STATE OF SUMMER ICHTHYOPLANKTON IN THE BLACK SEA

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Abstract. The results of 8 Ukrainian and 4 Turkish ichthyoplankton surveys carried out during 1986-1996 in the Black Sea in the frame work of "TU-Black Sea program" are presented. In total, eggs of 28 and larvae of 44 fish species were found in the Black Sea. For the first time it could be verified that the mackerel *Scomber scombrus*, the blennid *Blennius ocellaris* and the recently introduced far east grey mullet *Mugil so-iuy* Bas spawn in the Black Sea. In comparison to the 1960's the average number of fish eggs and larvae decreased sharply during the last decade (from 160 larvae. m^{-3} in the 1960's to average <10 larvae m^{-3} in the period 1991-1996). Due to environmental deterioration the traditional spawning grounds became less important since 1988, whilst an increasing spawning activity was observed in open waters. In combination with ichthyoplanktonic, hydrological and acoustic methods the fine structure of the distribution of ichthyoplankton in fronts and mesoscale eddies were studied. In these regions the accumulation of ichthyoplankton could reach abundances one order of magnitude higher than in neighbouring areas. Average abundance of 20-100 eggs m^{-2} of anchovy and horse-mackerel are common in these water formations.

1. Introduction

In the Black Sea investigations on the distribution of ichthyoplankton started in the early 1950's. During the 1950's and 1960's the average egg number of all fish species in the range of some thousands per m^{-2} and larvae some hundreds per m^{-2} [4, 7, 12].

Since the beginning of the 1970's, disturbances in the ecological condition of the Black Sea started, particularly in the shallow coastal areas of the north western area. Over-regulation of river flows, the extensive use of fertilisers and chemicals in agriculture, and the removal of soil or sand along the coastal areas must have adversely affected the ichthyoplankton of the Black Sea in two ways. Firstly, it is known that 90% of fish species with a summer reproduction cycle spawn in the coastal waters of the Black Sea [1, 4, 7] and hence spawning population would inevitably be affected due to changes in water quality in these regions. Secondly the highest mortality rate during the

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life span of fish occurs at the early stages of ontogenesis which normally take place in the coastal areas.

Another profound change in the ichthyoplankton of the Black Sea has been caused by the recent introduced ctenophore *Mnemiopsis leidyi*, which became very fast the dominant species in terms of biomass (wet weight) among zooplankton. This species is a voracious predator on zooplankton and became the main food competitor of pelagic plankton feeding fishes and their larvae. Besides being a food competitor, it feeds on the eggs and particularly larvae of fish. In experimental conditions *M. leidyi* with a length of 2-2.5 cm consumed larvae of *E. encrasicolus*. Yolk sack larvae were eaten with high preference [9]. It was estimated that one individual consume 4-8 fish larvae a day. During its spawning period in summer *Mnemiopsis* is able to consume 74% of the present fish larvae [14].

Such events underlined must have resulted in significant changes in the abundance and distribution of the Black Sea ichthyoplankton. The aim of this paper is to outline these changes.

2. Materials and Methods

The present evaluation is based on the data of eight cruises carried out in the northern and four cruises in the southern Black Sea between 1986 and 1996 (Fig. 1). The ichthyoplankton was collected with the R/V "Prof. Vodyanitsky" (IBSS, Institute of Biology of the Southern Seas, Ukrainian Academy of Science; Ukraine) and R/V"Bilim" (IMS-METU, Institute of Marine Sciences, Middle East Technical University; Turkey).

The ichthyoplankton were sampled by vertical hauls using the Hensen net, Bogorov-Rass net and the Juday net. Additionally horizontal tows were also carried out with the Melnikov's trawl [10] in the Ukranian EEZ. Details of nets, vessel, and other information concerning the sampling procedure are summarized in Niermann et al. [11, 15].

During the collection period a total of 3500 ichthyoplankton samples were analysed from the northern and 540 samples from the southern Black Sea.

The estimation of fishes at early stage of ontogenesis were carried out by using acoustic techniques [2]. As adult fishes, fish larvae have gas filled swim-bladders, which reflect the sound waves. This pecularity is a quite good acoustic target, which differentiates fish larvae from other plankton organisms.

3. Results and Discussion

3.1 SPECIES COMPOSITION

Within our surveys (1986-1996) eggs of 28 and larvae of 44 fish species were found in the Black Sea (Table 1). Ichthyoplankton studies in very coastal areas of the southern

Black Sea where not carried out, therefore the precise number of coastal fish species is missing in this list for this region.

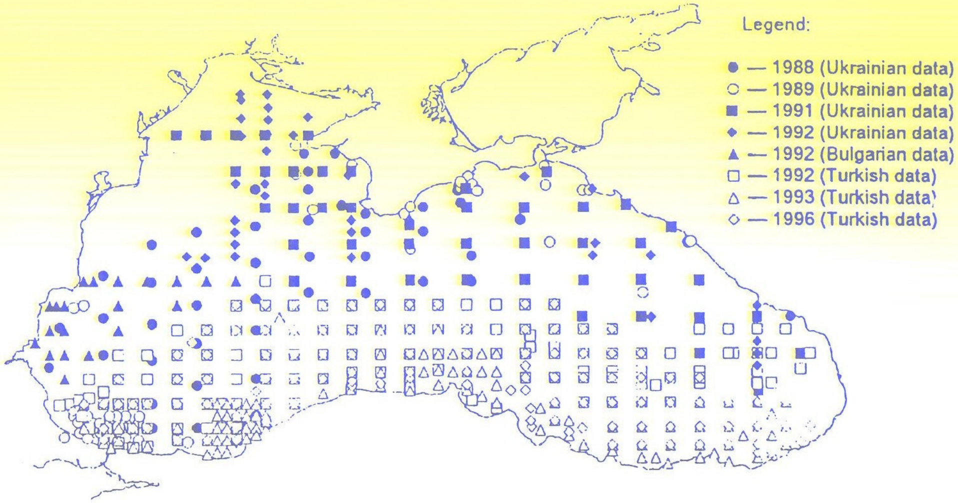

Figure 1. Ichthyoplankton sampling stations in the Black Sea during 1988-1996.

During the surveys 1991-1996 it could be verified for the first time, that the Sea of Marmara anchovy, the mackerel *Scomber scombrus* and the blennid *Blennius ocellaris* spawn in the Black Sea. [8]. These findings conclude the discussion of whether these species spawn in the Black Sea or not, which was going on for a long time [4].

Further on, eggs of the far east grey mullet *Mugil so-iuy* Bas were found for the first time in the Black Sea. This finding proved that this species which was introduced into the northern lagoons during 1972-1986, now spawns along the Ukranian, Russian, Georgian and Turkish coasts. Considerable quantities of adult individuals of this species were also found along Turkish Aegean coast down to Izmir region in 1996 (personal observation).

3.2 CHANGES IN THE ABUNDANCE

During the 1930's the northwestern area was characterised by a considerable diversity of ichthyoplankton, with eggs of 35 fish species in summer time. Especially the Karkinitsky gulf was the place of mass reproduction of many fish species including anchovy, horse-mackerel, red-mullet, and grey-mullet [7]. During the 1950's and 1960's up to 2000 anchovy eggs per square meter from the horizontal tow near the surface was common; the egg number for red-mullet and horse-mackerel were 4400 and 1250 respectively [12].

During the 1950-70 period, four pelagic fishes *Engraulis encrasicolus, Trachurus mediterraneus, Mullus barbatus* and *Diplodus annularis* consisted 96% of the total egg

TABLE 1. Qualitative composition of eggs and larvae in the Black Sea in summer during 1986-1996. (+ found, - not found)

Species	North		South	
	Egg	Larva	Egg	Larva
Atherina boyeri bonapartii Boulenger	-	+	-	-
Atherina hepsetus L.	-	+	-	-
Engraulis encrasicolus (L)	-	-	+	-
Engraulis encrasicolus ponticus Alcksandrov	+	+	+	+
Gaidropsarus mediterraneus (L)	+	-	-	-
Merlangius merlangus euxinus (Nordmann)	+	+	+	+
Ophidion rochei Muller	+	+	-	-
Sprattus sprattus phalericus	+	+	+	+
Belone belone euxini Gunther	-	+	-	-
Syngnathus schmidti Popov	-	+	-	-
Liza aurata (Risso)	+	-	+	-
Mugil cephalus L.	+	-	-	-
Liza saliens (Risso)	+	+	+	-
Mugil so-iuy Bas	+	-	+	-
Serranus scriba (L)	+	-	+	-
Pomatomus saltatrix (L)	+	+	+	-
Trachurus mediterraneus Staindachner	+	+	+	+
Boops boops (L)	-	+	-	+
Diplodus annularis (L)	+	+	+	+
Sciaena umbra L.	+	+	+	-
Mullus barbatus ponticus Essipov	+	+	+	+
Chromis chromis (L.)	-	+	-	-
Ctenolabrus rupestris (L.)	+	+	+	-
Symphodus cinereus (Bonnaterre)	-	+	-	-
Symphodus ocellatus Forssnal	-	+	-	-
Symphodus tinca L.	-	+	-	-
Symphodus rostratus (Bloch)	-	+	-	-
Symphodus roissali (Risso)	-	+	-	-
Trachinus draco L.	-	+	-	-
Uranoscopus scaber L.	+	-	-	-
Sarda sarda (Bloch)	+	+	-	-
Xiphias gladius L.	+	-	-	-
Gobius niger jozo L.	-	+	-	-
Pomatoschistus marmaratus (Risso)	-	+	-	+
P. minutus elongatus (Canestrini)	-	+	-	+
Gobius sp.	-	+	-	-
Callionymus pusillus Delaroche	+	+	+	-
Scomber scombrus L.	-	-	-	+
Aidablennius sphynx (Valenciennes)	-	+	-	-
Lipophrys pavo (Risso)	-	+	-	+
Parablennius sanguinolentus Pallas	-	+	-	+
P.tentacularis (Brunnich)	-	+	-	+
Coryphoblennius galerita (L)	-	+	-	+
Parablennius zvonimiri (Kolombatovic)	-	+	-	-

TABLE 1. (Continued)

Blennius ocellaris L.	-	-	-	+
Tripterygion tripteronotus (Risso)	-	+	-	-
Scorpaena porcus L.	+	+	-	-
Trigla lucerna L.	+	+	-	-
Psetta maxima maeotica (Pallas)	+	+	-	-
Solea nasuta (Pallas)	+	+	-	-
Arnoglossus kessleri Schmidti	+	-	+	-
Platichthys flesus luscus (Pallas)	+	-	-	-
Diplecogaster bimaculata euxinica Murgoci	+	-	-	-
Lepadogaster candollei Risso	-	+	-	+
L. lepadogaster lepadogaster (Bonnaterre)	-	+	-	-

and larva number [4]. The average numbers of fish eggs and larvae in coastal waters were 216 m^{-2} and 41 m^{-2}, respectively. Corresponding values for the offshore regions were 189 eggs m^{-2} and 30 larvae m^{-2}.

Due the changes of the Black Sea ecosystem the abundance of ichthyoplankton of the Black Sea fluctuated considerably and now appears to be at a low level, comparable to that of oligotrophic seas like the Mediterranean (Table 2).

TABLE 2. Average number of fish larvae in different seas

Region	Number of fish larvae (ind. m^{-3})
Azov Sea 1962-1963 [7]	570
Mediterranean Sea 1958-1962 [7]	17
Red Sea and Gulf of Aden 1966 [7]	75
Black Sea 1962-1963 [7]	160
1988	29
1989	7
1992	1
Southern Black Sea 1996	9

Compared with the previous years, during 1988 the number of eggs had decreased 2-4 fold, the number of larval 2-9 fold, both in coastal and offshore waters in different regions of the Black Sea. During 1989, when the *M. leidyi* reached its peak biomass in the Black Sea [16], a 2 fold decrease of the ichthyoplankton abundance was found all over the Black Sea [7]. The northwestern Black Sea, the main spawning area for many valuable fish species suffered most.

3.3 SPAWNING AREAS

The main spawning areas of many fish species are the coastal regions, especially the northwestern shelf. At the end of 1980's / beginning of 1990's the importance of open waters as spawning areas in the Black Sea increased considerably, when the environmental conditions of the coastal waters and the northwestern shelf became worse. These shifts of the spawning areas was observed by several pelagic fishes, most notable for *Engraulis encrasicolus* and *Trachurus mediterraneus* [7]. At the beginning of 1988, besides coastal regions, areas (at the scale of several of km) with high number of eggs and larvae of *E. encrasicolus* and *T. mediterraneus* were observed in the open waters of the Black Sea. [6].

Possible reasons for the shift of the spawning grounds could be the lack of sufficient food for the spawning fish stock and pollution. During the late 1980's/beginning of the 1990's the biomass of the fodder zooplankton decreased and the species composition of the fodder zooplankton changed drastically[17]. This was related with changes of the environment due to chemical pollution, strong eutrophication and other anthropogenic impacts, like damming and dredging. A change in the zooplankton composition due to climatic variability was also suggested [18, 19]. Certainly the mass reproduction of *Mnemiopsis*, particularly in the traditional spawning grounds of the thermophilic fish species is another reason for the declining of the biomass of the fodder zooplankton. Owing to the big population size, *M. leidyi* are able to consume the main part of zooplankton in these coastal zones, which led to a migration of the spawning anchovy and horse-mackerel stocks to offshore areas.

The pollution of the Black Sea by toxicants and the feeding of *Mnemiopsis* on ichthyoplankton influenced the survival of fish larvae. The relation of larvae to eggs of *Engraulis encrasicolus* and *Trachurus mediterraneus* varied from 30 to 50% during the 1950's and 1960's in the sea. In the early 1990's the relation of larvae to eggs decreased to 0.1-7% in the northern Black Sea and to 1.2-5% in Turkish waters. In July 1995 average number of eggs of anchovy in Sevastopol Bay was quite high (37 m^{-2}) and was comparable to that of 1950 and 1960's, however the percentage of larvae to eggs was only 7%, which indicates a high larval mortality.

It seems that ichthyoplankton is in a worse state in the northern part, which is more shallow and more exposed to anthropogenic impacts, than in the southern part, of the Black Sea, which is deeper and less polluted by industrial and residential wastes.

3.4 SPATIAL DISTRIBUTION

Anchovy and horse-mackerel spawning start usually in the coastal areas with a sea surface temperature higher than 16-17°C. High concentrations of eggs (100 m^{-2} in 1987, up to 30 m^{-2} in 1991, up to 577 m^{-2} in 1996) were found in a narrow coastal zone in the northern and southern Black Sea [11]. The spawning increases with the warming of the sea surface layer, which occurs earlier in the eastern Black Sea than its west.

The spatial distribution of ichthyoplankton is extremely heterogenous and is determined by convergence and divergence areas in the coastal and open regions of the sea. High concentrations of ichthyoplankton are linked with dynamical processes, forming stable zones in the surface layer. Thus high aggregations of ichthyoplankton were concentrated at the open sea border of the Rim current, of mushroom eddies (August 1991), of cyclonic gyres (August 1991), and of coastal upwelling, in zones

linked with gaps in the isopycnic relief and in local zones of convergence (August 1989, near-Bosphorus region). In these areas (for example at the Rim current) local accumulations of ichthyoplankton (as well as adult fish) with an extent of several miles were observed in concentrations exceeding abundances as one order of magnitude higher than in neighbouring areas (Figs. 2, 3, 4). Average abundance of 20-100 eggs m^{-2} (maximum values > 100 eggs m^{-2}) of anchovy and horse-mackerel are common in these stable zones [13].

Such local accumulations of ichthyoplankton occur due to the flow character (polyfrontality) of the main frontal zone, e.g. by the existence of several strong convergent flows at its edge. Such structures can be obtained only in simultaneous use of acoustic method for registration of fish larvae and towed CTD as in Fig. 5a.

The duration of ichthyoplankton accumulation is dependent on water dynamics. Observations in August 1991 have shown, that simultaneously with the weakening and the disintegration of local frontal zones the ichthyoplankton was "washed out".

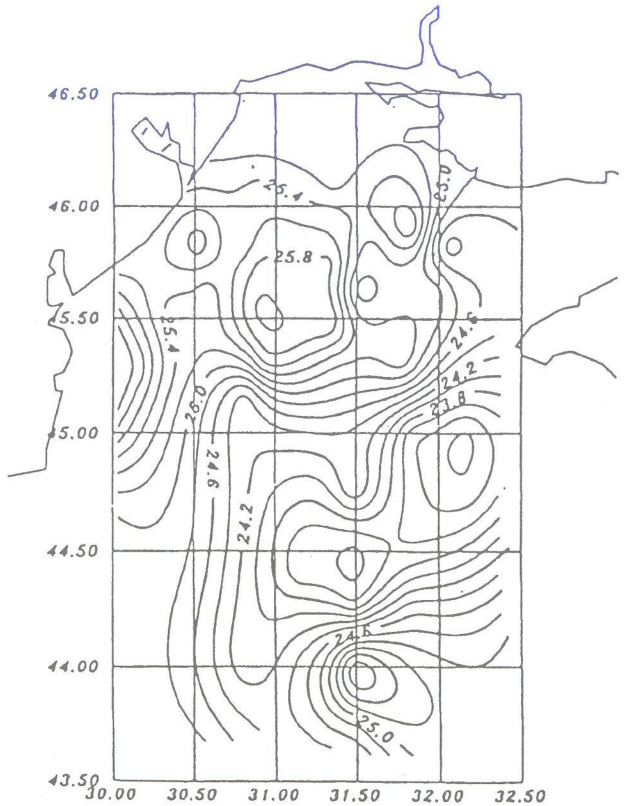

Figure 2. Distribution of surface temperature in August 1991.

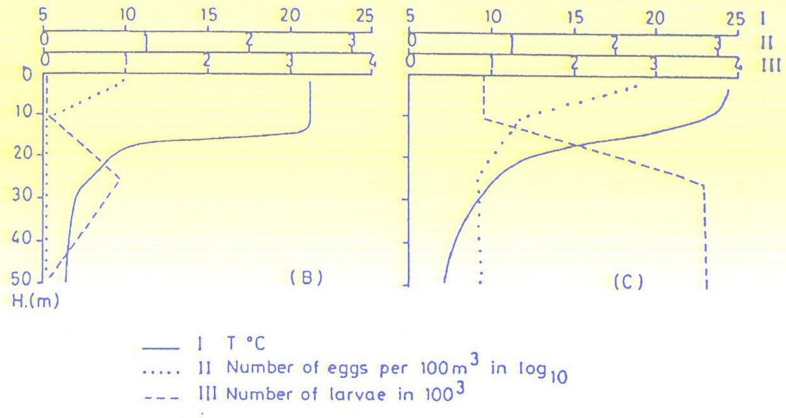

Figure 5b,c. The vertical distribution of fish eggs and larvae in 0-50 m layer in two sampling locations near frontal zone in July 1992 (Caucasus region, see also Fig. 5a).

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