ISSN: 0001-5113 AADRAY	ACTA ADRIAT., 55(2): 213 - 218, 2014	ORIGINAL SCIENTIFIC PAPER

Changes in the 'Mean Temperature of the Catch': application of a new concept to the North-eastern Aegean Sea

Çetin KESKIN[1*] and Daniel PAULY[2]

[1] Faculty of Fisheries, University of Istanbul, Ordu St. No: 200, 34470 Laleli, İstanbul,Turkey

[2] Sea Around Us, Fisheries Centre, 2202 Main Mall, University of British Columbia, BC, Canada, V6T 1Z4

[*]Corresponding author, e-mail: seahorse@istanbul.edu.tr

Two trawl surveys in the Northeastern Aegean Sea, conducted in 1997 and 2007 yielded a catch composition which, when re-expressed through the new concept of 'mean temperature of the catch' (MTC) yielded an MTC increase of 0.25 0^C per decade, which is higher of the global MTC increase rate between 1970 and 2006, but slightly lower than the observed temperature increase in the Northeastern Aegean region, i.e., 0.26 0^C per decade. The result confirmed that global warming is impacting fisheries catch in the Northeastern Aegean Sea, and can be used for adaptation of regional fisheries management plan.

Key words: fish, mean temperature of the catch, climate change, eastern Mediterranean

INTRODUCTION

Climate change is expected to intensify in the next decades, and impact fish populations and fisheries catches (CHEUNG *et al.*, 2012) and hence the economics of fisheries (SUMAILA *et al.* 2011). Climate change globally affects marine fish mainly through changes in their metabolic rate (PAULY 1981; 2010), which in turn impact on their distribution patterns and hence community structure and the ecosystems in which these are embedded (DULVY *et al.*, 2008). Temperature and ocean chemistry directly affect the physiology, growth and reproduction of marine organisms. Fishes in warmer waters are expected to have a smaller maximum body size and smaller size at first maturity, which are important factors affecting population dynamics and productivity (PAULY, 1981, 2010; CHEUNG *et al.*, 2010).

In the Mediterranean Sea, temperature has been rising for the last 20–30 years and surface warming, in the eastern Mediterranean during the last two decades, is much more rapid than in its western part (SKLIRIS *et al.*, 2011). Indeed, the warming rate over 1992–2008 is much higher than the estimated global mean warming rate over the same period, while at the regional scale, the variability of Sea Surface Temperature (SST) in the Aegean Sea is driven by the large-scale natural atmospheric variability.

SKLIRIS *et al.* (2011) point out that the warming trend in the southern part of the Aegean is slightly stronger (nearly 0.047 $^0C \cdot year^{-1}$) than in the northern part (0.042 $^0C \cdot year^{-1}$) and much higher in the grid point adjacent to the Dardanelles Straits over the same period (0.026 $^0C \cdot year^{-1}$). Increasing SST in the area is mainly induced by increased heat transport through the Cretan

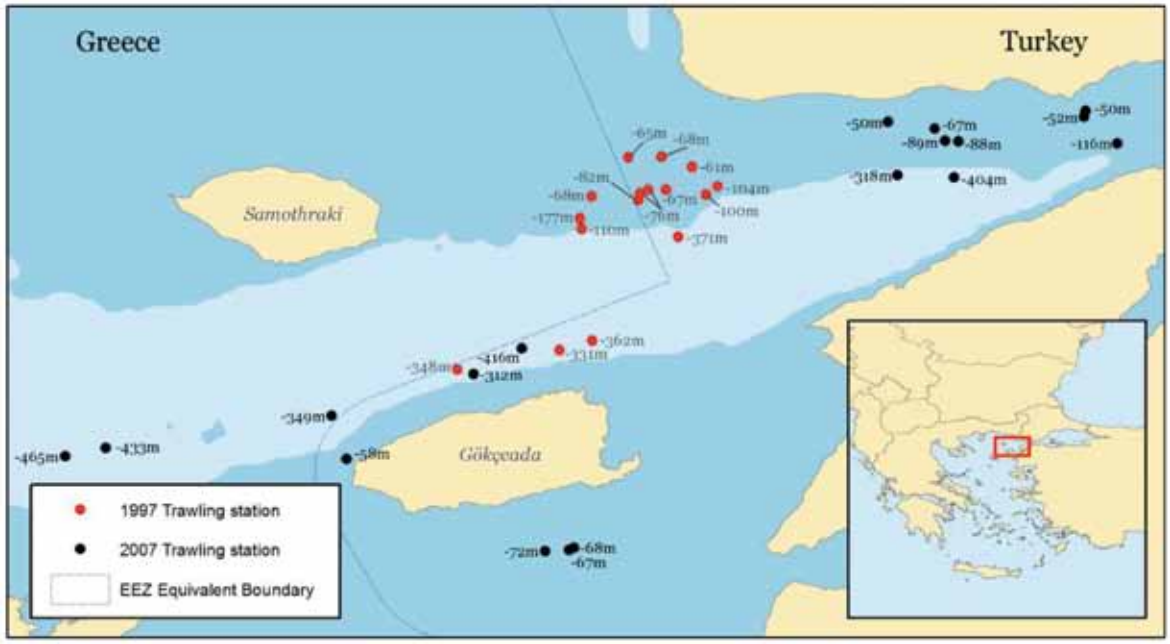

Fig. 1. Map of survey area and samplings stations in the North Aegean Sea in 1997-and 2007

Arc straits and/or by the atmospheric forcing variability rather than an increased warming of the BSW inflow (SKLIRIS *et al.*, 2011). The northward extension of native and non-indigenous warm water fish in the Mediterranean Sea is a response to the increasing water temperature after the mid-1980s (GOLANI & APPELBAUM-GOLANI, 2010; KATSANEVAKIS *et al*., 2013).

Temperature changes in the ocean strongly impact fish communities structure, which, given a strong exploitation rate, will be also reflected in the composition of survey and/or commercial fisheries catches (CHEUNG *et al.* 2013). The 'mean temperature of the catch', as new concept proposed by CHEUNG *et al.* (2013) was used to analyze changes in fish communities of the western, central and eastern subareas in the Mediterranean Sea (TSIKLIRAS & STERGIOU, 2014). KESKIN *et al.* (2011a, b) demonstrated differences between in the fish communities of northeastern Aegean Sea and the Levantine and Marmara Seas, which can be attributed to the difference in their SSTs. Here, we show that the change, from 1997 to 2007, of the species composition of survey trawl catches in the northeastern Aegean can be attributed to the increases of SST in the Eastern Mediterranean.

MATERIAL AND METHODS

In 1997, KARA & GURBET (1999) carried out a total of 16 survey trawl hauls, ranging from 50 to 400 m depth, around Gökçeada Island and Saroz Bay (Fig. 1), using a ship of opportunity (a commercial trawler). The stretched (diamond) meshes of the trawl cod end were 44 mm and the estimated vertical and horizontal openings of the gear were 10 m and 1.25 m, respectively. The trawl catch data were transformed to mean density estimates by species (here re-expressed as $kg \cdot km^{-2}$).

In 2007, a trawl survey was performed in the same general area by R/V *Yunus-S* (Fig. 1); a total of 18 hauls were performed, ranging from 70 to 400 m depth. The stretched (diamond) mesh size of the cod end was 36 mm and the estimated vertical and horizontal openings were 2 m and 19 m, respectively. Again, the catch was re-expressed as mean density ($kg \cdot km^{-2}$).

As it might be seen from Fig. 1, the 2007 hauls were taken to the East, West and South of the 1997 hauls, and thus should have sampled similar habitats, especially as they sampled similar depths (1997: mean depth = 193 m, s.d. = 162; 2007: mean depth = 154 mean, s.d. =122; *t-test*: df: 32, t=0.780, p=0.271).

The occurrence of a temperature-induced change in species composition was tested using the Mean Temperature of the Catch index (MTC) proposed by CHEUNG *et al.* (2013), defined as

$$\mathrm{MTC_{yr}} = \sum_{i}^{n} T_i C_y / \sum_{i}^{n} C_{i,y}$$

where $C_{i,y,r}$ is catch of species i in a given region in year yr; T_i is the median temperature preference of each species (from the Supplementary Online Material of Cheung et al. 2013) and n is the total number of species. The MTC index was applied to the 16 species common to both the 1997 survey of KARA & GURBET (1999) and the 2007 survey of R/V Yunus-S (Table 1).

	B_{1997}	B_{2007}	TP
Engraulis encrasicolus	1,311	3	19
Lophius piscatorius; L. budegassa	7,619	155	20
Merluccius merluccius	29,476	462	18
Mullus barbatus	437	211	17
Mullus surmuletus	187	0.3	19
Pagellus erythrinus	1,672	145	18
Phycis blennoides	1,187	26	16
Raja clavata	4,122	38	17
Scomber japonicus	1,287	0.2	23
Scorpaena scrofa	312	0.2	25
Solea solea; Citharus linguatula	312	24	19
Squalus acanthias	14,613	339	16
Trachurus trachurus	1,561	9	18
Trigla lyra	1,749	109	24
Trisopterus minutus	8,181	36	15
Zeus faber	1,311	22	23

Table 1. Biomass densities (B; kg·km^{-2}) of major species in two bottom trawl surveys in the Northern Aegean (1997 and 2007), in descending order of their median temperature preference (TP; 0^C). See text for sources

RESULTS AND DISCUSSION

The MTC calculated from the data in Table 1 increased from 17.76 ^{0}C in 1997 to 18.01 ^{0}C. The MTC difference between two periods (0.25 ^{0}C) was slightly higher than that obtained for MTC increase for non-tropical regions, i.e., 0.23 ^{0}C per decade between 1970 and 2006 (see cross in Fig. 2), but lower than the observed temperature increase in this region, i.e., 0.26 ^{0}C per decade (SKLIRIS *et al.*, 2011; see black dot in Fig.2).

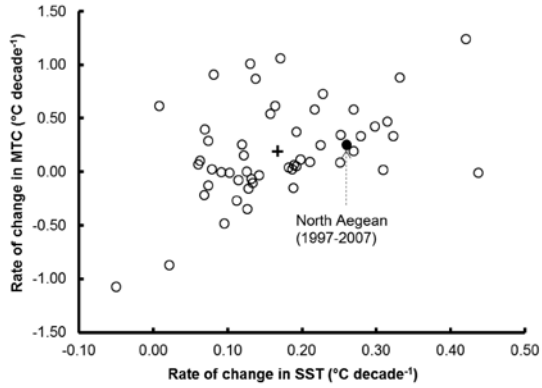

Fig. 2. Decadal changes of the mean temperature of the catch (MTC) against observed increases of sea surface temperature (SST) in non-tropical marine ecosystems. Open dots: Large Marine Ecosystems (LME) from Fig. 3a in Cheung et al. (2013); black dot: Northeasternn Aegean Sea (this study). Note that the latter data point is close to the mean of the points for the LME (cross; see text)

We do not believe that the difference in mesh sizes (44 vs. 36 mm in 1997 and 2007, respectively) biased our results, because the small fish that are differentially caught by these mesh sizes contribute little to the catch in weight of trawlers, even though their numbers can be high (KESKIN *et al.* 2011a). The weight of the catch, however, is what is used to compute estimates of the mean temperature of the catch (MTC; see above). Moreover, there is no correlation between the median temperatures preferences of our fish species and their length, and hence a mesh size that would, e.g., favour small fish would not affect the MTC estimates.

Overall, this study replicated at a smaller scale the results of the global study by CHEUNG *et al.* (2013). The whole Mediterranean has become warmer, but it is not homogenous. In the Northern Aegean, the 20–40 m thick surface layer with a temperature of 8.8-25 °C and salinity of 31.8-38.3 (PAZI, 2008) is occupied mainly by cold Black Sea Water. These water characteristics also explain why the MTC in the northeastern part of the Aegean Sea was lower than in the eastern Mediterranean as a whole, 0.29 ^{0}C

per decade between 1970 and 2010 (TSIKLIRAS & STERGIOU, 2014). Yet, a general warming is observed throughout the Aegean basin since 1992, mainly due to increasing heat transport and atmospheric forcing (SKLIRIS *et al.*, 2011). While our results corroborate that changes in the catch composition in the North-eastern Aegean Sea can be induced by climate change, which should be useful for regional fisheries management planning, they are based on data that were not sampled for the purpose and which may be biased. It would be appropriate, therefore, to perform trawl surveys rigorously matching earlier ones, and which would verify the inferences presented here.

ACKNOWLEDGEMENTS

Çetin KESKIN would like to thank TUBITAK International Post-doctoral Research Fellowship Programme for supporting 5 months in Fisheries Centre at the University of British Colombia (Canada). Daniel PAULY acknowledges support from the Sea Around Us, a scientific collaboration between the University of British Columbia and the Pew Charitable Trusts.

REFERENCES

CHEUNG, W.W.L., R. WATSON & P. PAULY. 2013. Signature of ocean warming in global fisheries catch. Nature. doi: 10.1038/nature12156

CHEUNG, W.W.L., J. PINNEGAR, G. MERINO, M.C. JONES & M. BARANGE. 2012. Review of climate change impacts on marine fisheries in the UK and Ireland. Aquat. Conserv. Mar. Freshwat. Ecosyst., 22: 368–388.

CHEUNG, W.W.L., V.W.Y. LAM, J. L. SARMIENTO, K. KEARNEY, R. WATSON, D. ZELLER & D. PAULY. 2010. Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Glob. Change Biol., 16: 24-35.

DULVY, N.K., S.I. ROGERS, S. JENNINGS, V. STELZENMÜLLER, S.R. DYE & H.R. SKJOLDAL. 2008. Climate change and deepening of the North Sea fish assemblage: a biotic indicator of warming seas. J. Appl. Ecol., 45: 1029-1039.

GOLANI, D. & B. APPELBAUM-GOLANI. 2010. Fish invasions of the Mediterranean Sea: Change and Renewal. In: D. Golani & B. Appelbaum-Golani (Editors). Pensoft Series Faunistica No 91. ISSN 1312-0174. Sofia, Bulgaria, 332 pp.

KARA, O.F. & R. GURBET. 1999. Investigation on industrial fishery of the Aegean Sea. The Republic of Turkey, Ministry of Agriculture and Rural Affairs, Bodrum, 5:135 pp.

KATSANEVAKIS, S., A. ZENETOS, C. BELCHIOR, & A.C. CARDOSO. 2013. Invading European Seas: assessing pathways of introduction of marine aliens. Ocean Coast. Manag.,76: 64–74.

KESKIN, Ç., F. ORDINES, B. GUIJARRO & E. MASSUTÍ. 2011a. Comparison of fish assemblages between the Sea of Marmara and the Aegean Sea (North-eastern Mediterranean). J. Mar. Biol. Assoc. U.K., 91(6): 1307-1318.

KESKIN, Ç., C. TURAN & D. ERGÜDEN. 2011b. Distribution of the Demersal Fishes on the Continental Shelves of the Levantine and North Aegean Seas (Eastern Mediterranean). Turkish Journal of Fisheries and Aquatic Sciences, 11(3): 413-423.

PAULY, D. 2010. Gasping fish and panting squids: oxygen, temperature and the growth of water-breathing animals. In: Excellence in Ecology Series International Ecology Institute, 22: p. 216.

PAULY, D. 1981. The relationships between gill surface area and growth performance in fish: a geneneralization of von Bertalanffy's theory of growth. Ber. Deutsch. Wissenschaft. Kommission Meeresforschung, 28: 251-282.

PAZI, I. 2008. Water mass properties and chemical characteristics in the Saros Gulf, Northeast Aegean Sea (Eastern Mediterranean). J. Mar. Systems, 74 : 698-710.

SKLIRIS, N., S.S. SOFIANOS, A. GKANASOS, P.

AXAOPOULOS, A. MANTZIAFOU, & V. VERVATIS. 2011. Long-term sea surface temperature variability in the Aegean Sea, A.I.O.L., 2(2): 125-139.

SUMAILA, U.R., W.W.L. CHEUNG, V.W.Y. LAM, D. PAULY & S. HERRICK. 2011. Climate change impacts on the biophysics and economics of world fisheries. Nature Clim. Change, 1: 449-456.

TSIKLIRAS, A.C. & K.I. STERGIOU. 2014. Mean temperature of the catch increases quickly in the Mediterranean Sea. Mar. Ecol. Prog. Ser., 515: 281-284.

Received: 25 February 2014
Accepted: 15 October 2014

Promjene u “srednjoj temperaturi ulova “: primjena novog koncepta u sjeveroistočnom Egejskom moru

Çetin KESKIN[1*] i Daniel PAULY[2]

[1] *Fakultet ribarstva, Sveučilište u Istanbulu, Ordu St. No: 200, 34470 Laleli, İstanbul, Turska*

[2] *“More oko nas”, Centar za ribarstvo, 2202 Main Mall, Sveučilište britanske Kolumbije, BC, Canada, V6T 1Z4*

**Kontakt adresa, e-mail: seahorse@istanbul.edu.tr*

SAŽETAK

Dva istraživanja koćarskih ulova u sjeveroistočnom Egejskom moru, provedena 1997. i 2007. godine dala su podatke o sastavu ulova, koji ponovno izraženi kroz novi koncept “srednja temperatura ulova “(MTC) daju rezultat da je MTC povećanje od 0,25 ^{0}C po desetljeću, što je više od globalnog MTC povećanja stope između 1970. i 2006. godine, ali i neznatno niže od povećanja promatrane temperature u sjeveroistočnoj regiji Egejskog mora, što bi bilo 0,26 ^{0}C po desetljeću.

Ovaj rezultat potvrđuje da globalno zatopljenje utječe na sastav lovina u ribarstvu sjeveroistočnog Egejskog mora, i može se koristiti u adapatacijama regionalnih planova upravljanja u ribarstvu.

Ključne riječi: riba, srednja temperatura ulova, klimatske promjene, istočni dio Mediterana