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RESEARCH PAPER

Data-poor Stock Assessment of Narrow-clawed Crayfish (*Pontastacus leptodactylus*) in Keban Dam Lake (Türkiye) Using CMSY Method

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Abstract

In this study, as a data-poor fish stock assessment method *CMSY* was used to assess the current stock status of the Keban reservoir crayfish stock due to not having further data set for using the data-rich models. A total of 27 years catch data (from 1995 to 2021) was used in the analysing process of study. Estimated *CMSY* model parameters with confidence intervals are as follows: r=0.426 (0.357 - 0.509) year^{-1}, k=146 (118 - 180) ton, MSY=15.7 (13.0 - 18.0) ton, B_{2021}=77.9 (59.5 - 86.7) ton, B_{MSY}=72.8 (58.9 - 89.9) ton, F_{2021}=0.295 (0.265 - 0.386) year^{-1}, F_{MSY} = 0.213 (0.179 - 0.254) year^{-1}, B_{2021}/B_{MSY} =1.07 (0.818 - 1.190) and F_{2021}/F_{MSY}=1.38 (1.240 - 1.81). Our study has found that the crayfish population in the Keban reservoir has been in decline due to overfishing since the late 1990s. However, the population has shown signs of recovery since 2013 due to reduced fishing activity. After all overexploitation occurred again in 2021. Our analysis also showed that the current quota of 30.5 tons is significantly higher than the MSY of 15.7 tons. Therefore, it is recommended to reduce the crayfish quota to 15.7 tons in order to sustain the population and prevent further decline.

Introduction

The policymakers have mostly ignored the conservation and management of inland fisheries; however, significant contributions are made by inland fisheries to food security and livelihoods locally, regionally, and globally (Cooke et al., 2021). Over 40% of the world's reported fish production is based on inland capture fisheries and aquaculture (Lynch et al., 2016). In addition to overfishing there are so many affects (such as, flow alterations, drought, invasive species, sedimentation, dams, and pollution) on sustainability of inland fisheries. Assessing stressors and their effects on global inland fisheries is fundamental for efficient management, monitoring, and conservation, but unlike marine fisheries, there is no standardized method to assess inland fisheries (Bartley et al., 2015; Cooke et al., 2016; Stokes et al., 2021).

Türkiye is a significant supplier of *Pontastacus leptodactylus*, a particularly well-liked aquatic product in Europe (Wickins & Lee, 2002; Harlıoğlu & Harlıoğlu, 2009).

There is no aquaculture production in Türkiye, and fishing is the only method used to produce *P. leptodactylus* (Cilbiz et al., 2020). Türkiye gathered 1011 tons of P. leptodactylus from 33 different water sources in 2021, and this output contributed the country's economy by more than 3 million $USD (Turkstat, 2022). One of the most important of these water resources is Keban Dam Lake (Harlıoğlu, 2008). In Keban Dam Lake, there are 28 fish species belonging to 7 families (Yıldırım et al., 2015). 10 of these species are caught by approximately 200 commercial fishing boats in the dam lake. Besides fish, crayfish (*Pontastacus leptodactylus* Eschscholtz, 1823) stocked in Keban Dam Lake and have been fished since 1994. Crayfish fishing, which started in 1994 only in Ağın region, spread to Kemaliye, Keban, Çemişgezek and Uluova regions, respectively (Yüksel & Duman, 2011; Demirol & Yüksel, 2014). 22 fishing boats are currently used for crayfish fishing in addition to fish in these regions.

Fyke nets are used for crayfish fishing in Keban Dam Lake, which are 18 mm mesh size (knot to knot), single-entry and double-strait, consisting of 5 circles, the first circle being "D", with a guiding net between them. Fyke nets are positioned on the bottom at a depth of 5 to 21 meters parallel to the shore and they are stay at water, continue fishing for 7 days. On the 8th day, the fyke nets are lifted and the crayfish are transferred to the landing points. A fishing area has been determined for each crayfish boat in Keban Dam Lake. The boats can only fishing crayfish in these areas that belong to them (Demirol & Yüksel, 2014).

Although there have been previous studies on the stock assessment of crayfish in Keban Reservoir (Yüksel et al., 2013; Demirol et al., 2017b), there is a lack of continuous data collection. The absence of continuous data makes it difficult to use data-rich stock assessment models to evaluate the crayfish stock in Keban Dam Lake. Therefore, to evaluate the crayfish stock, it is necessary to use a limited data stock assessment model that is consistent with the FAO's Sustainable Development Goals.

In recent years, there have been numerous mathematical methods developed to assess data-poor stocks. These new methods are important for international and national fisheries management organizations (Andrašūnas et al., 2022). The Food and Agriculture Organization (FAO) of the United Nations (UN) is responsible for monitoring global progress in the sustainable use of fisheries resources in achieving the Sustainable Development Goals (SDGs) (Target 14.4). In the SDG Indicator 14.4.1 (FAO, 2022), maximum sustainable yield (MSY) is used as a reference point for evaluating sustainability, and the CMSY method is used to calculate it (Andrašūnas et al., 2022). Given that only catch data is available, the CMSY method was chosen as a data-poor stock assessment method. The aim of this study is to provide the necessary knowledge for the sustainable management of the data-poor crayfish population in Keban Dam Lake, which is an important crayfish stock in Türkiye.

Material and Method

Study Area

Keban Dam was built on the Euphrates River between 1965 and 1975 for the purpose of generating electricity. The dam stands 210 meters tall above the river bed and the lake it creates has a volume of 31000 hm^3 and a surface area of 675 km^2 at its normal water level. The Keban Dam Lake is the third largest lake or reservoir in Türkiye by surface area. It is located in eastern Türkiye about 10 km downstream from the point where the Murat and Karasu Rivers merge to form the Euphrates River (Figure 1). When it was first built, the Keban Dam provided 20% of Türkiye's electricity needs. In addition to its electricity generation capabilities, the large volume of water in the lake has also created potential for fisheries. Fishing has been carried out in the provinces of Elazig, Tunceli, and Erzincan, which have shores on the Keban Dam Lake, since the late 1970s (DSİ, 2022).

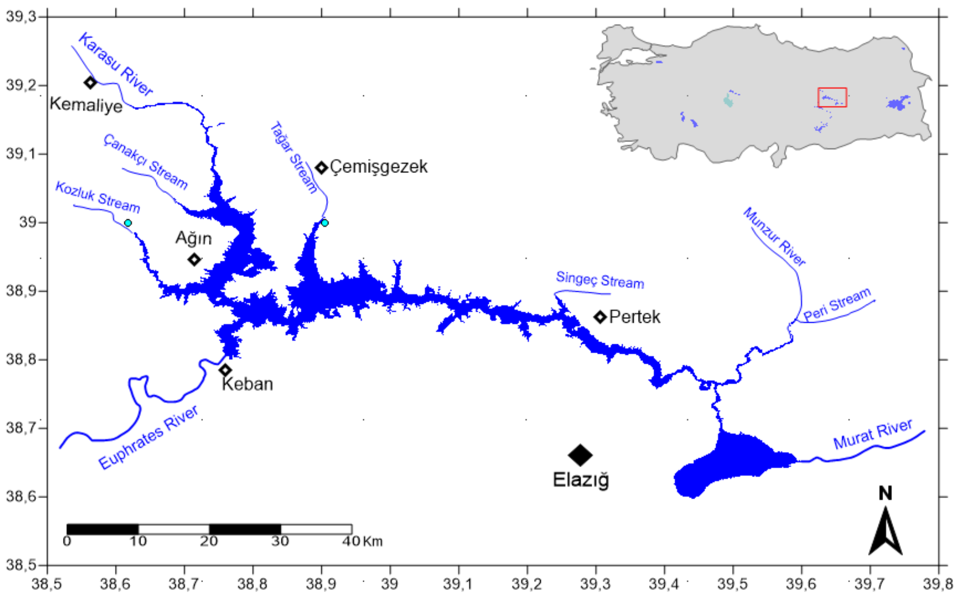

Figure 1. Keban Dam Lake and its location

In 1997-2000, the lake was divided into 16 fishing areas, and fishing has continued in these areas up to the present day (Anonymous, 1982; Celayir et al., 2006).

Data Collection

For this study, a total of 28 years of catch data were collected for the period between 1994 and 2021. The data set used in the analyses includes all of the crayfish catches in Keban Dam Lake throughout its history, with the exception of 1994, for which the reason for the decrease in annual catch between 1994 and 1995 is unknown. The catch data for the period between 1994 and 2013 were obtained from Demirol and Yüksel (2014), while the catch data for the following years were calculated using the crayfish sales records of 22 boats that fished in the lake between 2014 and 2021. These sales records are thought to be the most reliable way to collect annual catch data for inland waters, as was done by Demirol and Yüksel (2014) and in this study. Demirol et al. (2015) found that in their study of Keban Dam Lake, the discard rate for crayfish fishing was quite high at 58%, but that the majority of discarded individuals were under the minimum landing size (MLS) and were returned to the region where they were caught alive, resulting in a low discard mortality rate. Therefore, the discard rate was not taken into account when calculating the annual catch in this study. Figure 2 shows the amount of crayfish caught in Keban Dam Lake between 1994 and 2021, as well as the status of the stock as explained in the discussion section.

CMSY

CMSY (version CMSY_2019_9f.R) model code Froese et al. (2019) was used the assessment of the crayfish stock of the Keban Dam Lake. R (v4.0.3) based R Studio (v1.3.1093) software were used in the calculations (R Core Team, 2021; R Studio Team, 2021).

This is an open-source fisheries stock assessment model and can be used where fisheries data is restricted. The model uses data from past on the catches of a species and its resilience. According to Holling (1973) resilience is generally defined as the ability of a system to respond to and absorb disturbances while maintaining essentially the same function and structure. These data are used to determine the initial parameters of the model. From the resilience and catch data, the model predicts the control parameters of the fishery (MSY, B_{MSY}, F_{MSY}), stock exploitation level (F/F_{MSY}) and relative stock size (B/B_{MSY}) (Froese et al., 2019). The *CMSY* model is based on Schaefer's surplus production model (*SPM*) (Schaefer, 1954) which is very simple and therefore very popular (Andrašūnas et al., 2022):

$$B_{t+1} = B_t + r.(1 - B_t/k)\cdot B_t - C_t \qquad (1)$$

Where B_t is the biomass, r is the intrinsic growth rate of population, k is the environmental carrying capacity (unexploited or initial biomass B_0), and C_t is the catch at time at t. In this model there are two unknown parameters which are r and k. Since depletion (d) is:

$$d = 1 - B_t/k \qquad (2)$$

The value of k in formula (1) can be found using prior knowledge about r and d (Zhou et al., 2018).

To modelling population the *CMSY* model uses production, information on the resilience of the species, population growth rate (r) and environmental carrying capacity (k) by iterative Markov Chain Monte Carlo approach. A pair of parameters (r, k) is applicable if the corresponding biomass trajectories predicted from the surplus production model are logical with catches in the sense that the biomass estimated by Formula (1) doesn't take negative values, and is consistent with priors relating to the relative biomass amounts at the starting and end of the time series (Froese et al., 2019). After the finding of an optimal pair of r and k, a time series of biomass (B) and fishing mortality (F) can be calculated, along with different indicators [Schaefer, 1954; Ricker, 1975; Andrašūnas et al., 2022).

$$MSY = r.k/4 \qquad (3)$$

$$F_{MSY} = 0.5.r \qquad (4)$$

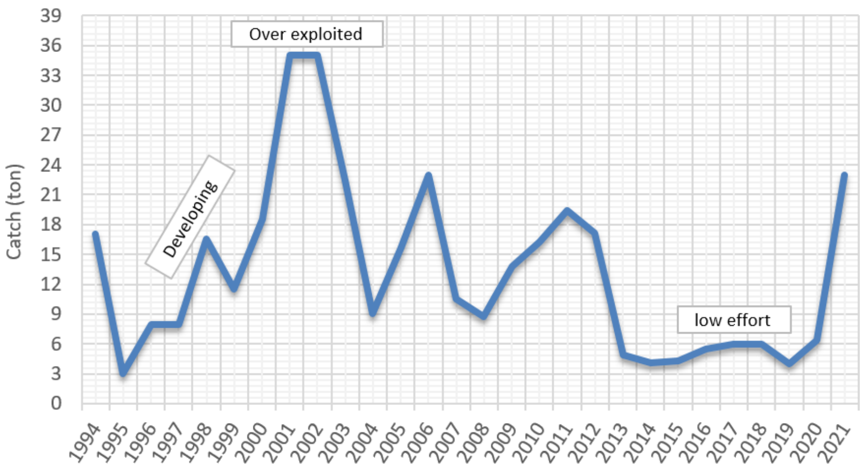

Figure 2. Crayfish caught and exploitation status of stock in Keban D.L.

$$B_{MSY} = 0.5.k \quad (5)$$

Stocks status can be characterized according to the F/F_{MSY} and B/B_{MSY} of the final year of a time series (Table 1).

Input Parameters and Data

Prior relative biomass (*B/k*) and resilience of species ranges corresponding to depletion levels at the start, medium and end time series are used as input parameters at model. Resilience is a prior prediction of resilience of species, which is related the intrinsic growth rate of the species. Suggested values are "very low", "low", "medium" and ʹʹhigh ʹʹ. The borders of these categories (r_{low} - r_{high}) are shown in Table 1.

The resilience value of the stock can be obtained from www.fishbaese.org or it can be calculated by using the relations of r with other parameters.

$$r = 2M = 2F_{MSY} = 3/t_{gen} = 9/t_{max} = 3K \quad (6)$$

In the formula r is the growth rate of the population, M is the natural mortality, F_{MSY} is the fishing mortality rate for *MSY*: $F_{MSY} = 0.5.r$, t_{gen} is the generation time of the population, t_{max} is the maximum age of individuals in the population and K is a parameter of the von Bertalanffy growth equation (Froese et al., 2017). The resilience values used in this study were determined based on Demirol et al. (2017a) on the crayfish population in Keban Dam Lake, which found that the average number of eggs in the population was only 129 eggs per individual. As a result, it was assumed that the resilience of the crayfish stock in the reservoir could be low, especially in comparison to fish populations.

The prior relative biomass (B/K), which is another input parameter for the CMSY model, was predicted based on the intervals suggested by Froese et al. (2019): nearly unexploited (0.75 - 1.0), low depletion (0.4 - 0.8), medium depletion (0.2 - 0.6), strong depletion (0.01 - 0.4), and very strong depletion (0.01 - 0.2). In this study, the pairs of r and B/K values were estimated based on expert decision according to the assumed depletion grade (Table 2).

Results

The CMSY method generates a report in two parts. The first part is based on the analysis of pairs of r and k values, and the second part is based on fisheries management. Figure 3A, illustrates all of the r-k pairs found in the analysis (shown in grey) and viable pairs (shown in dark grey) that are consistent with catch data and other information used in the model. Figure 3B, provides a more detailed view of the analysis of the viable r-k pairs shown in Figure 3A. The dashed rectangle represents the range of values specified as input parameters. The blue cross in the center of the graph indicates the optimal r-k pair estimated by the CMSY model, and the horizontal and vertical bars represent the 95% confidence intervals for r and k. According to the CMSY model, the resilience (r) of the crayfish population in Keban Dam Lake is 0.426 year-1 (95% CI=0.357 - 0.509) and the carrying capacity (k) is 146 tons (95% CI=118 - 180).

The CMSY method estimates key parameters such as the maximum sustainable yield (MSY), fishing mortality (F), fishing mortality corresponding to MSY (F_{MSY}), biomass (B), and biomass corresponding to MSY (B_{MSY}) for fisheries management. Table 3 shows that the crayfish catch in 2021 (22.95 tons) was higher than the MSY (15.70 tons). The table also shows that the biomass in 2021 (77.9 tons) was higher than the sustainable biomass (B_{MSY}) of 72.8 tons, but the fishing mortality in 2021 (F_{2021}: 0.295 year^{-1}) was higher than the fishing mortality corresponding to MSY (F_{MSY}: 0.213 year^{-1}). This suggests that while the crayfish population may be in relatively good condition, the fishing pressure on the population is increasing.

The ratios B/B_{MSY} and F/F_{MSY} can be used to classify the status of the stock according to the definitions in Table 1. In the case of the crayfish stock in Keban Dam Lake, the values of B/B_{MSY} and F/F_{MSY} were calculated 1.07 and 1.38, respectively. According to Table 1, these values do not correspond to any of the defined categories. However, because B_{2021}/B_{MSY} is slightly higher than 1 and F_{2021}/F_{MSY} is higher than 1, the stock can be considered to be "fully overfished" based on the 2021 data.

Table 1. Resilience categories and r-values (Froese et al., 2019)

Resilience	r_{low} - r_{high}
Very low	0.015 - 0.1
Low	0.05 - 0.5
Medium	0.2 - 0.8
High	0.6 - 1.5

Table 2. Input parameters for *CMSY* model*

Resilience	Analyzed years	Start *B/k* low-high	Intermediate year	Intermediate *B/k* Low-high	End *B/k* Low-high
0.05 - 0.5	1995 - 2021	0.75 - 1.00	2001	0.6 - 0.8	0.4 - 0.6

*Start: the year the analysis started, Intermediate: assigned year in the time series, End: final year of analysis

Figure 4 presents the results of the CMSY analysis through a series of graphs. Graph A (upper left) shows the catch relative to the maximum sustainable yield (MSY), with the 95% confidence limits indicated in grey. Graph B (upper right) shows the relative exploitation (F/F_{MSY}) and graph C (lower left) shows the development of relative biomass (B/B_{MSY}), with the grey area indicating uncertainty. Graph D (lower right) is a Kobe chart, which shows the time series of fishing pressure (F/F_{MSY}) on the Y-axis and stock size (B/B_{MSY}) on the X-axis. The Kobe chart is divided into four zones: the orange zone indicates that the stock size is healthy but is at risk of being overfished; the red zone indicates that the stock is overexploited and the biomass is insufficient to produce the maximum sustainable yield; the yellow zone indicates that fishing effort is decreasing and the insufficient stock size is improving; and the green zone, which is the target of fisheries management, indicates that fishing pressure is sustainable and the stock size is sufficient to achieve the maximum sustainable yield. The yellow area around the triangle, which represents the evaluation for the last year, shows the 50% confidence interval, the grey area shows the 80% confidence interval, and the dark grey area shows the 95% confidence interval. The legend at the top right of the graph indicates the percentages of the 95% confidence interval area falling into each of the colored zones (Froese et al., 2019). Figure 4A, displays the annual catch of crayfish in Keban D. L. from 1995 to 2021. The dashed line running parallel to the x-axis from the middle of the graph represents the maximum sustainable yield (MSY) of 15.7 tons, as calculated using CMSY. The dark grey area represents the 95% confidence interval for the MSY, ranging from 13 to 18 tons. As shown in the graph, the annual catch exceeded the upper limit of the MSY (18 tons) in the years 2000, 2001, 2002, 2003, 2011, and 2021.

Figure 4B, illustrates the stock exploitation over the analyzed period. The dashed line on the graph indicates the highest acceptable level of the F/Fmsy value, which is "1." When the value is above "1," the stock is overexploited, as shown on the graph. It can also be seen that the stock was overfished between 2001 and 2012. From 2012, the fishing pressure decreased below the maximum sustainable level, but in the last year, the stock was once again overexploited.

Figure 4C, displays the variation of the relative biomass over time. In an unexploited stock, the B/B_{MSY} value is expected to be high, as seen in 1995. However, as fishing pressure increased, this value fell below "1" in 2002. With the decrease in fishing effort since 2013, the value has begun to rise again and exceeded "1" once more in 2020.

Figure 4D, shows that the crayfish population was in the green zone in 1995 when fishing began. In the following years, as fishing pressure increased, the population moved into the orange zone and then the red zone. However, as fishing pressure decreased first

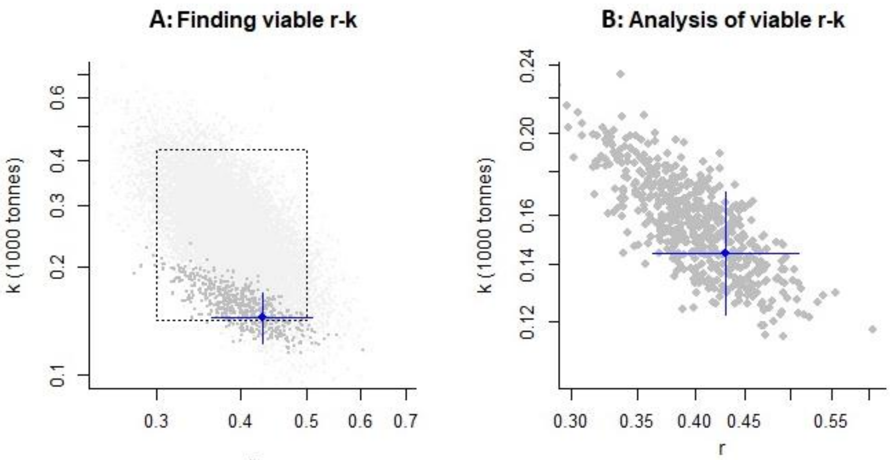

Figure 3. Viable r-k pairs.

Table 3. The results of *CMSY* analysis.

Stock Status	Parameters	Value	Dimension	95% *CI*
	C_{2021}	22.95	ton	-
	r	0.426	year^{-1}	0.357 - 0.509
	k	146	ton	118 - 180
	MSY	15.70	ton	13.0 - 18.0
Fully overfished stock	B_{2021}	77.9	ton	59.5 – 86.7
	B_{MSY}	72.8	ton	58.9 - 89.9
	F_{2021}	0.295	year^{-1}	0.265 - 0.386
	F_{MSY}	0.213	year^{-1}	0.179 - 0.254
	B_{2021}/ B_{MSY}	1.07	-	0.818 - 1.190
	F_{2021}/F_{MSY}	1.38	-	1.240 - 1.810

the population entered the recovery phase (yellow zone) than returned to the green zone. In 2021, overfishing caused the population to shift back towards the orange zone.

The CMSY model indicates that the crayfish stock in the Keban Dam Lake is overexploited. The F/F_{MSY} value was above "1" for most of the study period, except between 2013 and 2020, and it has increased again in the past year. The B/B_{MSY} value was below "1" from 2002 and continued to decline until 2013. However, it has been on the rise since 2013 and exceeded "1" in 2020. The MSY established by the model (15.7 ton, 95% CI= 13.0-18.0) was exceeded in the following periods: 2001-2003, 2006, 2010-2012, and 2021.

Discussion

To help achieve the FAO's sustainability goals, it is important to assess the status of natural aquatic resources. However, in many cases, we have limited data available. For example, in the case of Keban Dam Lake crayfish, we only have annual catch data. While there have been previous stock assessment studies by Yüksel et al. (2013) and Demirol et al. (2017b) on this species, there is no continuous data collection. Despite this, we do have uninterrupted catch data from 1994, when crayfish fishing began in Keban Dam Lake, until the present (2021). In addition, many scientific studies have been conducted that help us understand the development of fisheries for crayfish in the reservoir (Demirol & Yüksel, 2013; Demirol & Yüksel, 2014; Demirol et al., 2015; Demirol et al., 2017a; Yüksel et al., 2020).

Crayfish fishing in Türkiye is permitted between July 1 and October 31 (Anonymous, 2020). A quota is established for each water source and fishing is not allowed to exceed this quota. The annual quota for crayfish in Keban Dam Lake is 30.5 tons. However, the actual amount of crayfish caught in most seasons is significantly lower than the quota. This is due to a number of factors, including the fact that each fisherman has a splitted fishing area. As a result, when the price of crayfish decreases (as it did between 2013 and 2020), fishermen may choose not to fishing and instead save the crayfish in their areas for seasons when fishing is more profitable.

Fishing for crayfish in Keban Dam Lake has started in 1994 in the Ağın region and spread to nearby areas in 2004. However, the crayfish did not naturally spread to these areas. Instead, fishermen have transported crayfish from the Ağın region to other locations (Demirol & Yüksel, 2014). When understanding to development of the crayfish population in the reservoir, it is important to consider the fact that crayfish have been transported to new areas by fishermen, rather than naturally spreading on their own. The crayfish population in Keban Dam Lake suffered a major decline in 2014 due to overfishing beginning in 2000. However, the expansion of crayfish fishing to other areas and the decrease in annual catches approaching the maximum sustainable yield (MSY) helped mitigate the collapse to some extent. The crayfish population was able to recover to some extent due to a decrease in fishing effort between 2013 and 2020, likely due to low prices (Figure 2). The relative biomass (B/K) values for the beginning, intermediate, and ending points of the data set were determined

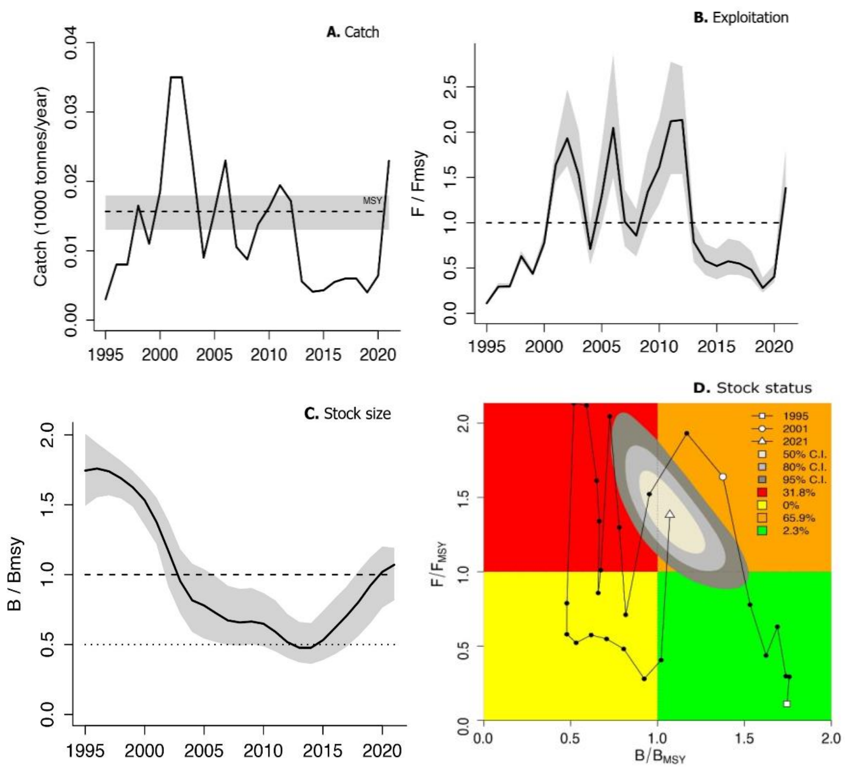

Figure 4. Result graphs of *CMSY* analysis.

based on the known history of the crayfish population meanwhile 1994 was not included in the analysis due to uncertainty about the cause of the decrease in catches from 1994 to 1995. According to Fitzgerald et al. (2018), the initial biomass depletion range should be set at 0.5-0.9 if the initial catch (C_{1995}) is less than one-fifth of the maximum catch, and 0.3-0.7 otherwise. In this case, the initial depletion level was set at 0.75 to 1.00, as the ratio of the initial catch to the maximum catch is approximately 1/11. The year 2001 was chosen as the intermediate year because it had the biggest catch. For the intermediate year the total depletion of the crayfish stock was estimated to be between 0.6 and 0.8 when combined with crayfish from other unexploited areas. For the end year of the analysis (2021), the crayfish stock depletion rate was estimated to range between 0.4 and 0.8. It is believed that the stock is approaching its carrying capacity due to low fishing effort in previous years.

As shown in Figure 4A, there are some years when the crayfish catch in the Keban reservoir exceeds the calculated MSY (15.7 tons) in our study, even reaching over 18 tons, which is the 95% upper confidence limit of the MSY. Additionally, there are some years between 2013 and 2020 where the annual catch has significantly decreased. It is clear from Figure 4B that the fluctuation in annual catch is due to the change in fishing pressure resulting from low prices for crayfish. As shown in Figure 4C, the effect of fishing pressure on biomass can be seen. As the fishing pressure increased, the biomass in the lake decreased and fell below the minimum level needed for maximum sustainable yield in 2002. As the fishing pressure decreased, the biomass increased over time and reached the minimum level needed for maximum sustainable yield again in 2013. Upon examining Figure 4D, which plots the stock exploitation level (F/F_{MSY}) and relative stock size (B/B_{MSY}) values, it can be seen that in 1995, when fishing began in the reservoir, the biomass was relatively high but the fishing pressure was low. As a result, the stock (represented by white squares) was in the green zone on the graph which is called "healthy stock" phase. In 2000, when the stock exploitation level (F/F_{MSY}) exceeded "1", the stock began to be overexploited. At this stage, represented by the orange zone on the graph, the biomass was still in good condition but was inevitably heading towards depletion. Due to the continued overfishing pressure, the decline in biomass continued and the stock entered the red zone on the graph, indicating an overexploited phase. The red zone on the graph represents an overfished state in which the biomass is insufficient to produce the maximum sustainable yield. In such cases, it is extremely important for fisheries management to immediately reduce fishing pressure in order to protect the stock and ensure the long-term sustainability of the fishery. Fortunately, the fishing effort has decreased since 2013 due to low prices, and as a result, the stock entered a recovery phase, represented by the yellow zone on the graph. The crayfish stock, which has been growing in the recovery phase for the past eight years with low fishing effort, finally returned the green "healthy stock" phase on the graph in 2020. However, in 2021, the final year of the data series, fishing pressure increased again and the stock entered the orange "overfishing" phase on the graph once more.

Based on the annual catch data for 2021, as shown in Table 4, it appears that the crayfish stock in Keban Dam Lake is overfished. However, it is important to note that the stock has been exploited at different levels over the years, as explained above the crayfish stock was not at risk in the past when the price acted as a balance. In modern fisheries management, this balance should be established through quotas. However, when comparing the MSY (15.7 tons) with the quota (30.5 tons) set for the crayfish stock, it can be seen that the quota is even above the upper limit (18 tons) of the 95% confidence interval of the MSY calculated in this study (Table 5).

FOther studies have been conducted in the reservoir to compare the quota for the crayfish stock. For example, Yüksel et al. (2013) calculated the catchable stock size (≥10 cm total length) for crayfish to be 28.45 tons (95% CI: 25.61-32.53) using the Leslie Regression Model: depletion model. In another study using the Schnabel Model, a multiple marking method, the MSY was estimated to be 26.7 tons (Demirol et al., 2017b). The crayfish quota in Keban Dam Lake is higher than these values. The scientific results from our study indicate the need to lower the quota for the crayfish stock in Keban Dam Lake.

Table 4. Characterization of fish stock status based on F/F_{MSY} and $B/_{BMSY}$ (Froese et al., 2016)

Stock Status	F/F_{MSY}	B/B_{MSY}
Healty stocks	<1	>1
Recovering stocks	<1	0.5 - 1
Fully overfished stocks	>1	0.5 - 1
Outside of safe biological limits	>1	0.2 - 0.5
Severely depleted stocks	>1	<0.2

Table 5. Catch quota for crayfish in 2021 and estimated *MSY*

Species	Quota	MSY	MSY 95% CI
Crayfish, Keban D.L.	30.5	15.7	13.0 - 18.0

Conclusions

In conclusion, the current study has found that the crayfish population in Keban reservoir which is one of the important sources of crayfish production of Türkiye is not being properly managed. Although there are management rules such as closed season and minimum landing size, the lack of accurate quotas puts the stock at serious risk. It is believed that 15.7 tonnes of annual catch is suitable for the stock to be sustainable. Therefore, it is recommended that the current quota of 30.5 tons be reduced to 15.7 tons. The studies by Free et al. (2020) and Andrašūnas et al. (2022) have demonstrated that the CMSY model, which is based on catch data, is effective in evaluating well-known fish populations. In this case, the CMSY model was also successful in evaluating the crayfish population in Keban reservoir and the results were consistent with other studies. Therefore, it is recommended that the CMSY model be used to assess other crayfish populations with limited data. To improve the precision of future stock assessments using the CMSY model, it is crucial to carefully monitor and record catch data, including illegal, unreported, and recreational catches, as well as CPUE (catch per unit effort) data.

Ethical Statement

This article does not contain any studies with human or animal subjects

Funding Information

This research received no external funding

Author Contribution

The author collected and analyzed the data, wrote the first draft of the manuscript, conducted the revisions, read and approved the submitted version

Conflict of Interest

The author declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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