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Research Article

The Effects of High Salinity on the Production of *Capoeta tinca* in A Naturally Contaminated River

Fitnat Güler EKMEKÇİ
Department of Biology, Hacettepe University, Beytepe, Ankara - TURKEY

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Abstract: The production properties of *Capoeta tinca*, the dominant fish population in a naturally contaminated stream in the Kızılırmak Basin, were studied together with the physical and chemical characteristics of the waters and evaluated in order to assess the impact of the high natural salinity on the fish population. The evaluation was based on comparisons of fish specimens caught from Acı stream, which is highly contaminated by a lithology of high salt content, and those from Terme stream, the uncontaminated freshwater branch, between May 1995 and May 1996. The salinity and electrical conductivity of Acı stream varied between 2‰ and 8.5‰, and 3028 µS25 °C and 14,273 µS25 °C respectively, while the salinity ranged from 0.5‰ to 1.5‰ and the electrical conductivity varied between 637 µS25 °C and 1570 µS25 °C in Terme stream. The results suggest that the high salinity caused a drastic reduction in the production of the fish population. The production was estimated to be 23.4 $gm^{-2}y^{-1}$ in the freshwater Terme stream, while it was only 0.54 $gm^{-2}y^{-1}$ in the highly saline Acı stream.

Key Words: *Capoeta tinca*, salinity, production, Turkey

Doğal Olarak Kontamine Olan Bir Akarsuda Yüksek Tuzluluğun *Capoeta tinca*'nın Prodüksiyonu Üzerine Etkileri

Özet: Yüksek doğal tuzluluğun balık populasyonlarına etkilerini araştırmak üzere Kızılırmak Havzasında bulunan ve litoloji kaynaklı kirlilik taşıyan akarsularda baskın balık populasyonu olan *Capoeta tinca*'nın prodüksiyon özellikleri suyun fiziksel ve kimyasal özellikleri ile birlikte değerlendirilmiştir. Değerlendirmelerde, yüksek oranda kontamine olan Acıçay'dan ve tatlısu özelliğindeki kolu Terme Çayı'ndan Mayıs 1995-Mayıs 1996 döneminde yakalanan balık örnekleri karşılaştırmalı olarak ele alınmıştır. Tuzluluk ve elektriksel iletkenlik Acıçay'da sırasıyla ‰ 2 – 8,5 ve 3028 - 14273 µS25°C iken, Terme Çayında tuzluluk ‰ 0,5 - 1,5 ve elektriksel iletkenlik de 637-1570 µS25°C arasında değişmektedir. Elde edilen sonuçlar, yüksek tuzluluğun balık populasyonlarındaki prodüksiyonda çok çarpıcı bir düşüşe sebep olduğunu düşündürmektedir. Terme Çayı'nda, tatlısuda prodüksiyon değeri 23,4 $gm^{-2}y^{-1}$ iken, yüksek oranda tuzlu olan Acıçay'da bu değer 0,54 $gm^{-2}y^{-1}$'dır.

Anahtar Sözcükler: *Capoeta tinca*, tuzluluk, prodüksiyon, Türkiye

Introduction

Production, as defined by Ivlev (1), is the total elaboration of fish tissue during any time interval Δt, including what is formed by individuals that do not survive to the end of Δt (2). The estimation of the production rate in natural fish in streams requires knowledge of the average biomass between two points in time and the growth rate. The biomass can be calculated using the balance between growth rate and mortality rate during the time in question. Production is an important parameter, because it is one of the most sensitive dynamic properties of populations and provides a good measure of the response of stocks not only to a fishery, development projects and stock augmentation, but also to water pollutants and contaminants and other similar environmental disturbances (3). This approach was used in the present study in order to demonstrate the effects of salinity on production of the freshwater fish *Capoeta tinca* population of Terme and Acı streams, two chemically distinct tributaries of the Kızılırmak River in Turkey. The annual production of many fish species has been estimated by many authors for a variety of waters in both lacustrine and riverine environments. In their valuable review, Mann and Penczak (4) concentrated on the problems of production in flowing waters. In Turkey there have been only a few studies on fish production, such as those by Ekmekçi (5) and Korkmaz and Atay (6).

Study Area

The study area is located in Central Anatolia in the Kızılırmak Basin. The catchment area of Acı stream is covered mainly by lithologic units, containing highly soluble gypsum and salt rock, which make the water highly saline: 2-8.5‰. Terme stream, in contrast, is a typical freshwater stream draining an area covered by insoluble silica rocks. Some of the physical characteristics of the sampling stations are listed in Table 1.

Table 1. Some physical properties of the sampling stations.

Parameter	Terme Stream	Acı Stream
Mean Width(m)	8.89	13.66
Mean Depth (m)	0.41	0.5
Length (m)	50	100
Area (m^2)	444	1366
Volume (m^3)	182.16	682.8
Velocity (ms^{-1})	0.5	0.6
Substratum	sand-gravel	sand-silty mud
Submerged Vegetation	none	none
Bank Vegetation	grass, bush, trees	grass, bush

Materials and Methods

Due to ecological differences between the selected sampling stations, fish specimens were caught by different methods. The high salinity in Acı stream did not allow electrofishing. Gill nets of 10-20 mm mesh size were used instead. The stream was closed at two ends to create a sampling patch where the nets were drifted five times. Electrofishing was successful in Terme stream in which the sampling site was closed at both ends by nets of 10 mm mesh size during electrofishing. A generator of 220 V-20 A was used for electrofishing and all fish in the sampling site were caught in 3-5 successive catches. Over one year seven samplings were carried out in order to obtain data in different seasons. The fish specimens were transported to the laboratories in iceboxes, where they were weighed (± 0.1 g), their fork length was measured, and scales were collected for age determination. Scales used for age determination were treated according to the method suggested by Lagler (7). Growth rates at every age were calculated as a first step in estimating production. Ricker's mathematical method was used in calculating production (2). The average biomass of different age groups for every sampling station was found and multiplied by the instantaneous growth rate (G) to estimate production. Production rates calculated for each age group were then summed and the total was divided by the sampling area to express it in $gm^{-2}y^{-1}$.

$$P = BG \quad G = (\ln W_2 - \ln W_1)/\Delta t \quad B = (B_1+B_2)/2$$

where P = production, G = instantaneous growth rate, B = average biomass, W_1 and W_2 = mean weight of fish at ages t_1 and t_2 respectively, B_1 and B_2 = total weight (biomass) of fish at ages t_1 and t_2 respectively.

Water temperature (T), specific electrical conductivity (EC), salinity (S), dissolved oxygen (DO) and pH were measured in the field. Water samples were collected seasonally and analyzed for major ions and nutrients. All in-situ measurements, sampling, preservation and analyses were obtained according to the APHA-AWWA-WPCF Standards (8).

Results

The chemical characteristics of the streams are summarized in Table 2. Being indicators of salinity originating from lithological contamination (chloride from salt rock and sulfate from gypsum), the temporal changes in EC, Cl, and SO_4 were monitored (Figures 1-3). Apart from the distinction between the two streams, the effect of dilution during the wet season is apparent in these figures. However, the major difference in the origin of Acı stream and Terme stream was evaluated by Schoeller's semi-logarithmic diagrams (Figures 4 and 5). Similar waters follow similar patterns and they are parallel on this diagram. This is not the case for Acı and Terme streams both in either dry or rainy seasons.

The numbers of fish and the production rates of *Capoeta tinca* populations in these two distinct streams differ significantly (Table 3). Although the production rate of Acı stream was 427 g per area of 1366 m^2 over 7 months (0.312 gm^{-2}), in Terme stream this figure was 6057 g per 444 m^2 (13.642 gm^{-2}), during the same period.

Discussion

It was stated by Mann and Penczak (4) that "as production is a synthesis of population biomass, recruitment and the instantaneous rates of growth and mortality, it is especially responsive to the welfare of the

Table 2. Temporal change of physical and chemical properties of Terme and Acı streams (All concentrations are in mg/l)

Date	Station	T (°C)	DO	pH	EC	S	$SO_4^{=}$	Cl^-	Ca^{++}	Mg^{++}	HCO_3^-	NH_3	NO_2^-	NO_3^-	PO_4^{-3}
May 95	Terme	18.8	7.4	8.02	819	0.5	165	10.2	44.5	33.7	5.3	0.32	0	0.88	0.02
	Acı	24.9	7.6	8.2	8512	5	1030	1300	276	49.3	3.05	0.06	0	2.76	0.07
Aug 95	Terme	20.4	7.2	8.39	885	1	311	19.9	50.7	42.2	4.75	0.41	0	1.32	0.07
	Acı	26.4	7.5	8.42	11473	6.8	1200	6126	371	73.4	3.55	1.91	0	5.6	0.07
Sept 95	Terme	24	6.8	7.9	1570	1.5	450	28.4	90.2	76.6	4.37	0.6	0.03	2.32	0.02
	Acı	24.5	7.8	8.18	14273	8.5	1400	7019	451	81.5	3.35	1.22	0.06	6.43	0.08
Nov 95	Terme	2	12.3	7.71	856	0.5	156	19.5	66.1	52.3	5.8	0.03	0.25	3.32	0.13
	Acı	2.8	10.8	7.55	4743	3	925	1021	251	123	5.35	0.48	0	5.9	0.9
Jan 95	Terme	1	13	8.3	776	0.5	78.1	15.2	72.1	40.1	5.95	0.06	0	3.63	0.13
	Acı	1	12.3	7.62	4563	2.5	563	783	200	96.1	5.56	0.58	0	5.63	0.46
Feb 95	Terme	5.3	11.8	7.65	637	0.5	71.9	11.3	64.1	34	5	0.04	0	2.4	0.12
	Acı	5.3	11	7.44	3028	2	563	564	180	68.1	5	0.8	0	5.36	0.21
May 96	Terme	16.5	9.2	8.18	716	0.5	67.5	10.2	54.1	29.2	6.4	0.02	0	0.66	0.01
	Acı	26.8	7	8.13	5298	3	1100	1212	295	40.1	4.8	0.92	0	5.3	0.2
Aug 96	Terme	32	7	7.88	1587	1.5	148	62	112	59.6	9.8	0	0	0	0.04
	Acı	34.5	9.6	7.85	18621	10.5	163	542	573	119	3.65	0.74	0	0	0.04
Jun 96	Terme	20	9.4	8.38	718	0	87.5		64.1	48.6	6.4	0.19	0		0.2
	Acı	24	9.2	7.96	9685	6	360		376	148	5	0.75	0		0.24

T: Temperature (°C); DO: Dissolved Oxygen (mg/l); EC: Electrical Conductivity (µS25 °C); S: Salinity (‰)

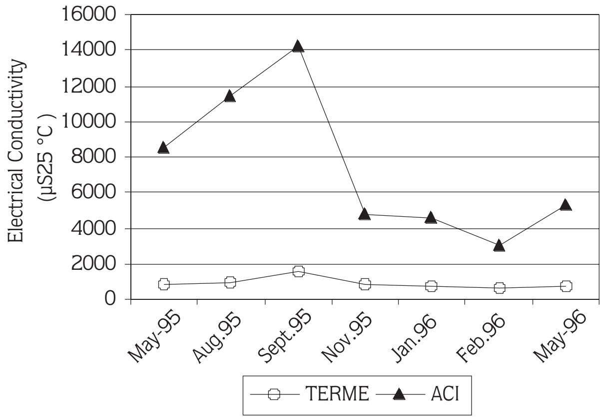

Figure 1. Temporal changes in specific electrical conductivity in Acı and Terme streams.

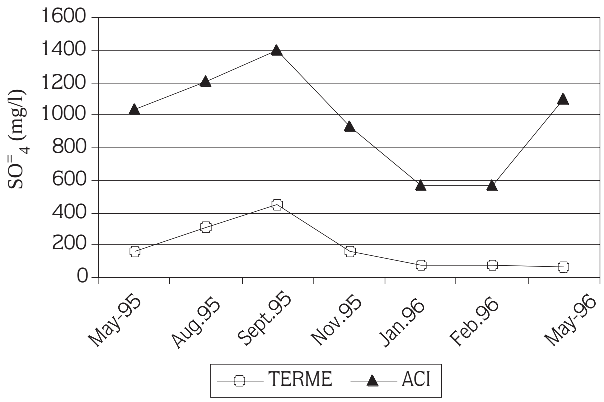

Figure 3. Temporal changes of sulfate in Acı and Terme streams.

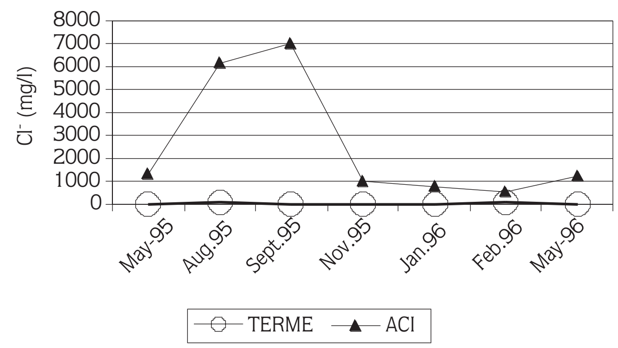

Figure 2. Temporal changes in chloride in Acı and Terme streams.

population and to the effects of environmental change". In the study area, due to natural factors salinity was found to be very high for inland waters. This area was partially covered by highly soluble gypsum and salt rock, which contaminated the streams flowing through it. As shown in Figures 4 and 5, the water quality of the two tributaries of Kızılırmak River differed. Some parameters such as the electrical conductivity, chloride and sulfate content of Acı and Terme streams also indicated this difference. During this study, in Acı stream maximum electrical conductivity was 14,273 µS25 °C, but in August 1996 this figure reached 18,621 µS25. There is a clear relationship between salinity and fish production. The production rate of *Capoeta tinca* in Acı stream was much

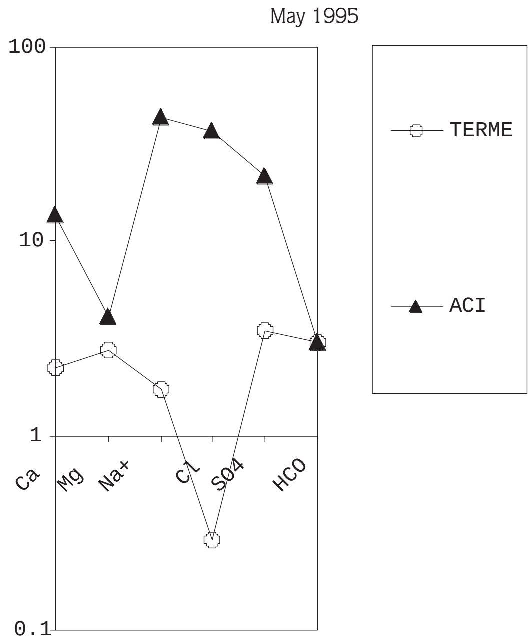

Figure 4. Schoeller's semi-logarithmic diagram for May 1995 (wet season) in Acı and Terme streams.

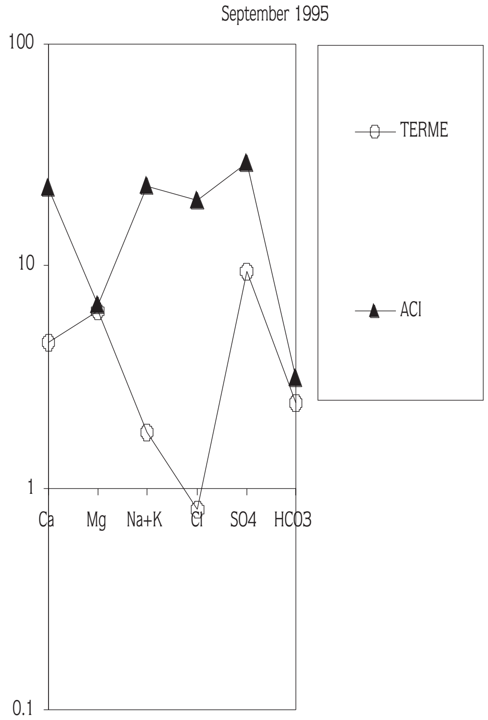

Figure 5. Schoeller's semi-logarithmic diagram for September 1995 (dry season) in Acı and Terme streams.

Table 3. Production of *Capoeta tinca* in Acı and Terme streams.

AGE (years)		N	W (g)	Bt (g)	B(g)	G	P
0	Acı	5	3.8	19	55.46	0.7	38.82
	Terme	283	2.77	783.9	1434.7	1.04	1492.06
I	Acı	12	7.66	91.92	98.61	0.42	41.2
	Terme	266	7.84	2085.4	2690.1	0.58	1569.26
II	Acı	9	11.7	105.3	80.25	0.45	36.11
	Terme	235	14.02	3294.7	2678.4	0.55	1473.12
III	Acı	3	18.4	55.2	156.4	1.25	195.5
	Terme	85	24.26	2062.1	1587.6	0.65	1031.95
IV	Acı	4	64.2	267.6	563.3	0.2	115.1
	Terme	24	46.38	1113.1	609.36	0.82	499.68
V	Acı	11	79	869			
	Terme	1	105.6	105.6			
		Σ P Acı Stream:	426.95				
		Σ P Terme Stream:	6057.07				

P Acı Stream = $(426.95g/1366m^2) \times 12/7) = 0.54\ gm^{-2}y^{-1}$
P Terme Stream = $(6057.07g/444m^2) \times 12/7) = 23.4\ gm^{-2}y^{-1}$

lower than that in Terme stream (Table 3), and it is clear that population density has a major role in the difference in production rates. Ekmekçi (5) found that there was no significant difference in the growth rates of *Capoeta tinca* in Terme and Acı streams. Egglishaw and Shackley (9) found that environmental factors influenced the population densities of *S. trutta* and *S. salar* in a Scottish stream and that growth rates were inversely proportional to population densities. Similar results were found in the present study; due to the high salinity in Acı stream the population density of *Capoeta tinca* was very low compared with that in Terme stream (Fig. 6). In addition, according to age distribution, the 0 age group was very low in Acı stream. The proportion of the number of fish in Acı stream increased with age. This may be related to the fact that the salinity is tolerated much less by young fish (10). Bohlen (11) states that during the non-reproductive season, young specimens and adults migrate into brackish water for feeding and growth but have to return to waters of low salinity for spawning, because the high salinity of the environment does not allow the successful development of the eggs.

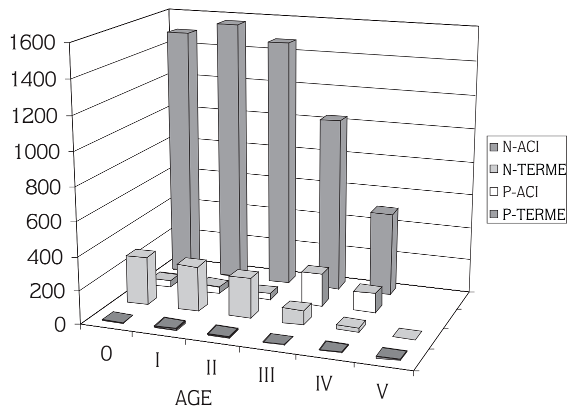

Figure 6. Comparison of N (Number of fish) and P (Production $gm^{-2}y^{-1}$) in the two streams.

Korkmaz and Atay (6) found the production of *Leuciscus cephalus* to be 1.67 $kgha^{-1}y^{-1}$, *Barbus plebejus* to be 6.10 $kgha^{-1}y^{-1}$, and of *Capoeta capoeta* to be 21.50 kgha-1y^{-1} in a tributary of Tohma stream.

Salts dissolved in the water permeate into the body of fish easily, mainly through the gills. The ability of fish to inhabit diverse and oscillating environments arises from a variety of adaptive physiological mechanisms. Owing to the location of the gill between the external and internal environments and its crucial role in gas transfer, Acıd-base balance, and ionic regulation, adaptive changes in branchial function are especially important. Compensatory adjustments of gill function originate from profound morphological changes (12). Generally, morphological adjustments to environmental changes are considered to be adaptive (13). In freshwater systems, salinity gives an extra cost of regulation, which may reduce the energy available for production. This was clearly shown by the significant difference between production rates of the same fish species in two streams of different salt content (see Table 3), although these two streams are located in the same geographical and hydro-meteorological system.

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