

Distribution of benthic macroinvertebrates in relation to physico-chemical properties in the Köyceğiz-Dalyan estuarine channel system (Mediterranean Sea, Turkey)

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The Köyceğiz-Dalyan Channel system is located between the ectogenic, crenogenic and meromictic Lake Köyceğiz and the Mediterranean Sea. Twenty one species belonging to Bryozoa, Gastropoda, Bivalvia, Polychaeta and Crustacea were found at 6 sampling sites from the channel entrance of Lake Köyceğiz to the Mediterranean Sea. The faunal assemblage of sampling sites 3 and 4 along the Dalyan Channel had the highest species diversity because of the almost similar effects of Lake Köyceğiz and the Mediterranean Sea on the benthic assemblages and stable salinity compared to the other stations. The distribution of species in the channel system is mainly affected by salinity, temperature, phosphate, Mg^{2+} , DO (dissolved oxygen) and SO_4^{2-} . Regular physical, chemical and biological monitoring of the channel system is recommended.

[**Key words** : Benthic macroinvertebrates, distribution, estuary, Köyceğiz-Dalyan Nature Reserve, Mediterranean Sea, physico-chemical variables, Turkey]

The Köyceğiz-Dalyan Nature Reserve is an important wetland area in south-western Turkey. The outflow of Lake Köyceğiz, which is commonly called the Dalyan River, follows a meandering bed, which enlarges into a labyrinth-like channel system discharging into the Mediterranean Sea at Dalyanağzı (Gorge). The estuarine area includes three lakes (Alagöl, Sülüngür and Sülüklü). The Dalyan Channel system is fed by Köyceğiz Lake water, Mediterranean Sea water, water from alluvial discharges and from sulfuric thermal springs located around and at the bottom of the channel system. Due to the complicated structure of the aquatic ecosystem, this region is one of the most important and sensitive wetland areas in Turkey. Its status was established as a Natural Reserve in the framework of the Barcelona Convention for the protection of the Mediterranean Sea. The hydrobiological properties and biodiversity of the aquatic ecosystem of the Köyceğiz-Dalyan region are reported earlier¹⁻³. The distribution of benthic macroinvertebrates of north-eastern Mediterranean estuarine ecosystems and their relation to physico-chemical variables are not well known⁴⁻⁷. The aim of this research is to determine the composition of macrofauna and the relationships between faunal distribution and the physico-chemical properties of the Dalyan Channel system.

Materials and Methods

The Köyceğiz-Dalyan estuarine channel system is 14 km in length and connects the ectogenic, crenogenic and meromictic Lake Köyceğiz and the Mediterranean Sea in the Köyceğiz-Dalyan Nature Reserve in south-western Turkey (Fig. 1). The maximum water depth in the channel system is 4.5 m. The water mass is formed from the combination of two different water layers; the mixohaline water of the mixolimnion of Lake Köyceğiz comprises the upper layer and the saline water of Mediterranean Sea and sulfuric thermal water sources comprises the lower layer. The salinity characteristics and water stratification show that the channel system is a positive, partially mixed (stations 1-4), vertically homogenous (Gorge, 5th station) and salt wedge estuary type (Alagöl, 6th station). The microtidal motion is semi-diurnal with a 12 hr 25 minute tidal period, and the spring tidal range does not exceed 30 cm in the study area and measurements have shown that water levels in the channel are always above sea level⁸. The water level of Lake Köyceğiz is 8 m higher than the Mediterranean Sea, and no significant water level changes were measured in the lake⁹. The typical Mediterranean climate with hot and dry summer, and mild wet winters prevail in the area.

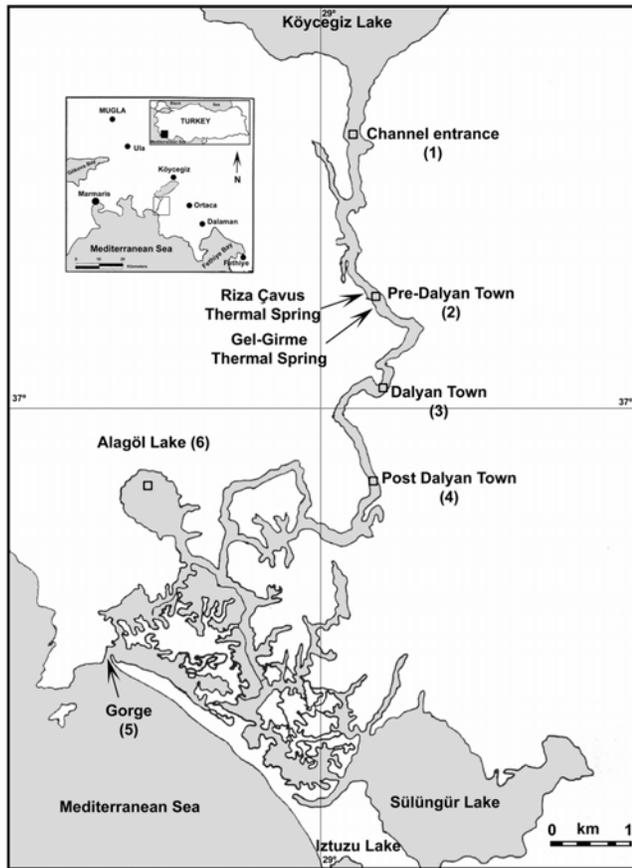


Fig. 1 — Map of study area

Based on long-term average data, the mean annual precipitation over the basin is 1202 mm. The mean annual temperature⁹ is about 18 °C. Critical habitats are created by dense bank vegetation comprising of *Myriophyllum spicatum* L., *Ruppia maritima* L., *Ipomea stolonifera* (Cyr.) J.F. Gmelin, *Phragmites australis* (Cav.) Trin ex Stendal, *Carex extensa* Grood, *Carex divulsa* Stokes subsp. *leersii* (Kneucker) W. Koch, *Juncus maritimus* Lam., *Cyperus capitatus* Vandelli, *Juncellus laevigatus* (L.) C.B. Clark subsp. *distachynos* (All) Davis, *Balboschoenus maritimus* (L.) Palla var. *cyanosa* (Roichb.) Kit. Tan. Et Otenge Yeboah, *Plantago cretica* L. at Dalyan Channel and *Typha domingensis* Pers. at Alagöl².

Six sampling sites were selected in the Dalyan Channel system (Fig. 1). In addition to the faunal samples, water samples were taken monthly at each station between August 1991 and September 1992. The depth of the channel varied from 1 to 4.5 m. Water samples were taken from surface and bottom and were evaluated as mean value. The sampling and methods used for water analysis have been given by

Kazancı & Girgin³. The salinity was determined according to the Venice System¹⁰. For faunal analysis, 3 replicate quantitative samples were collected at each station during the sampling period by means of Eckman grab with a surface area of 0.185 m². Qualitative supplementary samples were taken for the collection of *Ficopomatus enigmaticus* and *Membranipora membranacea*. The samples were sieved in the field through a 0.5 mm screen. The species diversity was estimated with Shannon's formula¹¹.

Results

Physico-chemical characteristics

In the channel, the surface water temperature was between 8.5 and 35.7 °C; the bottom temperature was between 8.9 and 30 °C. The annual mean temperature ranged from 20.9 °C to 21.3 °C along the channel system while it was 22.8 °C in Alagöl Lake (Table 1). The channel system was alkaline with annual mean pH ranging from 8.1 to 8.42. The annual mean pH in Alagöl Lake was 8.07. The annual mean dissolved oxygen ranged between 6.05 mg/l (in the Pre-Dalyan Town) and 6.6 mg/l (in the Channel entrance). In Alagöl Lake the annual mean dissolved oxygen was 5.9 mg/l. Annual mean conductivity ranged from 4.5 to 12.6 mS/cm in the channel system (Table 1). The conductivity of the bottom layer, being affected by five different types of water, was higher than the surface layer. Bayarı *et al.*⁹ stated that these are cold karstic and associated waters, thermal waters of the Dalaman Basin, waters of Köyceğiz Lake, thermal waters of Köyceğiz Lake and of the Dalyan Channel system (Sultaniye, Gelgirme and Rıza Çavuş thermal springs) and seawater. The annual mean conductivity increased from the channel entrance to the Gorge. The highest annual mean conductivity was determined as 14.6 mS/cm in Alagöl Lake (Table 1).

Rıza Çavuş and Gelgirme thermal springs (Fig. 1) affected the channel system directly with their high SO₄²⁻ concentrations (a minimum of 0.6 g/l and a maximum of 60 g/l)³. The annual mean SO₄²⁻ concentrations were high; ranging from 10.6 g/l (in the Post-Dalyan Town) to 14.8 g/l (in the Gorge). It was 13.7 g/l in the Alagöl Lake.

Salinity variation was observed from the channel entrance to the Gorge because of the water exchange between the lake and the sea (Table 1). Based on annual mean salinity, the Dalyan Channel was divided as follows: "the mixo-mesohaline (5-18‰)", comprising

Table 1 — Annual mean of physico-chemical variables of Dalyan Channel System
 [T= Temperature, DO= Dissolved oxygen, EC= Electrical conductivity]

Parameters	Channel Entrance	Pre-Dalyan Town	Dalyan Town	Post-Dalyan Town	Gorge	Alagöl Lake
T (°C)	20.9	21.2	21.2	21.3	20.9	22.8
pH	8.42	8.34	8.33	8.28	8.1	8.07
DO (mg/l)	6.6	6.05	6.2	6.4	6.1	5.9
EC (mS/cm)	4.5	4.7	6.2	7.7	12.6	14.6
Ca ²⁺ (mg/l)	173	205.3	238.8	270.5	407.9	444.9
Mg ²⁺ (mg/l)	309.6	338.6	460.7	601.8	1057.6	954.2
Salinity (‰)	8	8.4	11.8	14.8	23.8	25.3
SO ₄ ²⁻ (g/l)	13.9	13.5	11.9	10.6	14.8	13.7
NH ₄ ⁺ -N (µg/l)	52	29	11	40	68	48
NO ₂ ⁻ -N (µg/l)	7.9	4.3	6.4	6	3.4	4.1
NO ₃ ⁻ -N (µg/l)	6.2	3.5	20.4	3.9	4.8	6.9
PO ₄ ³⁻ -P (µg/l)	0.18	0.32	0.35	0.35	0.52	0.27

the sampling sites at the channel entrance (8 ‰), the Pre-Dalyan Town (8.4 ‰), the Dalyan Town (11.8 ‰), the Post-Dalyan Town (14.8 ‰) and the “mixo-polyhaline (18-30 ‰)”, comprising the sampling sites at the Gorge (23.8 ‰) and the Alagöl Lake (25.3 ‰).

While annual mean Ca²⁺ concentration was determined as 173 mg/l in the Channel entrance, it was 407.9 mg/l in the Gorge. Ca²⁺ concentration was high in the system due to sedimentary rocks and karstic limestone. Annual mean Mg²⁺ concentration was higher than Ca²⁺ concentration in the channel. It was 309.6 mg/l in the channel entrance but reaching a maximum of 1057.6 mg/l in the Gorge. The sea was dominating factor effecting the chemical composition of the system especially in the part of the channel near the sea. For that reason Mg²⁺ concentration was higher than Ca²⁺ concentration in the channel system gradually increasing from the channel entrance to the Gorge. Also in Alagöl Lake, annual means of Ca²⁺ and Mg²⁺ concentrations were high (Table 1).

Ammonia, nitrite, nitrate and phosphate were not high in the channel system (Table 1).

Benthic fauna

From the 6 sampling sites, a total of 3016 individuals belonging to 21 macrobenthic species were determined representing the major taxa Bryozoa, Gastropoda, Bivalvia, Polychaeta and Crustacea (Table 2). Gastropoda was the predominant taxon (8 species representing 38.1 % of the fauna and 68.4 % of the total abundance). Crustaceans, with 6 species, was the second most important taxon (28.6 % of the fauna but only the 13.6 % of the total abundance) (Table 2).

Theodoxus fluviatilis was dominant in the channel entrance and the Pre-Dalyan Town (Table 2). It constituted the major benthic macroinvertebrate fauna, comprising 59.7% and 42.6% (respectively) of total benthic macroinvertebrates, followed by *Melanoides tuberculata* (33.3% and 19.6%). In the Dalyan Town station Gammaridae gen. sp. 2 constituted the major benthic macroinvertebrate fauna, comprising 24.4% of total benthic macroinvertebrates, followed by the bivalves *Abra ovata* (18.5%), *Parvicardium ovale* (15.6%) and *Parvicardium exiguum* (13.7%) in the Dalyan Town. In the Post-Dalyan Town, *Sphaeroma serratum* constituted the major benthic macroinvertebrate fauna, comprising 44.9% of total benthic macroinvertebrates, followed by Gammaridae gen. sp. 1 (15.3%) (Table 2). The above mentioned sampling sites were mixo-mesohaline. *Theodoxus fluviatilis*, Gammaridae gen. sp. 2 and *S. serratum* were dominant taxa in the mixo-mesohaline sampling sites.

In the mixo-polyhaline Gorge *A. ovata* constituted the major benthic macroinvertebrate fauna, comprising 43.9% of total benthic macroinvertebrates, followed by *Bittium reticulatum* from Gastropoda (34.2%) (Table 2). In the Alagöl Lake *Hydrobia ulvae* constituted the major benthic macroinvertebrate fauna, comprising 69.7% of total benthic macroinvertebrates and followed by the bivalve *Mytilaster minimus* (18.2%). *Hydrobia ulvae* was also found in the channel entrance (0.5% of total benthic macroinvertebrates) and in the Post-Dalyan Town (1.9% of total benthic macroinvertebrates) (Table 2).

The diversity values ranged from 1.00 (in the 6th site) to 2.00 (in the 3rd site). The diversity values were

higher (2.00 and 1.83) in the 3rd and 4th sampling sites where the salinity values were 11.8 and 14.8‰, respectively. The diversity values were lower (1.00 and 1.02) in the 6th and 1st sites where the salinity values were 25.3 and 8‰ respectively.

Discussion

In the Dalyan Channel system, the gradual increase of salinity is due to the contribution of seawater which is diffused along the main channel. The salinity also increased from the surface to the bottom.

Ficopomatus enigmaticus is an euryhaline and cosmopolitan polychaete living in calcareous tubes⁷. In the Dalyan Channel system it was found in 5 sampling sites in which the tube aggregates were attached mainly to *Typha* roots where the salinity varied between 8 and 25.3‰. It was not recorded in the Gorge due to lack of hard substratum. *Mytilaster minimus*, *Membranipora mebranacea*, *Balanus* sp., *Hediste diversicolor* were found associated with *F. enigmaticus* formations in Dalyan Channel system. Special emphasis must be placed on the population of *F. enigmaticus* which forms a substratum colonised by many other species. The encrustations of these animals form reef-like clumps of tubes up to 1 m in diameter¹. *Phragmites* vegetation with *F. enigmaticus* formations constitute a critical habitat for various organisms.

*Heterotanais guernei*¹² and *Sphaeroma serratum*⁵ are brackish water species found in mixo-mesohaline zone where the salinity was between 8 and 14.8‰, *S. serratum* was the dominant species in the 4th sampling site. The euryoecous and cosmopolitan *H. diversicolor* is a well known brackish water (estuarine) species¹³. It was found in the first four sampling sites at low abundance, far from the sea where the salinity varied between 8 and 14.8‰. *Planorbis planorbis* is a freshwater species¹⁴ with salinity limits below 4‰ and is distributed in low abundance at five sampling sites where the salinity was between 8 and 25.3‰. Although dominant in the Gorge, *Abra ovata* was also found at all the other stations. The bivalve *A. ovata* is a characteristic species of the “euryhaline and eurythermal biocoenosis in brackish waters” and very common in the Mediterranean lagoons and estuaries¹³.

Most of the benthic animals and plants in estuaries are euryhaline species of marine origin, except in regions with a salinity below 5‰ (oligohaline zone). Some species are adapted to intermediate salinities of brackish water. Some of the dominant species in

estuaries and lagoons are traditionally referred to as brackish water species; for example, *Hydrobia ulvae*. Alternatively this species is truly a brackish water coloniser or it is marine opportunist¹³. In this study, it was found in the 1st (salinity 8‰), 4th (salinity 14.8‰) and 6th (salinity 25.3‰) sampling sites. The first two sampling sites were brackish. The first sampling site which is located nearest the lake is characterised by two freshwater-estuarine species, *Theodoxus fluviatilis* and *Melanoides tuberculata*¹⁴. *Theodoxus fluviatilis* was dominant in site 1. The sixth sampling site, Lake Alagöl, located near the Mediterranean Sea is accepted as brackish-marine and is characterised by two marine and brackish water species *H. ulvae*¹³ and *M. minimus*¹² with *H. ulvae* being the dominant species in site 6.

The relatively stable salinity level provides favourable developmental conditions for many animals¹⁵. The brackish water species were well adapted to conditions at the 3rd sampling site where the salinity was 11.8‰ and diversity value was 2.00. This is at the limit between the brackish-marine and brackish water¹⁵ and had the highest diversity in the channel system. The diversity index of the Gorge station was low (1.30) because of variations in the local sand transport around the inlet during the year and the seasonal change in the cross-section of the channel⁸.

Despite its status as Natural Reserve, the Köyceğiz-Dalyan region is increasingly exploited for tourism. The tourism activities should be regulated and the aquatic ecosystem including the channel system, Lake Köyceğiz, the thermal and cold ground water sources, and the running waters should be monitored by using physical, chemical and biological variables.

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