Herpetology Notes, volume 13: 531-541 (2020) (published online on 28 June 2020)

Assessing population status and conservation of endangered Marmaris salamander, *Lycisalamandra flavimembris* (Mutz and Steinfartz, 1995), in southwestern Turkey

Dilara Arslan[1,2,3], Çağdaş Yaşar[1,4], Akın İzgin[1,4], and Kerim Çiçek[4,*]

Abstract. The Marmaris salamander is an endemic and endangered amphibian species in Southwestern Anatolia. Here, we estimated some population parameters of the Marmaris salamander by conducting a total of 40 days of intensive sampling across 5 different sites. We marked 323 salamanders with visible implant elastomer between 2017 and 2019 and recaptured 46 of them. The population consists of 36% juveniles, 27.9 % males, and 35.9% females with a female-biased sex ratio (m: f= 0.77) was observed. We estimated population density per site to be between 10 and 42 indiv./ha. The capture probability ranged from 0.15 to 0.54 and the survival rate ranged from 0.53 to 0.86 among the populations. Based purely on models of habitat suitability, the geographic distribution of the Marmaris salamander is likely to shrink by 9–62% in the next 30-50 years. The most important threats are land use conversion, climate change, and forest fires. If no action is taken some populations of the species might go extinct.

Keywords. Anatolia, Conservation, Ecological Niche Modelling, Marmaris salamander, Population Dynamics

Introduction

Declining amphibian populations on daily basis (e.g. Blaustein & Wake, 1990; Alfold & Richards, 1999; Houlahan et al., 2000) has shown that accelerated research for the ecology of species to be a necessity (Pechmann & Wilbur, 1994; Meyer et al., 1998; Wake, 1998). Understanding the factors affecting population dynamics is of critical importance in many fields of basic and applied biology.

The leading threat to amphibian populations worldwide is habitat loss and degradation (Chanson et al., 2008; Sodhi et al., 2008; Hof et al., 2011). Most amphibians need a very specific microhabitat with appropriate conditions such as moisture, temperature, pH and refuges (Bishop et al., 2012). They spend most of their lives in one or two terrestrial environments and seasonally migrate to a different, usually aquatic environment, to breed (Bishop et al., 2012). Declines in amphibian populations have been well documented, but most studies are of frogs and toads (AmphibiaWeb 2020): there is little attention given to salamanders, around half of which are listed as Threatened in the IUCN Red List (Sparreboom, 2014).

Lycian salamanders are terrestrial, viviparous salamanders and endemic to the southwestern coast of Turkey and several Aegean islands (Sparreboom, 2014; Veith et al., 2016). They spend their lives deep inside humid crevices of boulder fields at the foot of karstic limestone slopes (Veith et al., 2001; Rödder et al., 2011). The genus *Lyciasalamandra* consists of seven species. Two are listed as Vulnerable VU [*L. luschani* (Steindachner, 1891)*, L. helverseni* (Pieper, 1963)]*,* four are listed Endangered EN, [*L. atifi (*Başoğlu, 1967)*, L. antalyana* (Başoğlu & Baran, 1976)*, L. fazilae* (Başoğlu & Atatür, 1974), *L. flavimembris* (Mutz & Steinfartz, 1995)] and one is listed as Critically Endangered CR, [*L. billae* (Franzen & Klewen, 1987)] in the IUCN Red List.

[1] Akdeniz Koruma Derneği (Mediterranean Conservation Society), 35100 Bornova/İzmir, Turkey.
[2] Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale (IMBE), Avignon Université, UMR CNRS IRD Aix Marseille Université, IUT Site Agroparc, Avignon Cedex 09, France.
[3] Institut de recherche pour la conservation des zones humides méditerranéennes Tour du Valat, Arles, France.
[4] Zoology Section, Department of Biology, Faculty of Science, Ege University, 35100, Izmir, Turkey.
[*] Corresponding author. E-Mail: kerim.cicek@ege.edu.tr

The Marmaris salamander (*L. flavimembris*) is distributed to the northwestern part of Muğla Province (Göçmen and Karış, 2017; Arslan et al., 2018; Başkale et al., 2019). Within its naturally restricted range, the major potential threats to the species are habitat loss due to forest fires, urbanization and overcollection for scientific purposes (Kaska et al., 2009; Başkale et al., 2018, 2019). Unfortunately, there are limited data on population trends and threats for this-species. Recent studies have found that the salamander is only found within approx. 115 km^2 of natural pine forest and maquis habitat (Arslan et al., 2018; Başkale et al., 2019). Continued threats are likely to have a major impact on this narrow habitat (Arslan et al., 2018; Başkale et al., 2019).

Terrestrial salamanders are one of the hardest groups of amphibians to study, and understand the ecology of, because of their cryptic life (Sparreboom, 2014). There is a need for more extensive rigorous monitoring programs to better evaluate the current population status of terrestrial salamanders, to inform models of future population distribution, and to predict the likely effects of conservation activities (Smith and Petranka, 2000). The ecology of the Marmaris salamander, for example, is largely based on limited observations in systematic studies (e.g., Göçmen and Akman, 2012; Şenol, 2015; Üzüm et al., 2015; Göçmen and Karış, 2017), with few studies focused on population ecology (Dereağzı, 2016; Başkale et al., 2019). The objectives of the present study were to: (1) determine several population parameters; (2) predict potential and future distribution (2050 and 2070); and (3) determine potential threats and make recommendations for the conservation of the Marmaris salamander in Muğla, Turkey.

Material and Methods

Study sites.—This study was carried out in Muğla Province, Turkey, between Marmaris in the southwest and Çiçekli Village 35 km to the northeast. We sampled 5 different sites: (1) Çiçekli village [37° 5' N, 28° 29' E, 600 m a.s.l.], (2) Turunç village [36° 46′ N, 28° 14′ E, 200 m a.s.l.], (3) Cennet Island. [36° 48′ N, 28° 17′ E, 350 m a.s.l] (4) Bayır village [36°43' N, 28° 8' E, 10 m a.s.l.], and (5) Selimiye village [36°41 N, 28° 6' E and 240 m a.s.l]. All sites were sampled 5 times per each field season between November 2017 and January 2019. We spent a total of 40 days in the field: 15 days across three sites in the first field season (November 2017-March 2018), and 25 days across all five sites in the second field season (November 2018-February 2019). The study sites are dominated by a typical Mediterranean forest ecosystem, mainly composed of pine woodland (*Pinus brutia*) and marquis scrubs (*Laurus nobilis, Arbutus andrachne, Pistacia terebinthus, Platanus orientalis, Olea europea, Quercus coccifera, Ceratonia silique, Cistus creticus, Cyclamen sp., Verbascum sp., Daphne sericea*).The forest ground is covered with mossy limestone or moist rocks (Vural et al., 1995). The maximum altitude in the study areas is 600 m a.s.l. The mean annual temperature in Muğla is 14.1 °C, with a range between 5.4 °C in January and 26.2°C in July. The average relative humidity is 63% and ranges between 45% and 80%. The climate is hot-summer Mediterranean (Beck et al., 2018) characterized dry summers and mild, wet winters between October and May (Turkish Meteorological Station, 2018).

Fieldwork.—We used a mark-recapture method to estimate population parameters. Four people carried out the salamander surveys at each of the five sites. We searched first by using a visual survey (without disturbing the habitat) and then by looking under limestone rocks. The area surveyed at each site was approximately 7 ha. To standardize sampling, four people surveyed each site for 40 minutes. All observed individuals were captured at night and in the early morning by hand and marked by visible implant elastomer (Northwest Marine Technology, Inc.). Before marking, we sprayed the area to be tagged with a local anaesthetic (Chloroethyl Cooling Spray) and after marking we applied a broad-spectrum pomade (a mix of Furacin, Bacturaban ve Stafinepomad) to the injected area to avoid contamination (Çiçek et al., 2011). All individuals were sexed by observing secondary sexual characters and released back to their capture site within 15-25 minutes of capture.

Population estimates.—The sampling period consisted of one or two years of data per sampling site, with each site sampled 5 times each year (Table 1). We used POPAN (Schwarz and Arnason, 1996) models in the program MARK vers. 9.0 (White and Burnham, 1999) to estimate super population size, apparent annual survival rate (ϕ) and annual recapture probability (p). The Akaike Information Criterion (AICc) was used to help choose the optimal model, with a lower AIC indicating the most parsimonious model (Burnham and Anderson, 2004). Combining the AICc and our interpretation of biological context, the constant survival and time-varying recapture [ϕ(.), p(t)] model was selected. The approximate population density at each site (d) was

Table 1. Population size, capture probability, survival rate and densities calculated annually for the Marmaris salamander.

Code	Location	Year	Pop. Size	SE	ϕ	p	Density
1	Çiçekli	2018	152	54.38	0.53	0.54	22
		2019	127	61.13	0.75	0.34	18
2	Turunç	2018	210	81.75	0.75	0.31	30
		2019	225	77.9	0.74	0.15	32
3	Cennet island	2018	178	113.94	0.86	0.21	25
		2019	74	39.29	0.56	0.50	10
4	Bayır	2019	295	130.16	0.75	0.35	42
5	Selimiye	2019	199	75.67	0.57	0.48	28

calculated by dividing the estimated population size (N,) by the area surveyed (a, ha).

Ecological Niche Modelling.—We performed ecological niche modelling on the Marmaris salamander under present (using data from 1950-2000) and future (2050, 2070) conditions. Prior to starting field studies, we carried out preliminary ecological niche modelling, using a maximum entropy approach and available published data, to organize our fieldwork and predict potential new localities. After finishing our fieldwork, we re-ran the model generate a prediction of the species' current and future potential distribution.

A total of 44 occurrences were obtained from current fieldwork and records in literature (Başoğlu and Atatür, 1974; Mutz and Steinfartz, 1995; Öz et al., 2004; Göçmen and Akman, 2012; Şenol, 2015; Üzüm et al., 2015; Dereağzı, 2016; Göçmen and Karış, 2017; Arslan et al., 2018). All records were geo-referenced by WGS-84 and mapped with ArcGIS v10.7. We created a 5km buffer around each occurrence via spThin (Aiello-Lammens et al., 2015) in R to minimize sampling bias (Merow et al., 2013; Boria et al., 2014; Fourcade et al., 2014).

We used 19 bioclimatic variables as predictor variables for the current and future distribution of *L. flavimembris*. We obtained all bioclimatic variables from the WorldClim database (Hijmans et al., 2005), at the spatial resolution of 30 arc seconds. We used only climate variables and not vegetation-derived predictors in the ecological niche modelling in order to assess climatic suitability and to avoid circular reasoning, as vegetation properties themselves depend on climate (Heikkinen et al., 2006; Ahmadi et al., 2019). The bioclimatic variables for 2050 (average for 2041-2060) and 2070 (average for 2061-2080) (WorldClim 1.4, http://www.worldclim.org/cmip5_30s), were obtained from intermediate (the representative concentration pathways, RCP4.5) and worst (RCP8.5) emission scenarios, and used for predicting the future distribution pattern of the species. The data set of "Hadley Global Environment Model 2 – Earth System", developed within the scope of the 5th Coupled Model Intercomparison Project (CMIP5) by the Met Office Hadley Centre (UK, http://www.metoffice.gov.uk/), was preferred. We buffered the climatic variables by 0.5 degrees using a minimum convex polygon representing the study area.

We removed some highly intercorrelated climate variables ($r > 0.9$ or < -0.9) to reduce the negative effect that might result from multicollinearity among the bioclimatic variables (Heikkinen et al., 2006; Dormann et al., 2013). We selected five climate variables [BIO2 - Mean Diurnal Range [Mean of monthly (max temp - min temp)], BIO4 - Temperature Seasonality (standard deviation *100), BIO10 - Mean Temperature of Warmest Quarter, BIO12 - Annual Precipitation, and BIO15 - Precipitation Seasonality (Coefficient of Variation)] based on the ecological requirements of the species (Veith et al., 2001; Sparreboom, 2014).

The geographic distribution of Marmaris salamander was modelled under present (1950-2000) and future (2050, 2070) bioclimatic conditions using maximum entropy modelling with MAXENT 3.4.1 (Phillips et al., 2020). The MAXENT algorithm is one of the most effective methods for ecological niche modelling (Elith et al., 2006).

It estimates species' distributions by finding the distribution of maximum entropy (i.e. closest to uniform) subject to the constraint that the expected value of each environmental variable (or its transform and/or interactions) under this estimated distribution matches its empirical average (Phillips et al., 2006). We used ENMeval (Muscarella et al., 2014) to balance goodness-of-fit and predictive capacity of the model. Because we were working with a relatively small data set (Pearson et al., 2007; Shcheglovitova and Anderson, 2013), we chose the randomly selected background approach, and k-1 jackknife method (Phillips et al., 2006).

Our models were constructed with regularization of multiplier values ranging from 0.5 to 10 (increments 0.5) and six different combinations of feature classes (L, LQ, H, LQH, LQHP; L: = linear, Q = square, H = hinge, P = product and T = threshold). This resulted in 100 individual model runs. The 10-percentile training presence logistic threshold approach (Liu et al., 2005) was applied for calculating distribution area.

The cloglog output was transformed into a continuous map to represent habitat suitability for *L. flavimembris* between 0 (unsuitable) to 1 (suitable). Model performance was evaluated from four evaluation metrics (AUCTest, AUCDiff, OR10, AICc) by ENMeval (Muscarella et al., 2014) in the R environment. The results were visualized with ArcGIS.

Threats and conservation activities.—Major threats and conservation suggestions for *L. flavimembris* were standardized according to the Open Standards methodology (2013, http://cmp-openstandards.org), using threats classification Version 2.0) and actions classification Version 2.0). Data were compiled from literature (Başoğlu and Atatür, 1974; Öz et al., 2004; Şenol, 2015; Üzüm et al., 2015; Dereağzı, 2016; Göçmen and Karış, 2017; Arslan et al. 2018; Başkale et al., 2018, 2019), Internet searches (Google, Yandex, Local forum website), and our observations in Marmaris and Ula between 2015 and 2019. During our fieldwork, we interviewed villagers, farmers, hunters, shepherds, and officers to learn their thoughts and knowledge on *L. flavimembris* (location of observations, phenology, attitudes etc.) and potential threats and possible conservation actions. For each threat factor, we assessed timing (i.e. past, current, or future), scope (i.e. the proportion of the total population affected) and severity (i.e. the magnitude of the declines caused by, or likely to be caused by, the threat) were assessed and then the threats were classified into three classes (Low, Medium, High) according to the open standards threat analysis. We created a conceptual model to understand the ultimate drivers of the threats and then identified possible conservation strategies according to our conceptual model.

Results

In total, 323 salamanders (36.2% juveniles; 27.9% males; 35.9% females) were captured and 46 individuals were recaptured. The population is female-biased (M: F= 0.77). During the two periods when *L. flavimembris* was most active, sex ratios were male-biased in January (M: F=1.6) but female-biased in February (M: F=0.5). Recapture rates were 17% at Site 1, 13% in Site 2 and 13% Site 3 from 2017-2019 during two sampling seasons: 9% at Site 4 and 8% at Site 5 in 2019 during second sampling season. Estimated population sizes ranged considerably among sites, from ~70 to 225 individuals (Table 1). Therefore, estimated population densities are of 10-42 individuals per hectare. The sites with the smallest population sizes were Çiçekli village (Site 1) in 2018 and Cennet island (Site 3) in 2019. The sites with the largest population were Turunç village (Site 3) in 2018 and Bayır Village (Site 4) in 2019 (Table 1).

The primary factors affecting the distribution of the species are annual precipitation (BIO12, 50.5%), mean diurnal range (BIO2, 31.2%), precipitation seasonality (BIO15, 9%), mean temperature of warmest quarter (BIO10, 7.5%) and temperature seasonality (BIO4, 1.9%). The mean AUC value of the current distribution consensus model is quite high (0.922). The current distribution model indicates that there are more climatically suitable habitats on the southern distribution of species (Figure 1). However, the climatic suitability is predicted to decline in the future, especially in the southern part of the species' range. According to RCP 4.5 model results, the distribution of the species will decrease by 4.1% by 2050 and 33.7% by 2070 (Figure 2). According to RCP 8.5 models results the distribution of the species will decrease by 8.6% by 2050 and 62.2% by 2070. The main threats to the population are land conversion, fires, and climate changes (Table 2).

Discussion

Amphibians are an important component of forest ecosystems and play an important role in food webs and nutrient cycling (Burton and Likens, 1975; Walker et al., 2018). Many amphibian species have become extinct over the past 50 years, largely due to intense human pressure, both direct and indirect (Houlahan et al., 2000; Wake and Vredenburg, 2008; Grant et al., 2016). There is definitely an urgent need for more attention on amphibian population dynamics by starting long-term monitoring programs to identify trends and inform strategies to reduce declines (Alford and Richards,

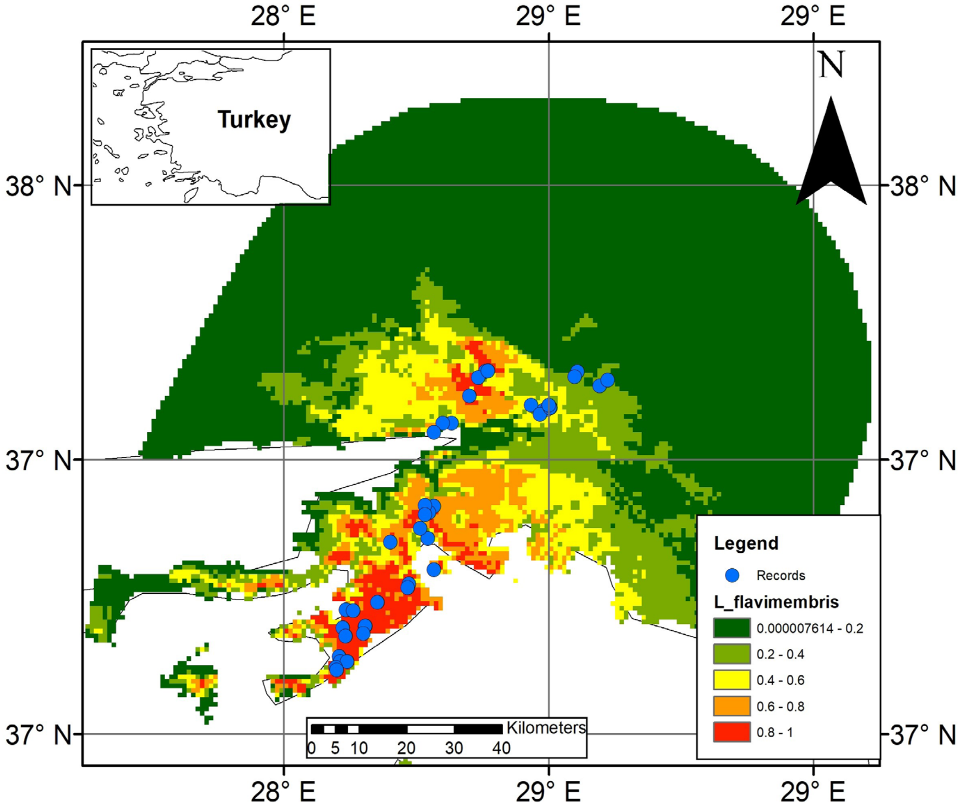

Figure 1. The known and potential distribution model of Marmaris salamander in Southwestern Anatolia. Probability of presence increases from greed to red.

Table 2. Threat analysis according to open standard methodology.

Threat Classification/ Definition	Explanation	Scope	Severity	Irreversibility	Rating
Residential and commercial development • Housing and urban areas • Tourism and recreation areas	Mediterranean marquis shrublands have been destroyed by fires and cut downs for the urbanization or agricultural purpose (Göçmen et al., 2011; Başkale et al., 2018, 2019).	High	Medium	Very High	**High**
Natural system modifications • Fire and fire suppression	Mediterranean marquis shrublands have been destroyed by fires and cut downs for the urbanization or agricultural purpose (Göçmen et al., 2011; Başkale et al., 2018, 2019).	High	High	High	**High**
Climate change and severe weather • Droughts • Temperature extremes	A widespread threat for the Lycian salamander as much as other species and has the highest pressure on the population (Hof et al., 2011; Rödder et al., 2011) and Current study results	Very High	High	Medium	**High**
Biological resource use - • Collecting animal for scientific purpose • pet source	According to the web search results pet trade (https://www.akvaryum.com/Forum) and scientific purpose literature (Başkale et al., 2019)	High	Medium	Medium	**Medium**

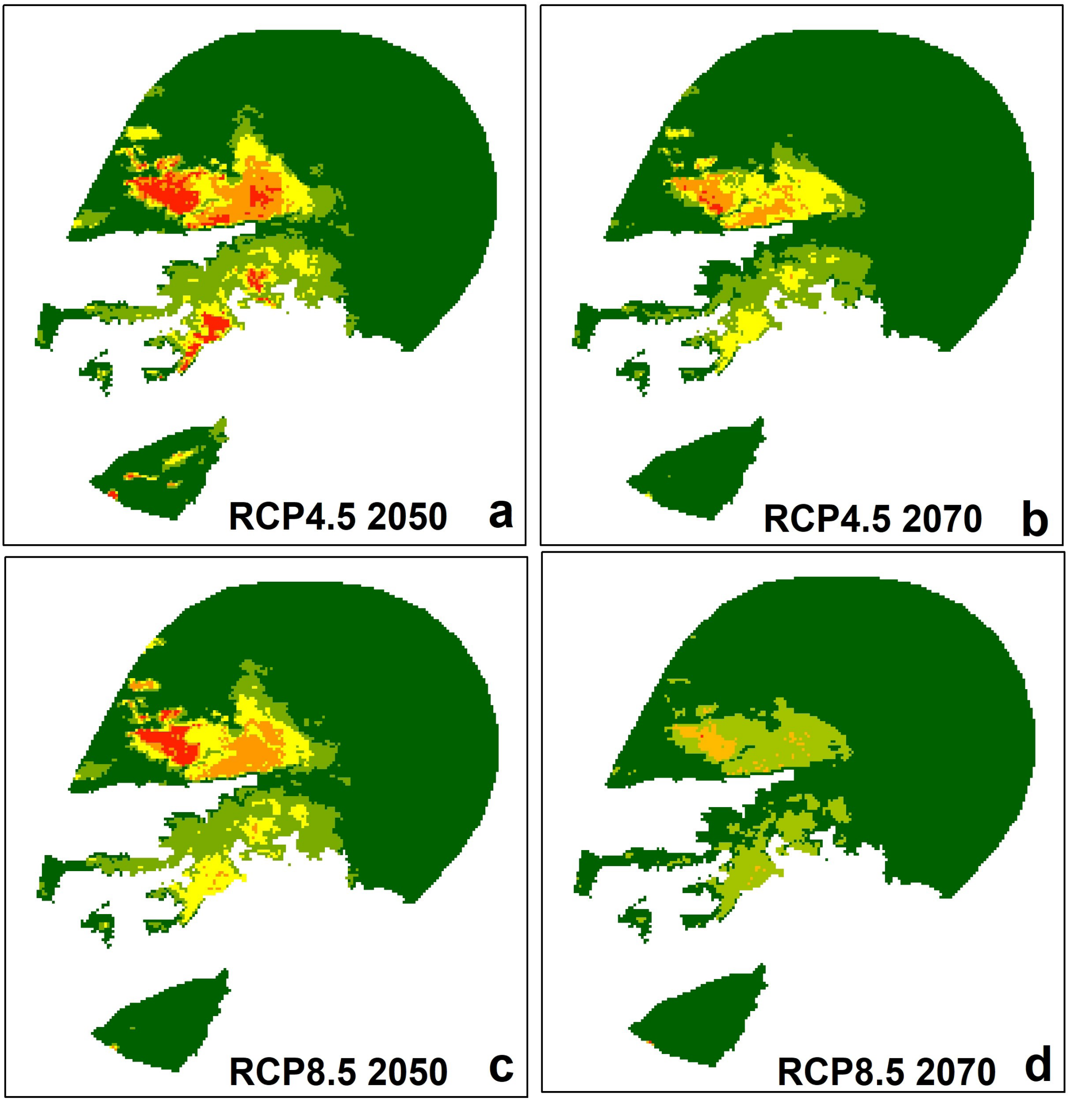

Figure 2. Future distribution projections (2050, 2070) of Marmaris salamander in Southwestern Anatolia, under two emissions scenarios. Probability of presence increases from green to red.

1999). Twenty-three per cent of amphibian species listed the IUCN Red List are Data Deficient: there is not enough information available to determine their threat status (Stuart et al., 2004).

Lycian salamanders play key roles in pine forest ecosystems in Mediterranean Turkey (reviewed by Veith et al., 2001; Sparreboom, 2014). Unfortunately, there is limited data on ecology of the group. The population size of *L. helverseni* was estimated as 5000 ind./ha in Kastellorizo, Greece (Papanayotou et al., 1997) and 10000 ind./ha by Veith et al. (2001) in Meis island (Greece). Two populations of *L. fazilae* have been studied, and their density was calculated as 21-44 ind./ha (Olgun, 2013) in Tersane island (Göcek/Muğla) and 8 ind./ha (Ildırşahin, 2019) in Türbelinaz (Alanya/Antalya).

There are only two studies on population densities of *L. flavimembris* (Dereağzı, 2016; Başkale et al., 2019). In these studies, population sizes were determined to be 5-13 ind./ha (Dereağzı, 2016) and 1-14 ind./ha

Table 3. Suggested conservation actions for the Marmaris salamander in Southwestern Anatolia (reviewed by Marmaris SAP) (Başkale et al., 2018).

Actions	Definition	Priority
A. Target Restoration / Stress Reduction Actions		
1. Land/water protection		
1.1 site/area protection	Enhancing viability/mitigating stress for the sites in terms of ecological management Biological control at a local scale.	Critical
1.2 Ecosystem & Natural Process (Re)Creation	Restoring severely degraded ecosystems, including ecosystem functions and processes, especially on a large scale	Critical
2. Species Management		
2.1 Species stewardship	Enhancing viability/mitigating stress for Lycian salamanders in terms of population management	Critical
2.2 Ex-Situ Conservation	Protecting the species by supporting captive breeding, with the aim of ultimately restoring them to their natural setting	Medium
B. Behavorial Change / Threat Reduction Actions		
3. Awareness Raising		
3.1 Outreach & Communications	Promoting desired awareness and/or emotions and subsequent behaviour change by providing information to target audiences through appropriate channels	Critical
3.2 Protests & Civil Disobedience	Promoting desired awareness and subsequent desired behaviour change by conducting protests, naming and shaming, civil disobedience, or sabotage activities	Critical
4. Law Enforcement & Prosecution		
4.1 Detection & Arrest	Detecting, directly stopping, and/or deterring violations of existing laws and policies	Critical
4.2 Criminal Prosecution & Conviction	Ensuring appropriate application of sanctions for violations of existing laws and policies	Important
5. Livelihood, Economic & Moral Incentives		
5.1 Linked Enterprises & Alternative Livelihoods	Developing enterprises that directly depend on the maintenance of natural resources or provide substitute livelihoods as a means of changing attitudes and behaviours	Important
5.2 Better Products & Management Practices	Developing, promoting and/or providing more environmentally friendly products or practices that substitute for environmentally damaging ones	Important
C. Enabling Condition Actions		
6. Conservation Designation & Planning		
6.1 Protected Area Designation &/or Acquisition	Legally or formally establishing or expanding public or private parks, reserves, and other protected areas roughly equivalent to IUCN Categories I-IV	Important
6.4 Conservation Planning	Planning for management of sites, species, or thematic conservation projects	Important

(Başkale et al., 2019). Başkale et al. (2019) reported the lowest population density in Taşlıca village and the maximum densities in Cennet island and Marmaris. We estimated the population size as 10–42 individuals per hectare, with a population size of 73–295 individuals per site. Despite the different methodologies used in these studies (Dereagzı, 2016; Başkale et al., 2019, and current study), they have all returned estimates of a similar magnitude.

Although our estimates overall are slightly higher than the previous studies, our estimate for Cennet island was approximately half that previously reported (Dereağzı, 2006, Başkale et al., 2019). Road construction has been carried out on Cennet island in 2019 and this could also negative effect on salamander populations. The sampling site of the Cennet island is destructed by construction and infrastructure activities.

Based on the current population distribution and literature reviews, we identified three major threats to Marmaris salamanders. The main threats to Marmaris salamander are land conversion, fires, and climate changes (Table 2). This species requires a unique and specific habitat/environment to survive. Parts of the Marmaris salamander habitat (natural pine forests and Mediterranean marquis) have been destroyed by fires or converted for urbanization or agriculture (Göçmen et al, 2011; Başkale et al., 2018, 2019).

Land-use changes by urbanization or agricultural activities are one of the major threats responsible for reducing the area of salamander habitats (Table 2). The most important conversion in the province of Muğla was in expanding agricultural lands and the urbanization since 2006 (Alp et al., 2015; Koca, 2015). In past two decades, the number of tourists in the region has increased in Marmaris which has important benefits for local people (Bostan et al., 2015). However, this increase in tourism is one of the most important drivers of increasing urbanization.

Forestry is a key factor affecting habitat quality of the terrestrial salamanders (Costa et al., 2014; Romano et al., 2018). Fires are one of the most important drivers in typical Mediterranean forest ecosystems. They have a positive impact on germination and/or seedling growth of the plant species in the region (Tavşanoğlu et al., 2017). However, intense fires are one of the most important threats to these sensitive ecosystems (FAO, Plan Bleu, 2018). Post fire recovery treatment experience in Mediterranean pine forests causes low plant variety composition and vegetation structure for example the results of plantation new pine seedlings at Marmaris (Ürker et al., 2018). Seventy per cent of the Mediterranean forests in Europe are generally poorly connected and fragmented due to fires or land use changes (Estreguil et al., 2013). In 2018, there were 299 fires observed and totally 150.66 ha of areas was burned in Muğla province (TCTOB, 2020). In 2017, 190 fires were observed, and 418.93 ha was burned in Muğla province (TCTOB, 2020).

Amphibians are extremely sensitive to small changes in their environment and need specific conditions, especially of temperature and moisture (Duellman and Trueb, 1994; Angilletta et al., 2002). Climatic changes can have a negative impact on breeding behaviour, affect reproductive success, and influence food availability (Carey and Alexander, 2003; Blaustein et al., 2010; Henle et al., 2010). Climate change is a one of the important threats for Lycian salamanders as much as other species and has the high effect on the population distribution (Hof et al., 2011; Rödder et al., 2011). According to our models, the southern populations of the species might disappear by 2050. Furthermore, the distribution of the species might be separated into two areas (Figure 2). It is also predicted that salamanders will lose most of their habitat by 2070 and the geographic distribution will greatly narrow.

The pet trade and overcollection for scientific purposes are two threats to Lycian salamanders which possibly have low effect on populations. The impact of these threats is probably limited compared to habitat loss and climate change. We observed that Marmaris salamanders were crushed to death on highways on rainy days during active periods and also reported by Başkale et al. (2018). Besides, the species were deliberately or accidentally killed by locals due to scared. Conversely, at some sampling sites (Bayır and Çiçekli villages), we saw that local people protect and respect the species because they consider it to be sacred.

Land use changes, a high number of fires, and climatic oscillation are threats not only Marmaris salamanders but also to other biodiversity in the Mediterranean region. To reduce the negative impact of these major threats, there is an urgent need for collaboration among all stakeholders. Suggested conservation actions for Marmaris salamanders are outlined in the species action plan, prepared in 2018 by Muğla National Parks (Başkale et al., 2018). We have planned some extra activities to protect the species (Table 3) and have started to implement some of them.

We suggest that the most important conservation activities for Marmaris salamander are (1) Site/area protection, i.e. controlling some key salamander habitats and not allowing any illegal activities; (2) Species Management, which will require long-term monitoring of the species, collaboration with all related stakeholders and increased law enforcement; and (3) Raising awareness, to improve locals knowledge about negative effects of their daily habits and land use (Table 3).

In conclusion, the population size, survival rate and structure of Marmaris salamanders are likely to vary depending on habitat quality and anthropogenic pressures. The species is mostly suffering from land use conversion, climate change, and forest fires. Its distributional range is very sensitive to these threats and is likely to shrink and/or fragment in the future. Future long-term studies should be planned by scientific communities, conservation agencies, and NGOs.

Acknowledgments: This project was funded for 2 years by Rufford Small Grants Foundation (Project Numbers: 27105-2 and 21425-1) and Akdeniz Koruma Derneği by support of the Directorate of Marmaris Branch of the 4th Regional Directorate of the Department of Nature Protection and National Parks of the Republic of Turkey. Also, we would like to thank Marmaris Municipality for logistical support and all volunteers who helped during the field work. We thank Nigel Taylor (Tour du Valat) and Ertuğrul Orbay Yazanlar for valuable comments and reviewing the English.

References

Ahmadi, M., Hemami, M.-R., Kaboli, M., Malekian, M., Zimmermann, N.E. (2019): Extinction risks of a Mediterranean neo-endemism complex of mountain vipers triggered by climate change. Scientific Reports **9**:6332.

Aiello-Lammens, M.E., Boria, R.A., Radosavljevic, A., Vilela, B., Anderson, R.P. (2015): spThin: A R package for spatial thinning of species occurrence records for use in ecological niche models. Ecography **38**:541–545.

Alford R.A., Richards, S.J. (1999): Global amphibian declines: a problem in applied ecology. Annual review of Ecology and Systematics **30**:133–165.

Alp, G., Algan, I.Y., Sertel, E. (2015): Determination of agricultural land changes in Muğla, Turkey using remotely sensed data and Corine methodology. Fourth International Conference on Agro-Geoinformatics (Agro-geoinformatics). IEEE, Istanbul, Turkey. p. 7–10

AmphibiaWeb. (2020): [Internet] <https://amphibiaweb.org> University of California, Berkeley, CA, USA. Accessed 9 Mar 2020.

Angilletta, M., Niewiarowski, P.H., Navas, C.A. (2002): The evolution of thermal physiology in ectotherms. Journal of Thermal Biology **27**: 249–268.

Arslan, D., Yaşar, Ç., Izgin, A., Şen, C., Çiçek, K. (2018): New sites of the endangered Marmaris Salamander, *Lyciasalamandra flavimembris* (Mutz and Steinfartz 1995) (Caudata: Salamandridae) from Muğla, Turkey. Amphibian & Reptile Conservation **12**:106–111.

Başkale, E., Sözbilen D., Özyılmaz, Y., Dilbe, Ö. (2019): Population Status and Threats against *Lyciasalamandra flavimembris* (Marmaris Lycian Salamander). Commagene Journal of Biology **3**: 37-43.

Başkale, E., Sözbilen, D., and Özyılmaz, Y. (2018): Marmaris Semenderi, *Lyciasalamandra flavimembris*, Tür Eylem Planı [National Species Action Plan for Marmaris Lycian Salamander, *Lyciasalamandra flavimembris*], Orman ve Su İşleri Bakanlığı, Ankara, Türkiye.

Başoğlu, M., Atatür, M.K. (1974): The subspecific division of the Lycian salamander, Mertensiella *luschani* (Steindachner) in Southwestern Anatolia. İstanbul Üniversitesi Fen Fakültesi Mecmuası Seri B **39**:147–155.

Beck, H.E., Zimmermann, N.E., McVicar, T.R., Vergopolan, N., Berg, A., Wood E.F. (2018): Present and future Köppen-Geiger climate classification maps at 1-km resolution. Scientific data **5**:180214.

Bishop, P.J., Angulo A., Lewis, J.P., Moore, R.D., Rabb, G.B., Moreno J.G. (2012): The Amphibian Extinction Crisis - what will it take to put the action into the Amphibian Conservation Action Plan? S.A.P.I.EN.S. Surveys and Perspectives Integrating Environment and Society, no 5.2.

Blaustein, A.R., Walls, S.C., Bancroft, B.A., Lawler, J.J., Searle, C.L., Gervasi, S.S. (2010): Direct and Indirect Effects of Climate Change on Amphibian Populations. Diversity **2**:281–313.

Boria, R.A., Olson, L.E., Goodman, S.M., Anderson, R.P. (2014): Spatial filtering to reduce sampling bias can improve the performance of ecological niche models. Ecological Modelling **275**:73–77.

Bostan, A., Zehra, Z., Akyurt Kurnaz, H. (2015): The Importance of Marmaris Tourism Industry on Development and the Causes That Influence the Russian Tourists Coming to Marmaris. p. 28–40 in. Chinese Business Review.

Burnham, K.P., Anderson, D.R. (2004): Multimodel inference: understanding AIC and BIC in model selection. Sociological Methods & Research **33**:261–304.

Burton, T.M., Likens, G.E. (1975): Salamander populations and biomass in the Hubbard Brook experimental forest, New Hampshire. Copeia **1975**: 541–546.

Carey, C., Alexander, M.A. (2003): Climate change and amphibian declines: is there a link? Diversity and Distributions **9**: 111-121.

Chanson, J., Hoffman, M., Cox, N., Stuart, S.N. (2008): The state of the world's amphibians. In: Stuart S.N., Hoffmann M., Chanson J.S., Cox N.A., Berridge R.J., Ramani P., Young B.E. (Eds.), Threatened Amphibians of the World, Lynx Edicions/ IUCN/Conservation International, Barcelona/Gland/Arlington, pp. 33–52.

Çiçek, K., Mermer, A., Tok, C.V. (2011): Population dynamics of *Rana macrocnemis* Boulenger, 1885 at Uludağ, Western Turkey. Zoology in the Middle East **53**:41–60.

Conservation Measures Partnership, (2020): The open standards for the practice of conservation. Available at https://cmp-openstandards.org/.21.01.2020.

Costa, A., Crovetto, F., and Salvidio, S. (2014): Assessing salamanders abundance and density with N-mixture model: preliminary results on a *Speleomantes strinatii* (Aellen, 1958) population. In: Atti X Congresso Nazionale Societas Herpetologica Italica, p. 57-62. 15-18 October 2014, Genova.

Dereağzı, E. (2016): Cennet Adası (Marmaris)'nda Yaşayan *Lyciasalamandra flavimembris* türünün populasyon yoğunluğunun saptanması. Unpublished Master Thesis, Ege University, Graduate School of Natural and Applied Science, Izmir, Turkey.

Dormann, C.F., Elith J., Bacher, S., Lautenbach, S. (2013): Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. Ecography **36**:27–46.

Duellman, W.E., Trueb, L. (1994): Biology of Amphibians. Johns Hopkins University Press.

Elith, J., Graham, C.H., Anderson, R.P., Zimmermann, N.E. (2006): Novel methods improve prediction of species' distributions from occurrence data. Ecography **29**: 129–151.

Estreguil, C., Caudullo, G., Miguel, J.S., Estreguil, C., Estreguil, C., Caudullo, G., Miguel, J.S. (2013): Connectivity of Natura 2000 forest sites- Executive report. European Commission Joint Research Centre Institute for Environment and Sustainability, Luxembourg.

FAO, Plan Bleu, (2018): State of Mediterranean Forests 2018. Food and Agriculture Organization of the United Nations, Rome and Plan Bleu, Marseil.

Fourcade, Y., Engler, J.O., Rödder D., Secondi J. (2014): Mapping species distributions with MAXENT using a geographically biased sample of presence data: a performance assessment of methods for correcting sampling bias. PLOS ONE **9**(5).

Göçmen, B., Akman, B. (2012): *Lyciasalamandra arikani* n. sp. & *L. yehudahi* n. sp. (Amphibia: Salamandridae), two new Lycian salamanders from Southwestern Anatolia. North-Western Journal of Zoology **8**: 181–194.

Göçmen, B., Karış. M. (2017): Comparative study on the endangered Marmaris Lycian salamander populations, *Lyciasalamandra flavimembris* (Mutz & Steinfartz, 1995) (Caudata: Salamandridae), with the description of several new localities. North-Western Journal of Zoology **13**:49–57.

Grant, E.H.C., Miller, D.A., Schmidt, B.R., Hossack, B.R. (2016): Quantitative evidence for the effects of multiple drivers on continental-scale amphibian declines. Scientific Reports **6**:25625.

Heikkinen, R.K., Luoto, M., Araújo, M.B., Virkkala, R., Thuiller, W., Sykes, M.T. (2006): Methods and uncertainties in bioclimatic envelope modelling under climate change. Progress in Physical Geography **30**:751–777.

Henle, M.K., Dick, M.D., Alex, M., Harpke, E., Kühn, M.I., and Schweiger, M.O. (2010): Climate change impacts on European amphibians and reptiles. Biodiversity and climate change. Strasbourg Cedex: Council of Europe Publishing p. 225–305.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., Jarvis, A. (2005): Very high-resolution interpolated climate surfaces for global land areas. International Journal of Climatology: A Journal of the Royal Meteorological Society **25**:1965–1978.

Hof, C., Araújo, M.B., Jetz, W., Rahbek, C. (2011). Additive threats from pathogens, climate and land-use change for global amphibian diversity. Nature, **480**:516–519.

Houlahan, J.E., Findlay, C.S., Schmidt, B.R., Meyer, A.H., Kuzmin, S.L. (2000): Quantitative evidence for global amphibian population declines. Nature **404**:752.

Ildırşahin, H. (2019): Türbelinaz'da (Alanya/Antalya) yaşayan Lyciasalamandra *atifi* (Başoğlu, 1967) (Urodela: Amphibia)'nin populasyon yoğunluğunun hesaplanması. Unpublished Master Thesis, Ege University, Graduate School of Natural and Applied Science, Izmir, Turkey.

Kaska, Y., Kumlutaş, Y., Avcı, A., Denoël, M. (2009): The IUCN Red List of Threatened Species. IUCN Red List of Threatened Species. Available at https://www.iucnredlist.org/en, 20.01.2020.

Koca, F. (2015): Muğla'da Kentsel Büyüme, Çeper-Kuşak Oluşumu ve Değişen Kent Formu. Türkiye Kentsel Morfoloji Sempozyumu/Temel Yaklaşımlar ve Teknikler Mersin University Publisher: 217–231.

Liu, C., Berry, P.M., Dawson, T.P., Pearson, R.G. (2005): Selecting thresholds of occurrence in the prediction of species distributions. Ecography **28**:385–393.

Merow, C., Smith, M.J., Silander, Jr J.A. (2013): A practical guide to MaxEnt for modeling species' distributions: what it does, and why inputs and settings matter. Ecography **36**:1058–1069.

Meyer, A.H., Schmidt, B.R., Grossenbacher, K. (1998). Analysis of three amphibian populations with quarter–century long time–series. Proceedings of the Royal Society of London. Series B: Biological Sciences, **265**: 523–528.

Muscarella, R., Galante, P.J., Soley-Guardia, M., Boria, R.A., Kass, J.M., Uriarte, M., Anderson, R.P. (2014): ENM eval: An R package for conducting spatially independent evaluations and estimating optimal model complexity for Maxent ecological niche models. Methods in Ecology and Evolution **5**:1198–1205.

Mutz, T., Steinfartz, S. (1995): *Mertensiella luschani flavimembris* ssp. n., eine neue Unterart des Lykischen Salamanders aus der Türkei (Caudata: Salamandridae). Salamandra **31**:137–148.

Olgun, M., (2013): Tersane Adasında (Göcek/Muğla) Yaşayan *Lyciasalamandra fazilae* (Başoğlu-Atatür 1974) (Urodela: Amphibia)'nin Populasyon Yoğunluğunun Hesaplanması. Unpublished Master Thesis, Ege University, Graduate School of Natural and Applied Science, Izmir, Turkey.

Öz, M., Düşen S., Tunç, M.R., Kumlutaş, Y., Durmuş, H., Kaska,Y. (2004): A morphological and taxonomical study on the subspecies of the Lycian salamander, *Mertensiella luschani*,(Steindachner, 1891)(Urodela: Salamandridae). Turkish Journal of Zoology **28**:237–244.

Papanayotou, K., Radea, K., Polymeni, R.M. (1997): Food habits and trophic availability of an insular population of *Mertensiella luschani* (Urodela) on the island of Kastellorizo (SE Aegean, Greece). in the 3rd World Congress in Herpetology, Prague.

Pearson, R.G., Raxworthy, C.J., Nakamura, M., Peterson, A.T. (2007): Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. Journal of Biogeography **34**:102–117.

Pechmann, J.H., Wilbur, H.M. (1994). Putting declining amphibian populations in perspective: natural fluctuations and human impacts. Herpetologica, **50**:65–84.

Phillips, S.J., Anderson, R.P., Schapire, R.E. (2006): Maximum entropy modeling of species geographic distributions. Ecological Modelling **190**:231–259.

Phillips, S.J., Dudík, M., Schapire, R.E., (2020): [Internet] Maxent software for modeling species niches and distributions (Version 3.4.1).

Rödder, D., Lötters, S., Öz, M., Bogaerts, S., Eleftherakos, K., Veith, M. (2011). A novel method to calculate climatic niche similarity among species with restricted ranges—the case of terrestrial Lycian salamanders. Organisms Diversity & Evolution **11**:409–423.

Romano, A., Costa, A., Salvidio, S., Menegon, M., Garollo, E., Tabarelli.de Fatis, K Miserocchi, D., Matteucci, G., Pedrini, P. (2018): Forest management and conservation of an elusive amphibian in the Alps: Habitat selection by the Golden Alpine Salamander reveals the importance of fine woody debris. Forest Ecology and Management **424**:338–344.

Schwarz, C.J., Arnason, A.N. (1996): A General Methodology for the Analysis of Capture-Recapture Experiments in Open Populations. Biometrics **52**:860–873.

Şenol, A. (2015): *Lyciasalamandra flavimembris* (Mutz and Steinfartz, 1995)'in (Amphibia: Urodela) taksonomik durumu. [The taxonomic status of *Lyciasalamandra flavimembris* (Mutz and Steinfartz, 1995) (Amphibia: Urodela)] Unpublished Master Thesis, Adnan Menderes University, Graduate School of Natural and Applied Science, Izmir, Turkey.

Shcheglovitova, M., Anderson, R.P. (2013): Estimating optimal complexity for ecological niche models: a jackknife approach for species with small sample sizes. Ecological Modelling **269**:9–17.

Smith, C.K., Petranka, J.W. (2000): Monitoring Terrestrial Salamanders: Repeatability and Validity of Area-Constrained Cover Object Searches. Journal of Herpetology **34**:547–557.

Sparreboom, M. (2014): Salamanders of the old world: the salamanders of Europe, Asia and northern Africa. Brill.

Stuart, S.N., Chanson, J.S., Cox, N.A., Young, B.E, Rodrigues, A.S.L., Fischman, D.L, Waller, R.W. (2004): Status and Trends of Amphibian Declines and Extinctions Worldwide. Science **306**:1783–1786.

Sodhi, N.S., Bickford, D., Diesmos, A.C., Lee, T.M., Koh, L.P., Brook, B.W., Bradshaw, C.J. (2008). Measuring the meltdown: drivers of global amphibian extinction and decline. PLOS ONE, **3**(2).

Tavşanoğlu, Ç., Ergan, G., Çatav Ş.S., Zare, G., Küçükakyüz, K., Özüdoğru, B. (2017): Multiple fire-related cues stimulate germination in *Chaenorhinum rubrifolium* (Plantaginaceae), a rare annual in the Mediterranean Basin. Seed Science Research **27**:26–38.

Turkish Meteorological Station [Meteoroloji Genel Müdürlüğü], (2018): Available at https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx. 20.01.2020

TCTOB., (2020): Türkiye Cumhuriyeti Tarım ve Orman Bakanlığı Resmi İstatistik Portalı Available at https://www.ogm.gov.tr/ekutuphane/Sayfalar/Istatistikler.aspx.

Ürker, O., Tavsanoglu, Ç., and Gürkan, B. (2018): Post-fire recovery of the plant community in *Pinus brutia* forests: active vs. indirect restoration techniques after salvage logging. iForest - Biogeosciences and Forestry **11**:635–642.

Üzüm, N., Avci, A., Bozkurt, E., and Olgun, K. (2015): A new subspecies of *Lyciasalamandra flavimembris* (Urodela: Salamandridae) from Muğla, southwestern Turkey. Turkish Journal of Zoology **39**:238–334.

Veith, M., Baran, İ., Godmann, O., Kiefer, A., Öz, M., and. Tunç, M.R. (2001): A revision of population designation and geographic distribution of the Lycian Salamander *Mertensiella luschani* (Steindachner, 1891). Zoology in the Middle East **22**:67–82.

Veith, M., Göçmen, B., Sotiropoulos, K., Kieren, S., Godmann O., and Steinfartz S. (2016): Seven at one blow: the origin of major lineages of the viviparous Lycian salamanders (Lyciasalamandra Veith and Steinfartz, 2004) was triggered by a single paleo-historic event. Amphibia-Reptilia **37**:373–387.

Vural, M., Duman, H., Güner, A., Dönmez, A.A., and Şağban, H. (1995): The vegetation of Köyceğiz-Dalyan (Muğla) specially protected area. The Turkish Journal of Botany **19**:431–476.

Wake, D.B., and Vredenburg, V.T. (2008): Are we in the midst of the sixth mass extinction? A view from the world of amphibians. Proceedings of the National Academy of Sciences **105**:11466–11473.

Walker, D.M., Murray, C.M., Talbert, D., Tinker, P., Graham, S.P., and Crowther T.W. (2018): A salamander's top down effect on fungal communities in a detritivore ecosystem. FEMS microbiology ecology **94**:168.

White, G.C., and Burnham K.P. (1999): Program MARK: survival estimation from populations of marked animals. Bird Study **46**: S120–S139.

Accepted by Yunke Wu