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Population Size and Microhabitat Requirements of *Salamandra infraimmaculata semenovi* in Zagros Mountain, Kurdistan Province, Iran

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Abstract.—**The Semenov's Salamander (*Salamandra infraimmaculata semenovi*) is distributed in western Iran, northeastern Iraq, and eastern Türkiye. We conducted six field surveys between 27 April and 1 June 2023 in a 1.67 ha area of western Kurdistan Province, Sarvabad County, Iran, to determine the size of a breeding population of *S. i. semenovi*. We also recorded habitat characteristics of this taxon during the breeding season. Based on capture-mark-release-recapture technique (Jolly-Seber), the breeding population ranged from 216 to 1,616 individuals. We estimated density of salamanders between 0.01 and 0.09/m2 in the mountainous area of Hazarkhani. We observed *Salamandra infraimmaculata semenovi* at an elevation of 1,720-1985 m, with an average slope of 28%. *Salamandra i. semenovi* preferred grassland habitats dominated by Golpar (*Heracleum persicum*), Chamomile (*Matricaria chamomilla*), Yarrow (*Achillea millefolium*), oats (*Avena* spp.), milkvetch (*Astragalus* spp.), clover (*Trifolium* spp.), and Common Nettle (*Urtica dioica*). Major threats to *S. i. semenovi* in the Kurdistan Province of Iran are land-use change, water source blocking, and water use by farmers for irrigation. We recommend prioritizing conservation actions that stop land-use changes, especially the conversion of natural grasslands into orchards and farmland. We also recommend raising awareness and educating local communities, particularly farmers, about the importance of *Salamandra infraimmaculata semenovi* as an indicator of habitat quality.**

Key Words.—Amphibia; capture-recapture technique; Caudata; Jolly-Seber method; Middle East region; Near-eastern Fire Salamander; Semenov's Salamander; true salamanders

Introduction

Amphibians are the most threatened vertebrates in the world (Mi et al. 2024), and almost 41% of amphibian species are at risk of extinction (International Union for Conservation of Nature [IUCN] 2025). Amphibians are an integral component of many ecosystems (Davic and Welsh 2004), and they play a prominent role in trophic dynamics; consequently, a decrease in their populations potentially can cause irreparable damage to the environment and other taxa (Gardner 2001). Amphibians perform a major role in ecosystem stability and are known as biological controllers (Husain and Hasan 2021) because they feed on invertebrates, especially insects. Additionally, salamanders can serve as indicators of stream health and aquatic habitat quality (Clipp and Anderson 2014). As ectothermic organisms, temperature affects most aspects of their life, making them suitable models for studying how animals are affected by changing temperatures caused by climate change (Taylor et al. 2020).

Amphibians are one of the most diverse groups of vertebrates, consisting of more than 8,863 species worldwide (Frost 2024). In Iran, 23 species of amphibians have been recorded (Safaei-Mahroo et al. 2025). The Near-eastern Fire Salamander (*Salamandra infraimmaculata*) has three subspecies in the Near and Middle East: *S. i. infraimmaculata* distributed in Palestine, Israel, Lebanon, Syria, southern and southwestern Türkiye; *S. i. orientalis*, in central and south-central Türkiye, and *S. i. semenovi*, in eastern Türkiye, northeastern Iraq, and western Iran (Joger and Steinfartz 1995; Degani 1996; Veith et al. 1998; Steinfartz et al. 2001; Böhme et al. 2013). The Semenov's Salamander (*S. i. semenovi*) is the easternmost member of fire salamanders (*Salamandra*). This taxon inhabits mountainous, humid meadows and forest areas adjacent to streams and springs with various plant species, including species of oak (*Quercus* spp.), walnuts (*Juglans* sp.), raspberries (*Rubus* sp.) and willows (*Salix* sp.; Safaei-Mahroo and Ghaffari 2020). *Salamandra infraimmaculata* is listed on the Red List of the IUCN as Near Threatened (IUCN 2023).

Monitoring populations of wildlife provides valuable information on their health, viability, and abundance (Segev et al. 2010), and is, therefore, an essential component of ecological studies and conservation efforts (Danielsen et al. 2005). Amphibians are sensitive to environmental changes, and destruction of their critical habitat is increasing; consequently, population monitoring is necessary to assess the viability and resilience of amphibians (Bernabò et al. 2024a) particularly salamanders. Capture-mark-recapture methods are effective techniques for estimating the population size of animals and assessing ecological hypotheses (Jolly 1965; Seber 1965; Lebreton et al. 1992; Williams et al. 2002; Bernabò et al. 2024b). These methods are used often in studies of amphibians (Schmidt 2004; Cayuela et al. 2014; Muths et al. 2018). Modification and loss of habitat are key drivers of decline in biological diversity (Brook et al. 2008); therefore, understanding habitat requirements of species facilitate development of conservation strategies (Johnson and Derocher 2020). Furthermore, understanding the microhabitat requirements of salamanders and newts can provide insight into factors that influence the distribution of these organisms (Zhao et al. 2022).

Because many species of amphibians are largely dependent on aquatic habitats for their survival, even slight changes to water sources could result in their local extinction (Mims et al. 2023). Globally, amphibians are threatened by habitat destruction, degradation, fragmentation, disease outbreaks, climate change, and alien species invasions (Ashrafzadeh et al. 2019; Mi et al. 2024). The main threats to amphibians in Iran are habitat destruction, alteration, and degradation (Safaei-Mahroo et al. 2023b). Primary threats to salamanders inhabiting the Zagros in Kurdistan Province include habitat fragmentation caused by construction of dams, water pollution, and overuse of water for irrigation (Safaei-Mahroo and Ghaffari 2020; Karimi et al. 2021).

Population sizes of amphibian species, especially salamanders, in Iran (Safaei-Mahroo et al. 2023a; Karimi et al. 2021) would be helpful for their conservation, in particular, understanding the population sizes and trends or habitat requirements of *Salamandra i. semenovi*. Identifying habitat characteristics is important for development of management plans (Unglaub et al. 2015). Effective salamander conservation requires estimating the population size and monitoring the habitat to ensure survival of the species. *Salamandra i. semenovi* is a priority for study due to its limited distribution, scant ecological and population information, and conservation needs. Understanding population dynamics and threats is crucial to implementing effective conservation strategies. The goal of our study was to estimate the population size and habitat characteristics of *S. i. semenovi* in Sarvabad County, western Iran, providing fundamental information to guide reliable conservation management decisions for this taxon.

Materials and Methods

Study area.—We conducted our study in a 1.67 ha mountainous area of Hazarkhani village, Sarvabad County, Kurdistan Province in western Iran (35°24’35”N, 46°03’60”E; Fig. 1). Vegetation cover was forest-pasture (60% dense pasture and 40% forest; Fig. 2). The average annual temperature is 12.8° C, and the average annual precipitation is 991.2 mm. This study area consisted of a mountainous, hilly area with two permanent brooks fed by several small springs (Hanafi and Hatami 2013).

Field methods.—We surveyed mountain brooks and streams for salamanders six times from late April to early June 2023 (27 April, 4 May, 11 May, 18 May, 25 May, and 1 June). We conducted our initial trip on 27 April during daylight (1100 to 1600) to select sites; we conducted all other surveys at night (from 2000 to 2300). We surveyed the habitat for newts on five occasions to estimate population size using the Jolly-Seber method. This design minimized disturbance and preserved natural population structure, while accounting for logistical constraints including difficult site access, limited financial resources, and time availability. Furthermore, 5–7 primary sampling units are recommended for robust estimation of abundance in JS models (Burnham 1987; Williams et al. 2002). Two people used flashlights to search for salamanders during each nighttime survey (six person-hours). We captured salamanders by hand on land and in shallow water. We used a toe clipping method to mark the salamanders and then released them at the location of their capture.

We recorded habitat characteristics, including elevation (using GPS; Garmin Map 78S), slope percentage (Compass software), vegetation cover percentage, dominant vegetation cover, distance to water resources, water, air and soil temperatures, and soil texture. We visually estimated vegetation

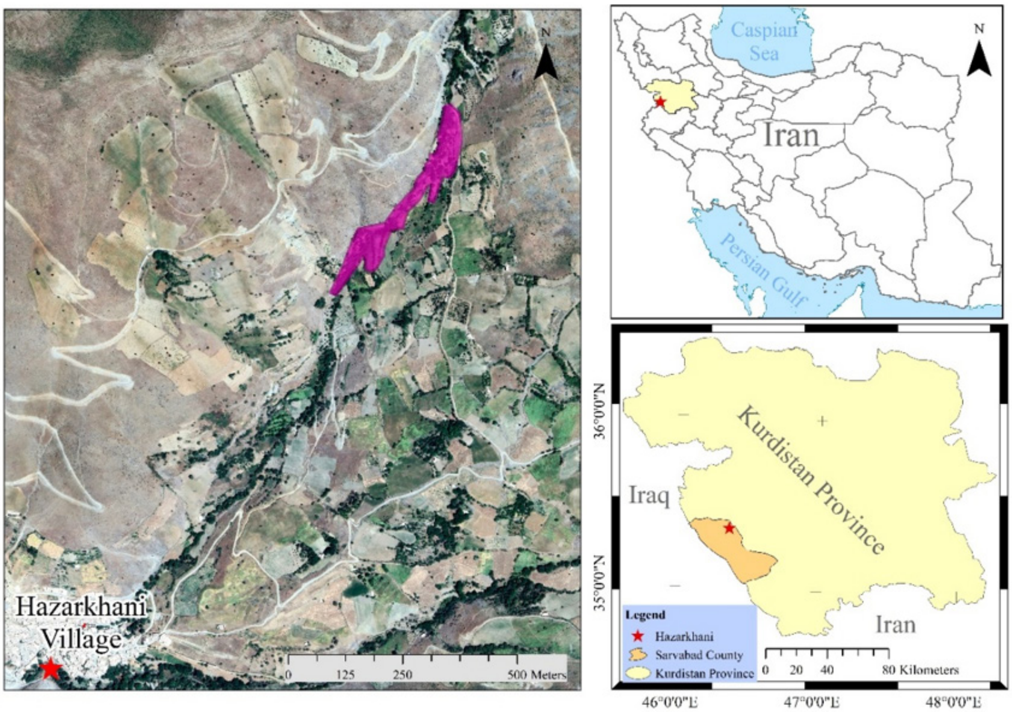

Figure 1. The location of the study area in the northeastern part of Hazarkhani Village, Sarvabad County, Kurdistan Province, Iran. A purple polygon indicates the boundary of the study area, and the red star indicates the location of Hazarkhani Village.

cover. We used a Mastech MS6520B thermometer (Dongguan Huayi Mastech Co. LTD., Guangdong, China) to record both water and soil temperatures, which we measured to the nearest 0.1° C. We measured soil values using the hydrometric method and entered them into the soil texture calculator website (https://calculator.academy/soil-triangle-calculator/). We determined soil texture (percentage of clay, silt, and sand) by the hydrometric method using a Orbital Shaker model Hlb501 (Behsan Company, Tehran, Iran). First, we weighed 50 g of soil and added 100 ml of Calgon (sodium hexametaphosphate) to it and then placed the mixture in the shaker for 2 h. Afterwards, we transferred the solution to a graduated cylinder and then increased its volume to 1,000 mL by adding distilled water. We measured the temperature of the solution, which we stirred with a stirring rod for 1 min, and then immediately placed a hydrometer inside the cylinder. We took our first reading after 40 seconds of stirring, and the second reading 2 h later.

Data analysis.—To estimate the population size, we used the capture-mark-release-recapture technique and Jolly-Seber model (Krebs 1989) in Ecological Methodology software (Exeter Software, East Setauket, USA). Restricting Jolly–Seber (JS) population estimation to adult *Salamandra infraimmaculata* (including the subspecies *semenovi*), as conducted by Bar-David et al. (2007), Segev et al. (2010), and Alvarez et al. (2015), is recommended because: (1) adults are the only life stage directly contributing to recruitment; (2) adult abundance reliably predicts future larval production and population viability; (3) the IUCN and national conservation strategies (e.g., in Turkey and Iran) prioritize protection of adult breeding aggregations; and (4) non-adult stages (larvae and juveniles) suffer high stochastic mortality, wide dispersal, and detection bias, rendering abundance estimates unreliable. Larvae and juveniles are typically scattered across streams, under rocks, or within logs. We included only adult salamanders (snout-vent length > 7 cm) in our analyses and estimated the population size of breeding *S. i. semenovi* (Alvarez et al. 2015). We used Pearson's Correlation Coefficients (the data meet parametric assumptions) to investigate the relationship between habitat variables and subspecies density.

Results

We captured 310 *S. i. semenovi* and recaptured 33 individuals (Appendix Table). We estimated the population size to be 216–1,616 individuals in an area of 1.67 ha (Table 1). The wide confidence

Figure 2. (A) The site of our population study of the Semenov's Salamander (*Salamandra infraimmaculata semenovi)* in Hazarkhani Village, Sarvabad County, Kurdistan Province, Iran. (B) View of an orchard within the study site. (C) Adult salamander near the stream, among debris. (D) An adult salamander between debris near a man-made wall. (E) Sub-adult individual. (F) A larval salamander in its natural habitat. (G) Drystone walls that provide moist shelter to this species in Hazarkhani. (H) Measuring and recording man-made stone walls. (Photographed by Barbod Safaei-Mahroo).

interval resulted primarily from the extremely low recapture rate (33/310 = 10.6%) rather than inherent population variability, and the ideal recapture rates is more than 30% of marked individuals (Williams et al. 2002). We estimated the mean density of salamanders as 700 salamanders/ha (95% confidence interval = 100–900) in the mountainous area of Hazarkhani. We found that *S. i. semenovi* prefer grassland habitats dominated by Golpar (*Heracleum persicum*), Chamomile (*Matricaria chamomilla*), Yarrow (*Achillea millefolium*), oats (*Avena* spp.), milkvetch (*Astragalus* spp.), clover (*Trifolium* spp.), and Common Nettle (*Urtica dioica*). Tree species found in this area include oak (*Quercus* spp.), Black Poplar (*Populus nigra*), Walnut (*Juglans regia*), Hawthorn (*Crataegus pseudoheterophylla*), Bramble (*Rubus sanctus*), and Dog Rose (*Rosa canina*). We found *S. i. semenovi* at an elevation of 1,720–1,985 m, with an average slope of 28%. During the study period, the average temperatures of soil, water, and air in the study area were 11.72° C, 11.16° C, and 12.53° C, respectively. The average percentages of clay, silt, and sand in the soil of the Hazarkhani habitat were measured as 32.66, 26.66, and 39.33, respectively (Table 2). According to the results, the soil in the Hazarkhani habitat has a loamy clay texture.

We observed aggregations of *S. i. semenovi* adjacent to irrigated ditches beneath man-made drystone construction used as shelters. Salamanders aggregated near man-made drystone walls with a height of 1.5–2 m and a length of 5–50 m (Fig. 2). We found them close to the main stream, under stones > 30 cm. We also found salamanders beneath the trunks and branches of trees that farmers used for dividing their farms. Our findings indicate that *S. i. semenovi* emerges from its refuge after dusk and then moves toward water. We observed this species inhabiting slow-flowing waters where temperatures ranged from 8.2° C to 14.8° C. We did not find larvae in the main stream because of the steep slope and stony bedrock. Additionally, due to the lack of constant water flow throughout the 24-h day, we did not find larvae in irrigated ditches. We did, however, observe large numbers of larvae in saturated soils near springs, and adults were abundant in moist soils in irrigated fields and ditches. We observed juveniles (metamorphs) and larvae in an area characterized by soaked soil, dense grass, and a water depth of 3–5 cm (Fig. 2). The syntopic amphibian species observed in the study area included Variable Toads (*Bufotes sitibundus*), Lemon-yellow Treefrogs (*Hyla savignyi*) and Long-legged Wood Frog (*Rana macrocnemis*).

Table 1. Population size estimate of Semenov's Salamander (*Salamandra infraimmaculata semenovi*) in Zagros Mountain, Kurdistan Province, Iran using Ecological Methodology software. The abbreviation CI = confidence interval.

Field survey	Population Estimation	Proportion Marked	Lower 95% CI	Upper 95% CI
1	–	–	–	–
2	216.9	0.09	101.5	830.2
3	2,148.3	0.04	834.3	9,164.9
4	1,616.6	0.18	579.8	7,867.7
5	–	0.22	–	–
Mean	1,327.26	–	–	–

Discussion

Protecting species requires reliable and accurate population estimates (Grimm et al. 2014). Evaluating local and regional population trends are important elements that should be considered (Hossack et al. 2013). Estimating population size for semi-aquatic species, especially nocturnal salamanders that spend most of their lives beneath litter, leaves, rocks, logs, and burrows during the day is difficult (Jung 2005) but crucial for establishing a baseline to determine future population trends (Phillips et al. 2001). Furthermore, land-use change and habitat destruction are increasing, making it essential to understand population size and habitat requirements to protect threatened amphibian species (Karami et al. 2023).

Local people in mountainous regions build drystone walls for two purposes: first, to delineate farmland boundaries, and second, to prevent soil erosion. Also, these habitats store water and humidity, they provide

Table 2. Habitat characteristics of the Semenov's Salamander (*Salamandra infraimmaculata semenovi*) in Sarvabad County, Kurdistan Province, Iran. The abbreviation SD = standard deviation.

Characteristics	Minimum	Maximum	Average	SD
Elevation (m)	1,529.00	1,932.00	1,720.70	142.36
Slope (%)	8.59	43.73	28.63	11.77
Vegetation cover (%)	38.00	58.00	47.00	6.00
Distance to water resource (m)	0.01	0.03	0.01	0.008
Water Temp. (°C)	8.20	14.80	11.16	1.43
Air Temp. (°C)	6.00	16.50	12.53	2.34
Soil Temp. (°C)	6.80	14.50	11.72	1.68
Clay (%)	20.00	40.00	32.66	11.01
Silt (%)	18.00	34.00	26.66	8.08
Sand (%)	26.00	62.00	39.33	19.73

suitable microhabitats for salamanders during the day. The estimated population of *S. i. semenovi* in the Hazarkhani habitat ranged from 216.9 to 1,616.6 individuals, with a mean of 1,327.26, within an area of 1.67 ha. The wide confidence interval may be due to the low recapture rate. The average salamander density was 700/ha in the mountainous region of Hazarkhani in this study. Alvarez et al. (2015) studied *Salamandra salamandra* populations in a small size and isolated urban habitat patch in Spain and estimated an average of 4,500 individuals/ha. Sinai et al. (2020) indicated that water depth and elevation are known as two important habitat variables of *Salamandra infraimmaculata* in Israel. *Salamandra. i. semenovi* occurs at elevations between 1,720–1,985 m in our study area. Water temperatures were lowest in mainstream waters, and highest in irrigated ditches. One of the most important factors influencing the presence and habitat selection of salamanders is soil moisture, which is essential for the survival of some species (Clipp and Anderson 2014). We did not find any larvae in the main stream, likely because the steep slope, rocky bed, and high-water velocity made it unsuitable for their presence.

Shelter availability is essential for amphibians (Basile et al. 2017). *Salamandra i. semenovi* congregate adjacent to irrigated ditches beneath man-made drystone walls to shelters. The drystone walls used in terrace farming hold water and slowly release it, making them an ideal moist shelter for *S. i. semenovi* and they are a vital habitat component because they reduce the risk of dehydration (Romano and Ruggiero 2008). Several species of amphibians are on the verge of extinction (Stuart et al. 2004). Salamander population declines and shifts in distribution are predominantly caused by anthropogenic activities (Clipp and Anderson 2014). According to our findings, the main threats to this subspecies are land-use change and habitat loss, blocking springs by siphoning off water for agricultural irrigation and entering livestock wastes and pesticides into water.

Our results provide a basis for the conservation of this species. We recommend that future studies address congregation and shelter use of *S. i. semenovi*. The main threats to *S. i. semenovi* in the study area include land use changes, water source blockages, and water use for agricultural irrigation by farmers. Additionally, the cutting and pruning of grassy vegetation by local people to feed their herds, and the use of herbicides and pesticides by locals, pollute the water and soil.

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Appendix

Appendix Table. Capture history of the Semenov's Salamander (*Salamandra infraimmaculata semenovi*) in Hazarkhani Village, Sarvabad County, Kurdistan Province, Iran from 27 April to 1 June 2023.

Date	Capture	Recapture 1	Recapture 2	Recapture 3	Recapture 4	Total
27 April	Pilot Survey	–	–	–	–	5
4 May	C1	–	–	–	–	40
11 May	C2	4	–	–	–	54
18 May	C3	–	3	–	–	80
25 May	C4	1	7	4	–	70
1 June	C5	3	3	6	2	66