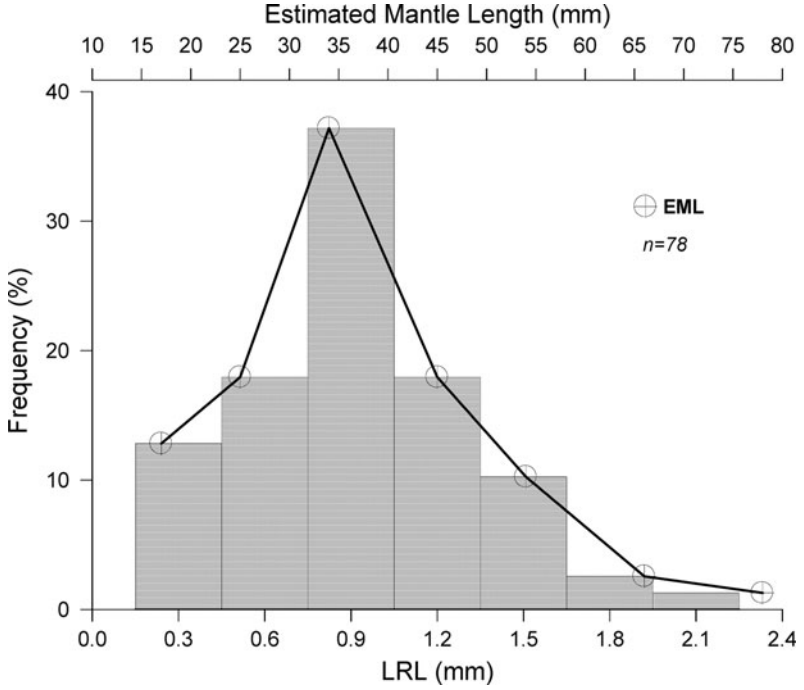

Fig. 3. Relative distribution of estimated mantle lengths based on lower rostral length of the beaks of *Onychoteuthis banksii* found in the stomach of albacore, *Thunnus alalunga*.

https://doi.org/10.1017/S0025315408002555 Published online by Cambridge University Press

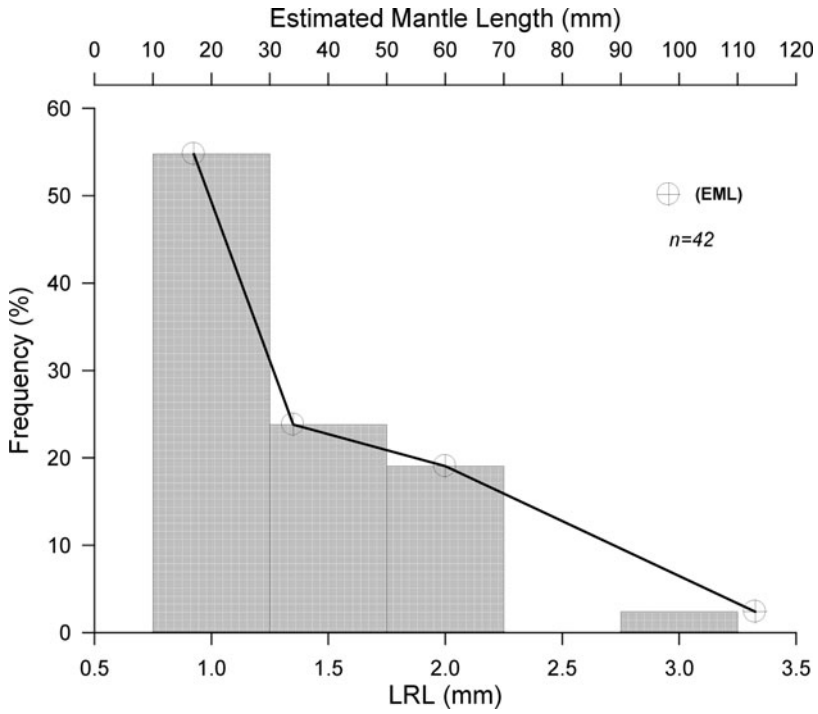

Fig. 4. Relative distribution of estimated mantle lengths based on lower rostral length of the beaks of *Todarodes sagittatus* found in the stomach of albacore, *Thunnus alalunga*.

results for swordfish (*Xiphias gladius*) (Bello (1991) 3.5%; Salman (2004) 25.5%), which might be due to the higher surface water temperature in the eastern Mediterranean (28–29°C) compared to the western Mediterranean Sea and Adriatic Sea, causing a higher number of the pelagic cephalopods to be distributed in the temperate surface waters.

Even the cephalopod species number in the Atlantic Ocean has been reported to be greater than that in the Mediterranean and Adriatic Seas (Mangold & Boletzky, 1987; Bello 1990); the deep waters around 1000 m in the eastern Mediterranean create an advantage for the distribution of oceanic species in the eastern Mediterranean compared to the Adriatic Sea.

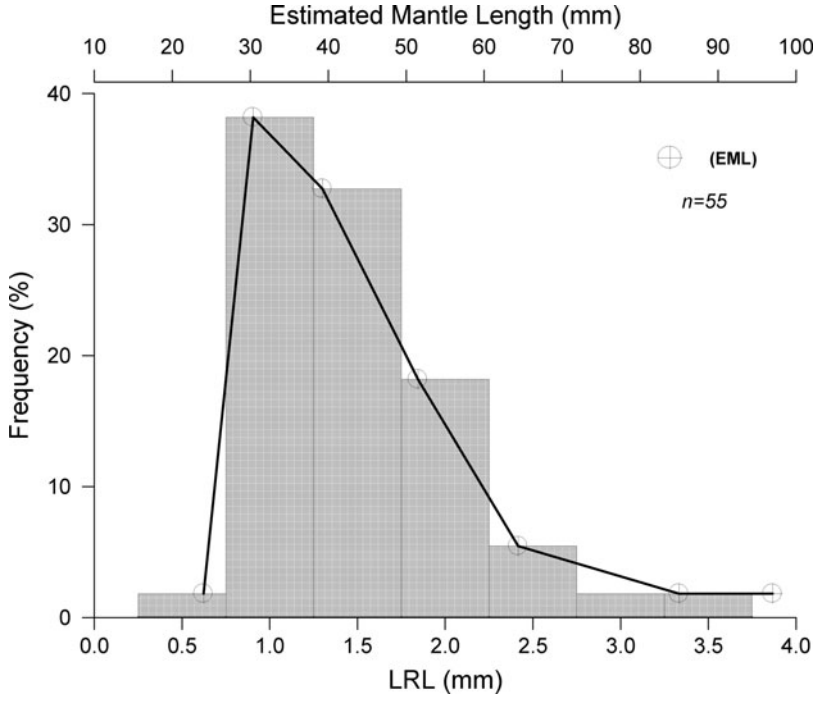

Fig. 5. Relative distribution of estimated mantle lengths based on lower rostral length of the beaks of *Chiroteuthis veranyi* found in the stomach of albacore, *Thunnus alalunga*.

https://doi.org/10.1017/S0025315408002555 Published online by Cambridge University Press

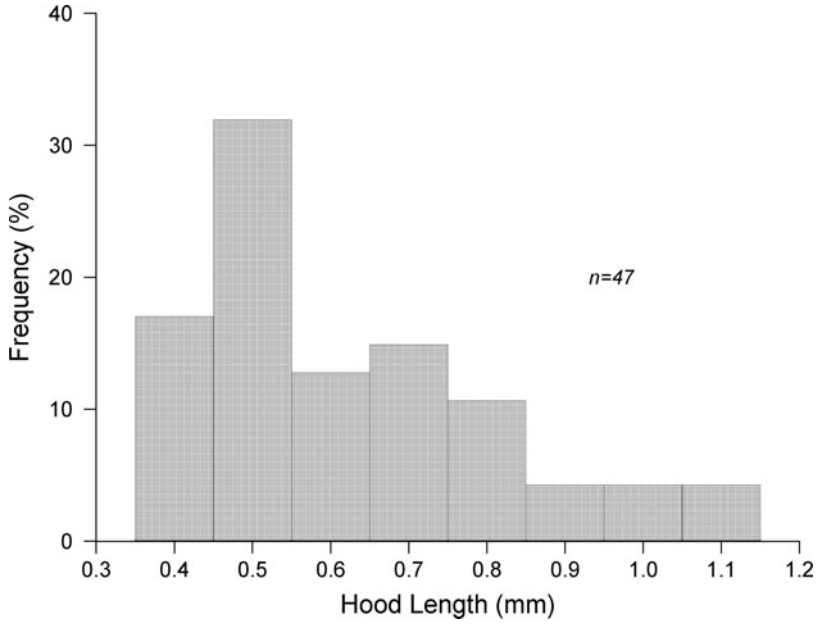

Fig. 6. Relative distribution of hood length of the beaks of *Tremoctopus violaceus* found in the stomach of albacore, *Thunnus alalunga*.

In the first study on the stomach contents of albacore in the Mediterranean Sea, and in the results given by Bello (1999) for the Adriatic Sea, cephalopods were also reported to be the most abundant group (29%), followed by fish and crustaceans (26%). Albacores of similar length to the individuals in this study were examined by Pusineri *et al.* (2005) in the Biscay Gulf, and these authors reported that fish were the most frequently found prey (92%) in the stomach, followed by cephalopods (29.4%). Similarly, Watanabe *et al.* (2004) reported that the main prey of albacores in the central North Pacific was fish (59%), followed by cephalopods (27%). These results showed that, like in other predators, the dominant prey of this opportunist species can vary according to the abundance of the different prey species in the waters where they live.

The cephalopods were reported to contain more fatty acids and minerals than fish (Okuzumi & Fujii, 2000). Due to the higher percentage of cephalopods as prey in our study area than in other regions of the Mediterranean, *T. alalunga* in the eastern Mediterranean may be growing faster than individuals in other regions. Future studies on the comparison of the diet and growth rates of this species in different regions of the Mediterranean Sea will have to provide the data necessary to understand the migration of albacore in the Mediterranean Sea and assess the importance of prey composition.

The white plastic pieces found in the stomach contents of the albacore with a rate of ∼10% indicate that in the open sea, pollution affects even the top predators.

ACKNOWLEDGEMENTS

This study was financially supported by the Scientific and Technological Research Council of Turkey (TUBITAK) No. 108-O-483 and the Research Fund of The University of Istanbul with the project number BYP/1761. We are grateful to the fishing companies DARDANEL (Canakkale, Turkey), GROUP SAGUN (Antalya, Turkey), the Turkish Bluefin Tuna Farmers Association (OYID), Mr Tuncay Seker, Dr Burcu Bilgin and Dr Elif Özgür for their help.

REFERENCES

Anonymous (2006) *Instructions for the regulation of commercial marine and inland fishery in 2006–2008 period.* Ankara: Turkish Ministry of Agriculture and Rural Affairs, 84 pp. [In Turkish.]

Arena P., Potosci A. and Cefali A. (1980) Risultati preliminari di studi sull'etá, l'accrescimento a la prima maturitá sessuale dell' alalunga *Thunnus alalunga* (Bonn. 1788) del Tirreno. *Memorie di Biologia Marina e di Oceanografia* 10, 71–81.

Arrizabalaga H., Costas E., Juste J., González-Garcés A., Nieto B. and López-Rodas V. (2004) Population structure of albacore *Thunnus alalunga* inferred from blood groups and tag–recapture analyses. *Marine Ecology Progress Series* 282, 245–252.

Bard F.X. (1981) *Le thon germon* (Thunnus alalunga) *de l'Océan Atlantique*. PhD thesis. University of Paris, 333 pp.

Bello G. (1990) The cephalopod fauna of the Adriatic. *Acta Adriatica* 31, 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, 312–324.

Bello G. (1999) Cephalopods in the diet of Albacore *Thunnus alalunga*, from the Adriatic Sea. *Journal of Molluscan Studies* 65, 233–240.

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, 422–480, 22 plates.

Clarke M.R. (1986) *A handbook for the identification of cephalopod beaks.* London and Oxford: Clarendon Press, xiii + 273 pp.

Dicenta A. (1975) Identificación de algunos huevos y larvas de túnidos en el Mediterráneo. *Boletin del Instituto Espanol de Oceanografia* 198, 1–21.

https://doi.org/10.1017/S0025315408002555 Published online by Cambridge University Press

FAO (1994) Expert consultation on stocks of large pelagic fishes in the Mediterranean area. Iraklion (Crete) Greece, 17–23 September 1992. *FAO Fisheries Report* 494, 308.

Hassani S., Antoine L. and Ridoux V. (1997) Diet of albacore, *Thunnus alalunga*, and dolphins, *Delphinus delphis* and *Stenella coeruleoalba*, caught in the north-east Atlantic drift-net fishery: a progress report. *Journal of Northwest Atlantic Fishery Science* 22, 199–123.

ICCAT (2006) *Report for Biennial Period, 2004–05* Part 1, 70–80.

Karakulak F.S., Bilgin B. and Gökoglu M. (2007) Albacore (*Thunnus alalunga* Bonnaterre 1788) fishery in the Antalya Bay (Levantine Basin). *Rapports du Congres de la CIESM* 38, 512.

Lu C.C. and Ickeringill R. (2002) Cephalopod beak identification and biomass estimation techniques: tool for dietary studies of southern. *Museum Victoria Science Reports* 6, 1–65.

Mangold K. and Boletzky S.V. (1987) Céphalopodes. Fiches FAO d'identification des espèces pour les besoins de la pêche. (Révision 1) *Méditerranée et Mer Noire. Zone de pêche* 37 Volume 1, 633–714 .

Mangold K. and Fioroni P. (1966) Morphologie et biometrie des mandibules de quelques Céphalopodes Méditerranéens. *Vie et Milieu* 17, 1139–1196.

Megalofonou P. (2000) Age and growth of Mediterranean albacore. *Journal of Fish Biology* 57, 700–715.

Okuzumi M. and Fujii T. (2000) *35th Anniversary Commemorative Publication Nutritional and functional properties of squid and cuttlefish*. Tokyo, Japan: National Cooperative Association of Squid Processors. 223 p.

Ortiz de Zárate V. (1987) Datos sobre la alimentación del Atún blanco (*Thunnus alalunga*) juvenil capturado en el Golfo de Vizcaya. *Collective Volume of Scientific Papers, ICCAT* 26, 243–247.

Pusineri C., Vasseur Y., Hassani S., Meynier L., Spitz J. and Ridoux V. (2005) Food and feeding ecology of juvenile albacore, *Thunnus alalunga*, of the Bay of Biscay: a case study. *ICES Journal of Marine Science* 62, 116–122.

Quetglas A., Alemany F., Carbonell A., Merella P. and Sanchez P. (1998) Some aspects of the biology of *Todarodes sagittatus* (Cephalopoda: mmastrephidae) from the Balearic Sea (Western Mediterranean). *Scientia Marina* 62, 73–82.

Relini O.L. (1995) Notes on midwater collections of *Heteroteuthis dispar* (Cephalopoda: Sepiolidae). *Bulletin de l'Institut Océanographique, Monaco* 16, 63–72.

Roper C.F.E. (1974) Vertical and seasonal distribution of pelagic cephalopods in the Mediterranean Sea, preliminary report. *Bulletin of the American Malacological Union* May 1974, 27–30.

Salman A. (2004) The role of cephalopods in the diet of swordfish (*Xiphias gladius* Linnaeus, 1758) in the Aegean Sea (eastern Mediterranean). *Bulletin of Marine Science* 74, 21–29.

Sweeney M.J. and Roper C.F.E. (1998) Classification, type localities and type repositories of recent cephalopods. In Voss N.A., Vecchione M., Toll R.B. and Sweeney M.J. (eds) *Systematics and biogeography of cephalopods*. Volume II, *Smithsonian Contributions to Zoology* 586, 561–599.

TUIK (2004) *Fishery statistics*. Ankara: Prime Ministry Republic of Turkey, Turkish Statistical Institute. [In Turkish.]

and

Watanabe H., Kubodera T., Masuda S. and Kawahari S. (2004) Feeding habits of albacore *Thunnus alalunga* in the transition region of the central North Pacific. *Fisheries Science* 70, 573–579.

Correspondence should be addressed to:
Alp Salman
Ege University Faculty of Fisheries
Department of Hydrobiology
35100 Bornova, İzmir, Turkey
email: alp.salman@ege.edu.tr