

Commercial vs. survey data in length-based stock assessment: insights from Turkish crayfish fisheries

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Abstract – In length-based stock assessments for data-poor fisheries, commercial fishing data is often used due to its cost-effectiveness and accessibility. However, factors such as gear selectivity, seasonal closures, minimum conservation reference size (MCRS) regulations, and market-driven harvesting practices can render commercial catch data unrepresentative of the true population structure. Reliance on such data without correction or complementary sampling may lead to biased stock assessments, undermining effective fisheries management. This study investigates how length data from commercial fisheries and experimental sampling influence the estimation of biological reference points (BRPs) and explores differences in catch compositions between these data sources. Between June 2021 and May 2022, a study was conducted at Lake Eğirdir (Isparta, Türkiye), involving 10 different stations. A total of 400 fyke nets were deployed, consisting of 200 experimental and 200 commercial ones. The experimental fyke nets had a stretched mesh size of 18 mm, while the commercial ones had a mesh size of 34 mm. These nets were evenly distributed, with 40 nets at each station. *TropFishR* package was used for estimating of the life history parameters and stock assessment. The comparison of catch composition was performed using “Length-dependent catch comparison” and “catch ratio” analyses through the *SELNET* program. As a result, it has been determined that, due to the potential size selectivity feature, the commercial fyke net is unsuccessful in catching small-sized individuals (<4 cm carapace length), while the experimental fyke net is unsuccessful in catching advanced-sized crayfish (>6.5 cm carapace length). The estimated BRPs showed significant differences depending on the data source, and there were also differences of up to 56% in the recommended total allowable catch (TAC) amounts. As a result, it is considered that relying solely on commercial or experimental fyke nets for crayfish may be misleading, and it would be more appropriate to use both for successful sampling and stock assessment.

Keywords: Data-limited fishery / Eğirdir Lake / fisheries management / length-based assessment / narrow-clawed crayfish / stock assessment

1 Introduction

Inland waters serve as a livelihood for 820 million people, and inland fisheries are of vital importance globally for numerous vulnerable groups in terms of social, economic, and nutritional aspects (Ainsworth et al., 2023; Coates, 2023). Global estimates of employment in inland fisheries vary significantly, but it is believed that approximately 17 million people work in this sector (Funge-Smith 2018; Coates, 2023). Despite the crucial role of inland fisheries, they have frequently been undervalued and overlooked at both national and regional levels, often pushed to the background in the frameworks of agriculture, water, environmental, and social policies (Cooke et al., 2016; Moutopoulos et al., 2022; Ainsworth et al., 2023). Several inland

fisheries worldwide are less well known than marine fisheries and are not subjected to science-based management decisions, raising concerns about their sustainability (Suresh et al., 2023). Inland fisheries have never been included in any prominent global fisheries assessments owing to data reliability issues (Cooke et al., 2016).

Understanding the status of fish stocks is essential for effective management (Ovando et al., 2022). Successful stock management can only be achieved through the collection of high-quality and comprehensive scientific fisheries data (such as for data-rich assessment models), which is then thoroughly assessed and applied in practice. However, formal stock assessments are lacking for at least half of the global catch and a vast majority of global fisheries, mainly due to insufficient data (Ovando et al., 2022).

Major commercial fish species typically have extensive datasets that can be incorporated into complex stock

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assessment models (e.g., [Methot and Wetzel 2013](#)); these data may involve time series of total removals (*I*), catch-at-length or –at-age (*II*), relative or absolute abundance indices (*III*), fishing effort (*IV*), and information on life-history parameters (*V*). The datasets in mentioned are generally unavailable for most of the small-scale fisheries ([Pons et al., 2020](#)), especially in developing countries ([Raza et al., 2022](#)) and inland fisheries ([Reis-Filho et al., 2023](#)). Traditional stock assessment methods not able to estimate sustainable fishing levels for the majority of world fish stocks due to a lack of data ([Raza et al., 2022](#)). Fisheries and stocks without comprehensive datasets are commonly referred to as “data-poor” or “data-limited” fisheries ([Costello et al., 2012](#); [Dowling et al., 2015](#)).

Length data provides a straightforward and efficient method for assessing the status of fish populations in inland system ([Miranda et al., 2024](#)). The length-frequency data from commercial catches are often the primary collected data type in data-limited fisheries, because they are relatively economical and easy to obtain ([Pilling et al., 2009](#); [Hordyk et al., 2015](#); [Mildenberger et al., 2017](#); [Chong et al., 2019](#)). Although [Kilada and Acuña \(2015\)](#) proposed a method for determining the chronological age of crustaceans using gastric mill ossicles, it has not gained widespread acceptance among assessors, and stock assessments of crustaceans are still predominantly based on a length-based approach ([Korkmaz et al., 2023](#); [Hashemi et al., 2024](#); [Jin et al., 2024](#); [Scanu et al., 2024](#)). However, relying solely on commercial fishing data for the necessary input in length-based stock assessment studies may risk the obtained sample not accurately representing the population. Landed catch data alone cannot reliably indicate stock growth and status ([Ovando et al., 2022](#)) as total landings are affected by multiple factors, such as market changes, changes in catchability and regulations, and reductions in fishing effort, changes in fish abundance ([de Mutsert et al., 2008](#)) in addition to fishing gear selectivity ([Fitzgerald et al., 2023](#); [Hordyk et al., 2015](#)). According to [Pauly and Morgan \(1987\)](#), the use of commercial length compositions is far less effective for length-based modal analysis compared to data obtained from research surveys, primarily due to the regulations on minimum mesh sizes and landing sizes in commercial fisheries. The use of incomplete length-frequency data in stock assessment can lead to the generation of erroneous results and, consequently, pose management issues.

Due to the ease and cost-effectiveness of data collection, commercial fishing data is commonly used in length-based stock assessment studies ([Alam et al., 2022](#); [Barua et al., 2023](#); [Da et al., 2023](#); [Dutta et al., 2023](#); [Kindong et al., 2022](#); [Tesfaye et al., 2021](#)). Commercial catch data often overestimate the health of fish stocks. For instance, catch trends may misrepresent actual stock status, leading to incorrect assessments of stock health ([Branch et al., 2011](#)). Such misclassifications can result in overexploitation, as managers may fail to recognize the true extent of depletion. Furthermore, improvements in fishing technology—termed *technological creep*—can obscure population declines. For example, advancements in trap designs for European lobsters created the illusion of stable or increasing catch rates even as stocks declined ([Kleiven et al., 2022](#)). Such delays in detecting declines can postpone critical management interventions, exacerbating overfishing and accelerating stock collapse, as seen in the case of Newfoundland's northern cod ([Walters & Maguire, 1996](#)).

In situations such as fishing gear selectivity and under sized landed catch (below the minimum conservation reference size: *MCRS*), some studies have utilized data from both sources (commercial and survey catch) to reduce the error rate in the population's length distribution ([Ersönmez et al., 2023](#); [Korkmaz et al., 2023](#); [Sarr et al., 2023](#)). In some studies, only survey data has been used ([Aydın & Tıraşın, 2023](#); [Cilbiz & Uysal, 2023](#); [Dağtekin, 2023](#); [Santos et al., 2023](#)). In previous studies, the sampling strategy, or in other words, how the sampling strategy or the data source used in assessments represents the population length distribution and its effects on the estimated biological reference points (*BRPs*) have not been clearly demonstrated. This study evaluates the effect of commercial, experimental, or/and combined data sources on biological reference point (BRP) estimates in a crayfish length-based stock assessment, alongside the catch efficiency of fishing gear across population length classes.

2 Material and methods

2.1 Study area

The study was conducted in Lake Eğirdir ([Fig. 1](#)), which serves as the primary crayfish harvesting centre in Türkiye. Ten sampling stations were utilized, each representing the fishing area of different fisheries cooperatives. Eğirdir Lake, the second largest freshwater resource in Türkiye, covers an area of 457 km² and is situated between latitude 37° 50' 41"–38° 16' 55" N and longitude 30° 57' 43"–30° 44' 39" E in the southwest of Türkiye ([Özseven et al., 2020](#); [Şener et al., 2019](#)).

2.2 Data collection

Both survey and commercial length data were collected with survey fishing. In the study, for obtaining commercial length data, it was preferred to use 34 mm stretched mesh size fyke nets (*Com.*) that fishermen use for fishing instead of collecting the length data of the catch made by the fishermen. The main reasons for this preference are (*I*) the closed season application for fishing (from 01 November to 30 June), resulting in an 8-month interruption in commercial fishing data, and (*II*) the idea that data for combined groups (commercial and experimental) are obtained from identical fishing trials. A total of 400 fyke nets were used in the study, 200 of which were commercial crayfish fyke net (*Com.*) and 200 of which were experimental crayfish fyke net (*Exp.*) with 18 mm stretched mesh size and poor length selectivity. General view and technical plan of fyke nets used in study were given as supplementary materials. At each of the ten stations, a total of 40 fyke nets were used (40 fyke net x 10 station), with 20 being commercial and 20 being experimental, randomly connected to each other from the end ropes of the last codend ([Fig. 2](#)). Fishing trials were conducted monthly from June 2021 to May 2022. Fishing trials were conducted at the same stations every month. The fyke nets were typically left to soak for two days unless any unforeseen issues arose, resulting in an average soak time of 48 hour. The captured crayfish were classified according to the sampling stations, and their carapace length (*CL*) and abdomen length (*AL*) were measured using a digital calliper with a sensitivity of 0.01 mm. The total length (*TL*) of each individual was calculated by adding

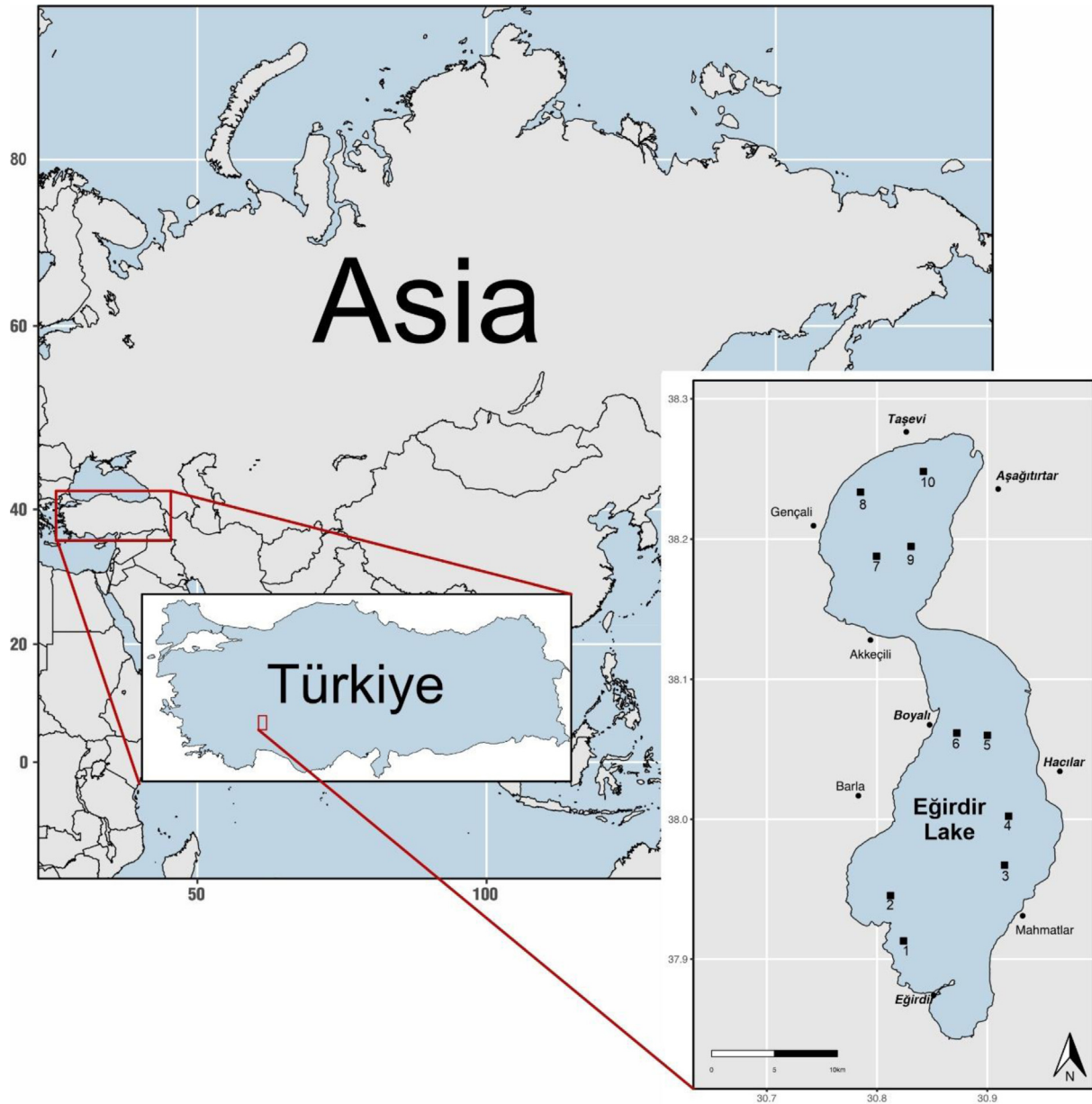


Fig. 1. Maps show global location of Eğirdir Lake and distribution of the 10 sampling stations on the lake.

together the carapace and abdomen lengths. The total weight (TW) of the crayfish was measured using digital scales with a sensitivity of 0.01 g. Additionally, the sex of the crayfish was determined macroscopically.

2.3 Stock assessment

The successful determination of the LWR parameters, which serve as input data for the Yield per Recruitment analysis, is crucial for accurate stock assessment. The relationship between length and weight of crayfish was described by equation [I]. In this equation, L represents the total or carapace length in centimetres, W represents the total weight in grams, and a and b values denote the constant

parameters of the equation (Froese, 2006). “ggtrendline” R package was used for computing of model parameters (Mei et al., 2022). A t-test was used to determine the b value different from 3 or not (Pauly, 1984). The computed a and b values for both sexes were utilized as input parameters for the “Yield per Recruit analysis” in TropFishR (v.1.6.3) R package (Taylor & Mildenerberger, 2017). The Electronic Length Frequency Analysis (ELEFAN) method was employed to estimate the growth parameters (Pauly & David, 1981). The data analysis was conducted using the TropFishR. The seasonally oscillating von Bertalanffy growth function (*soVBGP*), developed by Somers (1988), was employed in modelling the growth of crayfish [II]. Optimisation of the growth parameters *ELEFAN* with *Generalized Simulated*

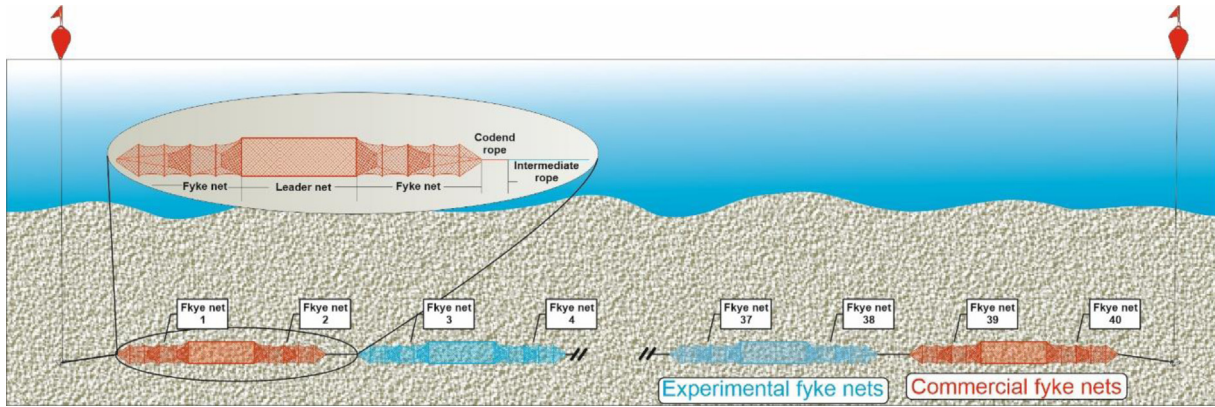


Fig. 2. General view of combined experimental fyke nets on the lake bottom.

Annealing (ELEFAN_SA) and *Genetic Algorithm (ELEFAN_GA)* function was used (Scrucca, 2013; Xiang et al., 2013). Natural mortality is estimated using the length-based updated Pauly estimator recommended by Then et al. (2015) [III]. The linearized length-converted catch curve method [IV] was used for estimating of the instantaneous rate of total mortality (Z) (Pauly, 1990; Pauly et al., 1995). The fishing mortality rate (F) was computed by equation [V]. The exploitation rate (E) was calculated by the formula [VI]. In the estimating of the stock size length-based virtual population analysis (*VPA*) was used (Jones, 1984). The Thompson and Bell (1934) model was used to estimate the relative yield per recruit (Y'/R) and reference points. Length-based spawning potential ratio (SPR) was estimated based on (Goodyear, 1993) [VII]. In this study, carapace length (in mm) was utilized in the length frequency analysis due to its more rigid structure compared to total length. The calculated optimal bin size (OBS) was approximately 3 mm using Wang et al. (2020)' equation [VIII]. As an input parameters of spawning potential ratio analysis, W_{mat} (weight at which 50% of the crayfish are mature) and L_{mat} (length at which 50% of the crayfish are mature) were applied as 17.33 g and 43.43 mm carapace length respectively by (Korkmaz et al., 2023). The stock assessment process was conducted through three groups: (I) crayfish collected only from *Exp.* fyke nets, (II) crayfish collected only from *Com.* fyke nets, and (III) pooled of both. This allowed the investigation of the combined effects of fyke nets with different size selectivity on the *BRPs*.

$$W = a \cdot L^b \quad (I)$$

$$L_t = L_{\infty} \left(1 - e^{-(K(t-t_0)+S(t)-S(t_0))} \right) \quad (II)$$

$$M = 4.118K^{0.73}L_{\infty}^{-0.33} \quad (III)$$

$$\log\left(\frac{N_i}{dt_i}\right) = a + b_t \quad (IV)$$

$$F = Z - M \quad (V)$$

$$E = \frac{F}{Z} \quad (VI)$$

$$SPR = \frac{SSPR_{fished}}{SSPR_{unfished}} \quad (VII)$$

$$OBS = 0.23 \times L_{max}^{0.6} \quad (VIII)$$

2.4 Catch efficiency

Length-dependent catch comparison and catch ratio analyses were conducted to compare the catch efficiency between commercial and experimental fyke net codend (Cerbule et al., 2021; Fakioğlu et al., 2023; Lomeli et al., 2020; Lomeli et al., 2021). The length-dependent catch comparison rate $CC(l,v)$ and catch ratio $CR(l,v)$ were estimated for the *P. leptodactylus* to investigate potential differences in catch efficiency for each. Equation [IX] was used by us for assessing of the relative length dependent catch comparison rate (CC_i) of changing from one codend to another codend (Lomeli et al., 2021; Cerbule et al., 2021; Fakioğlu et al., 2023). The modelled catch comparison rate $CC(l,v)$ that experimentally was expressed by equation [IX] was obtained using maximum likelihood estimation by minimizing the Expression [X] (Lomeli et al., 2021; Fakioğlu et al., 2023). The experimental CC_i was modelled by the function $CC(l,v)$ using the equation [XI] (Fakioğlu et al., 2023). Catch ratio $CR(l,v)$ equation [XII] was used for providing of direct relative value of catch efficiency between compared experimental and commercial fyke net codend (Lomeli et al., 2021; Cerbule et al., 2021; Fakioğlu et al., 2023). Double bootstrapping method with 1000 bootstrap repetitions was used for estimating of the Efron 95% (Efron, 1982) confidence intervals (*CIs*) for both catch comparison and catch ratio. Catch efficiency equilibrium points of compared panels were 0.5 for catch comparison rate and 1.0 catch ratio (Fakioğlu et al., 2023). The statistical software *SELNET* was used for relative catch efficiency analysis in this study (Herrmann et al., 2016; Herrmann et al., 2012).

Table 1. Monthly carapace length distribution (mm) of *P. leptodactylus* by sampling codend.

Month	Fyke net	N	Min-Max	Mean±SE	CI (%95)	p*
Jun-21	Com.	440	21.54–80.62	46.18±0.478	0.939	<0.001
	Exp.	331	25.66–67.59	41.83±0.472	0.928	
Jul-21	Com.	307	32.32–75.26	45.79±0.398	0.784	<0.001
	Exp.	214	17.36–73.63	41.84±0.456	0.899	
Aug-21	Com.	359	33.30–72.48	48.04±0.355	0.698	<0.001
	Exp.	258	15.35–65.31	38.83±0.754	1.485	
Sep-21	Com.	275	24.88–69.52	48.98±0.388	0.764	<0.001
	Exp.	386	15.83–66.19	35.61±0.502	0.988	
Oct-21	Com.	212	26.99–71.80	49.57±0.621	1.223	<0.001
	Exp.	273	19.24–64.78	35.94±0.529	1.041	
Nov-21	Com.	343	26.68–76.21	52.69±0.529	1.040	<0.001
	Exp.	272	21.70–70.67	41.73±0.653	1.285	
Dec-21	Com.	856	33.20–76.91	51.44±0.260	0.510	<0.001
	Exp.	767	23.63–71.24	45.27±0.314	0.617	
Jan-22	Com.	11	45.23–63.63	52.80±1.581	3.523	>0.05
	Exp.	26	44.26–62.06	51.22±0.763	1.571	
Feb-22	Com.	147	26.03–70.37	50.63±0.749	1.480	<0.001
	Exp.	385	19.45–68.17	42.59±0.554	1.089	
Mar-22	Com.	668	26.44–75.22	50.50±0.325	0.639	<0.05
	Exp.	689	21.41–73.56	48.52±0.391	0.767	
Apr-22	Com.	1251	26.81–79.38	52.22±0.231	0.453	<0.001
	Exp.	922	20.49–73.41	48.46±0.330	0.648	
May-22	Com.	674	30.15–73.74	51.22±0.287	0.564	<0.001
	Exp.	614	25.36–77.79	45.96±0.404	0.794	
Total	Com.	5543	21.54–80.62	50.39±0.113	0.221	<0.001
	Exp.	5137	15.35–77.49	44.09±0.149	0.292	

p*: Carapace length comparison of crayfish between different fyke nets for same month.

$$CC_l = \frac{\sum_{j=1}^h \left\{ \frac{nd_{lj}}{qd_j} \right\}}{\sum_{j=1}^h \left\{ \frac{nd_{lj}}{qd_j} + \frac{ns_{lj}}{qs_j} \right\}} \quad (\text{IX})$$

$$-\sum_{j=1}^h \sum_l \left\{ \frac{nd_{lj}}{qd_j} \ln[CC(l, v)] + \frac{ns_{lj}}{qs_j} \ln[1.0 - CC(l, v)] \right\} \quad (\text{X})$$

$$CC(l, v) = \frac{\exp[f(l, v_0, \dots, v_k)]}{1 + \exp[f(l, v_0, \dots, v_k)]} \quad (\text{XI})$$

$$CR(l, v) = \frac{CC(l, v)}{[1 - CC(l, v)]}. \quad (\text{XII})$$

2.5 Statistical analysis

For the statistical comparison of mean carapace lengths among codends, *t*-tests were used for data with a normal distribution, while the Wilcoxon rank-sum test (Mann–Whitney *U* test) was employed for data with a non-normal distribution. The Kolmogorov–Smirnov (*K-S*) test was used to

determine whether there was a difference in length frequency distributions among codend types (*Com.*, *Exp.*, *Comb.*) in the sample. The data were analysed using the *rstatix* v0.7.2 (Kassambara, 2023) and *fishmethods* v1.12-1 (Nelson, 2023) packages, while visualization was performed using the *ggplot2* v3.4.4 (Wickham, 2016) package in the Rstudio v2023.12.0 (RStudioTeam, 2023) program.

3 Results

3.1 Catch composition

At the end of the fishing experiments, a total of 10,680 crayfish were captured. The total length range was 30.23–163.38 mm (50.00–163.38 mm for commercial catches and 30.23–148.41 mm for experimental catches) and the carapace length ranged from 15.35 to 80.62 mm. The sample consists of 49.5% females and 50.5% males. In the evaluation made in numbers, January was the least productive month, with only 0.3% of crayfish caught, while April was the most productive, with 20.3% of the total catch. A statistical difference in the mean carapace lengths of crayfish from commercial and experimental codends was observed ($p < 0.01$). While there was no statistical difference between the mean carapace lengths according to sex ($p > 0.05$), there was a statistical difference between the mean total lengths ($p < 0.05$) lengths. This difference was significant in all months except January

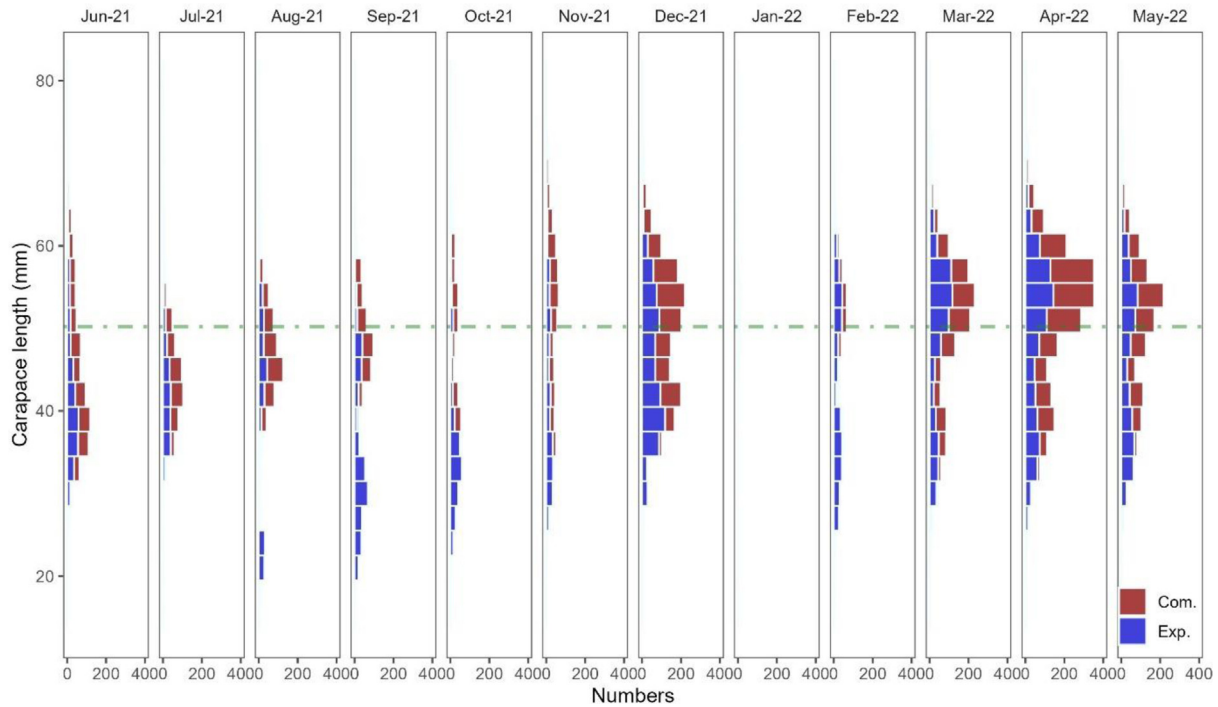


Fig. 3. Length frequency distribution of *P. leptodactylus* by codend type and sampling month (The dashed green horizontal line represents MCRS).

Table 2. Results of the *K-S* test used to compare length frequency distributions between pairs of codends.

Codend 1	Codend 2	<i>K-S</i> statistic (<i>D</i> value)	<i>p</i>	Decision
<i>Com.</i>	<i>Exp.</i>	0.269	<0.001	H_0 rejected
<i>Comb.</i>	<i>Com.</i>	0.129	0.08	H_0 accepted
<i>Comb.</i>	<i>Exp.</i>	0.141	0.12	H_0 accepted

H_0 = Two dataset values are from the same continuous distribution.

(Tab. 1). The length frequency distribution of caught crayfish by sampling month and codend type (Fig. 3) indicates that the experimental fyke net with a smaller mesh size is generally more effective in catching smaller crayfish in all months. In contrast, the commercial fyke net is more effective in catching larger size crayfish. The length frequency distribution of the crayfish varies according to the sampling month.

The results of the *K-S* test used to determine whether there is a difference in the pooled length frequency distributions of caught crayfish in different codends are given in Table 2. While a statistical difference was found in the *Com.* ~ *Exp.* comparison, there was no statistical difference in the length frequency distribution between the captures of the two pooled nets and those obtained individually in each net (*Exp.* and *Com.*).

3.2 Length-weight relationship (LWR)

Therefore, in the study, the *LWR* of crayfish were determined separately based on the fyke nets they were caught (Tab. 3). The *b* value for crayfish caught in the *Com.*

codend (3.199) was found to be slightly higher compared to those caught with *Exp.* (3.062). As a result, all three groups exhibited allometric growth type.

3.3 Growth properties

The *simulated annealing algorithm* was found to be more successful in estimating the *VBG* parameters of *Com.* and *Exp.* groups, while the *genetic algorithm* was more successful in estimating the *VBG* parameters for the *Comb.* group within the maximum score value. The *K*, L_∞ and t_0 parameters were estimated as 0.32 year⁻¹, 85.38 mm ve -0.36 year for *Com.* groups; 0.54 year⁻¹, 86.62 mm ve -0.24 year for *Exp.* groups and 0.57 year⁻¹, 87.54 mm ve -0.09 year for *Comb.* groups respectively. While the L_∞ values were found to be close to each other, it can be said that especially the *K* parameter is significantly influenced by the fyke net used in the sampling (Tab. 4). The seasonally oscillating growth curves were fitted for three data set by using growth parameters given in Table 4 (Fig. 4).

Table 3. LWR model parameters of *P. leptodactylus*.

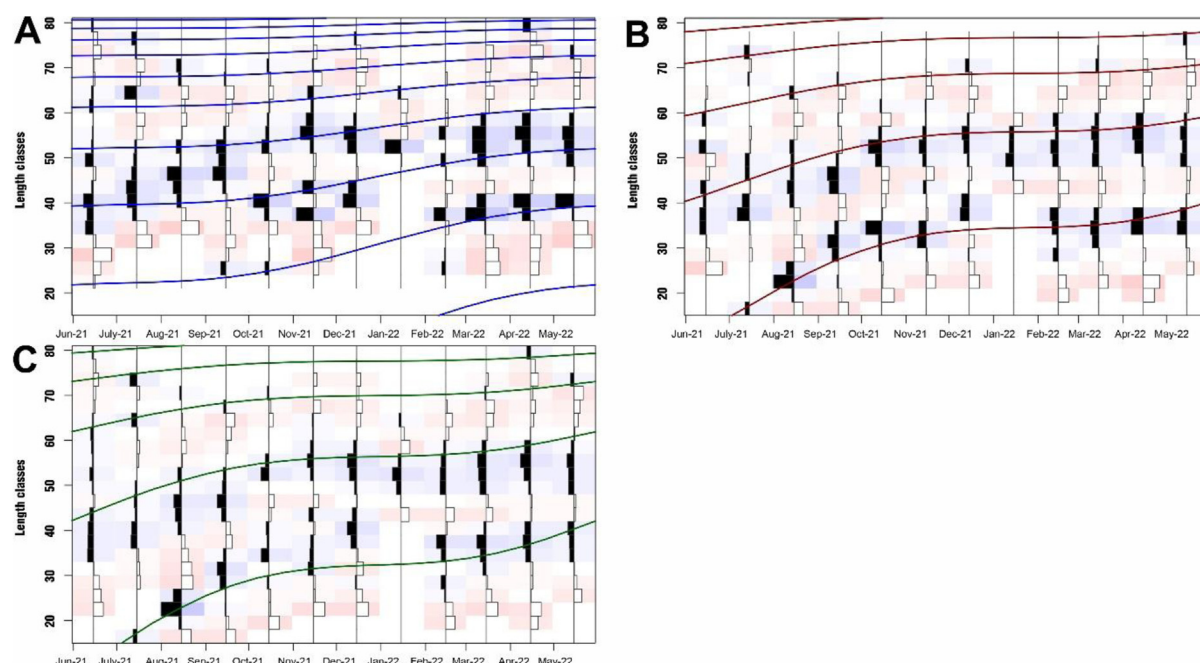
Codend	n	Min-Max (TL, cm)	Parameters					t_s
			a	b	95% CI of b	r^2	p	
Com.	5543	5.00–16.34	0.016	3.199	3.186–3.213	0.92	<0.001	16.54 ^a
Exp.	5137	3.02–14.84	0.022	3.062	3.051–3.073	0.96	<0.001	7.16 ^b
Comb.	10680	3.02–16.34	0.018	3.150	3.141–3.159	0.95	<0.001	20.52 ^c

^a($t_s > t_{0.05}$, 5543 = 1.64); ^b($t_s > t_{0.05}$, 5137 = 1.64); ^c($t_s > t_{0.05}$, 10680 = 1.64).

Table 4. von Bertalanffy Growth Function (VBGF) parameters of *P. leptodactylus* by caught codend groups.

Parameters	Res_SA			Res_GA		
	Com.	Exp.	Comb.	Com.	Exp.	Comb.
$K \text{ year}^{-1}$	0.32	0.54	0.53	0.44	0.57	0.57
$L_\infty \text{ (mm)}$	85.38	86.62	88.98	83.32	85.15	87.54
$t_o \text{ (year)}$	-0.36	-0.24	-0.22	-0.17	-0.09	-0.09
Rn_max	0.239	0.291	0.333	0.235	0.276	0.347

Accepted parameters, in order to Rn_max (highest value of fitness function), marked with bold.

**Fig. 4.** Length-frequency histograms with the fitted growth curves (A: Commercial catch data B: Experimental catch data C: Combined Data).

3.4 Evaluating of stock status

Significant differences in $BRPs$ were identified according to the sampling group in the study. The current F values were estimated as 1.26, 3.14, and 1.35 for the *Com.*, *Exp.*, *Comb.* groups, respectively. The total mortality coefficient (Z) showed a significant difference ranging from 1.68 to 3.74 among the groups. The exploitation value (E) varied between 0.75 and 0.84. The F_{curr}/F_{max} values, which are important indicators of the exploitation status of the stock, were computed as 1.22,

2.01, and 1.95 for the *Com.*, *Exp.*, and *Comb.* groups, respectively (the desired value is below 1). The SPR value is computed as the highest for the *Com.* group at 0.25 and the lowest for the *Comb.* group at 0.17 (Tab. 5).

3.5 Catch efficiency between codends

In the carapace length class of 1.5–3.5 cm, the *Exp.* codend is much more effective, there is relative equality at 4.0 cm, and

Table 5. The impact of alterations in fishing mortality on the *BRP* of *P. leptodactylus* by sampled fyke nets.

Groups	Levels	Parameters							
		<i>F</i>	<i>M</i>	<i>Z</i>	<i>E</i>	<i>YPR</i>	<i>BPR</i>	<i>SPB</i>	<i>SPR</i>
<i>Com.</i>	<i>01</i>	0.46	–	–	0.29	56.14	–	–	0.41
	<i>04</i>	0.47	–	–	0.30	56.41	171.16	–	0.40
	<i>05</i>	0.32	–	–	0.20	50.73	209.51	–	0.50
	<i>Max.</i>	1.03	–	–	0.65	60.91	108.89	–	0.26
	<i>Cur.</i>	1.26	0.42	1.68	0.75	222.58	382.03	191.23	0.25
<i>Exp.</i>	<i>01</i>	0.68	–	–	0.18	49.11	–	–	0.42
	<i>04</i>	0.75	–	–	0.20	50.16	98.57	–	0.40
	<i>05</i>	0.50	–	–	0.13	44.93	121.97	–	0.50
	<i>Max.</i>	1.56	–	–	0.42	53.6	64.77	–	0.26
	<i>Cur.</i>	3.14	0.60	3.74	0.84	194.94	179.49	89.82	0.20
<i>Comb.</i>	<i>01</i>	0.65	–	–	0.20	59.19	–	–	0.41
	<i>04</i>	0.67	–	–	0.21	59.6	117.23	–	0.40
	<i>05</i>	0.46	–	–	0.14	53.44	144.71	–	0.49
	<i>Max.</i>	1.35	–	–	0.42	64.03	74.82	–	0.25
	<i>Cur.</i>	2.63	0.63	3.26	0.81	226.9	183.75	91.95	0.17

between 4.5 and 8.0 cm, the *Com.* codend is more effective (Fig. 5). According to the “S” type selectivity curve approach (assuming that all individuals above a certain size at retention level 1 are caught), in the *CR* curve, which is expected to remain stable at the 0.5 level in a certain size class, and in the *CC* curve, which is expected to remain stable at the 1.0 level, it is observed that the effectiveness of the *Com.* codend increases compared to the *Exp.* codend above 4.5 cm carapace length (Fig. 5).

The catch comparison (Fig. 5) and catch ratio analysis results (Tab. 6) for *P. leptodactylus* showed that there was significant difference in catch ratio between the *Com.* and *Exp.* in 5.0–6.5 cm fyke net on any length classes.

4 Discussion

In the current study, which aims to determine the effects of different data sources on *BRPs* in the context of the data-poor fisheries, it is believed that the commercial catch data obtained entirely from research surveys is consistent with data obtained from fishermen in other studies. In the study conducted by Çapkin et al. (2023) to determine the bycatch rates in crayfish fisheries in Türkiye, the total length ranges of crayfish caught by fishermen were reported as 55.0–156.0 mm, 50.0–153.0 mm, 60.5–151.5 mm and 64.0–145.0 mm in Eğirdir Lake, Hirfanlı Dam, Keban Dam and Porsuk Dam, respectively. In this context, it can be stated that the reported total length range is quite similar to our study (50.00–163.38 mm). The current study, which was carried out with 10,680 samples with a total length range of 30.23–163.38 mm, was compared with other studies carried out in relation to *P. leptodactylus* in terms of number of samples, sampling technique and length range; Bök et al. (2010) used a special fyke net rigged with a smaller mesh size (20 mm) in addition to the commercial fyke net, 2438 crayfish in the range of 33–156 mm *TL*; Bolat and Kaya (2016) used commercial fyke net in their study and caught 3008 crayfish in the range of 66–168 mm *TL*; Büyükçapar et al. (2006) caught 553 crayfish in the *TL* range

63.09–148.01 mm; Cilbiz (2020) sampled 5920 crayfish with a *TL* range of 39.34–153.39 mm, using a fyke net rigged with 18 mm mesh size; Demiroğlu et al. (2015) reported the total length range of the caught crayfish in a study using commercial pinter as 109.00–215.00 mm. Considering the results of other studies, it can be said that sampling using only commercial fyke nets results in a narrower length range of crayfish, and the minimum length of caught crayfish is relatively large.

The differences in catch composition between *Com.* and *Exp.* fyke nets were evident from statistically significant variations in average total length, length frequency distributions, and catch ratios. The primary factor driving these differences is likely the size selectivity of the fishing gear. Cilbiz et al. (2022) reported that crayfish fyke nets equipped with 34-mm diamond mesh (*Com.*) exhibit size selectivity and that increasing mesh size raises the average length at 50% retention probability (*L*₅₀). Given this, the *Com.* codend—with its larger mesh size—likely permits greater escape of small crayfish compared to the *Exp.* codend. Consequently, its use may lead to biased representations of the population's true size distribution.

The lower sampling of individuals in the small length class from the *Com.* codend can be explained by the selectivity of the fyke net. According to Cilbiz et al. (2022), the *Com.* codend has a length selectivity, even if it is weak. On the other hand, the relatively lower number of individuals in the large length class from the *Exp.* codend compared to the *Com.* codend may be more closely related to the behaviour of the prey towards the fishing gear. In general, active fishing gears can catch fish against their will. However, the effectiveness of passive fishing gears, such as pinter, in capturing prey depends on the preferences of the prey, namely its behaviour towards the fishing gear. When evaluated in this context, the lower capture of individuals in the large length class in the *Exp.* codend may be attributed to the likelihood that these individuals chose not to enter the fyke net (due to the weak selectivity of the *Exp.* codend with a small mesh size), rather than the possibility that they left after entering the fyke net. Due to their cannibalistic behaviour, large individuals entering the fyke net to feed on the

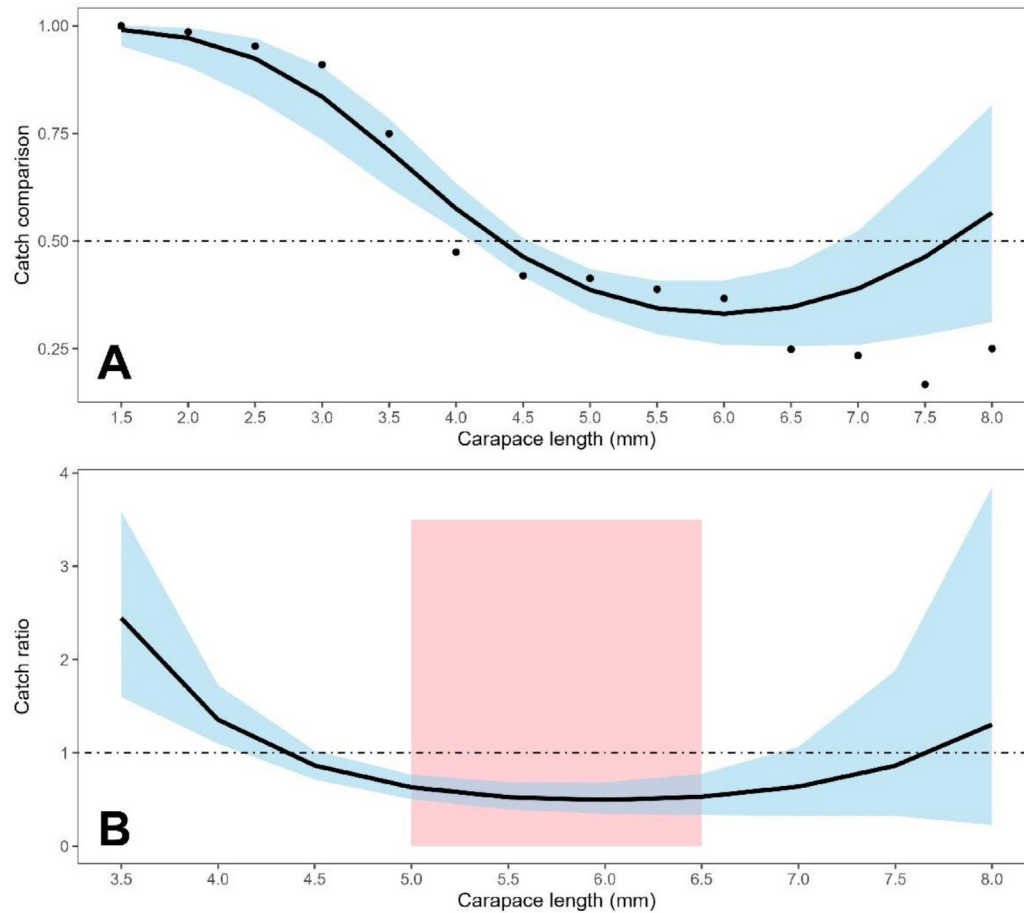


Fig. 5. Catch comparison rate (A) and catch ratio (B) of *Com.~Exp.* codend for *P. leptodactylus*. On the upper: the curve (black solid line) represents the modelled catch efficiency fitted to the experimental points (black circles). The blue band represents 95% confidence intervals. The 0.5 dotted horizontal line represents equivalence in catch rates between the two fyke nets. On the bottom: catch ratio curve (black solid line) with 95% confidence intervals (blue band). The 1.0 dotted horizontal line represents the point at which both fyke net have an equal catch rate. Light red areas describe statistical differences in length class.

Table 6. Results of catch ratio (CR) (in %) at different lengths and fit statistics for the catch comparison analysis for *P. leptodactylus*.

CL (cm)	CR (%)		CL (mm)	CR (%)	
	Mean	CI (%95)		Mean	CI (%95)
1.5	*	*	5.0	63.03	(50.92–75.68)
2.0	*	*	5.5	52.42	(40.75–66.38)
2.5	*	*	6.0	49.52	(35.09–65.47)
3.0	*	*	6.5	52.93	(33.44–76.74)
3.5	244.49	(174.29–343.66)	7.0	63.76	(34.65–106.78)
4.0	135.61	(110.65–170.00)	7.5	86.23	(33.73–179.80)
4.5	86.42	(71.99–103.73)	8.0	130.38	(29.99–354.27)

Values in brackets represent 95% confidence limits. *: Out of data range. Catch ratio results marked in bold represent significant difference in catch efficiency between commercial and experimental fyke net codend.

juveniles in the *Com.* codend (I), small crayfish trying to escape from them (II), or large males attempting to enter the fyke net for mating with females during the breeding period (III) may have caused such a difference in catch composition.

Despite equal fishing effort, variations are observed in the monthly catch numbers in our study. This situation is likely

influenced by several factors (I) operational issues (e.g., freezing of the lake surface in January), (II) biological characteristics of the species (e.g., high mobility associated with mating behavior in December, recruitment in April), and (III) fishing pressure (decrease in catch quantity towards the fishing season in September and October).

Table 7. Summary result of some stock assessment studies conducted on *P. leptodactylus*.

Author	Locality	Sex&Group	L_{∞}	K	Z	F	M	E
Deval et al. (2007)	Some northern Marmara reservoirs	♀♀+♂♂	80.80	0.40	2.11	1.53	0.578	0.72
Berber et al. (2012)	Manyas Lake	♀♀	73.45	0.61	1.87	1.06	0.81	0.57
		♂♂	81.90	0.55	1.52	0.82	0.70	0.54
	Uluabat Lake	♀♀	74.96	0.46	1.78	1.13	0.65	0.63
	İznik Lake	♂♂	76.81	0.51	1.69	0.91	0.68	0.57
		♀♀	71.47	0.41	1.79	1.19	0.60	0.66
Korkmaz et al. (2023)	Eğirdir Lake	♂♂	69.97	0.68	1.78	0.03	0.85	0.53
		♀♀	89.07	0.54	—	—	—	—
		♂♂	87.02	0.57	—	—	—	—
Current study	Eğirdir Lake	♀♀+♂♂	86.06	0.59	3.02	2.38	0.64	0.78
		♀♀+♂♂ <i>Com.</i>	85.38	0.32	1.68	1.26	0.42	0.75
		<i>Exp.</i>	86.62	0.54	3.74	3.14	0.60	0.84
		<i>Comb.</i>	87.54	0.57	3.26	2.63	0.63	0.81

Table 8. Advised TAC scenarios by $BRPs$.

Groups	$F_{current}$	F for SPR_{target}	$F_{over-applied}$	$TAC_{advised}$
<i>Com.</i>	1.26	0.47	0.79	373.02
<i>Exp.</i>	3.14	0.75	2.39	238.85
<i>Comb.</i>	2.63	0.67	1.96	254.75

* $SPR_{target}=0.40$ and $TAC_{current}=1000$ ton.

In the previous LWR studies of *P. leptodactylus*, b values were reported as 2.64336 (Harlioglu, 1999), 2.8433 (Bolat, 2001), 2.850 (Balık et al., 2005), 3.224 (Bök et al., 2010), 2.7918 (Bolat & Kaya, 2016), and 3.215 (Korkmaz et al., 2023). The b value, considering the entire sample, was found to be 3.150 in the current study. The differences in the reported b values for the same species in previous studies are thought to be attributed to the applied sampling technique, sampling period (monthly or seasonal), and other species-specific biological characteristics (such as female/male ratio, extremity lost, presence of pleopodal egg, soft or hard shell etc...). For successful sampling in crayfish, fishing should be spread throughout the year. Especially during the breeding season, females carrying pleopodal eggs under their abdomen increase the total weight (TW), leading to an increase in the b value. Olusoji et al. (2010) reported that differences in the parameters of length-weight relationships across seasons and years can be influenced by factors such as temperature, salinity, food (quantity and quality), sex, and maturity stage. Capturing crayfish during the moulting period when their shells have not yet hardened sufficiently may result in the TW being below the expected value, leading to a lower b value. Another factor that could affect the LWR parameters in crayfish is the loss of extremities. These lost extremities, often due to intraspecific competition or diseases, can lead to the crayfish's TW being measured lower than normal. Cilbiz (2010), reports that the claw meat yield of male individuals in especially larger length classes is almost equal to the abdominal meat yield. Regarding the sampling technique, it is reported that using of gill net with same mesh size in fishing trial can lead to errors in computing of b value (Froese, 2006; Kipling, 1962). On the other hand, LWR in fishes can be affected by habitat, area, seasonal effect,

degree of stomach fullness, gonad maturation, sex, health, and variances in observed length ranges, among others (Tesch, 1971; Barua et al., 2023). The parameters of the LWR equation “ a ” and “ b ” use as input parameters in the computing of yield per recruit analysis. Therefore, accurately determining the LWR parameters is crucial for the successful completion of the stock assessment process.

The total mortality coefficient (Z) showed significant differences according to the sampling group in the study. In the *Exp.* group, crayfish mostly in the small length class were modelled with a maximum relative age of 4, while in the *Com.* group where crayfish with larger length classes were caught, the maximum relative ages were modelled as 7. In this case, since the point where the catch curve intersects the X-axis is closer to the origin, the slope of the line is higher, resulting in a higher total mortality coefficient for the *Exp.* group compared to the *Com.* codend. Taking into account the estimated F_{curr}/F_{max} values for the sampling groups, it is computed that in order to reduce fishing mortality to the F_{max} level, fishing pressure needs to be reduced by 18.25% based on *Com.*, 50.32% for *Exp.*, and 48.67% for the *Comb.* group data. While the use of only commercial codend (*Com.*) in the fishing leads to the conclusion that the stock is relatively better, in the other two scenarios (*Exp.*–*Comb.*) where the population is better sampled, the situation appears to be more critical. In other studies, on the *P. lepodactylus* (Tab. 7), the $VBGF$ parameters L_{∞} values range from 69.97 to 89.07 mm carapace length, and the K (Brody growth coefficient) value varies between 0.41 and 0.68. The variation is thought to be due to factors such as the sampling period and frequency, technical specifications of the used sampling codend, the feeding status of crayfish, sex ratio of subsample, and the level of fishing pressure applied by commercial fishermen.

The total allowable catch (*TAC*) amounts to be recommended for the following year are given in Table 8 by adapting the rates of reduction in fishing mortality that should be realised at target *SPR* 0.40 to the *TAC* 1000 tonnes applied in the previous fishing period. The extra *F* applied in the evaluation with data gained from *Com.* is estimated to be 0.79 and 2.39 in the evaluation with *Exp.* data. In this framework, there is a very high difference of %56 between the recommended *TAC* amount. The assessment results with the pooled from *Com.* and *Exp.* data can be considered closer to the outcomes obtained from the *Exp.* codend. The observed differences in these size-based assessments are primarily attributed to variations in the size selectivity of *Com.* and *Exp.* codends. In this context, accurate gear selectivity data improves the fitting of population dynamics models, which is essential for assessing population viability and establishing harvest regulations. Studies have demonstrated that incorporating gear selectivity into models reduces bias, particularly when data on larger fish are scarce or sampling methods vary across populations (Mitchell et al., 2019; Li & Wagner, 2019).

5 Conclusion

As a result, the failure of the *Exp.* codend to sampling of individuals in the large length class and the failure of the *Com.* codend to sampling of small individuals have been clearly determined through both *K-S* and *CC* as well as *CR* analyses. It is thought that relying solely on either the *Com.* or *Exp.* codend alone will not accurately represent the crayfish population. Instead, using fyke net with different mesh sizes is considered a more accurate approach for successfully capturing all length classes. In future studies, conducting more comprehensive research to develop a methodology akin to the European standard “Water quality – Sampling of fish with multi-mesh gillnets (DS/EN 14757)” for crayfish sampling with fyke net would be beneficial.

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Conflicts of interest

The authors declare no competing interests.

Data availability statement

The data used in this study are available from the corresponding author, upon reasonable request.

Author contribution statement

B.K. collected the data. M.C. analysed the data. M.C. and Y. B. wrote the first draft of the manuscript. M.C., B.K. and Y. B. contributed to manuscript revision, and read and approved the submitted version.

Data accessibility

All data and supplementary materials are available from the corresponding author upon request.

Ethics approval

The authors declare all research to be completed in compliance with animal care standards and regulations.

Supplementary material

Figure 1. Technical plan of a fyke net used for collecting commercial catch data.

Figure 2. Technical plan of a fyke net used for collecting survey data.

The Supplementary Material is available at <https://www.alr-journal.org/10.1051/alr/2025008/olm>.

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