**Rapid Communication**

# Southernmost record of *Gymnocephalus cernua* (Linnaeus, 1758) in European lakes

Alessandra Cera*, Camilla Marandola and Massimiliano Scalici

*Department of Sciences, University of Roma Tre, Viale G. Marconi 446, 00146 Roma, Italy*

**Corresponding author*

E-mail: *alessandra.cera@uniroma3.it*

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## Abstract

We report the presence of the alien freshwater teleost *Gymnocephalus cernua* in the volcanic lake of Bracciano in central Italy. The contribution of local citizens was essential for this finding, particularly the interviews with local professional fishermen made it possible to report the presence of this species. To confirm this datum, some specimens were collected and identified at the species level by morphological characteristics. Biological parameters were collected (standard length, mass, sex, mass of gonads and of digestive tracts) from each specimen. From the observation of gonads, we confirm the presence of mature individuals in Lake Bracciano during autumn 2020. This report represents the southernmost data for this species in the European distribution range. For this reason, this population may be further studied to evaluate the adaptability and invasiveness potential of this species in southern habitats, particularly in volcanic lakes.

**Key words:** ruffe, alien species, Mediterranean region, lentic freshwater, citizen science

## Introduction

*Gymnocephalus cernua* (Linnaeus, 1758), commonly named Eurasian ruffe (hereafter ruffe), is an invertebrate-feeding fish of the Family Percidae (Collette 1963; Elshoud-Oldenhave and Osse 1976; Sloss et al. 2004). The ruffe is a generalist species with high adaptability in freshwater, but can also inhabit marine waters. Its native distribution range is wide, including inland waters of central-Eastern-Northern Europe and Asia, and the seacoasts of Scandinavia in the Baltic Sea to the coasts of Netherlands and Great Britain (Gutsch and Hoffman 2016). In addition, several reports indicate populations in non-native ranges, including for instance lakes and reservoirs in the Alps, Northern Europe (Great Britain, Norway), the Mediterranean Region and the North American Great Lakes (Adams and Tippett 1991; Kålås 1995; Volta et al. 2013; Zhang et al. 2019; Arab et al. 2020). In Italy, the first report of the ruffe comes from the Isonzo River in Northern Italy and dates to the 1980s (Chiara 1986). However, the ruffe has spread over the years mainly in the North, i.e. in the Adda River

(Chiozzi 1995) which is a tributary of Po River; in the Po river, which is the longest and largest Italian river system (De Curtis and Rossi 1999); in two small lakes, Ghirla and Mergozzo, in the catchment of Lake Maggiore (Volta et al. 2013); and in the lakes Corbara and Piediluco connected to Tevere River, which is the main river in central Italy and crosses the city of Rome (Carosi et al. 1998; Lorenzoni et al. 2007).

The geographic range of ruffe appears to be expanding to new water bodies in recent years. The factors causing its introductions are usually unknown, but may include shipping, bait bucket, and use of canals; however, it is quite sure that the occurrence of ruffe in the Great Lakes was due to ballast water (Gutsch and Hoffman 2016).

Ruffe is considered an invasive species in non-native habitats, in particular competing for its niche with other percids, causing a change of preferred habitat in *Perca fluviatilis* Linnaeus, 1758 and significantly slower growth in *Perca flavescens* (Mitchill, 1814) in laboratory experiments (Henseler et al. 2020; Newman et al. 2020). Indeed, even a field study provides an indirect observation of the negative impacts of ruffe on *P. fluviatilis* due to a high niche overlap (Lorenzoni et al. 2007).

Presence of *P. fluviatilis* is confirmed in the study area considered in this report (i.e. Lake Bracciano) (Costantini et al. 2018), causing concerns for the interactions with ruffe, if confirmed in the lake. Indeed, fishing activities may be impacted by the invasion of the ruffe as it has no economic relevance nowadays, although in the past it was regularly consumed and even considered a delicacy (Svanberg and Locker 2020). On the contrary *P. fluviatilis* is of great economic interest as it is also a local and tourist food resource, especially for tourists from the densely populated city of Rome (which has about 3 million inhabitants).

In this report we present and discuss the presence of *G. cernua* in Lake Bracciano.

## Materials and methods

### *Study area*

Lake Bracciano is an oligo-mesotrophic, warm monomictic, sub-circular volcanic lake, belonging to the volcanic tectonic depression of the Sabatini Volcanic District (Barbanti et al. 1996; De Rita et al. 1996; Margaritora et al. 2003). The lake is located at 42°7′31.90″N; 12°14′36.49″E at an altitude of 164 m a.s.l.; the surface is 57 $km^2$ with a water volume of 5050 $10^6$ $m^3$; the mean depth is 88.6 m, while the maximum depth is 165 m; the mean water residence time is 137 years; the catchment area is 147,483 $km^2$ (Margaritora et al. 2003; Rossi et al. 2019). Minor springs introduce water into the lake, while the emissary river (River Arrone) is dry in the upper part, i.e. the one connecting with the lake surface water (Rossi et al. 2019). It is noteworthy reporting a drought event in 2017, which stressed the ecosystem of Lake Bracciano as the lake's water level touched 193 cm below the hydrometric zero (Rossi et al. 2019).

Lake Bracciano is the volcanic lake in central Italy with the best environmental quality if we analyse the zooplankton community, littoral vegetation, and macrobenthos (Margaritora et al. 2003). Chemical analyses of the water generally show good quality, although they also highlight high levels of fluoride, due to the volcanic origin of the lake, and a recent rise in nitrogen concentration (Catalani et al. 2006). Furthermore, species of conservation interest occur in the lake, e.g. *Rutilus rubilio* (Bonaparte, 1837) and *Padogobius nigricans* (Canestrini, 1867). In fact, Lake Bracciano is an area protected by national and international regulations (Regional Law number 36/99; Ministerial Decree 06/12/2016; Natura 2000 ecological network—Decision n. 2019/22 of the European Commission—document reference number C(2018) 8534; codes IT6030085 and IT6030010).

Regarding non-native species, we report the introduction in Lake Bracciano of the North-American centrarchids *Micropterus salmoides* Lacépède, 1802, *Lepomis gibbosus* (Linnaeus, 1758) (Marinelli et al. 2007), and (to be confirmed) *Lepomis macrochirus* Rafinesque, 1819 (Scalici *pers. comm.*).

### *Interview of local fishermen*

Nowadays, the use of interviews with local citizens with respect to establishing a connection with the scientific world is a common practice of citizen science (Ferreira-Rodríguez et al. 2021; Jesus et al. 2021). In this work, we contacted the local fishermen of a professional cooperative working in Lake Bracciano through the Regional Park. By the means of informal talking, we gathered information on the status of the different species of the lake based on the fishing abundance trends based on their experience. During this conversation, the fishermen highlighted the abundant presence of a new fish, which they called "*acerina*" (i.e. common name but not the accepted name of the genus *Gymnocephalus*). "*Acerina*" is perceived as a recent negative problem impacting unhooking activities due to its spines. Although this information fits with the description of *Gymnocephalus*, an accurate identification based solely on the interview was not possible.

### *Data collection from specimen*

The sampled *Acerina* specimens were collected by fishermen of Lake Bracciano while fishing commercial species on November 27th, 2020. Thereafter, we provided a taxonomic identification. Scientific literature and atlas were used for the identification (Specziár and Vida 1995; Tsyba and Kokodiy 2017). The presence of the tapetum lucidum, which is a reflective layer of the retina that help in nocturnal vision, reported as a diagnostic parameter for the genus *Gymnocephalus* (Sandström 1999) was checked by observing the reflectance of the eye (Somiya 1980). We provide


**Figure 1.** (A) Specimen of *Gymnocephalus cernua* collected from Lake Bracciano on November 2020. Standard length of the specimen shown: 11 cm. (B) Details of diagnostic parameter: the arrow indicates the opercle with one spine. Photograph by Camilla Marandola.

a photographic report of an entire specimen and the diagnostic parameter of the single spine of the opercle (Figure 1).

Biological data were collected from each specimen: standard length (cm); mass (g); sex; mass of gonads (g); mass of the gastrointestinal tract (g). Sexual maturity was visually determined by macroscopic observations of the gonads according to WKMATCH reference scale, which describes different stages of maturity: immature, developing, spawning, regressing, omitted spawning, and abnormal (ICES 2014). The gonadosomatic index (GSI) was calculated to provide baseline information on spawning in Lake Bracciano. The GSI is calculated by the following formula: GSI = 100 × gonad weight (g) / body weight (gut inclusive) (g). The age class of each specimen is proposed, based on the back calculated lengths in Lorenzoni et al. (2009), which analyses the age-length relationship of the assemblage of this species in Lake Piediluco, the report known as the closest to Lake Bracciano.

## Results

Seven specimens of "*Acerina*" were collected from the sampling. We can confirm that these specimens do belong to the genus *Gymnocephalus*, specifically *G. cernua* (Figure 1).

The biological data highlight that the individuals have a mean standard length of 10.6 ± 1.1 cm; a mean total mass of 23.3 ± 6.9 g; mean mass of gonads of 0.8 ± 0.5 g; and mean mass of the gastrointestinal tract of 0.4 ± 0.2 g (Table 1). Adult specimens of both sexes were collected, with a prevalence

**Table 1.** Biological data collected from the specimen of *Gymnocephalus cernua*. The minimum and maximum values for each category are in bold.

| Specimen | Standard length (cm) | Mass (g) | Sex | Mass of gonads (g) | Mass of the gastrointestinal tract (g) | Age class | GSI[a] | Maturity[b] |
|---|---|---|---|---|---|---|---|---|
| A1 | 11.0 | 26.9 | F | 0.8 | 0.3 | 2 | 3.0 | Developing |
| A2 | 10.9 | 28.1 | M | **1.8** | **0.7** | 3 | **6.4** | Spawning |
| A3 | **12.1** | **30.4** | M | 0.6 | 0.6 | **3–4**[c] | 2.0 | Developing |
| A4 | **8.8** | **13.0** | F | **0.4** | **0.1** | **1** | 3.1 | Immature |
| A5 | 10.5 | 21.2 | F | **0.4** | 0.3 | 1–2[c] | **1.9** | Immature |
| A6 | 9.6 | 15.1 | F | 0.7 | 0.3 | 1–2[c] | 4.6 | Developing |
| A7 | 11.3 | 28.3 | F | 0.9 | 0.3 | 2 | 3.2 | Developing |
| Mean | 10.6 | 23.3 | – | 0.8 | 0.4 | – | 3.4 | – |
| Standard deviation | 1.1 | 6.9 | – | 0.5 | 0.2 | – | 1.6 | – |

[a] Gonadosomatic Index
[b] According to WKMATCH scale: Immature = A; Developing = B; Spawning = C.
[c] The age class is unsure as the value is outside the range of reference in the back calculations provided by Lorenzoni et al. 2009

of females (Table 1). The mean GSI is 3.4 ± 1.6 (Table 1). Developing gonads were observed in females (A1, A6, A7) and a male (A3); two females (A4, A5) were labelled as immature; one male was spawning (A2) (Table 1). The individuals belong to different age classes, from 1 to 4 (Table 1). As the gonads of A5 are evaluated immature, A5 is probably aged 1 year (Table 1).

## Discussion

The information collected from the specimens of *G. cernua* suggests that a stable population is established in Lake Bracciano, due to the presence of individuals of different age classes. The spawning period is usually assessed by the end of winter and eventually summer (Hokanson 1977). Accordingly, we found developing gonads in older females in our sample. However, we also found a mature male, which had mature gonads outside of the spawning seasons. It could be a late batch spawning, occurring in autumn instead of summer. However, a report evaluating the GSI of non-native *G. cernua* in a Norwegian lake indicates that males mature in October, some months earlier than females, which mature more gradually from September to the peak in April (Kålås 1995). A sampling conducted throughout the year could provide an overview of the reproductive cycle of *G. cernua* in Lake Bracciano.

The presence of *G. cernua* in Lake Bracciano describes the expansion of this species in central Italy beyond the River Tiber basin, where two reports indicate its occurrence, specifically in the Lakes Corbara and Piediluco respectively in 1998 and 2009 (Carosi et al. 1998; Lorenzoni et al. 2009). It is unsure if the range of *G. cernua* is expanding in central Italy due to the dispersion of individuals in the mentioned locations or due to another event of introduction, such as bait buckets. The origin of this population of *G. cernua* needs to be further confirmed, for instance by molecular analysis.

Regardless of the source, it can be expected that once in the lake, *G. cernua* may have found a favourable habitat. According to the scientific literature, the ruffe is usually occurring in sandy or silty benthic habitats up to 200 m deep (Gutsch and Hoffman 2016). Lake Bracciano, which has a maximum depth of 165 m, provides these suitable habitats as its coasts are sandy while silty sediments can be found at greater depths. In addition, extreme events caused by climate change help the introduction of alien species (Walther et al. 2009), which is what may have happened at Lake Bracciano. The recent drought has stressed the communities living in the ecosystems of Lake Bracciano, thus potentially favouring alien species such as the ruffe. In this regard, we propose two aspects that could have favoured ruffe: the creation of suitable habitats and the lower resistance of competitors or predators. Lake Bracciano is considered a semi-closed space due to the loss of contact with the sea, because of its emissary drought, and by the presence of small tributaries. Inland lakes, particularly isolated, are especially vulnerable to ruffe adverse effect (Gutsch and Hoffman 2016).

The adaptability of *G. cernua* to the Mediterranean region is of regional relevance as it seems that *G. cernua* is expanding to Southern Countries. Indeed, a recent report confirms its presence in Algeria (Arab et al. 2020). The impacts of ruffe on Mediterranean ecosystems are rarely studied. Only one study is available from the current scientific literature and assesses that the niche of *G. cernua* and *P. fluviatilis* overlap, especially in the young age classes, thus possibly representing a cause of the negative trend of the population of *P. fluviatilis* in the examined lake (Lorenzoni et al. 2007).The recent expansion of *G. cernua* into Mediterranean freshwater needs to be thoroughly monitored in future years to evaluate whether conservation measures are to be taken to protect the local biodiversity.

In regard to effective monitoring assessment, a timely report of new introductions of *G. cernua* is mandatory for an up to date analysis of its range. Citizen science, particularly interviews with local professional fishermen, can be a valuable aid in gathering preliminary information on recent changes in the fish community and, more in general, can provide insights into the health status of the freshwater body.

## Conclusions

We report the presence of *Gymnocephalus cernua* in Lake Bracciano, a volcanic lake in central Italy, representing the southernmost record for European lentic freshwater according to the available scientific literature. It is suggested that the expansion of *G. cernua* in the Mediterranean region will be closely monitored in future years. Indeed, this species has a great adaptability as it is a temperature generalist species, able to adapt its diet based on the available food resources and a competitor in the dark due to its enhanced nocturnal vision. At all the sites of occurrence, *G. cernua* has the potential to negatively affect other species, including the native ones. This causes concerns for the conservation of protected species and habitats in a biodiversity hotspot such as the Mediterranean biogeographic region.

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