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Research Article Araştırma Makalesi

A study on the Bioecological Characteristics of the Exotic Pumpkinseed (*Lepomis gibbosus*) Population in Gökpınar Dam Lake (Western Anatolia, Türkiye)

Gökpınar Baraj Gölü (Batı Anadolu, Türkiye)'ndeki Egzotik Güneş Levreği Popülasyonunun (*Lepomis gibbosus*) Biyo-Ekolojik Özellikleri Üzerine Bir Araştırma

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Abstract: This study was conducted to determine some bioecological characteristics of *Lepomis gibbosus* (L. 1758), commonly known as pumpkinseed sunfish, which spreads in Gökpınar Dam Lake (*GDL*) in Denizli Province. The fish samples were captured with an experimental seine net and multimesh gillnet from May 2019 to April 2020. During the samplings, certain physicochemical parameters of *GDL* were measured, habitat utilization, relations to environmental variables, feeding habits and interspecific interactions with other fishes of *L. gibbosus* individuals were observed. It is observed that *GDL* provides a suitable habitat for *L. gibbosus* in terms of water quality and other ecological requirements. A total of 1005 *L. gibbosus* individuals, consisting of 302 females, 605 males, and 98 juveniles, were sampled throughout the study, and biometric studies were conducted. In the population males were found to be dominant. The averages were determined as follows; total length as 5.82±2.09 cm (2.46-11.34), weight as 4.94±4.67g (0.20-34.65), and condition factor as 1.71±0.24. The ages were determined between 0+ to II+and Age-length relationship (VBGE) was estimated as $L_{t=}19.85\left(1-e^{-0.2744(t+0.272)}\right)$ Spawning occurs between April and June in individuals at the age of I+. It has been observed that the species exhibits good growth rates in this habitat, displays opportunistic omnivorous feeding behavior, preys on another invasive alien species, *Gambusia holbrooki*, present in the lake, and competes with the same species for habitat sharing. It has been determined that *L. gibbosus* has formed a self-sustaining population in *GDL*, but it utilizes a limited lake area as its habitat. In conclusion, *GDL* is considered as a hydrologically unstable and highly variable habitat. *L. gibbosus* population of *GDL* exhibits significant similarities in terms of bioecological characteristics with populations that spread outside its natural spreading area. As *L.gibbosus* is an exotic fish and might be have invasive traits, it is necessary to monitor of the population regularly, and control measures should be taken to prevent its spread to other inland water bodies.

Keywords
- Age
- Growth
- Reproduction
- Feeding behavior
- Habitat adaptation

Özet: Bu çalışma, Denizli İli Gökpınar Baraj Gölünde (*GBG*) yayılım gösteren güneş levreği *Lepomis gibbosus* (L. 1758)'un biyoekolojik özelliklerini belirlemek amacıyla yapılmıştır. Balık örnekleri Mayıs 2019-Nisan 2020 arasında deneysel ığrıp ve uzatma ağlarıyla yakalanmış, örnekleme esnasında *GBG*'nün bazı fizikokimyasal parametreleri ölçülmüş, kaynağın kullanımı, çevresel değişkenler, bireylerin çevreyle etkileşimleri gözlemlenmiştir. *GBG*'nün *L. gibbosus*'un su kalitesi ve diğer ekolojik istekleri bakımından uygun bir habitat olduğu görülmektedir. Çalışmada 302 dişi, 605 erkek ve 98 jüvenil toplam 1005 adet *L. gibbosus* bireyi üzerinde biyometrik çalışmalar yapılmıştır. Erkeklerin baskın olduğu görülen popülasyonda, ortalama toplam boy

Anahtar kelimeler
- Yaş
- Büyüme
- Üreme
- Beslenme davranışı
- Habitat uyumu

5.82±2.09cm, (2.46-11.34), ağırlık 4.94±4.67g (0.20- 34.65) ve kondisyon faktörü (1.71±0.24), yaş 0+- II+ arasında tespit edilmiş, yaş-boy ilişkisi (*VBBE*) Lt = 19.85 (1–e $^{-0.274)\ (\ t\ +\ 0.272\ )}$) olarak belirlenmiştir. Üremenin I+ yaşlı bireylerde Nisan-Haziran arasında gerçekleştirdiği tespit edilmiştir. Türün bu habitatta oransal olarak iyi büyüdüğü, fırsatçı omnivor beslenme gösterdiği, gölde yaşayan diğer bir istilacı yabancı tür *Gambusia holbrooki* yi av olarak kullandığı ve aynı türle habitat paylaşımı için rekabet ettiği görülmüştür. *L. gibbosus*'un *GBG* de kendi kendini sürdürebilir bir popülasyon oluşturduğu ancak kısıtlı bir alanı habitat olarak kullanabildiği tespit edilmiştir. Sonuç olarak, *L. gibbosus* hidrolojik olarak kararsız ve çok değişken bir habitat olarak değerlendirilen *GDL* de, biyoekolojik özellikler bakımından doğal yaşama alanı dışındaki popülasyonlar ile büyük ölçüde benzerlik göstermektedir. *L.gibbosus* egzotik bir balık olduğundan ve istilacı özelliklere sahip olabileceğinden, popülasyonun düzenli olarak izlenmesi ve diğer iç su kaynaklarına yayılmaması için kontrol önlemlerinin alınması gerekmektedir.

1. INTRODUCTION

In the United Nations Rio Convention on Biological Diversity (1992), biodiversity is defined as "the variability among living organisms from all sources including, among others, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species, and of ecosystems" (Topçu, 2012). Biological diversity, which is attributed great importance on a global scale, is being harmed under the pressures of diverse and interacting ecosystems, and this situation is progressively leading to the loss of biodiversity (Omann et al., 2009). It is known that the main threats to biodiversity include habitat loss, climate change, and bioinvasion caused by exotic/alien species. In terms of freshwater fish species, Türkiye has the highest biodiversity among all countries in the Mediterranean basin (Topçu, 2012).

Considering that Türkiye's inland waters are home to over 400 freshwater fish species originating from Europe, Asia, and Africa, and that more than 30% of these species are considered endemic, it is evident that Türkiye possesses a significant biological richness that needs to be carefully preserved (Ekmekçi et al., 2013).

The European Union Council Regulation (708/2007), defines exotic/alien species as follows: " (a) aquatic species and subspecies that are found outside their known natural range and potential range of distribution; (b) organisms of any kind, regardless of their natural range or potential for spread, that have polyploid or artificially hybridized reproductive capacity" (Tarkan, 2013).

The entry pathways (vectors) of alien-invasive species into a new region are always, directly or indirectly, but invariably, facilitated by human activities (Tarkan, 2013). One of the most significant vectors for these introductions is fish stocking efforts. During these stocking efforts, it is known that both translocated species and foreign species enter new habitats. Within both groups, there are species that are completely unintentionally introduced as well. A study has reported that out of a total of 54 species, 7 of them were unintentionally introduced through stocking efforts. Therefore fish stocking is recognized as a significant vector in biological invasions (İnnal, 2012).

The presence of the North American origin species *L. gibbosus* is known in various European countries including England, France, Spain, the Netherlands, Belgium, Germany, throughout the Danube River basin, Bulgaria, and Greece. The entry of this species into Türkiye was first recorded in 1982 in the Ipsala Canal (Edirne). Its introduction to the country occurred through the Meriç River, which is associated with Greece and Bulgaria (Erk'akan, 1983).

L. gibbosus can form large populations due to reproductive advantages, such as an extended spawning period, the partial release of relatively large eggs during spawning, and a low age of sexual maturity. This species is considered to have a high invasive potential because of its ability to feed on a wide range of different organisms and its well-developed adaptability to new habitats (Ekmekçi et al., 2013). Artificial water bodies, including reservoirs, ponds, irrigation and drainage channels, which serve as emerging habitats, as well as degraded and stressed habitats with irregular water regimes and pollution impacts, are suitable environments for the successful establishment of alien and/or invasive species (Ekmekçi et al., 2013).

Denizli Gökpınar Dam Lake (*GDL*) carries the habitat characteristics mentioned above, and it is observed to have a dense population of *L. gibbosus* individuals along its shores (Çetinkaya, 2018) .

The aim of this study was to assess the ecological status of *GDL* and examine the bioecological characteristics of exotic and potentially invasive *L. gibbosus* population in terms of population structure, growth, condition, reproduction, food and feeding. The study also aimed to evaluate the species' ecological relationships within the habitat.

2. MATERIALS and METHODS

Gökpınar Dam Lake (*GDL*), also known as Vali Recep Yazıcıoğlu Reservoir, is located in the province of Denizli within Büyük Menderes River basin. It was constructed for irrigation purposes and became operational in 2004. The *GDL* is fed by various water sources including the Tekke and İğdeli streams, drainage channels, and surface runoff. The *GDL* has a minimum water elevation of 317 meters and a maximum of 336.2 meters, covers an area of 1.98 km^2, and has a storage volume of 28.2 hm^3 (DSİ, 1989). The storaged water is used for irrigation, and excess water is discharged into the Büyük Menderes River through the Çürüksu Stream. Two sampling stations have been designated within the *GDL*. Station 1 (37°46'07" N; 29°07'29" E) is located on the southwestern shore of the reservoir, near the water inlet. At the station with low shoreline slope and moderate vegetation, the bottom is characterized as firm and partially rocky. Station 2 (37°47'03" N; 29°07'58" E) is located on the northern side of the reservoir, near the dam structure. It has a similar ground structure to Station 1 but with a steeper bottom slope compared to Station 1 (Figure 1).

Figure 1. *GDL* and location of stations

2.1. Sampling and Analyses

The physicochemical variables were determined on-site using a portable measurement device (YSI Pro Plus). Sampling was conducted using an experimental beach seine net with mesh sizes of 5mm and 15mm. When the water level was unsuitable for the use of this fishing gear, extension nets with multiple mesh sizes (net panel length of 35m, net panel depth of 6m, and mesh sizes of 10, 15, 20, 40,

55, 70, 80, and 100mm) were also employed. In fish sampling, ethical principles have been adhered to in accordance with the animal welfare laws, guidelines, and policies of the Republic of Türkiye. The samples were fixed in a 5% formaldehyde solution and transported to the laboratory for further analysis.

2.2. Measurement, Examination, and Calculations

Individuals' standard, fork, and total lengths measurements were taken with a digital caliper with a precision of 0.01 mm, while weight measurements were performed using a digital precision scale with a precision of 0.001 g. Furthermore the conversion ratios for fork and standard length values to total length values have been calculated as 1.06 and 1.23, respectively, based on the data obtained from our measurements. In the calculation of the length-weight relationship, the exponential equation $W = a \times L^b$was transformed into a linear form by taking the logarithms of the length (L) and weight (W) values. This transformation resulted in the equation $Log(W) = Log(a) + b \times Log\ (L)$Subsequently, a regression analysis was conducted to determine the *a* and *b* parameters. In analysis, total lengths and weights were used (Ricker, 1975; Çetinkaya et al., 2005).

In the determination of age groups, modal progression analysis (Bhattacharya method) was used in the dataset created with the frequency data of sampled individuals' lengths. A threshold of seperation index SI ≥ 2.0, was employed to identify the "modal" lengths corresponding to each age group by FiSAT-II Age-length relationship (VBGE) $L_t = L\infty\left(1 - e^{-k(t-t0)}\right)$) was determined using a two-stage regression process based on age groups and the corresponding modal lengths. Growth performance was calculated using VBGE parameters $\varphi' = log\ log\ 10(K) + 2\ log\ log\ 10\ (L\infty)$ (Ricker, 1975; Gaynalio et al., 2005; Çetinkaya et al., 2005). The condition of individuals was calculated using isometric (Fulton) $K = \frac{W}{L^3} \times 100$ where *W* weight and *L* total length of the individuals (Ricker, 1975).

Sex determination was performed by examining the gonads under naked eye and stereo microscope, considering fish size and the developmental stage of the gonads. Spawning period was determined by observing the changes in Gonadosomatic Index ($GS\dot{I}\ (\%) = \frac{GW}{W-GW} \times 100$) values, where *GW* gonad weight g *W* body weight g (Kınacıgil et al., 2008). Fecundity was calculated using the gravimetric method from ovarian samples obtained from sexually mature individuals during the spawning period (Karataş et al., 2005). For the analysis of stomach contents, the entire digestive tract was removed, labeled, and preserved in a 4% formaldehyde solution. Subsequently, the contents were examined under a stereo microscope, and the items were identified and counted at the group level (Gökçe et al., 2005). Calculations, regression processes, statistical analyses, comparisons were performed and graphs driven using MS Excel, SPSS 25.0, and FiSAT II softwares (Çetinkaya, 2015).

3. RESULTS

3.1. Water Quality and Environmental Conditions in *GDL*

The Büyük Menderes River (BMR) and its basin are the largest among the rivers and basins in Western Anatolia. The *GDL* and its water source, Tekke Creek, are one of the sources of the BMR within the boundaries of Denizli (Çetinkaya, 2018). The *GDL* is fed by Tekke Creek, which collects several small sources in the vicinity, along with surface runoff, drainage channels, and precipitation water. Significant annual fluctuations occur in the water level of the *GDL*. Due to irrigation water abstraction and insufficient rainfall, by mid-autumn, approximately one-third of the surface area of *GDL* remains completely dry. Tekke Creek, under such conditions, reaches the water body of the dam lake with a weak flow. In the coastal areas, particularly in the western part, aquatic macrophytes are predominantly present, while in the areas that remain dry, terrestrial plants thrive during late summer and autumn. A large portion of these terrestrial plants are submerged underwater during the late spring to early summer period. Some of the water quality parameters measured in *GDL* are presented in Table 1.

Table 1. Water quality parameters measured in monthly samples in the *GDL*.

Months	Temp. (°C)	pH	DO (mg/l)	DOS (%)	EC (25°C µS/cm)	Salinity (ppt)
May 2019	23.0	8.43	10.19	123.4	549.0	0.28
June 2019	26.2	9.11	9.05	110.2	499.5	0.23
July 2019	25.9	8.99	10.21	128.7	501.7	0.24
August 2019	27.5	9.23	11.49	151.2	472.7	0.22
September 2019	24.1	9.45	8.94	110.5	505.0	0.25
October 2019	17.8	8.72	6.79	73.9	501.0	0.28
November 2019	10.9	8.96	9.19	93.2	162.9	0.11
December 2019	10.7	8.12	7.01	70.3	445.4	0.28
January 2020	10.3	8.82	6.85	63.0	437.9	0.30
February 2020	11.5	9.37	7.97	76.7	459.5	0.30
March 2020	11.6	9.35	8.3	79.8	459.3	0.30
April 2020	17.9	8.87	9.08	94.8	467.5	0.29
Maximum	**27.5**	**9.45**	**11.49**	**151.2**	**549.0**	**0.30**
Mean	**18.1**	**8.95**	**8.76**	**98.0**	**455.1**	**0.26**
Stand.Dev.	**6.9**	**0.40**	**1.46**	**27.2**	**97.2**	**0.05**

The water level in *GDL* significantly fluctuates throughout the year, and during the summer season, particularly high levels of pollution caused by solid waste are observed. It has been determined that the pollutants concentrated mostly on the western shores of the lake are transported to the *GDL* through water inlets. Domestic waste, on the other hand, is predominantly found in the southern shores. It has been observed that numerous rainwater drainage channels discharge into *GDL*, positioning the lake as a recipient environment for wastewater. During the summer months, intense turbidity, foaming, and the presence of dead rodents and a large number of dying or dead *C. gibelio* individuals have been observed on the southwestern shores. The areas between Gökpınar Source and the dam lake are densely used for agricultural and livestock activities. While domestic waste is directed to the sewage system in this region, it is evident that pollutants and nutrient elements derived from agriculture and livestock can easily reach *GDL* through rainfall, surface runoff, and drainage channels.

3.2. Fish species

During the sampling, a total of 10 fish species were identified, including 8 species captured during the sampling surveys and 2 species caught by recreational anglers. These species include *L. gibbosus* (Linnaeus, 1758), *Carassius gibelio,* (Bloch, 1782), *Vimba mirabilis*, (Ladiges,1960), *Chondrostoma turnai*, (Güçlü, Küçük, Turan, Çiftçi & Mutlu, 2018), *Squalius fellowesi*, (Günther, 1868), *Atherina boyeri*, (Risso, 1810), *Alburnus demiri*, (Özuluğ and Freyhof, 2008),*Cyprinus carpio,* (Linnaeus, 1758), *Silurus glanis* (Linnaeus, 1758),*G. holbrooki* (Girard, 1859). *G. holbrooki* was observed abundantly at both stations. In a study investigating the freshwater biodiversity of Denizli Province, 64 fish species were identified in the inland waters of the province, with 5 of them recorded as exotic/invasive species. Additionally, the presence of 8 species was detected in the *GDL* in the same study (Çetinkaya, 2018). At the stations, more than 1000 fish were captured in a single seine operation between April and September, while over 5000 fish were caught during June and July. Only the species *G. holbrooki* and *L. gibbosus* were observed in the coastal samplings. These exotic species are the dominant species in the coast of *GDL*. The most dominant species observed in the samples caught with the seine net is *G. holbrooki*. The occurrence rate of this species in sampling was 20% in April-May, 50% in June-September, and 100% in October-March. Both species were not found in coastal samplings during the other months (November-February). All of the caught species other than *L. gibbosus* and *G. holbrooki* were captured by multimesh gillnet.

3.3. Observations on *L. gibbosus*

During the study, careful observations were made on individuals of *L. gibbosus*, and the following points stood out regarding their swimming, feeding, and reproductive behaviors:

Routine swimming behavior: Individuals of *L. gibbosus*, found in small groups, exhibit aggressive behavior while also displaying high sensitivity to environmental stimuli. In addition, they demonstrate curious and cautious behavior. During periods of high water temperature, a considerable number of *L. gibbosus* individuals are observed in a side-by-side and horizontally oriented position to the shoreline, closely following the water's edge and seemingly monitoring their surroundings. Although they may suddenly change their position in response to external stimuli, it has been observed that *L. gibbosus* individuals tend to reposition themselves and continue monitoring their surroundings rather than leaving the area.

Feeding behavior: L. gibbosus exhibits various feeding behaviors. They are typically observed feeding on the bottom and consuming benthic macroinvertebrates. In addition, they have been observed consuming filamentous algae with attached fish eggs. It has been observed that an important feeding strategy of *L. gibbosus* is active "strategic predation" behavior. Whole or fragmented individuals of *G. holbrooki* were frequently encountered in the examined stomach contents. During strategic predation, a behavior observed is the group of *L. gibbosus* individuals separating a single *G. holbrooki* individual from the school, herding it towards the shore without allowing it to escape. Once the *G. holbrooki* individual has no more escape route, it is observed that the *L. gibbosus* individuals proceed to tear it apart and consume it. Subsequently, it has been observed that the same group of *L. gibbosus* individuals moves away from the shoreline again, and they trap another individual until it reaches the shore, where they consume it. This behavior can be repeated several times in the same location. Furthermore, it has been observed that they eagerly attack externally supplied baits (such as bread) and feed alongside *G. holbrooki* on the same bait during these instances.

3.4. The structure and composition of *L. gibbosus* population

Between May 2019 and April 2020, a total of 1005 *L. gibbosus* individuals were examined, and they were found to consist of three different age groups. The individuals comprised 30.05% females, 60.21% males, and 9.76% juveniles, resulting in a female:male ratio of 1:2.00 (Figure 2).

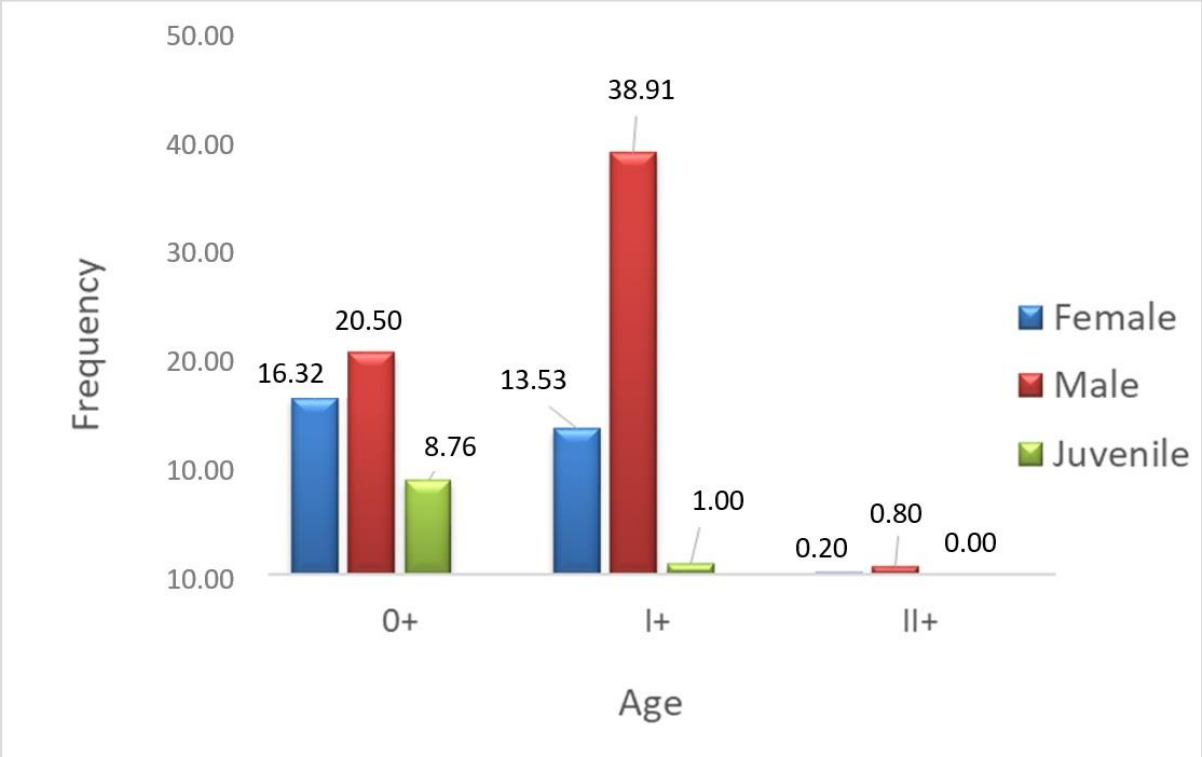

Figure 2. Age distribution of *L. gibbosus* based on sex

Total lengths (TL) of *L. gibbosus* individuals ranged from 2.46 cm to 11.34 cm. TL values varied between 2.55 cm and 10.99 cm for females and between 2.46 cm and 11.34 cm for males. The mean TL for all samples was calculated as 5.82±2.09 cm. Weights (W) ranged from 0.20 g to 34.65 g for *L. gibbosus* individuals. Weights varied between 0.20 g and 25.99 g for females, 0.22 g and 34.65 g for males, and 0.25 g and 10.29 g for juveniles. The mean weight (W) for all samples was recorded as 4.94±4.67 g. The majority of individuals (45.87%) consist of small-sized individuals ranging from 0.01 g to 3.00 g weight group. The growth pattern is isometric, and no significant difference ($p>0.05$) was found in (*b*) among females, males, and juveniles. "The length-weight relationships for the general population, females, males, and juveniles in the population are as follows, the graph for the population is provided in Figure 3."

Female: $W\ (g)= 0.0142xTL\ (cm)^{3.0855}$ (r=0.9929), (n= 302)
Male: $W\ (g)= 0.0126xTL\ (cm)^{3.1801}$ (r=0.9942), (n= 605)
Juvenil: $W\ (g)= 0.0167xTL\ (cm)^{2.9697}$ (r=0.9944), (n= 98)
General: $W\ (g)= 0.0131xTL\ (cm)^{3.1521}$ (r=0.9945), (n= 1005)

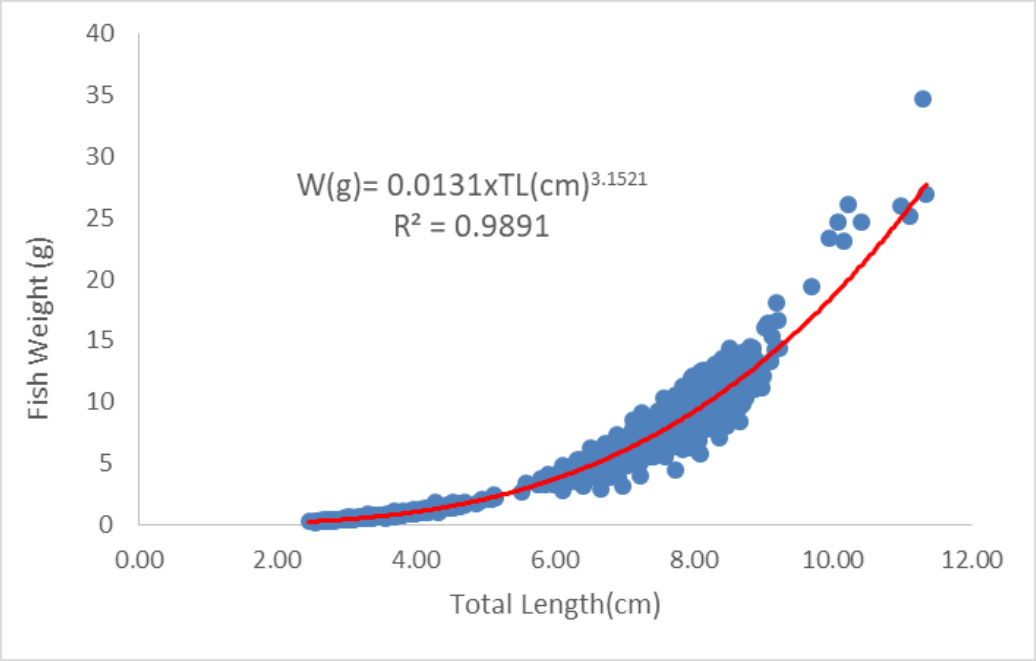

Figure 3. Length-weight relationship in the *L. gibbosus* population

Growth and Condition: The age-length relationship (VBGE) was determined as $Lt = 19.85\ (1–e^{-0.274)\ (t + 0.272)})$, and the growth performance was determined as φ'=2.034 (Figure 4). The relative growth values between age groups were calculated as follows: a transition from 0+ to I+ year class growth rate of 104.61%, while a transition from I+ to II+ years resulted in a growth rate of 39.34%. The highest relative growth occurs during the first year.

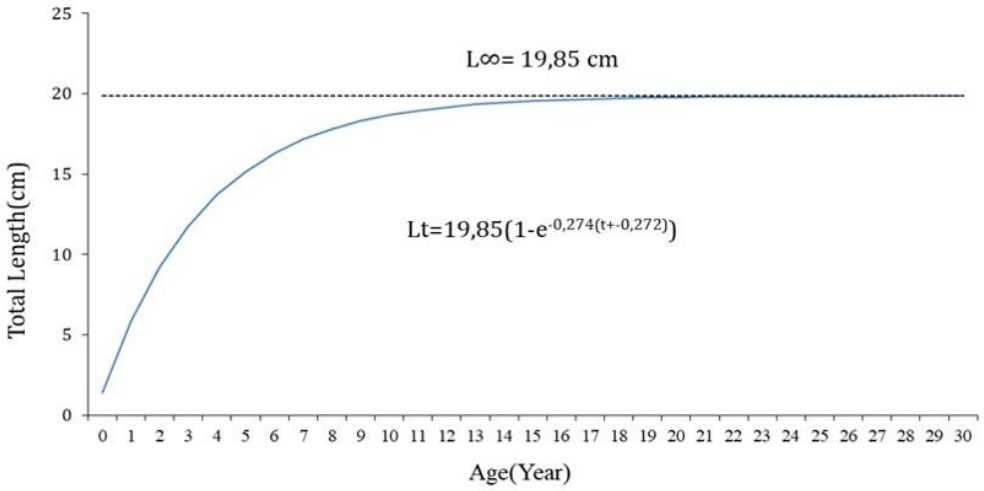

Figure 4. *GDL L. gibbosus* population VBGE age-length curve.

The condition factor was calculated based on sex, months, and age. There was no significant difference in the condition factor values between sexes, and average condition was estimated as 1.71 However, it was observed that individuals in the age group II+ exhibited higher condition factors.

3.5. Reproductive characteristics

It has been observed that gonad development in the population starts in March and continues until May, spawning primarily begins in May and lasts until July (Figure 5). In the examination conducted on 33 female individuals in which fully developed eggs were observed in April and May, it was determined that all of these individuals belonged to the I+ age group, and their reproductive age was considered as I+. The minimum number of eggs per female was determined as 819, the maximum was 5913, and the average was 3056 eggs per female. The average diameter of mature eggs was found to be 0.59 mm (ranging from 0.43 mm to 0.91 mm).

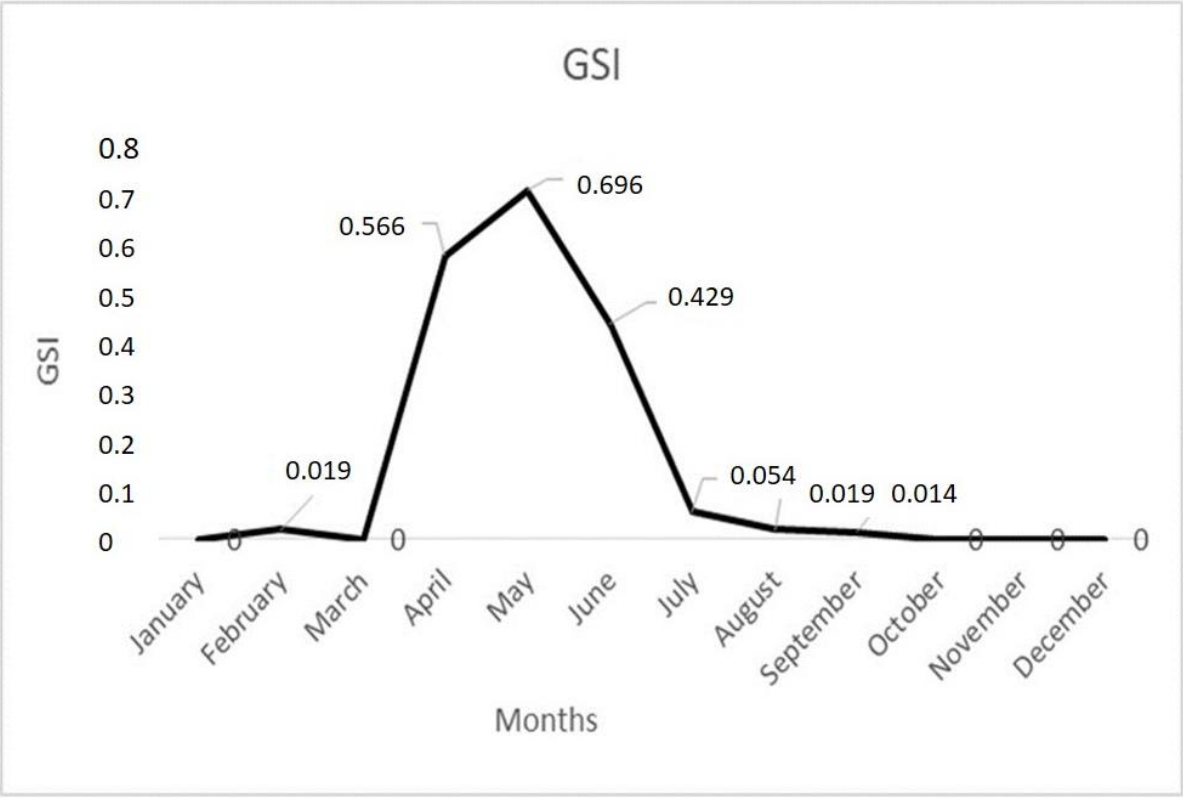

Figure 5. Variation in GSI of female individuals in the *L. gibbosus* population of *GDL*

3.6. Feeding

The examined digestive tract contents have shown that *L. gibbosus* predominantly feeds on zooplankton (crustaceans) in all sizes. In addition, stomach analysis revealed the presence of chironomid larvae, fish eggs, whole and fragmented fish (*G. holbrooki*), and fish scales. It has also been observed that *L. gibbosus* individuals captured during the same sampling period can feed on completely different organisms from each other. In one individual, the entire digestive tract was filled with chironomid larvae, while in another individual, the entire digestive tract contained only fish eggs. In yet another individual, only one or two whole *G. holbrooki* individuals were found in the digestive tract.

4. DISCUSSION and CONCLUSION

GDL has a relatively small surface area, and occuring significant annual fluctuations in water levels are directly affected by the size of the catchment area. Due to water usage and hydrological changes that occur seasonally, significant differences occur in the substrate characteristics, fauna and flora dependent on the ground, general vegetation, water quality, and overall habitat. In addition to that, *GDL* is also influenced by the surrounding areas (rainwater drainage, solid waste, human activities, agriculture, aquaculture, etc.). Based on this information, *GDL* is considered as a habitat that does not exhibit stable ecosystem integrity and shows significant spatial and temporal changes.

Three different age groups have been identified in the population: 0+, I+, and II+. In a study covering 9 countries and 36 regions in Europe, the presence of populations belonging to the age group of 4 to 9 years was reported (Copp & Fox, 2007). Considering the limitations of sampling in *GDL*, it is likely that the population may reach up to the III+ age group, suggesting a total of four age groups. The reasons for identifying fewer age groups proportionally could be related to the scarcity of individuals belonging to larger age groups and their lower chances of being captured or it could also be due to the population being relatively new or in the early stages of formation. Furthermore, the majority of sampled individuals belonging to the 0+ and I+ age groups could be related to a higher natural mortality rate and the availability of suitable and sufficient food resources. Indeed, another possibility could be the limited sampling area within the habitat, and these areas may not yield productive catches, especially during periods outside of the spring and summer seasons, which encompass the breeding season. As a result, it might be challenging to reach older individuals during these periods. The majority of samples have been obtained from coastal areas, especially during the breeding season and its aftermath. In these areas, it is possible that smaller males tend to stay longer for nest guarding, which could contribute to this result. Danylchuk & Fox (1996) found that the nest-building activity was initiated by 4+ and 5+ year-old male individuals, but later, in the nesting areas, they observed the presence of 70% smaller male individuals.

In the *L. gibbosus* population of *GDL*, no sexual dimorphism has been observed; therefore, sex determination cannot be made based on external appearance. During the breeding season, it has been observed that males guard the nest where eggs are deposited and remain in a cautious vigilance state to defend the nest against other fish. The F:M ratio was determined as 1:1.26 in the 0+ age group, 1:2.88 in the I+ age group, and 1:4 in the II+ age group. The overall sex ratio (F:M) was found to be 1:2.00, although it varied between sampling periods (1:16.4 in May, 1:1.84 in June, 1:1.28 in July, 1:1.6 in August, 1:1.2 in September, 1:1.3 in February, and 1:2.5 in April). The samples were obtained through shore seine fishing and offshore gillnet fishing in July 2019. In the samples obtained from coastal fishing, the F:M ratio was found to be 1:2.1, whereas in the offshore samples, it was found to be 1:1. The values obtained from the coastal samples differ from the expected 1:1 ratio predicted by the Fisher model based on Mendelian genetics (Ganikhodjaev et al., 2013) ($\chi 2$ test, $p < 0.05$). It is known that *L. gibbosus* exhibits nest-building behavior and active nest guarding by male individuals during the breeding season (Zieba et al., 2018). Additionally, it has been reported that around the nest, 0 and 1 year-old male fish are relatively more abundant compared to 2 , 3 , and 4 year-old parent males (Almeida et al., 2012). The presence of multiple males to fertilize the eggs deposited by a female is considered an adaptation that contributes to the success of *L.* gibbosus in colonizing new habitats and sustaining their populations, in addition to other adaptive traits (Almeida et al., 2012). Based on this information, the observed F:M ratio of 1:16.4, particularly during the breeding-intensive month of

May, and the proportional male-biased population structure in coastal areas can be explained. In the population, the maximum total length measured was 11.4 cm, and in VBGE L∞ was estimated to be 19.85cm.

Although it has been reported that *L. gibbosus* can reach a maximum size of 40 cm (Çetinkaya, 2006), it is not known whether this high size value belongs to its natural range or to the regions where it is considered an exotic species. When the length averages of individuals sampled from *GDL* were examined by age, it was observed that the 0+ age group had similar averages to those of N. America, the 1+ age group had averages similar to those of Sarıçay (Türkiye), Europe, and N.America, and the 2+ age group had averages close to those of N. America. These data indicate that the growth values of *L. gibbosus* in the population of Gökpınar Reservoir are similar to those in other habitats where it is introduced (Table 2).

Table 2. Age-specific total length values of *L. gibbosus* in *GDL* and other selected populations.

Region	Age groups			References
	0+	1+	2+	
Büyük Menderes Basin *	-	6.74	9.40	Bay, 2010
Sarıçay (Muğla- Türkiye)	7.21	7.96	9.22	Top, 2012
Europa[1]**	4.92	7.50	9.42	Copp et al., 2004
North America[2]**	4.31	7.38	10.09	Copp et al., 2004
***GDL* (Denizli)**	**3.69**	**7.55**	**10.52**	**This study**

* Fork length values have been converted to total length values (1.06).
** Standard length values have been converted to total length values (1.23)
[1] Averages of 8 Country 12 region
[2] Averages of 2 Country 24 region

The fish weights in the *GDL* population ranged from 0.20 to 34.65 grams. The estimated value of W∞ calculated from VBGE was 161.41 grams. While it is stated that *L. gibbosus* can reach a weight of 600 grams in different habitats (Çetinkaya, 2006), the individual weighing 75.74 grams sampled from the Lower Sakarya Basin is recorded as the heaviest individual in Turkish waters (Reis et al., 2018).

The length-weight relationship provides important information about growth characteristics, ontogenetic development, and population dynamics in fish populations (Khanom et al., 2020). In *GDL*, the length-weight relationship for *L. gibbosus* has been determined as $W= 0.0131xTL^{3.1521}$ (r=0.9945), (n= 1005). When examining the length-weight relationships in some studies regarding this species (Table 3), it can be observed that there is a general similarity across all populations. Upon examining the mentioned data, it can be observed that *L. gibbosus* populations exhibit successful habitat adaptation and food competition. They exhibit isometric weight gain parallel to their length, and in some habitats, they are capable of positive allometric growth.

Table 3. Length-weight relationships in different *L. gibbosus* populations

Populations	a	b	R^{2**}	Growth pattern
Büyük Menderes* (Bay 2010)	0.0189	3.0301	0.929	Isometric
Sarıçay (Muğla) (Top, 2012)	0.0149	3.0800	0.971	Isometric
Western Mediterranean (lentic) (Çiçek et al., 2022)	0.0080	3.4910	0.950	+ Allometric
Western Mediterranean (lotic) (Çiçek et al., 2022)	0.0130	3.1380	0.987	+ Allometric

İber peninsula* (Andreu-Soler et al., 2006)	0.0150	2.9800	0.969	Isometric
Croatia (Treer et al., 2008)	0.0121	3.2140	0.960	+ Allometric
This study	**0.0131**	**3.1521**	**0.9891**	**+ Allometric**

*Measurements were taken using FL (fork length) value.
**R^2 coefficient of determination.

The age-length relationship was determined as $L_{t=}19.85\left(1-e^{-0.2744(t+0.272)}\right)$. When the mean SL values provided by Copp et al. (2004) are converted to TL, the average lengths for European populations are found to be 15.76 cm, while for American populations, the average length is 20.74 cm. However, the length values measured within the natural habitats of the species are higher. In *GDL*, it has been determined that the measured length values fall between those of Europe and America (19.85 cm), while the growth performance value (φ'=2.034) is calculated to be lower than that of the N.American and European populations (Copp et al., 2004).

Condition, in females, reaches its highest level in April (2.05), while in males, it is observed in May (2.06). The recorded high values during the period when the examined stomachs were not fully filled are likely related to gonad development/growth. The annual average condition of females and males (~1.71) was found to be similar ($p > 0.05$). In Western Mediterranean lentic system populations, the condition was determined to be 2.00, while in lotic systems, it was found to be 1.65 (Çiçek et al., 2022). The populations of *L. gibbosus* living in lentic habitats have higher condition due to their more stable and diverse feeding alternatives.

In certain *L. gibbosus* populations, the %GSI values of males were found to be inconclusive in determining the breeding season (Danylchuk & Fox, 1994). In *GDL*, it has been observed that reproduction takes place between April and June based on the changes in the %GSI of females. During this period, males, which are easily observable from the shore, exhibit nest guarding/defensive behaviors, further supporting this finding.

L. gibbosus feeds on various prey items such as fish, gastropods, adult and larval odonates, ephemeropterans, dipteran larvae and pupae, trichopterans, coleopterans, terrestrial insects, and more (Godinho et al., 1997; Locke et al., 2013). The species also exhibits a broad feeding spectrum in *GDL*. While zooplankton is predominantly observed in stomach analyses, it has been recorded that they also feed effectively on fish (*G. holbrooki*) and fish eggs.

L. gibbosus is considered an invasive species in all regions outside of N.America, its native range. *L. gibbosus*, which began to appear in Europe in the early 1900s, has been successful in many countries by adapting well to the entered habitats and establishing self-sustaining populations until today (Copp & Fox, 2007). *L. gibbosus*, which has a high tolerance for environmental conditions, tends to prefer cooler waters compared to other *Lepomis* species. However, the hydrological cycle of small rivers unique to the Mediterranean region is shaped by reduced flow during the summer and the formation of isolated ponds. In this regard, ecologically varying conditions throughout the year can become critical for the success of the species. Therefore, it is natural to expect differences in the bioecological characteristics between the native populations of *L. gibbosus* in North America and the populations in Europe where it was introduced later (Gutiérrez-Estrada et al., 2000). The fact that *L. gibbosus*, which generally prefers clean waters in its native range (Jordan et al., 2009), can be found in polluted *GDL* indicates its high ecological tolerance.

According to life history theory, females tend to invest in growth and delay maturity. The effect of this is observed as an increase in fecundity later on. However, if there is a constraint on growth, as observed in many populations of *L. gibbosus* after their introduction, the age and size at first maturity will decrease to minimize reproductive loss. The cost of early maturity is known as a shortened lifespan. In this regard, it is expected that there will be fewer age groups in European and Anatolian populations compared to Canadian and N.American populations (Gutiérrez-Estrada et al., 2000).

L. gibbosus, besides being a food source for many fish species in its native range of N. America, is also known as a specific food source for waterbirds (Jordan et al., 2009). It is observed that predatory water birds can feed on this species from time to time in *GDL*. Additionally, the predator of *L. gibbosus*, known as *S. glanis*, is also present in *GDL*. However, in the examined stomach content of

one *S. glanis*, no *L. gibbosus* or remnants were observed. As of yet, no studies have been found regarding the role of *L. gibbosus* as either prey or predator in the food chain of inland waters in Türkiye.

In this regard, we consider it important to monitor the settlement and developments of *L. gibbosus* in different habitats in Türkiye as well as to conduct bioecological studies on all non-native species.

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CONFLICT OF INTEREST

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

AUTHOR CONTRIBUTIONS

Fiction, Literature, Methodology, Performing the experiment, Data analysis, Manuscript writing: UGY, OÇ; Supervision: OÇ. All authors approved the final draft.

DATA AVAILABILITY STATEMENT

Data supporting the findings of the present study are available from the corresponding author upon reasonable request.

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