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RESEARCH PAPER

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A Comprehensive Study on Sustainable Fisheries and Environmental Factors in an Eastern Mediterranean Freshwater Lake

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Abstract

It was aimed to determine the fishery potential of a freshwater lake in the Eastern Mediterranean where fishing is prohibited, however considered to be reopened for fishing activities. Kocagöl is located on the western part of the Turkish Mediterranean coast. Fisheries is important for the local people for livelihood. Especially, the Mugilid catch is important for local Mediterranean small-scale fishermen. Fishery related parameters (Catch per Unit Effort, growth, mortality, exploitation rate, reference points), biomass, physical (temperature, salinity, pH, turbidity and dissolved oxygen) and chemical (nitrite nitrogen, nitrate nitrogen, ammonium nitrogen and total phosphorus) water parameters were determined. A generalized linear model was established between catch and physical environmental parameters. In general, exploitation rates of the main target, Mugilidae, species are at safe levels. However, selectivity and Lopt parameters showed that the mesh sizes should be increased to provide more sustainable fishery in the area. A controlled fishing practice in this fragile and sensitive area will constitute an environment for the sustainable use of fishery resources in the region. According to results, limit reference points are better for fisheries management plans. This study is an example for eastern Mediterranean freshwater fishery management regulations.

Introduction

Fishery activities in Türkiye are divided into three categories. These are marine water capture, inland water capture, and aquaculture. Fishing performance in inland waters is mostly lake-based. Fishing in inland waters also contributes economically to regions where it occurs. For such activities, which also ensure the development of rural areas, for sustainable fisheries, it is of great significance to scientifically determine reserve estimates of existing water resources and implement these estimates without compromising reserves. In 2023, fishery production was approximately 1,01 million tons in Türkiye. 33.532 tons of this fishery production consisted of caught inland water (3.3%) (TUIK, 2024).

Many studies have been conducted on river and lake fisheries in Türkiye's inland waters in different locations. The topics of the scientific studies are diverse such as exploitation (Cerim *et al*., 2019), age and growth (Çakır *et al*., 2016), sustainability and economy (Rad & Rad 2012), gillnet selectivity (Çat & Yüksel, 2014), invasiveness (Aksu *et al.*, 2021) and genetic (Ağdamar *et al*., 2020). These scientific studies could be more diversified.

Examining the stock structure and size of existing fish stocks in fishing areas, determining the optimal amount of product that can be harvested annually by the stock, and the sustained and maximum productivity of the stock is important to increase the catch and production. Because improving catch performance without information on population size and harvest numbers may lead to irreparable losses in the future (Becer Özvarol & İkiz, 2008). Therefore, stock analysis and population estimation have become increasingly important in recent years. Fisheries authorities are managing fisheries as best they can primarily base on these forecasts.

Kocagöl (Dalaman, Muğla, Türkiye) is located on the southern west coast of Turkish Mediterranean and has a special geographical location due to having connection to the sea. This feature makes it an excellent feeding, sheltering, and breeding area for many fish. However, commercial fishing is prohibited in Kocagöl and it is a potential fishery area for local fishermen. The stock status of the Kocagöl has not been studied yet. It was believed that if the fishery prohibition of the Kocagöl is repealed, the Kocagöl area could become a small-scale fishery area. Therefore, the present study is a preliminary study that describes the fishery potential of the Kocagöl.

Kocagöl has been a fishery restricted area for a long time. However, in recent years, Kocagöl has been considered to be reopened to sustainable fishing by the management authorities. Knowing the fish population in Kocagöl will allow the start of sustainable fishing activities there. In this study, Kocagöl's fishery potential was investigated and suggestions were given to fishery management authorities for further fishery regulations. Although the subject of reopening closed areas to fishing may sound strange at first, the management model presented in this regional study can serve as an example for sustainable fishing practices in nearby areas that have been closed to fishing for a long time.

Materials & Methods

Study Area

The study was conducted between March 2022 and February 2023 in Kocagöl, Dalaman, Muğla. Kocagöl is located on the south west of Türkiye. The area has a connection between the Mediterranean by Karasu brook (≈5200 m). Therefore, it is affected leastwise by sea water (Figure 1). Maximum depth of Kocagöl is 29.3 meters. While the upper side of the Kocagöl is mainly reedy with no more than 2-3 meters depth, the lower side shore has rocky and sandy substrates. Total area of Kocagöl was calculated as 324.64 hectares.

Fishing Trials

In the sampling process, a wooden 6 meters long fishing boat has a 9.9 HP diesel engine was used. Sampling was conducted monthly. Nets with different mesh sizes and different types were used to determine which nets can contribute to sustainability. Fyke nets (15 mm mesh size) and different mesh size monofilament (polyamide) trammel nets (22 mm, 28 mm, 30 mm, 32 mm, 36 mm, 42 mm) were used in samplings. All nets were released near sunset and collected at sunrise. The samples were separated and tagged by mesh sizes. Whole samples were stored in ice and brought to the laboratory on the same day.

Samples collected in compliance with Muğla Sıtkı Koçman University, Local Ethics Committee for Aquatic Animal Experimentation.

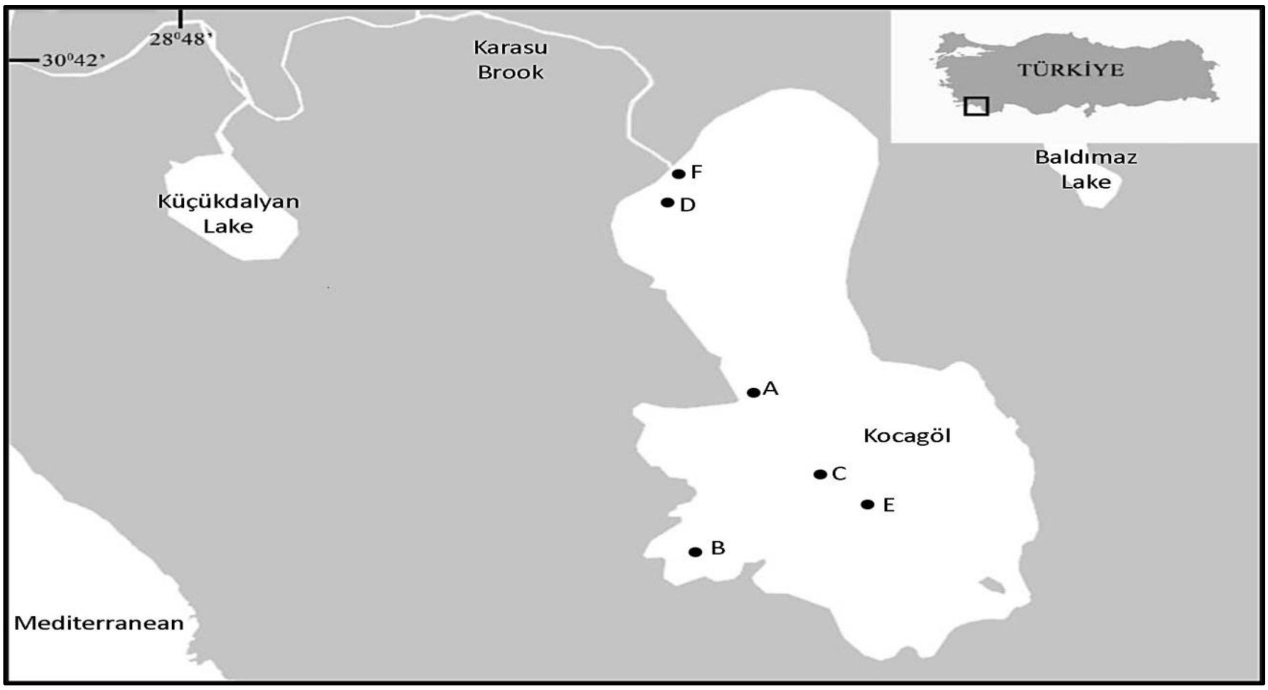

Figure 1. Study area, Kocagöl (A, B, C, D, E and F show the water sampling points).

Obtaining Physical and Chemical Water Parameters

All parameters were recorded monthly. Totally, physical water parameters (temperature, salinity, pH, turbidity, dissolved oxygen) were recorded from different six stations in sampling days (Figure 1). Two stations (D and F) were on the upper side of Kocagöl and four (A, B, C and E) were on the lower side. YSI Professional plus multiparameter was used in this process.

Secchi-disk was used to determine the light transmittance and turbidity. Water samples were taken from under one meter of the surface from all stations to analyze nitrite nitrogen (NO2-N, mg/L), nitrate nitrogen (NO3-N, mg/L), ammonium nitrogen (NH4-N, mg/L) and total phosphorus (TP, mg/L). Agilent Cary60 UV/Vis spectrophotometer was used in these analyses.

Laboratory Examinations

All fish were separated by species. Grey mullet species were determined according to Buhan (1998) and Balık *et al*. (1992) and other species were determined according to Whitehead *et al*. (1986) and Fricke *et al*. (2023).

After species separation, total lengths of all individuals were measured with measurement boards with nearest 0.1 cm and weighted with 0.01 g precision balance.

Otoliths and scales were used for age determination. Otoliths were extracted and stayed in alcohol to remove blood and tissues. After the cleaning process, otoliths were broken from the focus point and burned with a spirit stove to smoke. Darkened otoliths were read under a stereo microscope to determine ages. On the other hand, the scales were taken from fish and cleaned with alcohol. After the cleaning process, ages were read directly under the microfiche reader. All age samples were read by three independent readers.

Fisheries Analysis

All formulas used in calculations/estimations were represented below;

Length-weight relationships;

$$W = aL^b$$ (Ricker, 1973)

Where; L: total length, W: total weight. If *b* value equals 3, means isometric growth, if *b*<3, means negative allometric growth and if *b*>3, means positive allometric growth. Difference between *b* value and isometric growth was tested with *t*-test.

Growth parameters;

$$L_t = L_\infty\left(1 - e^{(-k(t-t_0))}\right)$$ (von Bertalanffy, 1957)

Where; L_t; length of t years old fish, k; growth coefficient, L_∞ (asymptotic length), t_0; theoretical age at zero length

Mean total length;

$$L_{mean} = \sum\left(C\left((L_1 + L_2)/2\right)\right)/n$$ (Beverton & Holt, 1956)

Where; n; total number of captured individuals; C; total number by length classes, ((L_1+L_2)/2; mean of the length classes)

Length at first capture;

$$L_c = \left(L' - k(L_\infty - L')\right)/Z$$ (Beverton & Holt, 1957)

Where; L_c; length at first capture, L'; mean total length, k; growth coefficient, L_∞=asymptotic length, Z; total mortality

Total mortality;

$$Z = \left(k(L_\infty - L_{mean})\right)/(L_{mean} - L')$$ (Beverton & Holt, 1956)

Where; Z= total mortality, k; growth coefficient, L_∞=asymptotic length, L_{mean}; mean total length, L'; the smallest length

Natural mortality;

$$M = 0.9849{L_\infty}^{-0.279}k^{0.6543}T^{0.4634}$$ (Pauly, 1980)

Where; M; natural mortality, k; growth coefficient, L_∞=asymptotic length, T; annual mean temperature

Fisheries mortality;

$$F = Z - M$$ (Gulland, 1971)

Where; Z; total mortality, F; current fishing mortality, M; natural mortality

Exploitation rate;

$$E = F/Z$$ (Gulland, 1971)

Reference points; $F_{opt} = 0.5M \quad F_{lim} = (2M)/3$ (Patterson, 1992)

$$E_{opt} = F_{opt}/\left(M + F_{opt}\right)$$ (Pauly & Morgan, 1987)

$$L_{opt} = L_\infty\left(\frac{3}{3+(M/K)}\right)$$ (Beverton & Holt, 1957)

Other reference points, $E_{0.1}$, $E_{0.5}$ and E_{max}, were calculated by Fisat-II.

Catch per Unit Effort;

$$F = D \cdot L \cdot 1000^{-1}$$

$$CPUE = W/F$$ (De Metrio & Megalafonou, 1988)

Where; F; fishing effort, D; fishing operation duration, L; daily total trammel net used in fishing operation, W; total weight of the catch biomass was estimated by Fisat-II with the VPA method.

Trammel net selectivity was calculated according to Holt (1963)'s indirect estimation method. To prevent confusion on terminological meaning, in the results section, optimum catch sizes of the nets and the reference point, L_{opt}, should not be mixed together.

Statistical Modeling

Firstly, relationships between water parameters were determined by Pearson's correlation. In Pearson's correlation test, correlation coefficients were interpreted according to given scale; 0.0–0.10; negligible correlation, 0.10–0.39; weak correlation, 0.40–0.69; moderate correlation, 0.70–0.89; strong correlation, 0.90–1.00; very strong correlation (Schober *et al*., 2018).

Normality of all monthly data, catch, temperature, salinity, pH, turbidity and dissolved oxygen, was checked by the Shapiro–Wilk test (P>0.05). Variance inflation factor was used to determine the multicollinearity problem. The threshold was chosen as 8 (Cerim *et al*., 2021; Cerim *et al*., 2023). Random forest was used for variable selection. Following this, the Generalized Linear Model (GLM) method was used for modeling. The Durbin-Watson test was used to detect auto-correlation.

Results

Totally, 10 species belong to 5 families were captured (Table 1). All species related estimations, length-frequencies, length-weight relations, age tables, mortality-reference points, gear selectivity, CPUE (Catch per Unit Effort) and VPA (Virtual Population Analysis) results were given in Supplementary material to avoid figure and table chaos.

The VPA graphical results were shown in Figure 2. Fisheries mortality, exploitation rate, mean captured length and reference points were estimated (Table 2). According to these values, recommendations were given to fishery management authorities.

Optimum catch sizes were calculated according to the mesh sizes. Results showed different optimum catch sizes and L_{opt} values of trammel nets (Table 3).

The correlation between water parameters were determined. While temperature is in negative strong relationship with pH (-0.72), it is in positive strong relationship with salinity (0.77). Turbidity is also in negative moderate relationship with dissolved oxygen (-0.64) (Figure 3).

The variable selection showed that salinity is the most effective variable for fishery area. In addition to this, temperature, pH, dissolved oxygen and turbidity follow salinity, respectively. Durbin-Watson Test results indicated that there is no auto-correlation in the model (1.93, P=0.656) (Figure 4).

According to GLM results, while the catch is positively affected by temperature, dissolved oxygen, pH and turbidity, it is negatively affected by salinity (Table 4).

Amount of Nutrients in Water Samples in Yearly

The minimum temperature values recorded in March 2022 ranged from 11.2 to 11.8°C, while the maximum temperature values in August 2022 ranged from 29.9 to 30.3°C. Minimum dissolved oxygen levels are between 3.01 and 5.04 mg/L. The pH in August 2022 is between 6.23 and 6.95, and in December 2022 it is between 8.22 and 8.38. The lowest salinity measured ranged from 4.05 to 12.16 mg/L. The maximum salinity in April 2022 is 4.51 ppt, and the maximum salinity in October 2022 is between 4.75 and 5.3 ppt. Mean values of the physicochemical water parameters are shown in Table 5.

The annual ammonia nitrogen concentration is 0.106-0.148 mg/L, the nitrite concentration is 0.001-0.014 mg/L, the nitrate concentration is 0.027-0.455 mg/L, and the phosphorus concentration is 0.011-0.039 mg/L. Mean values of the water parameters are shown in Table 6.

Table 1. Number and percentages of captured species (C; commercial, NC; non-commercial)

Family	Species	N	Commercial importance	% by Species	% by Family
Mugilidae	*Chelon auratus*	574	C	16.88	34.58
	Mugil cephalus	274	C	8.06	
	Chelon labrosus	268	C	7.88	
	Chelon saliens	60	C	1.76	
Anguillidae	*Anguilla anguilla*	124	C	3.64	3.64
Cyprinidae	*Capoeta aydinensis*	13	NC	0.38	1.38
	Carassius gibelio	20	NC	0.59	
	Cyprinus carpio	14	C	0.41	
Siluridae	*Silurus glanis*	7	C	0.21	0.21
Cichlidae	*Coptodon zillii*	2047	NC	60.19	60.19
	TOTAL	3401		100	

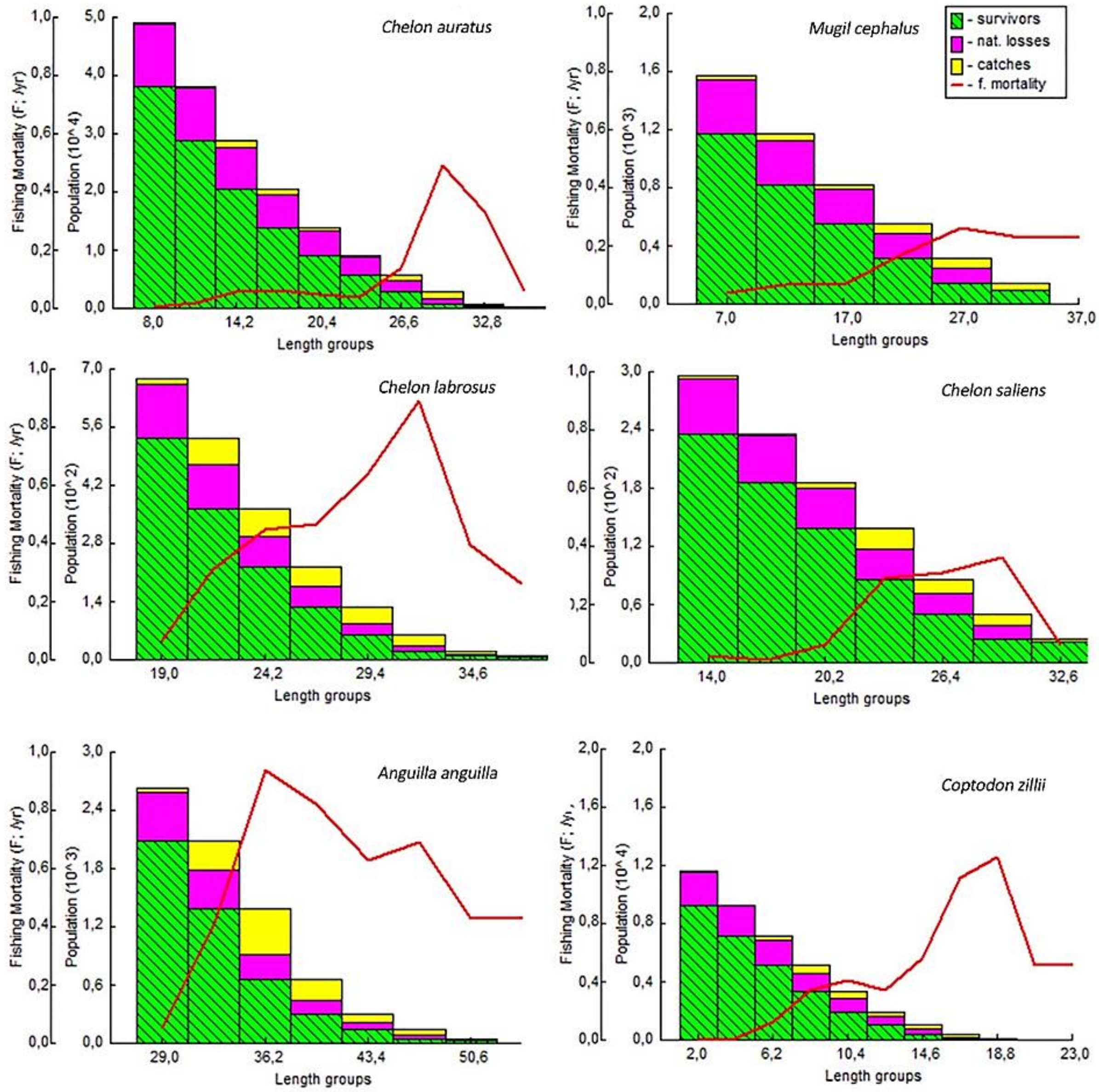

Figure 2. Virtual Population Analysis for *C. auratus*, *M. cephalus*, *C. labrosus*, *C. saliens*. *A. anguilla* and *C. zillii* from the eastern Mediterranean.

Discussion

Comments on Fishery for Fishery Management

Seven of ten captured species are commercial. *C. zillii* and *C. aydinensis*, *C. gibelio* are non-commercial species, however, they constituted 61.19% of the catch, totally. In the meaning of commercial importance, while *C. auratus* is the most captured species (16.88%), *M. cephalus* follows it with 8.06%. In the Cyprinidae family, especially *C. carpio*, although the total length and total weight of individuals are high, the number of individuals is relatively low compared to other species (Supplementary material).

According to VPA results, fishing pressure starts at the 26 cm length group for *C. auratus*. Similarly, Reis (2018) found that the fishery pressure starts at the 30 cm length group for *C. auratus*. This variation may be originated from fishing gear. Reis (2018) used barrier traps and in this study, it was used trammel nets. It can be said selectivity of trammel net is a little bit lower than barrier traps. On the other hand, in length at first maturity perspective, Kesiktaş *et al*. (2020) found that lengths at first maturity of *C. auratus* are 26.2 cm for males and 24.1 cm for females, respectively. Owing to low length at first maturity sizes, the fishing pressure in this study starts at the border of length at maturity sizes. Moreover, El-Aiatt *et al*. (2022) found that the lengths at first maturity of *M. cephalus* are 29.8 cm and 30 cm for males and females, respectively. Furthermore, according to Koutrakis (2011), length at first maturity of *C. saliens* (unsexed) is 26.9 cm FL (equals to nearly 27.8 cm TL, Froese & Pauly 2023). Moreover, Campillo (1992) estimated that the lengths at first maturity of *C. labrosus*

Table 2. Fisheries mortality, exploitation rate, mean captured length and reference points values

	Mortality (y^{-1}), Exploitation rate and Mean length (cm)	Reference Points			
	F	F_{opt}	F_{lim}		
Chelon auratus	0.06	0.18	0.25		
Mugil cephalus	0.23	0.24	0.32		
Chelon labrosus	0.26	0.245	0.33		
Chelon saliens	0.06	0.22	0.29		
Anguilla anguilla	0.43	0.25	0.34		
Coptodon zillii	0.51	0.41	0.55		
	E	E_{opt}	E_{10}	E_{50}	E_{max}
Chelon auratus	0.14	0.5	1	0.5	1
Mugil cephalus	0.33	0.5	0.76	0.37	0.88
Chelon labrosus	0.35	0.5	1.00	0.41	1.00
Chelon saliens	0.11	0.5	1.00	0.48	1.00
Anguilla anguilla	0.46	0.5	0.77	0.38	0.89
Coptodon zillii	0.38	0.5	0.41	0.28	0.49
	L_{mean}	L_c	L_{opt}		
Chelon auratus	22.8	46.64	43.67		
Mugil cephalus	23.7	25.75	49.90		
Chelon labrosus	26.77	29.84	47.80		
Chelon saliens	26.31	45.08	49.89		
Anguilla anguilla	39.4	35.29	38.28		
Coptodon zillii	11.82	5.71	23.66		

Table 3. Optimum catch sizes of nets and reference points

	Optimum catch sizes					Reference Points
	Fyke net	22 mm	28 mm	30 mm	32 mm	L_{opt}
Chelon auratus	15.33	22.48	28.61	30.65	32.70	43.67
Mugil cephalus	13.01	19.09	24.29	26.03	27.76	49.90
Chelon labrosus		43.29	55.10	59.04	62.97	47.80
Chelon saliens		19.27	24.52		28.03	49.89
Captadon zillii	9.55	14.01	17.83	19.10	20.38	23.66

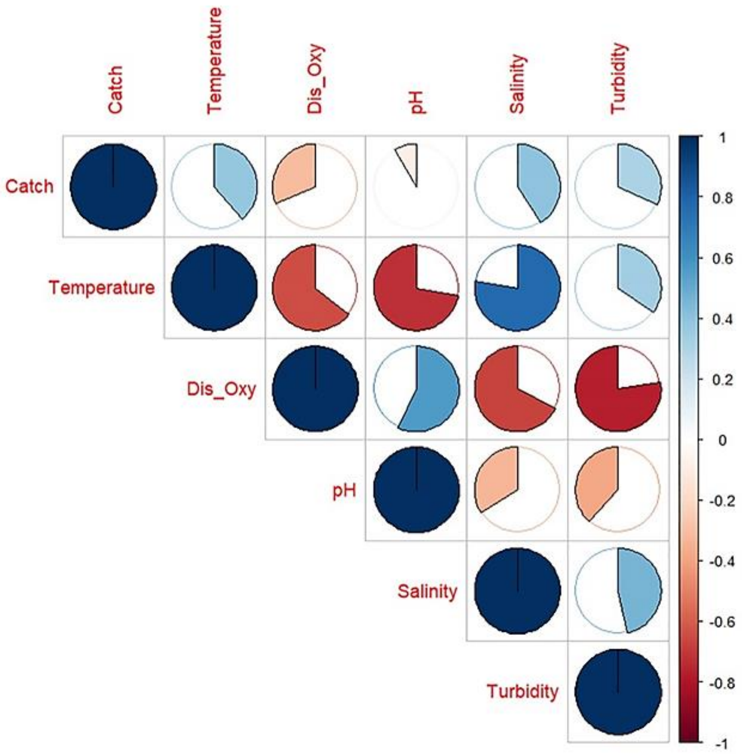

Figure 3. Correlation between physical water parameters and catch.

are 29.5 cm SL for females (approximately 34.3 cm TL, Froese & Pauly, 2023) and 25 cm SL for males (approximately 29.1 cm TL, Froese & Pauly, 2023). In this study, fishing pressure on *M. cephalus*, *C. saliens* and *C. labrosus* starts below the length at first maturity of these species and *C. auratus* should also be counted in these species. If the fishery management wants to decide on the relative lengths at the fishing pressure starts, mesh sizes of the nets should be increased to compensate for the reproduction.

Moreover, the fishing pressure on *A. anguilla* starts at a 29 cm length group. Cattrijsse and Hampel (2000) stated that lengths at first maturity are 37.5 cm for males and 55 cm for females. Due to the low catch size of *A. anguilla* compared with length at maturity, the mesh sizes of fyke nets should be increased.

Lastly, VPA results of *C. zillii* showed that fishing pressure starts on 6 cm length class. Additionally, the highest fishing pressure starts on the 14 cm length class. The lower fishing pressure may be due to small-mesh size fyke nets and higher fishing pressure may be due to trammel nets. Rabie *et al*. (2021) found that the lengths at first maturity as 9.7 cm for females and 8.5 cm for males, respectively. When comparing our results with Rabie *et al*. (2021), fishing pressure in this study starts at lower length classes than lengths at first maturity. In the meaning of sustainable reproduction, mesh size of fyke nets should be increased. On the other hand, Sarıbaş (2022) mentioned that *C. zilli* is an invasive species in Köyceğiz lake is too close to Kocagöl lake. In this sense, if *C. zilli* is an invasive species in our study area, using fyke nets is a proper method to struggle with this species.

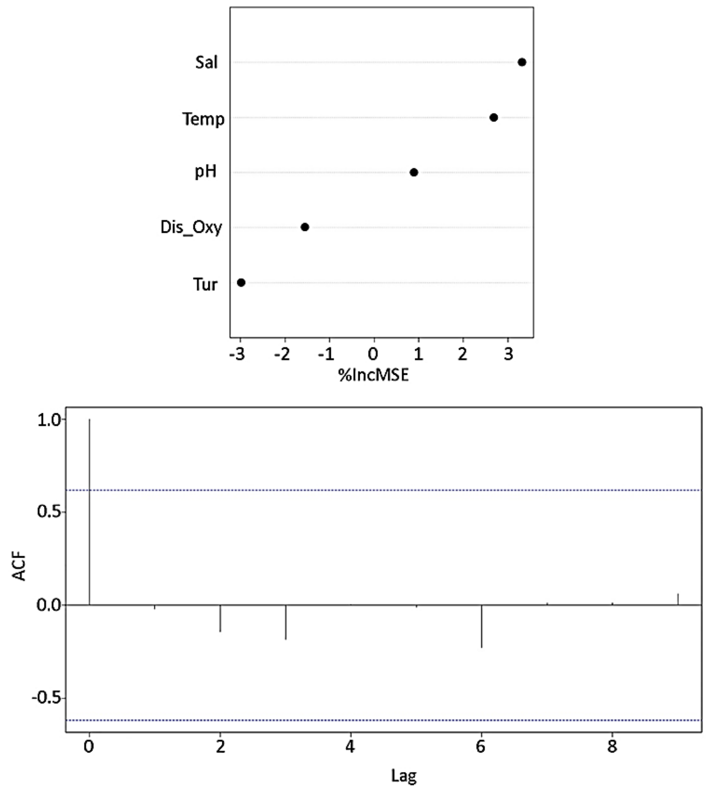

Figure 4. Important variables and auto-correlation.

Table 4. Model results

	Intercept	Temperature	Dissolved Oxygen	pH	Salinity	Turbidity	R^2	RMSE	MAE
Coefficients	-1.021	1.241	1.093	1.581	-0.665	1.698	0.52	0.33	0.18
CPUE	-1.021 + 1.241*Temperature + 1.093*Dissolved Oxygen + 1.581*pH + -0.665*Salinity + 1.698*Turbidity								

Table 5. Mean values of physicochemical water parameters of the Kocagöl

	Mar.22	Apr.22	May.22	Jun.22	Jul.22	Aug.22	Sep.22	Oct.22	Nov.22	Dec.22	Jan.23	Feb.23
Temperature (°C)	11.6	19.5	23.6	29.0	29.6	30.0	24.7	21.8	17.4	14.5	13.4	14.5
Oxygen saturation (%)	112.1	98.6	87.9	95.7	91.9	66.5	50.4	56.6	61.3	76.5	83.4	92.4
pH	8.76	7.43	7.83	8.10	7.60	6.57	7.53	7.89	8.31	8.33	8.19	8.13
Salinity (ppt)	4.17	4.35	4.80	5.20	5.17	4.97	4.89	4.84	5.41	4.30	4.21	4.17
Turbidity	2.0	1.5	2.5	2.6	2.7	4.9	4.1	3.0	3.4	3.4	2.7	2.4

Table 6. Mean seasonal values of ammonia nitrogen, nitrite, nitrate and phosphorus concentrations (BDL; Below Detection Limits)

	Spring	Summer	Autumn	Winter
Ammonia nitrogen (mg/L)	BDL	BDL	BDL	0.147
Nitrite (mg/L)	0.042	0.052	0.003	0.004
Nitrate (mg/L)	0.250	0.283	0.027	0.027
Phosphorus (mg/L)	0.0252	0.029	BDL	BDL

Current fishing mortality varies by species. In Mugilidae species, current fishing mortality of *C. labrosus* (0.26 y^{-1}) is a little bit higher than the reference point F_{opt} (0.25 y^{-1}). In spite of this, it is lower than F_{lim} (0.33 y^{-1}). On the other hand, current exploitation rate (0.35) is lower than the other reference points, E_{opt} (0.5), E_{10} (1.0), E_{50} (0.41), E_{max} (1.0). Moreover, L_{mean} (26.77 cm) and L_c (29.84 cm) is lower than L_{opt} (47.8 cm). On the condition that the captured sizes stay stable, exploitation rate could be increased for *C. labrosus* (Table 7).

In *A. anguilla*, current fishing mortality (0.43 y^{-1}) is higher than the reference points F_{opt} (0.25 y^{-1}) and F_{lim} (0.34 y^{-1}). Although the current exploitation rate (0.46) is lower than E_{opt} (0.5), E_{10} (0.77) and E_{max} (0.89), it is higher than E_{50} (0.38). Furthermore, while L_{mean} (39.4 cm) is higher than L_{opt} (38.28 cm), L_c (35.29 cm) is lower than L_{opt}. The results are complicated in *A. anguilla* fishery. However, it is more logical to know the species' life history for making decisions on its fishery management. The maturity sizes mentioned in previous paragraphs (in VPA discussion) should be considered. Therefore, the same fishery management rule (increase in mesh size of fyke nets) could be applied.

According to selectivity parameters, if L_{opt} will be considered, all catch sizes for species, without *C. laborus* captured by 28 mm, 30 mm and 32 mm mesh size, are lower than L_{opt} (Table 8). Therefore, comparing the selectivity parameters and L_{opt} could be the first fishery management offer. Increase in fish length, logically, leads to an increase in fish weight. If selectivity is included in this application, more yield can be obtained by catching fewer large-sized individuals. A fishery that produces less individual but more yield can contribute more to sustainability. Thus, sustainability could be obtained for these species.

Catch and Environmental Parameters Relationships

Many studies on the relationship between fishery and environmental parameters indicated that environmental parameters affect fishery landings (Ceyhan *et al*., 2018; Ceyhan & Tosunoğlu, 2022; Cerim *et al*., 2023). Therefore, interactions between fishery and environmental parameters were tried to understand with statistical modeling. However, according to model results, environmental parameters have no effect on the catch. As seen in the Table 4, coefficients of the variables are pretty close to each other. This finding is supported by catch-environmental parameters graphs and correlation between catch and environmental parameters tab (Supplementary material). The gray mullet catch is 58.2% of the total catch. In the adjacent region (Köyceğiz lagoon), Reis (2018) separated the gray mullet species into two basic migratory behaviors as winter fish (migration occurs in winter times) (*Chelon labrosus, Chelon auratus*) and summer fish (migration occurs in summer times) (*Mugil cephalus, Chelon saliens*). In winter and summer times, gray mullets are captured in barrier traps while the gray mullets during migration. *Chelon auratus* is the most captured Mugilidae species in the present study. When the salinity decreases, *Chelon auratus* catch increases. Increase in catch occurs in winter times that occurrence of low salinity with precipitations. Shaha *et al*. (2022) observed that salinity, water temperature, and chlorophyll-a have effects on fish distribution and assemblages. Moreover, for example, leaping gray mullet (*Chelon saliens*) reproduce at sea (Balık *et al*., 2011). Balık *et al*. (2011) found that the increase in GSI values of *Chelon saliens* is triggered by temperature in Beymelek lagoon, eastern Mediterranean. Thus, temperature triggered spawning behavior leads to migration. In this study, considerable peak changes/relations between catch and environmental parameters have not been observed at the same time. However, if both temperature and catch are considered together, gray mullet migration may be triggered by temperature in the study area. Literature is confusing in the meaning of decline in fishery landings. Makwinja and M'balaka (2017) indicated that while precipitation has a positive effect on fishery landings, temperature does not affect the catch. Hydrological factors (water quality parameters) affect the water inflow and nutrient flows to inland water bodies. Rainfall is one of the main factors affecting the entire chain of mineralogical events of lakes (Chifamba, 2000). Physicochemical water parameters fall within the acceptable range for fish (Stickney, 2017). In a more clear expression environmental criteria (temperature, dissolved oxygen, pH, salinity, ammonia, nitrite and nitrate) values are within the range of fish species identified in the lake, including mullet, eel, Capoeta, Tilapia, Prussian carp and common carp (Boyd & Tucker, 1998; Ernst, 2000; Bhatnagar & Devi, 2013). Kumar *et al.* (2013) mentioned that the temperature and the fishing pressure effect landings. These opposing findings about fishery landings may be originated from other regional differences (latitude, altitude, connection between sea etc.) or complicated relationships between environmental

Table 7. Comparing fishing mortality, exploitation rate and catch sizes with reference points (↑; should be increased, ↓; should be decreased)

Species	Considerations							
	F	**F_{opt}**	**F**	**F_{lim}**				
Chelon auratus	↑	0.19	↑	0.25				
Mugil cephalus	↑	0.24	↑	0.32				
Chelon labrosus	↓	0.25	↑	0.33				
Chelon saliens	↑	0.22	↑	0.29				
Anguilla anguilla	↓	0.26	↓	0.34				
Coptodon zillii	↓	0.41	↑	0.55				
	E	**E_{opt}**	**E**	**E_{10}**	**E**	**E_{50}**	**E**	**E_{max}**
Chelon auratus	↑	0.50	↑	1.00	↑	0.50	↑	1.00
Mugil cephalus	↑	0.50	↑	0.76	↑	0.37	↑	0.88
Chelon labrosus	↑	0.50	↑	1.00	↑	0.41	↑	1.00
Chelon saliens	↑	0.50	↑	1.00	↑	0.48	↑	1.00
Anguilla anguilla	↑	0.50	↑	0.77	↓	0.38	↑	0.89
Coptodon zillii	↑	0.50	↑	0.41	↓	0.28	↑	0.49
	L_{mean}	**L_{opt}**	**L_c**	**L_{opt}**				
Chelon auratus	↑	43.67	↓	43.67				
Mugil cephalus	↑	49.90	↑	49.90				
Chelon labrosus	↑	47.80	↑	47.80				
Chelon saliens	↑	49.89	↑	49.89				
Anguilla anguilla	↓	38.28	↑	38.28				
Coptodon zillii	↑	23.66	↑	23.66				

Table 8. Comparing optimum catch sizes and reference point, L_{opt} (↑; catch size should be increased, ↓; catch size should be decreased)

Species	Fyke net	22 mm	28 mm	30 mm	32 mm	L_{opt}
Chelon auratus	↑	↑	↑	↑	↑	43.67
Mugil cephalus	↑	↑	↑	↑	↑	49.90
Chelon labrosus		↑	↓	↓	↓	47.80
Chelon saliens		↑	↑		↑	49.89
Captadon zilli	↑	↑	↑	↑	↑	23.66

parameters. In the meaning of complicated relationships, Robertis *et al*. (2003) indicated that visibility is negatively affected by turbidity. Moreover, Paaijmans *et al*. (2008) found that turbidity increases temperature by absorbing and scattering the sunlight. Furthermore, Nyanti *et al*. (2018) revealed that increase in temperature, low pH and high suspended solids affect negatively fish survival and this may be an indicator of fish movement to find a better place. In this sense, catch may be positively affected by increased turbidity.

According to these scientific literatures, the environmental parameters have complicated relationships. More than their singular effects, the combined effects of environmental parameters on fishery landings are more logical in our opinion.

Consequently, as it is known, these areas are very sensitive and fragile. The study area is suitable for fishing activities. However, it should be done in a controlled manner, that is, by a certain number of fishermen using a certain type and quantity of fishing gear. Otherwise, the use of Kocagöl for random fishing activities will cause more harm than good to the region. In allow fishing in Kocagöl, it is important to structure a controlled and ecosystem-based fishery in the region. Thus, it is certain that Kocagöl will make a sustainable economic contribution to the region in the management planning to be made in line with the specified recommendations.

Ethical Statement

Not applicable.

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Author Contribution

First Author; writing – original draft, writing – review and editing, data analysis, visualization. Second Author; writing – original draft, writing – review and editing

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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