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RESEARCH PAPER

Quantitative Fishery Assessment of Data-Limited *Sander lucioperca*: Tools for Fisheries Management and Conservation

Meriem Bousseba[1,*], Loubna Ferraj[1], Sara Ouahb[1], Mohammed Droussi[2], Mustapha Hasnaoui[1]

[1]Environmental, Ecological and Agro-Industrial Engineering Laboratory, Sciences and Techniques Faculty, Sultan Moulay Slimane University, 23020 Beni-Mellal, Morocco.
[2]International expert in aquaculture, 23020 Beni-Mellal, Morocco.

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Corresponding Author
E-mail: meriembousseba@gmail.com

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Abstract

Sander lucioperca is one of the species whose fishing has significantly expanded over the past decades worldwide. This situation has raised growing concerns about the risk of over-exploitation of the species as a commercial target. Thus, to improve the long-term sustainability of this fishery, it is necessary to implement an efficient management strategy founded on a rigorous scientific assessment of the current status of the stock. Given that information on catches and fishing effort for this species is not available in Morocco, this study aims therefore to assess the stock status of the *Sander lucioperca* population in Al Massira Dam Lake using length-based data-limited methods. The estimates of total mortality (Z) and natural mortality rates (M) were 0.58 year^{-1} and 0.25 year^{-1}, respectively. The estimated fishing mortality rate (F=0.33) exceeded the fishing mortality ratio corresponding to the maximum sustainable yield (F_{max}=0.22), with an exploitation rate of 0.57, which is above the reference level (0.5). This suggests that the *Sander lucioperca* stock in Al Massira Reservoir is overexploited. The results presented here offer new key tools for assessing the stock of this species' population, thereby aiding in its management.

Introduction

Sander lucioperca (Linnaeus, 1758) is a piscivorous fish belonging to the family Percidae, found in both fresh and brackish water ecosystems (Kottelat & Freyhof, 2007). *S. lucioperca*, native to the major rivers of Eastern Europe, is naturally distributed between the Elbe in the west, the area around the northern Baltic Sea and south-west Russia (Deelder & Willemsen, 1958; Sonesten, 1991). *S. lucioperca* is one of the most predatory fish in aquatic ecosystems and is of great ecological importance as well as significant economic value. It is important for local and recreational fisheries (Cowx, 1997; Lappalainen, 2001).

The predatory *S. lucioperca*, which eats herbivorus species, is essential in regulating phytophagous fish species, which are employed to purify waters, especially in lakes and reservoirs (Van Densen & Grimm, 1988). The fish was introduced in 1939 in Morocco into the Middle Atlas lakes, the reservoirs and certain rivers, where it has developed stable populations (Azeroual, 2003). *S. lucioperca* is among the most precious fish in freshwater fisheries (Nikolić et al., 2023). These fisheries have become an important social and economic sector, offering employment, nutrition, and food to the communities. Although its socio-economic importance is considerable, to date no study has been performed to assess the stock status of the *S. lucioperca* population in Morocco.

Artisanal fisheries, which often have limited data, suffer from a lack of information on catches, surveys and species biology (FAO, 2015). Despite making up more than 50% of worldwide fisheries and providing employment for around 90% of fishers, these fisheries have difficulty gathering appropriate data (Salgueiro-Otero et al., 2022). The aggregation of catches in national statistics masks their contribution and prevents stock assessment (Zeller et al., 2023). Small-scale fishing communities, particularly those living near the Al Massira Reservoir, remain neglected and their contribution to nutritional security is frequently ignored. The lack of data makes fisheries management more complex and hinders efforts to promote food security and livelihoods (Tilley et al., 2018).

Globally, 12% of fisheries are well-managed or have a good stock assessment (FAO, 2019). Providing reliable assessments and management measures, on the other hand, rest on sound science-research, and is crucial to sustaining fisheries resources for the benefit of the current generations as well as generations to come (Tesfaye & Wolff, 2015). Traditional stock assessment approaches informed by capture and fishing effort data are often successful in providing management advice (Dowling et al., 2019). However, those models are not feasible across many data-limited fisheries (Chrysafi & Kuparinen 2016). Instead, length-based models provide a robust and resource-efficient solution for fisheries management (Hilborn & Ovando, 2014; Wibisono, 2021). Length data collection is a simple, inexpensive and widely-used method by fisheries scientist in evaluating data-poor fisheries (Quinn & Deriso 1999). Consequently, several length-based stock assessment methods exist for scientific management of fisheries (Costello et al. 2012; Chrysafi & Kuparinen 2016; Pons et al. 2019). Though length-based approaches cannot provide the reliability demonstrated by catch-based methods, they still can lead to more robust and less biased estimated values, so relevant for preliminary management in data-limited fisheries (Pons et al., 2019).

To determine whether the stock of the S. *lucioperca* population in the Al Massira Reservoir is under excessive fishing pressure, which is likely to affect the size structure of this species and threaten its long-term sustainability, this research aims to provide, for the first time in Morocco, new information on the stock status of *S. lucioperca* population, particularly in Al Massira Dam Lake, using length-based data-limited methods. It also proposes management recommendations and effective control measures for the sustainable exploitation of this fishery, which are currently lacking.

Materials and Methods

Study Area

The Al Massira Reservoir is a concrete dam situated on the middle course of the Oum Er-Rabi river, 70 km south of Settat, between 32 28'32'' North and 7 32'15'' West (Figure 1). With a capacity of 2.760 million m^3 and a maximum depth of 40 m, Al Massira Dam Lake is considered the second biggest artificial reservoir in Morocco, after Bin El Ouidane Dam (Alaoui et al., 2000). Consequently, this large reservoir plays an important role as an aquatic ecosystem in the region and harbors a variety of ecologically and economically important fish, such as the actively fished *S. lucioperca*, thus it represents a good target to investigate. The Lake of Al Massira Dam, represents a natural resource with a great economic potential for local communities. Source of our drinking water, fishery, irrigation and one the major source of hydroelectric energy (Darwall et al.,2014).

Fish Treatment

In Al Massira Reservoir, fishing occurs with nets measuring between 25 and 65 mm in mesh size, capturing many sizes of *S. lucioperca*, irrespective of age. This approach maximizes the catch of various representative groups of the population. Hooks are also used to target larger specimens. A total of 704 *S. lucioperca* individuals, caught during targeted fishing in this reservoir, were examined to assess the stock status. This sample, representative and encompassing all size classes of the total population, was collected randomly each month from commercial fisheries over a 12-month period (January to December 2021).

In the laboratory, each fish was measured using a graduated ichthyometer (model KH-PISCIS-80-22) with a precision of 0.1 cm, recording the total length (Lt in cm), which represents the distance between the mouth's end and the caudal fin's tip. We utilized an electronic scale (Sartorius Entris 2202-1S) accurate to 0.1 g for weighing, recording the total weight (Wt in g).

Stock Assessment Indicators

Length-weight Relationship

The length-weight relationship was estimated by the power function (Le Cren, 1951):

$$Wt=aLt^b \quad (1)$$

The intercept is represented by *a*, and the slope by *b* of the regression line (Froese, 2006). Converting this equation into logarithmic form($\log\ (\mathrm{Wt}) = \log(a) + b\ \log(\mathrm{Lt})$), the variables *a* and *b* were determined through linear regression (Zar, 1999). The length-weight relationship indicates isometric growth where b=3, positive growth where b>3 and negative growth where b<3 (Froese, 2006).

Growth Parameters

Von Bertalanffy growth parameter estimate (VBGP) of *S. lucioperca* was performed by applying the ELEFAN_GA method, integreted within the "TropFishR" package (Mildenberger et al. 2017), based on the length frequency distribution of the total monthly catches during the one-year (2021) analysis period. According to the maximum body length of each species, the LFQ data were classified, in order to eliminate uncertainty and to increase the plausibility of the VBGP estimate (Wang et al. 2020):

$$\text{Optimum bin size (OBS)}=0.3\text{x}L_{max}^{0.6} \quad (2)$$

With: OBS is the ideal interval size used to group electronic length-frequency analysis data (ELEFAN).

The growth study was founded on Von Bertalanffy's oscillating seasonal growth function (soVBGF) (Pauly 1980):

$$\mathrm{Lt} = \mathrm{L}\infty\left\{1 - \mathrm{e}^{-[\mathrm{K}(\mathrm{t}-\mathrm{t}_0)+\mathrm{S}(\mathrm{t})-\mathrm{S}(\mathrm{t}_0)]}\right\} \quad (3)$$

Where $\mathrm{S}(\mathrm{t}) = \frac{CK}{2\pi\sin 2\pi(\mathrm{t}-\mathrm{t}_\mathrm{s})}, \mathrm{S}(\mathrm{t}_0) = \frac{CK}{2\pi\sin 2\pi(\mathrm{t}_0-\mathrm{t}_\mathrm{s})}$

Where Lt corresponds to the fish size at time t, L_∞ denotes the asymptotic length (cm), K is the coefficient of growth (year-^{1}), t_0 represents the theoretical age when the fish size equals zero. To simplify the analysis, seasonal growth was not considered in this study, C is a constant that presents the oscillation amplitude, and ts represents the fraction of the year when the sinusoidal oscillation starts (Pauly 1980; Sparre and Venema 1998). In "TropFishR", the parameter t_0 is replaced by the parameter t_anchor, which represents the annually repeated growth curves (Taylor and Mildenberger 2017). The L_∞ initial value was estimated using the equation suggested by Pauly (1984):

$$\mathrm{L}\infty = \mathrm{Lmax}/0.95 \quad (4)$$

Where L_{max} is the maximum fish length.

L_∞±20% was the search area for the ELEFAN_GA samples. The growth performance index (Ø′) was determined by the Pauly and Munro (1984) formula in order to compare our findings to those obtained in other regions.

$$\emptyset' = \log_{10}\mathrm{K} + 2\log_{10}\mathrm{L}\infty \quad (5)$$

Estimation of Mortality Parameters and Exploration Rate

Total mortality rate (Z) was obtained using the linearized capture curve converted to length (Pauly, 1983) within the "TropFishR package" (Mildenberger et al., 2017; Taylor & Mildenberger, 2017). After estimating

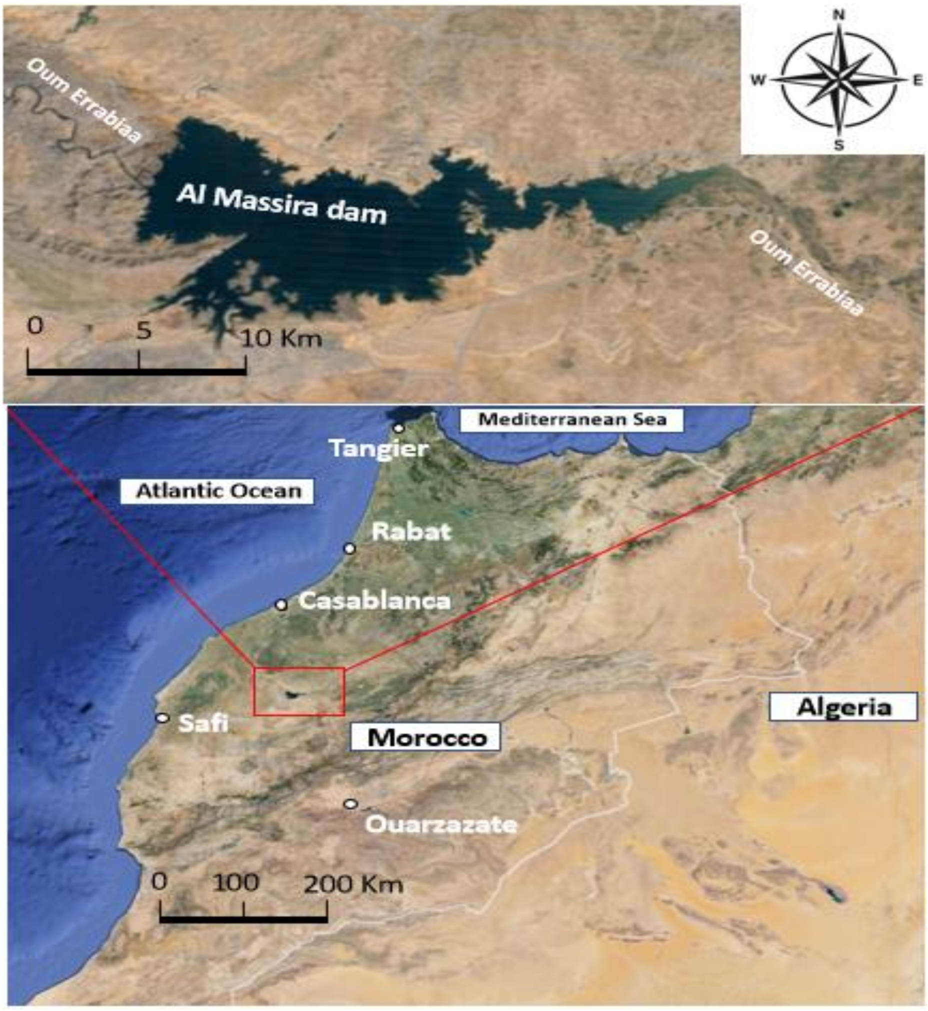

Figure 1. Study area map (Al Massira Reservoir), Morocco.

Z, the natural mortality rate (M) was calculated by the empirical formula suggested by Then et al. (2015):

$$M = 4.118 \times K^{0.73} \times L\infty^{-0.333} \quad (6)$$

Fishing mortality (F) and exploitation rates (E) were then calculated by the functions:

$$F = Z - M \text{ and } E = {}^{F}/_{Z} \quad (7)$$

The calculated exploitation rate (E) was subsequently assessed against the reference

value proposed by Gulland (1971), which indicates 0.5 as the higher level for sustainable exploitation.

Probability of Capture

The probability of capture has been computed using the length-converted capture curve (Pauly & Munro, 1984) allowing the extrapolation of the left descending limb of the curve for each length class. Capture probability is the ratio between captures (N) and the number of available individuals (N/P), thus enabling estimation of the length at first capture (Lc) (Pauly, 1987).

Yield Per Recruit

Thompson and Bell's (1934) length-based yield per recruit (YPR) model was employed to assess the levels of exploitation of *S. lucioperca* for optimum yield. The estimated reference levels include:

- The fishing mortality and exploitation yielding the highest yield per recruit (F_{max}) and corresponding exploitation (E_{max}).
- The levels of fishing mortality and exploitation that decrease the spawning biomass to 50% of its unexploited state (F0.5 and E0.5).
- The fishing mortality and exploitation rates at which the slope of the yield-per-recruit curve at the origin is reduced to 10% (F0.1 and E0.1).

The yield isopleths were utilized to estimate the impacts of variations in both fishing mortality and selectivity ($Lc/L\infty$).

Statistical Analysis

To check whether the *'b'* value differed significantly from the predictions associated with isometric growth (b=3), a student's t-test was performed. A significant difference from 3 (P<0.05) indicates a major or minor allometric growth, while no difference (P>0.05) suggests isometric growth. Growth, mortality and exploitation parameters were evaluated within the 'TropFishR' package (Mildenberger et al., 2017). All statistical analyses were carried out using R-Studio software, version 4.2.2.

Results

Length Frequency Distribution

Table 1 provides the number of specimens sampled each month with a total of 704 individuals. The size frequency distributions of *S. lucioperca* in this study varied from 21 to 72 cm. The most frequently caught individuals measured between 21 and 25 cm in total length (286 individuals) (Figure 2). Furthermore, different fish species such as *Lepomis gibbosus*, *Micropterus salmoides*, *Oreochromis niloticus*, *Rutilus rutilus* and *Cyprinus carpio*, have been captured in the same habitat (Al Massira Dam Lake) as *S. lucioperca*, highlighting the significant ecological diversity of this reservoir.

Length-weight Relationship

The lowest total weight recorded was 75 g, with a minimum total length of 21 cm. The highest total weight registered was 2915 g, corresponding to a maximum total length of 72 cm. The biometric relationship relating total length to the total weight indicates a significant majoring allometry (b>3, P<0.001) (Table 2). This indicates that weight grows proportionally faster than length. The value of the regression coefficient is very close to 1 (R=0.98), which reflects a strong association of length and weight.

Growth Parameters

The Von Bertalanffy growth equation parameters for *S. lucioperca*, are summarized in Table 3. The findings obtained are: $L\infty$=86.67 cm, K=0.24 year^{-1}, t_anchor=0.49, ts=0.48 and C=0.69. The growth performance (Ø′) was 3.25.

Mortality Parameters and Exploration Rate

The total mortality rate (Z) of *S. lucioperca*, derived from the length-converted catch curve, is 0.58 year^{-1} (Figure 3a), with a natural mortality of 0.25 year^{-1} estimated by using the Then et al. (2015) method. The estimated fishing mortality rate (F) is 0.33 year^{-1}, with an exploitation ratio (E) of 0.57 (Table 4). Using these values, the back-projection of the descending part of the capture curve yielded an average size at first capture (Lc) of 22.45 cm (Figure 3b).

Yield-Per-Recruit (YPR)

The biological reference levels of the fishing mortality and exploitation rates (F_{max}, F0.1, F0.5, E_{max}, E0.1, and E0.5) are presented in Table 5. The YPR model's graphical output is shown in Figure 4. The results suggest that the maximum yield can be reached at F_{max} and E_{max} values of 0.22 year^{-1} and 0.38, respectively. Likewise, obtaining 50% annual yield from the biomass corresponds to F0.5 and E0.5 values of 0.10 year^{-1} and 0.19. The biologically optimal yield can be achieved with F0.1=0.18 year^{-1} and E0.1=0.31, respectively.

Discussion

Although the *S. lucioperca* fishery holds considerable importance for continental communities for employment, food security, and income, it has never been given priority by the Moroccan regulatory authorities. Consequently, catch-based data for a thorough stock assessment are lacking in Morocco. Due to the lack of chronological or age-related catch data, length-based methods are becoming increasingly common in data-limited fisheries, where length data are easily gathered (Mzingirwa et al., 2020). This study fills crucial gaps in terms of data and regulation in the Moroccan fishing sector. Given a sector poorly regulated and lacking resources, it offers a clear reference basis for the design, adequate development of guess policies. This is the first time these methods based on length were used to assess the stock of *S. lucioperca* in the Moroccan. This novelty not only equips decision-makers with critical information for the construction of sustainable and effective fisheries management strategies, but also emphasizes the need to design fisheries policies that consider the respective challenges and opportunities

The length frequency distribution analysis of the *S. lucioperca* indicated that the most captured individuals had a total length ranging between 20 and 25 cm. Thus,

Table 1. Number of *S. lucioperca* individuals sampled each month

Mouths	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
IndividualsNumber	66	54	56	60	56	59	61	54	63	55	68	52

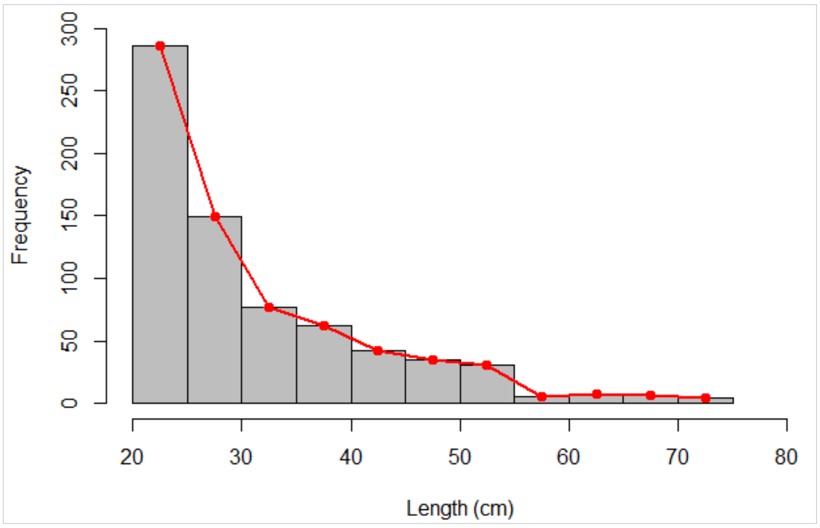

Figure 2. Size-frequency distribution of *S. lucioperca*.

Table 2. Length-weight relationships and Student's *t* test of *S. lucioperca*

Coefficients	Estimate	Standard error	t-value	P-value
a	-2.51	0.045	55.89	< 2. 2e-16
b	3.26	0.030	106.98	< 2. 2e-16

Table 3. Growth parameters and scores of *S. lucioperca*

Parameters	Value
L∞ (cm)	86.67
K (year^{-1})	0.24
t_anchor	0.49
Ts	0.48
C	0.69
Ø′	3.25
Rn_max score	0.46

Rn=The quality of the model estimation fit.

small fish species largely dominate the catches of the commercial fleet. This can be attributed to the exploitation of the population through intense fishing by artisanal fishermen, who often employing non-selective gillnets, leading to the capture of large numbers of much smaller individuals due to the lack of regulation of gear in Al Massira Dam Lake. However, the significant presence of small individuals may also indicate substantial recruitment in the population (Lasker, 1981). In many fisheries, a significant number of juveniles may indicate the productivity of a particular generation rather than overfishing (Myers & Barrowman, 1996). However, if recruitment is not supported by a sufficiently robust spawning stock, especially when excessive fishing pressure affects primary spawners, it could lead to long-term stock depletion (Walters & Martell, 2004). Therefore, distinguishing between high exploitation and high recruitment requires further research on reproductive success, environmental factors, and interannual variations in recruitment strength (Fogarty & Murawski, 1998; Sundby & Nakken, 2008).

The allometric coefficient obtained in this study ($b>3$, $P<0.001$) indicates positive allometric growth for this species, suggesting that its weight increases at a higher rate than its size. A majoring allometry was also revealed for the same species in Tunisian reservoirs (M'Hetli et al. 2011), in France (Argillier et al. 2012), and Algeria (Bouamra et al. 2017). However, minorizing allometry with *b* less than 3 was reported by Cernisencu and Staras (1992) in Romania and by Becer and Ikiz (1999) in Turkey. On the other hand, the work of Ilhan and San (2015) revealed an isometric allometry of *S. lucioperca* in Turkey. The allometry coefficient varies with several factors, including habitat, season, age, sex, physiological conditions, health, gonad maturity diet and stomach fullness, growth rate and yearly changes in environmental conditions (Li et al., 2013; Hossain et al., 2015), which could explain its variation between different regions.

The growth parameters L_∞ and k found in this research, as well as those found in other studies, are presented in Table 6. The Ø' test revealed variations in these parameters across regions (Table 6), which can be attributed to several factors. These include water conditions, metabolic rate, food availability, pollution, and fishing pressure (Sparre & Venema, 1998). Fishing pressure, particularly size-selective fishing, is a well-

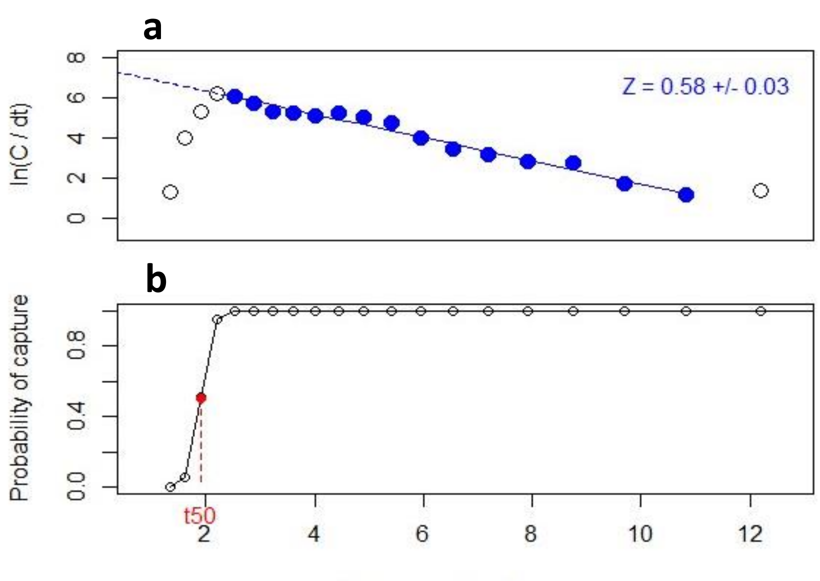

Figure 3. Length-converted capture curve illustrating the total mortality (Z) (a) the estimated probability of capture derived from the left descending extrapolation of this curve (b).

Table 4. Mortality parameters, exploitation rate, and selectivity of *S. lucioperca*

Z (year^{-1})	M (year^{-1})	F (year^{-1})	E	Lc (cm)
0.58	0.25	0.33	0.57	22.45

Table 5. Biological reference points obtained from the yield-per-recruit model based on length (Thompson & Bell, 1934)

F01	F_{max}	F05	E01	E_{max}	E05
0.18	0.22	0.10	0.31	0.38	0.19

documented evolutionary selection factor that favors traits such as slower growth or earlier maturation (Favro et al., 1979; Law, 1979; Law & Rowell, 1993). This can further reduce the population yield (Law & Grey, 1989; Stokes et al., 1993). Moreover, water temperature directly influences fish growth by affecting their physiology (Weatherley & Gills, 1987), or indirectly by increasing the availability of food (Karås & Neuman, 1981). Numerous research studies have reported that temperature positively affects the growth of *S. lucioperca* (Ložys, 2004; Heikinheimo et al., 2014; Bouamra et al., 2017). Intraspecific variation in growth is influenced by trophic factors, including prey availability and quality. For example, zooplanktivores have a slower growth than their piscivorous counterpart (Mooij et al., 1994; Frankiewicz et al., 1996). Faster growth rates are typically found in areas with higher prey abundance or more favorable environmental conditions (Lorenzen and Enberg, 2001). In Al Massira Dam Lake, *S. lucioperca* primarily feeds on the abundant perch (Bousseba et al., 2020), which may explain its favorable growth in this habitat.

Genetic structure and trophic differences can have important implications for fisheries management. The genetic diversity defined by local adaptations must be conserved to ensure resilience of populations (Stearns, 1992; Lahnsteiner & Jagsch, 2005) and to preventing transfers between populations (Zhuo et al., 2012; Xiao et al., 2013; Araki & Schmid, 2010). Consideration of genetic connectivity is also needed in stock assessments to address inbreeding and trait loss (Stearns, 1992). Prey availability is also a primary influence on fish growth and reproductive success, which directly influences the growth and reproduction of *S. lucioperca* (Witmer et al., 2000; Calenge et al., 2004). Thus, fisheries management should not only regulate exploitation but also maintain food resources to sustain ecosystem balance (Redpath, 2001; Ziegltrum, 2004). Integrating these factors ensures conservation strategies align with ecological and genetic dynamics for long-term sustainability.

In general, the total mortality rate Z varies between different authors and regions (Table 7), which can be attributed to the divergence in fishing patterns, as well as to the values of L_∞ and K. The total mortality rate Z (0.58 year^{1}) reported in this study is close to that found (Z=0.47 year^{-1}) by Ozvarol and Ikiz (2008) in the Karacaoren Dam in Turkey, while it is lower than what has been reported by Toujani and Kraiem (2002) in Tunisia, by Balik et al. (2004) in Turkey, by Bouamra et al. (2017) in Algeria, and by Ibănescu et al. (2019) in Romania. Furthermore, the natural mortality rate (M)

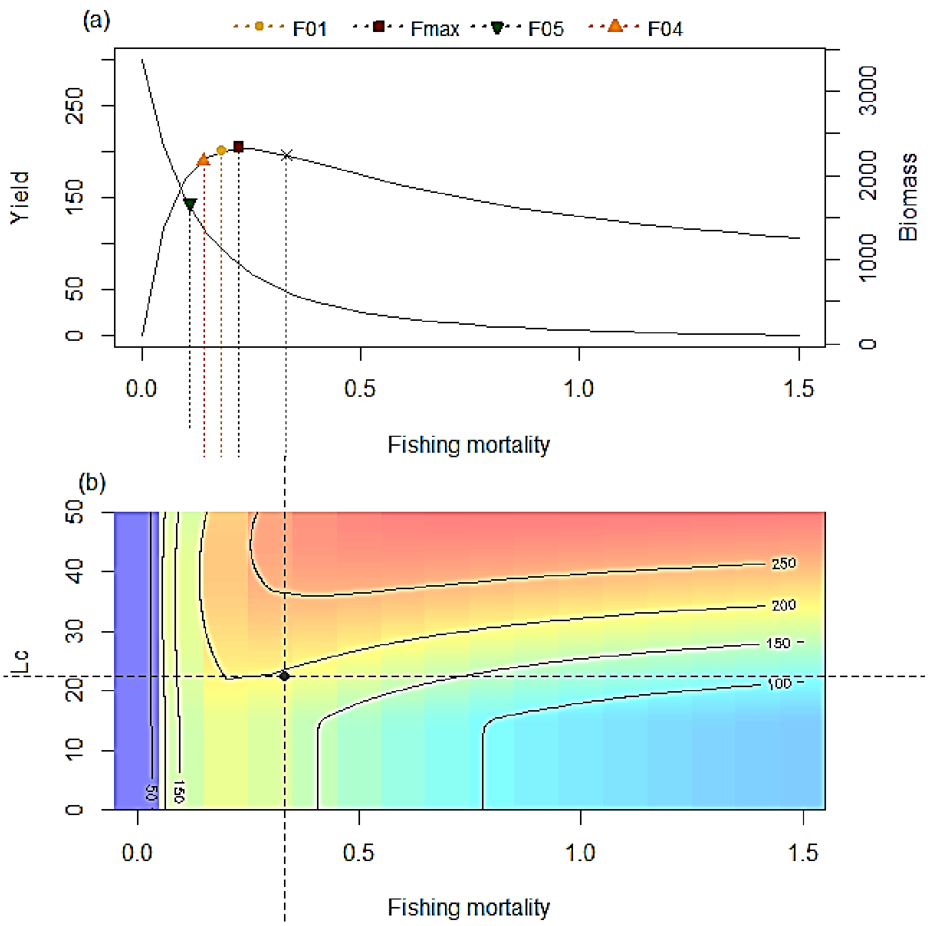

Figure 4. Yield and biomass analysis curve per recruit (a), and isopleth diagram illustrating the effect of different fishing mortality and Lc values on the relative YPR (b).

also shows variation among regions (Table 7). Several factors have been associated to natural mortality, such as predation, lack of food, diseases, aging, stress, and pollution (Yongo & Outa, 2016). The variations observed could therefore be linked to these factors. The estimate of length at first capture (Lc=22.45 cm) of *S. lucioperca* in the current study is lower than its length at first maturity (Lm), as reported by several studies conducted in different regions (Ruuhijärvi & Hyvärinen, 1996; M'Hetli, 2001; Poulet, 2004). This indicates that juvenile fish have been captured and excluded from the stock (using 25 mm mesh size nets). As a result, the stock's first spawners are being targeted by fishing, which will reduce the biomass of the stock's spawners and lead to a failure in recruitment and, consequently, the population's collapse.

Comparing the levels of fishing mortality (F) and exploitation (E) found in our study with the recommended levels (F_{max} and E_{max}) is essential for assessing a strategy for the sustainable management of an exploited fish stock. These key parameters, which are widely used, guide management measures aimed at achieving maximum sustainable yield (MSY) while maintaining stock productivity (Rochet & Trenkel, 2009). Furthermore, it is essential to evaluate the performance of fishing gear and its level of selectivity. The prediction model (Y'/R) applied in this study enabled us to determine the stock status in terms of various reference levels (Mildenberger et al., 2017) and to derive means of control, in particular monitoring fishing effort and regulating the selectivity of gear.

The model reveals that the *S. lucioperca* stock in the Al Massira reservoir is overexploited, with an exploitation rate (E=0.57) exceeding both the optimal reference rate (E=0.5) and the maximum threshold (E_{max}=0.38), confirming the urgency of the situation. In addition, estimated fishing mortality (F=0.33 yr^{-1}) exceeded the acceptable limit (F_{max}=0.22 yr^{-1}), confirming excessive fishing pressure. These results are consistent with studies conducted in Tunisia (Toujani & Kraiem, 2002), Turkey (Balik et al., 2004; Özayrol & İkiz, 2008), Algeria (Bouamra, 2017) and Romania (Ibănescu et al., 2019) (Table 7).

It is essential to take immediate action to attenuate the effects of fishing pressure and ensure the sustainability of this population, thereby ensuring the long-term future of the fishery. To achieve this objective, it is imperative to define size limits and increase mesh sizes to restrict the catch of juveniles, allowing them to achieve their sexual maturity and spawn at least once. This will help to renew the population and support the balance of the local aquatic ecosystem. The establishment of well-defined closed areas and periods during the spawning and recruitment periods should also be a priority measure, as it will help to reduce juvenile and spawning mortality and promote the improvement of the spawning stock. Reducing fishing mortality by controlling fishing effort is also a key strategy. This may involve limiting the number of fishing boats or the number of fishing hours per day. To improve the effectiveness of these measures, it is crucial to involve the local fishing community in implementing size restrictions, respecting closed seasons and reducing fishing effort. This could be done through training sessions and awareness-raising workshops on the long-term benefits of these practices for the sustainability of their resources. Economic incentives, including financial compensation for seasonal closures, could also be applied to mitigate the impact on fishermen's livelihoods, while ensuring sustainable fisheries. Reconciling these restrictions with fishermen's dependence on fishing will require close collaboration with local stakeholders to ensure the economic profitability of fishing while maintaining sustainable practices.

Table 6. Von Bertalanffy parameters equation obtained in different regions in comparison with present study data

Areas	*a*	*b*	L∞	K	Ø'	Authors
Erkek Lake (Turkey)	$9.71.10^{-3}$	2.95	94.86	0.09	2.91	Becer and Ikiz (1999)
Danube Delta, Sinoe Lake (Romania)	$1.50.10^{-2}$	2.89	91.10	0.14	3.07	Cernisencu and Staras (1992)
Tunisian Reservoirs	5.10^{-6}	3.06	-	-	-	M'Hetli et al. (2011)
Treignat Reservoir (France)	$4.78.10^{-6}$	3.05	74.40	0.07	2.62	Argillier et al. (2012)
Castillon reservoir (France)	$1.91.10^{-6}$	3.25	98.60	0.03	2.46	Argillier et al. (2012)
Nature Reserve "Koviljsko-Petrovaradinski Rit" (Serbia)	-	-	49.55	0.25	2.78	Lujić et al. (2013)
Lake Marmara (Turkey)	$9.1.10^{-3}$	2.996	-	-	-	Ilhan and San (2015)
Ghrib Reservoir (Algeria)	$3.3.10^{-3}$	3.237	125.72	0.13	3.31	Bouamra et al. (2017)
Al Massira Reservoir (Morocco)	-2.51	3.26	86.67	0.24	3.25	Present study

Table 7. Different mortality coefficients in different areas

Z (year^{-1})	M (year^{-1})	F (year^{-1})	Areas	Authors
1.186	0.415	0.771	Sidi Salem Reservoir, Tunisia	Toujani et Kraiem (2002)
1.27	0.185	1.085	Lake Igirdir, Turkey	Balik et al. (2004)
0.47	0.22	0.25	Karacaoren Reservoir, Turkey	Ozvarol et Ikiz (2008)
1.42	0.62	0.80	Ghrib Reservoir, Algeria	Bouamra (2017)
2.18	0.512	1.668	Lac Danube, Romania	Ibănescu et al. (2019)
0.58	0.25	0.33	Al Massira Reservoir, Morocco	Present study

Conclusion

This study has revealed crucial questions about the state of the *S. lucioperca* stock in the Al Massira Reservoir, and one of the most remarkable results of this research is that this species is largely overexploited. The current challenge consists of increasing the minimum length at first capture and to widen the mesh size to reduce the catch of juveniles, which will enable stocks to be rebuilt. In addition, it is suggested that research be conducted into the volumes of by-catches according to the various mesh sizes in order to assess their impact more accurately and strengthen decision-making in terms of regulations. Additionally, it is necessary to define areas and periods of fishing closures to ensure a security margin, thereby promoting the reproduction of adults and the natural recovery of the population. This study could significantly contribute to the development of an effective and sustainable management plan for the fishery resources of this reservoir. Implementing these recommendations would not only protect the *S. lucioperca* stock but also ensure the long-term livelihoods of local fishing communities and preserve the ecological balance of the reservoir. This research provides a preliminary foundation for the sustainable management of the *S. lucioperca* population in Al Massira Reservoir. Future research on fishing effort, socio-economic impacts, and ecological factors is essential to refine these recommendations and ensure a comprehensive management plan based on long-term catch data, which would provide a better understanding of the evolution in fish population and the impact of measures implemented over an extended period.

Ethical Statement

All procedures involving fish in the study were conducted in accordance with European Union Directive no: 2010/63.

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Author Contribution

All authors agree to be accountable for the content and conclusions of the article. They contributed to the final manuscript as follows: MB participated in conceptualization, data compilation, investigation, data analysis, and manuscript writing. LF and SO contributed to data collection, investigation, and data interpretation. MD participated in designing the study, review, and correction. MH supervised, revised, and edited.

Conflict of Interest

The authors 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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