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EXPLORING DOCTOR FISH (*Garra rufa*, HECKEL, 1846) BREEDING: A CONCISE REVIEW

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Abstract
Garra rufa is a fish species belonging to the Cyprinidae family. Referred to as the "Doctor Fish" due to its utilization in the treatment of certain skin diseases, *Garra rufa* can easily thrive even in high-temperature thermal waters. When these fish come into contact with individuals entering thermal waters, they create a massaging effect through their mouth-touch actions on the human body. Consequently, these fish are widely used in the tourism sector, particularly in SPA centers. This method of use has spread to many regions worldwide. Each year, millions of *Garra rufa* are used in this manner. Therefore, active businesses globally require a substantial number of healthy fish annually. To meet the necessary demand, there is a need for *Garra rufa* aquaculture facilities. Except for a few small-scale entrepreneurs in Türkiye, there are no professionally managed *Garra rufa* aquaculture operations. To fill this gap in the field, supporting the cultivation of this species is vital. This article provides fundamental and general information about *Garra rufa* aquaculture. Sharing such information with the public is important in offering ideas to aspiring entrepreneurs interested in cultivating this species.

Keywords: *Garra rufa*, doctor fish, spafish, aquaculture, breeding

Introduction
The red garra, *Garra rufa,* is a species of fish widely distributed in the basins of the Tigris-Euphrates and Mesopotamia, covering certain coastal rivers in southern Türkiye and northern Syria, and extending to Pleistocene arms, as well as encompassing the borders of Iraq and Iran (Kosswig, 1952; Menon, 1964; Karaman, 1971; Kuru, 1971, 1979; Bianco & Banarescu, 1982; Krupp, 1985; Krupp et al., 1989; Coad, 1995; Geldiay & Balık, 1996; Goren & Ortal, 1999;

Koyun, 2011). Furthermore, reports indicate its distribution in the Jordan and Orontes drainage basins (Krupp & Schneider, 1989). Recognized colloquially as the "Doctor Fish" due to its utilization in the treatment of various skin diseases, particularly psoriasis, *Garra rufa* is acknowledged and known by the public under this designation. In the Turkish literature, it has been named as the "Nibbling Fish" or "Oily Fish." The therapeutic characteristic of this fish was first understood incidentally during an event occurring in the thermal waters (Fish SPA) within the boundaries of Sivas province. Following this incident, the presence of this fish in the region drew attention, leading to the development of the idea for the local residents to benefit from the effects of this fish alongside the thermal springs. As a result, *Garra rufa* and the Sivas SPAs started to be associated, hence the use of names such as "Sivas Kangal Fish" or "Kangal Fish." Owing to being referred to as the Sivas Kangal fish for an extended period, a misconception arose in the public opinion suggesting that this species exclusively inhabited the thermal waters of Sivas and was not found elsewhere. However, as indicated in the aforementioned sources, it is well understood that this species has a significantly broad distribution across different geographic regions. Recent studies have reported the presence of this species in the Ceyhan River and its branches in the southern region of Türkiye (Kara and Alp, 2004). Additionally, it is found in Mersin (Mezitli stream and Müftü stream), Hatay (Orontes River), and Kahramanmaraş (Andırın district Kesis stream) provinces (Karahan, 2007). Presently, known as *Garra rufa*, the species is distributed in many freshwater sources in the southern regions of Türkiye.

The individuals of *Garra rufa* possess relatively elongated and slender bodies, covered with large scales. The nose tip is blunt and exhibits papules. The dorsal fin starts before the ventral fins and has a straight, rigid edge. Their coloration remains uniform throughout the entire body, generally being a light brown. However, particularly during winter months, it has been observed that the colors are not uniform across the body, with irregularly distributed black spots.

The average lifespan of *Garra rufa* in the wild is between 4 to 6 years. The spawning period in their natural habitat occurs between May and August. However, under laboratory conditions, it is known that females can lay eggs multiple times in a year (Çelik & Çelik, 2015; Çelik, 2021). The number of eggs per individual can vary between 150 and 1000 (Çelik & Çelik, 2015). Both males and females of this species can reach sexual maturity at the age of 1 year.

There are approximately 100 species of the "*Garra*" genus worldwide. However, none of them are as effective in treating skin diseases as *Garra rufa* (Volpe et al., 2019). *Garra rufa* is globally recognized by names such as "Doctor Fish" or "Spafish." There are scientific sources demonstrating the use of these fish in the alternative treatment of various skin conditions like psoriasis and eczema, showcasing their therapeutic effects (Bhattacharya, 2016; Wildgoose, 2012).

In addition to their use in alternative medicine, the tapping movements made by the fish's mouths on the human body stimulate nerve endings in that area, induce a sensation of relaxation due to the effects of enzymes in their mouths, and ultimately present a natural massage effect. This feature of the fish is utilized not only for health purposes but entirely for providing people with massages in a range of establishments including hotels, SPAs, thermal facilities, beauty centers, massage parlors, and hair salons. The usage has become so widespread that in many developed countries like the United Kingdom, the United States, the Netherlands, and Germany there are SPAs exclusively dedicated to services provided by Doctor Fish. In Türkiye, the use of these fish in the SPAs of 5-star hotels, especially in the Antalya region, is increasingly growing to cater to people's needs.

The collection, fishing, commercial use, and export of *Garra rufa* from natural habitats in Türkiye have been prohibited. However, *Garra rufa* that has been somehow taken out of the country in past years is being bred and marketed to many countries, including Türkiye, by foreign entrepreneurs. It is estimated that Indonesia alone exports approximately 15,000-20,000 *Garra rufa* per week (Wildgoose, 2012). Additionally, some European countries are also involved in production and export. Despite being endemic to Türkiye, *Garra rufa* remains excluded from this global trade. In fact, there are attempts to fulfill the domestic demand for doctor fish within the country by importing fish from abroad. On the other hand, despite being banned, thousands of fish are collected from natural sources and introduced into the market every year.

In Türkiye, despite legal restrictions, the harvesting, commercialization, and illicit export of this fish persist. Establishing regulated production facilities for the cultivation of doctor fish aimed at exportation is crucial. This strategic initiative aims to curtail unlawful practices, uncontrolled harvesting from natural habitats, and to enforce market regulations. Such measures would generate foreign currency for Türkiye. Urgent establishment of doctor fish production and breeding facilities within Türkiye would yield substantial benefits. Simultaneously, it is advantageous for local entrepreneurs engaged in the trade to expeditiously establish sanctioned and regulated production facilities, supporting the shift towards national production. By adhering to legitimate and controlled methods, satisfying the local demand for this fish becomes achievable. This methodology ensures the conservation of the doctor fish population within Türkiye's natural resources while contributing to the country's economy through regulated assistance in both domestic and international trade.

Breeding Conditions of *Garra rufa*

The eggs are approximately 1.5-2 mm in diameter, opaque white, demersal, and non-adhesive in structure (Çelik, 2021). Breeding parents who prefer rocky habitats have the ability to eat their eggs. Under suitable environmental conditions, the eggs laid by the breeding adults hatch between 34 and 60 hours, depending on the water temperature. Before incubation, if necessary, the eggs can be subjected to a disinfection process. This can involve the application of 5 mg/L methylene blue for a duration of 40-60 minutes. To prevent fungal contamination of the eggs, it is recommended to use UV filters or methylene blue formulations. It is essential to ensure the disinfectant ratios are well-adjusted for successful egg hatching. Moreover, water temperature influences egg hatching. It is known that the eggs of this species can hatch between 24-32°C (Çelik, 2021).

The onset of larval rearing begins with the completion of the embryonic development of the eggs and the hatching of the larvae. Larval rearing is conducted under controlled conditions in isolated areas within growing tanks. The process of larval rearing comprises three phases: the larval stage, transition to powdered feeding, and further growth.

In the case of doctor fish, the larval stage spans approximately 15 days at a water temperature of 24-28°C. Larvae appear highly transparent for the first 1-2 days after hatching from the eggs. Without careful observation, the larvae at the bottom of the tank might not be visible. These larvae possess a relatively large yolk sac, and their mouths open around the third day. Subsequently, from this stage, they should be fed with Artemia. Transition to powdered feed should be initiated after the initial two weeks of the larval period (beyond 15 days). Between the 15th and 30th days, the larvae are fed a mixture of Artemia and powdered feed, while after the 30th day, they are solely fed with powdered feed (Çelik, 2021). The success rate at the end

of the larval period, ranging from 40% to 70%, depends on the applied rearing techniques as well as the quality of the eggs.

Upon completion of the larval phase between days 15 to 30, larvae are adapted to microparticulate (powdered) feeding from live prey. This adaptation process can take place in the tanks where hatching occurs. These tanks consist of glass aquariums, with volumes ranging from 20 to 100 liters, featuring flat bottoms and various sizes. They are simple, static structures with manual inlet and outlet water connections that are not recirculating. For disease risk reduction, open-loop systems are more beneficial at this stage. The illumination period in the larval unit is set at 12 hours and can be adjusted using automatic timers. Water supplied to the tanks must pass through ultraviolet filtration. Following successful hatching, the survival rate of the larvae typically ranges from 80% to 90% under normal conditions (Çelik, 2021).

At 30 days old, the larvae are transferred to rearing tanks. Ideally, square, rectangular, or cylindrical tanks with volumes ranging from 1 to 5 m^3 are used in the rearing unit. The water temperature is maintained between 23-29°C, with a 12-hour lighting cycle. The rearing system operates as a closed-loop system, filtering the water with turnover rates varying from 80-150% per hour, based on fish size and stocking density. Feeding rates range from 2% to 4%. The survival rate typically fluctuates between 90-95% in the absence of disease outbreaks.

Scientific research suggests that when optimal conditions are provided for *Garra rufa* cultivation, commercial production is viable. Studies on the species' cultivation have demonstrated that it can be easily reproduced and reared under culture conditions (Çelik, 2021).

Production of this species may be permitted for once to gather necessary broodstock from Türkiye's natural resources, subject to approval from relevant departments of the Ministry of Food, Agriculture, and Livestock. This matter requires the Ministry's opinion and approval. If the Ministry does not grant permission, the required broodstock can be imported from abroad for production.

There is no strict requirement to limit the types and sizes of pools used in the production and aquaculture stages of this species. However, the following measurements are recommended for a Doctor Fish breeding facility.

Table 1. Recommended Characteristics of Pools/Tanks for *Garra rufa* Farming (Unpublished preliminary results)

Pond/Tank	Dimensions (cm)	Tank Construction	Stock Density (fish/m^3)	Others
Broodstock	100 x 50 x 50 (Rectangular)	Glass, plastic, or polyester	80 (♂:♀, 20:20)	Closed system
Larva	50 x 30 x 20 (Rectangular)	Glass, plastic, or polyester	3000-5000	Independent tanks
Juvenile (Grow-out)	120 x 100 x 100 (Rectangular/Square)	Plastic or polyester	1000	Closed system

Note: The pool or tank sizes provided in this table are sufficient for Doctor Fish (*Garra rufa*) breeding. However, the use of tanks on a smaller or larger scale than the given measurements is possible.

Table 2. Water Quantities and Characteristics for *Garra rufa* Breeding (Unpublished preliminary results)

Unit	Water Flow (lt/min)	Water Temperature (°C)	pH	Daily Water Change Rate (%)	Other
Broodstock Unit	3-5	26-29	7-9	5-10	Closed Circuit
Larval Unit	1-3	26-29	7-9	1-5	Independent Tanks
Fry Unit (rearing tanks)	7-10	24-28	7-9	10-20	Closed Circuit

Note: The provided water specifications for Doctor Fish breeding are outlined in this table. These water qualities are recommended based on preliminary scientific research. Therefore, these attributes are of a suggestive nature and not limiting.

Table 3. Characteristics of Feeds Usable in *Garra rufa* Aquaculture (Sevgili et al., 2023).

Protein Rate (%)	25%	30%	35%	40%	45%
Fish Meal	8.0	8.0	8.0	8.0	8.0
Sunflower Seed Cake	4.0	4.0	4.0	4.0	4.0
Corn Gluten	9.5	13.5	17.5	21.5	25.5
Soybean Meal	19.0	24.5	29.5	34.5	39.5
Wheat Flour	12.0	12.0	12.0	12.0	12.0
Corn Starch	37.8	28.3	19.3	10.3	1.3
Fish Oil	4.0	4.0	4.0	4.0	4.0
Soybean Oil	4.0	4.0	4.0	4.0	4.0
Vitamin	0.7	0.7	0.7	0.7	0.7
Mineral	0.9	0.9	0.9	0.9	0.9
Total (%)	100.0	100.0	100.0	100.0	100.0

Garra rufa are known to be mostly herbivorous, but they have also been observed to feed on carnivorous or detritivorous foods. Therefore, these fish need to be fed with different protein-containing feeds throughout their life periods. In culture conditions, these fish can be fed with feeds prepared with the above ratios (Table 3). In addition to these, trout, sea bream, and sea bass feeds available on the market, as well as various brands of aquarium fish feeds, are also used in the feeding of these fish. However, the healthiest option for intensive culture conditions is the use of some of the above formulas.

While the juveniles are fed with feeds with a higher protein content, the protein content should be decreased as the growth increases. The feeding rates start at 8-10% in juveniles and are reduced to 2-4% for the larger individuals. The feed conversion rates (FCR) of these fish in culture conditions are around 1.5-2. With this feeding strategy the fish can reach a live weight of 2.5-3 g and a total length of 5-6 cm in a period of 6-8 months. In other words, a general calculation shows that 4.5-6 g (5.25 g in average) of feed is needed to reach 3 g in weight within a period of 6-8 months.

For example;
In order to grow 10,000 individuals of doctor fish, each weighing 3 g, the total amount of feed required can be estimated by the following equations:

$$3\ g\ x\ 10000\ individuals = 30000\ g$$

$$\left[\frac{(30000\ x\ 5.25\ g)}{3}\right] / 1000 = 52.5\ kg$$

The formulae above show that the estimated amount of diet necessary for 10.000 individuals of doctor fish, each with an average weight of 3 g, would be found as 52.5 kg.

Conclusion

Meeting the demand for *Garra rufa* without causing harm to natural stocks necessitates acquiring this species through cultivation. Over the years, a sector has naturally emerged based on the preferences of individuals. The use of doctor fish has found its place within the tourism sector. Currently, there are very few hotels that do not offer services with small or large pools under the name 'spafish.' Particularly in the SPA centers of in large-scale holiday complexes along the Mediterranean coast line, doctor fish are almost universally used. Hotels now include these fish in their marketing and sales packages, that increases their reason for preference. Therefore, the use of doctor fish in Türkiye is becoming increasingly widespread. In such a rapidly growing commercial area, several million live fish are needed every year. It is highly recommended to meet this increasing demand through cultivation instead of depleting natural stocks or resorting to imports, which eventually might reduce the ecosystem impacts of tourism activities via spafish services. Support for such initiatives by relevant government institutions is crucial for the national economy, sustainability of natural resources, and their preservation in healthy manner. The establishment of one or more aquaculture facilities engaged in doctor fish production could fill the existing gap in this field for the sustainability of natural resources.

Ethical approval

Not applicable.

Data availability statement

The authors declare that data can be provided by corresponding author upon reasonable request.

Conflicts of interest

There is no conflict of interests for publishing this study.

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Contribution of authors

İhsan Çelik: Investigation, Methodology, Writing original draft, Editing.
Pinar Çelik: Conceptualization, Data curation, Formal analysis, Writing original draft, Editing.
Mustafa Barış: Resources, Supervision, Validation, Review, Editing.
Fatih Öğretmen: Resources, Supervision, Validation, Review, Editing.
All authors have read and agreed to the published version of the manuscript.

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