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New Localities Extend the Range of *Rana bedriagae caralitana* Arıkan, 1988 (Anura: Ranidae) Further West and Suggest Specific Status

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Abstract: Multivariate morphometric analyses revealed that the range of *Rana bedriagae caralitana* extends further west to include Çardak in Denizli (western Turkey). The presence of the forms *caralitana* and nominate *bedriagae* syntopically may indicate species status for the former.

Key Words: Ranidae, *Rana ridibunda*, *Rana bedriagae caralitana*, morphometry, systematics, distribution range, Turkey.

Yeni Kayıtlar *Rana bedriagae caralitana* Arıkan, 1988 (Anura: Ranidae) Yayılışını Batıda Genişletiyor ve Ayrı Tür Olduğuna İşaret Ediyor

Özet: Çokdeğişkenli morfometrik analizlere göre *Rana bedriagae caralitana*'nın yayılışı batıda Çardak-Denizli'yi (Ege Bölgesi) kapsayacak şekilde genişlemiştir. Aynı yörede *caralitana* ve nominat *bedriagae* formlarının bir arada kaydedilmeleri *caralitana*'nın ayrı bir tür olduğuna işaret edebilir.

Anahtar Sözcükler: Ranidae, *Rana ridibunda*, *Rana bedriagae caralitana*, morfometri, sistematik, yayılış, Türkiye.

Introduction

The water frogs in Turkey have been described as a homogenous group that belong to *Rana ridibunda* Pallas, 1771 by various authors (1-6), although Bodenheimer (2) earlier mentioned the presence of relatively large specimens with orange venters in Lake Beyşehir. Arıkan (7) found that specimens from Lake Beyşehir differ significantly from other populations in the pattern and coloration of their ventral side and he described them as a new subspecies, *Rana ridibunda caralitana*. Atatür et al. (8) found that in addition to Lake Beyşehir, the range of this taxon extended to Lake Eğirdir, Lake Suğla and Çarşamba creek (Konya). Arıkan et al. (9) investigated water frogs from Gölcük (Isparta) and Hotamış lakes morphologically and found that these frogs are *R. r. caralitana*. Arıkan et al. (10) stated that İvriz (Ereğli/Konya) populations also belong to this form.

Finally, Budak et al. (11) reported the presence of the form *caralitana* at Işıklı Lake in Çivril (Denizli).

Water frogs of southwestern Asia (including western Turkey) were named *Rana levantina* Schneider, Sinch & Nevo, 1992 after analyses of their mating call structure (12, 13). Following Beerli (14) and Dubois & Ohler (15), this name was replaced with *Rana bedriagae* Camerano, 1882, which was available, and hence according to the rule of priority, it should be used instead of the former. Beerli (14) and Jdeidi et al. (16) showed that Anatolian frogs have different allozyme markers than those in the Balkans. They also have distinct vocalizations (17, 18) and mitochondrial DNA markers (19) when compared with *R. ridibunda* from the type locality or from the Balkans. Berger (20) found that F1 or B1 generations in *bedriagae* x *ridibunda* or *bedriagae* x *kurtmuelleri* crosses were infertile or had developmental abnormalities.

Therefore, water frogs in Asian Turkey (including the subspecies *caralitana*) are now accepted to be *R. bedriagae* (17, 18).

In this study, we present results based on analysis of the morphological characters of specimens collected from Denizli to Konya and compare them with those from the surrounding localities.

Materials and Methods

Fifty-two adult specimens were collected from Beyşehir, Ereğli, Isparta, Akşehir, Çardak and Çivril (all actual or potential sites for the form *caralitana*) during 1997-1999 (Figure 1). Additionally, 134 adult specimens were collected from Ankara, Adana, Antalya, Bodrum and Manyas (all with nominate subspecies) within the same period. Collected specimens were transported alive to the Biology Department at Middle East Technical University and their morphometric and descriptive parameters were measured and recorded. Measured parameters are given below:

- 1- Body length (length from tip of snout to dorsal edge of vent).
- 2- Head width between eardrum (minimal width of head between eardrums).

3- Head width between eyes (width of head between the front side of the eyes).

4- Length of head (from medium point between forelegs to tip of snout).

5- Femur length (from center of anus to the knee).

6- Tibia length (from convex surface of knee to convex surface of heel).

7- Foot length (from convex surface of heel to the tip of longest toe).

8- First toe length (from tip of inner toe to distal basal end of inner metatarsal tubercle).

9- Tubercle length (from distal to proximal basal edge of inner metatarsal tubercle).

10- Nostril-eye distance (from the nostril to the anterior edge of eye).

11- Dorsal color (coded as 1=brown with dark spots, 2=dark with black spots, 3=green with dark spots, 4=brown green with dark spots, 5=brown without spots, 6=green with white spots).

12- Ventral color (coded as 1=white without spots, 2=white with black spots, 3=white with yellowish orange color).

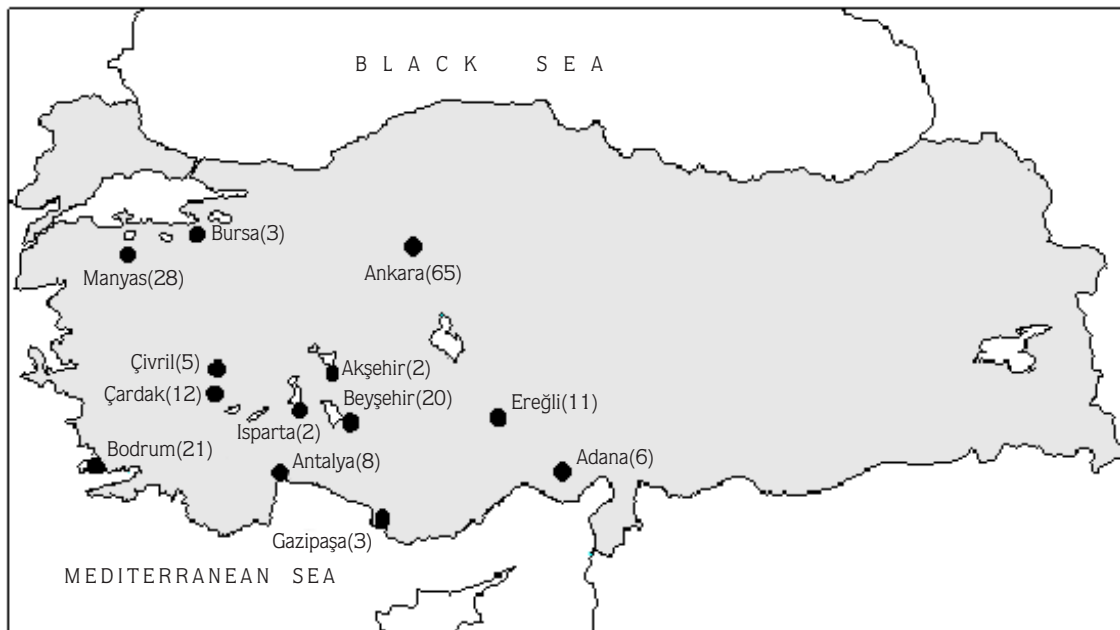


Figure 1. Map of Turkey showing the localities and number of frogs sampled.

13- Dorsal stripe (coded as 0=dorsal stripe absent, 1= dorsal stripe present).

Specimens collected from all localities were included in principal component (PCA) and discriminant function (DFA) analyses to reveal underlying variations and to classify individuals. However, in the rare case of only one individual being present in a group (i.e., locality) for DFA, then this locality was not included in the analysis. Multivariate analyses were carried out with the software packages SYN-TAX (21) and NT-SYS (22).

Results

The average values, range and standard deviations for all the variables measured are given in Tables 1 and 2. Frogs collected from the Lakes District are larger and the ventral side of the body including the underside of the head and the extremities is characterized by the presence of large yellowish orange spots. In all the populations the dorsal color is variable, with most frogs being basically light or dark brown or green with scattered irregularly sized dark spots. Except for the dorsal color, all the variables measured are significantly different ($p < 0.01$) between the two forms.

Principal component analysis was carried out only on metric variables and it revealed two axes (Table 3). The first axis has positive high loadings for most variables, and hence probably reflects overall size. The second axis has high loadings on the variables "first toe" and "tubercle length" only, indicating different body proportions among the populations.

Table 1. Descriptive Statistics (males, n= 76)

| Character | Mean & Std. Error | Minimum | Maximum |
|-----------------------|-------------------|---------|---------|
| Body length | 8.16 ± 0.16 | 5.00 | 11.00 |
| Head wid. bt. eardrum | 2.18 ± 0.05 | 1.30 | 4.20 |
| Head width bet. eyes | 1.19 ± 0.02 | 0.70 | 1.65 |
| Head length | 3.35 ± 0.07 | 2.30 | 4.80 |
| Femur length | 4.13 ± 0.09 | 1.75 | 5.80 |
| Tibia length | 4.21 ± 0.08 | 2.70 | 5.40 |
| Foot length | 6.24 ± 0.13 | 4.00 | 8.50 |
| First toe length | 1.26 ± 0.04 | 0.65 | 2.10 |
| Tubercul length | 0.49 ± 0.01 | 0.25 | 0.75 |
| Nostril-eye dst. | 0.63 ± 0.02 | 0.20 | 0.92 |
| Dorsal color | 1.50 ± 0.09 | 1.00 | 4.00 |
| Ventral color | 1.89 ± 0.09 | 1.00 | 3.00 |
| Dorsal stripe | 0.42 ± 0.06 | 0.00 | 1.00 |

Table 2. Descriptive Statistics (females, n=108)

| Character | Mean & Std. Error | Minimum | Maximum |
|-----------------------|-------------------|---------|---------|
| Body length | 8.90 ± 0.15 | 4.80 | 11.90 |
| Head wid. bt. eardrum | 2.34 ± 0.04 | 1.20 | 3.20 |
| Head width bet. eyes | 1.27 ± 0.02 | 0.70 | 1.80 |
| Head length | 3.51 ± 0.05 | 1.90 | 5.00 |
| Femur length | 4.54 ± 0.07 | 2.40 | 7.50 |
| Tibia length | 4.60 ± 0.06 | 2.40 | 6.00 |
| Foot length | 6.70 ± 0.10 | 3.80 | 9.60 |
| First toe length | 1.34 ± 0.03 | 0.80 | 2.00 |
| Tubercul length | 0.52 ± 0.01 | 0.20 | 0.75 |
| Nostril-eye dst. | 0.67 ± 0.11 | 0.30 | 0.92 |
| Dorsal color | 1.74 ± 0.07 | 1.00 | 7.00 |
| Ventral color | 1.90 ± 0.07 | 1.00 | 3.00 |
| Dorsal stripe | 0.42 ± 0.05 | 0.00 | 1.00 |

Table 3. Factor Loadings (Varimax normalized)

| Character | Factor 1 | Factor 2 |
|-----------------------|----------|----------|
| Body length | 0.867 | 0.423 |
| Head wid. bt. eardrum | 0.848 | 0.353 |
| Head width bet. eyes | 0.759 | 0.527 |
| Head length | 0.832 | 0.451 |
| Femur length | 0.853 | 0.415 |
| Tibia length | 0.874 | 0.386 |
| Foot length | 0.829 | 0.500 |
| First toe length | 0.332 | 0.871 |
| Tubercul length | 0.429 | 0.812 |
| Nostril-eye dst. | 0.555 | 0.665 |
| Expl. Var | 5.521 | 3.217 |
| Prp. Totl | 0.552 | 0.322 |

Discriminant function analysis of these two groups (made up of both sexes) by stepwise forward regression resulted in high rates of correct classification (Table 4). The only exceptions to correct classifications were two individuals from Çardak and one individual from Akşehir, which were classified within the non-Lakes District group. Visual comparison of discriminant function scores for the two groups showed good separation (Figure 2). The only significant overlap involved the three individuals mentioned above. Standardized coefficients give the magnitudes and directions of the (unique) contributions of the variables to the only canonical root obtained. The most discriminating variables were foot and tibia lengths, followed by ventral color, head length and total body size (Table 5). Further discriminant function analysis of the

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Table 4. Classification Matrix (Rows: Observed classifications, Columns: Predicted classifications)

| | % correct | "bedriagae" | "caralitana" |
|----------------|-----------|-------------|--------------|
| Non L-District | 100 | 133 | 0 |
| Lakes District | 94 | 3 | 48 |
| Total | 97 | 136 | 48 |

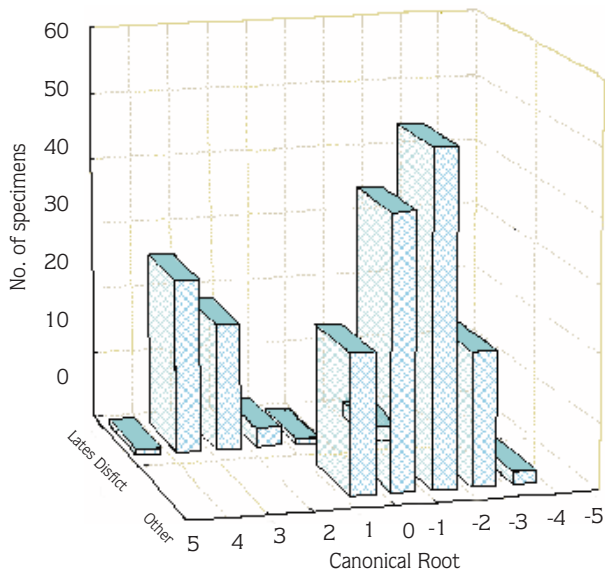


Figure 2. Distribution of discriminant function scores for the Lakes District and non-Lakes District specimens.

Table 5. Standardized Coefficients for Canonical Variables

| Character | Coefficient |
|---------------------|-------------|
| Ventral color | 0.545 |
| Foot length | 1.01147 |
| Tibia | -1.70416 |
| Tubercule length | 0.27175 |
| Dorsal stripe | 0.27244 |
| Head length | 0.49775 |
| H.width b. eardrums | 0.35601 |
| First toe length | 0.23734 |
| Body length | -0.47786 |
| Dorsal color | 0.14985 |
| Femur length | 0.27121 |
| Eigenval | 3.15440 |
| Cum. Prop | 1.00000 |

groups separately for each sex also revealed good separations (Figures 3 and 4). For females, there were slight overlaps among Çardak (and Beyşehir) populations on the one hand, and Antalya and Bodrum populations on the other. For males, there was only a very slight overlap between Çardak and Antalya populations.

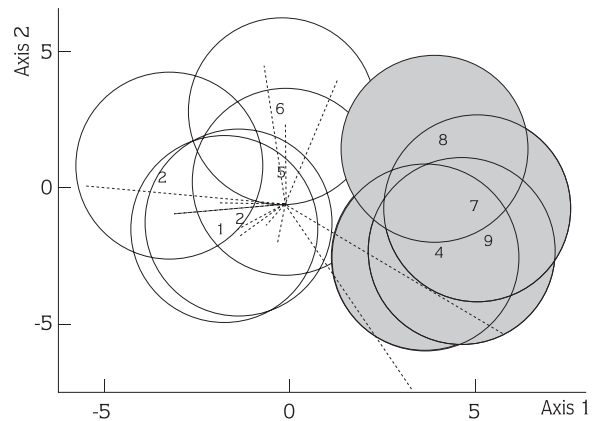


Figure 3. Discriminant function analysis results for female frogs. Circles represent 95% isodensity limits around each centroid (1: Ankara, 2: Adana, 3: Manyas, 4: Beyşehir, 5: Antalya, 6: Bodrum, 7: Ereğli, 8: Çardak, 9: Çivril. Darker circles are Lakes District populations)

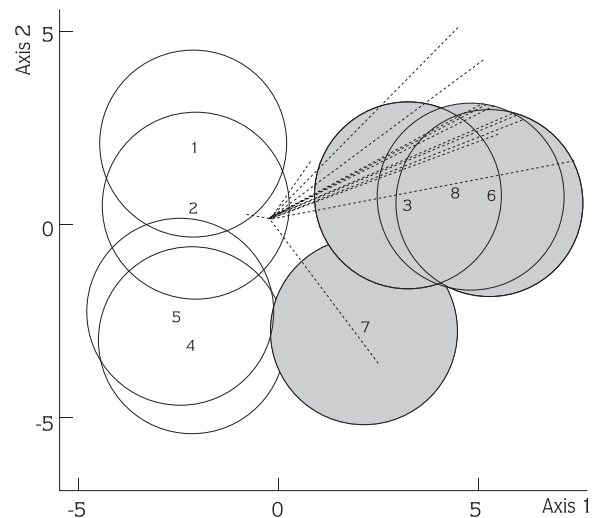


Figure 4. Discriminant function analysis results for male frogs. Circles represent 95% isodensity limits around each centroid (1: Ankara, 2: Manyas, 3: Beyşehir, 4: Antalya, 5: Bodrum, 6: Ereğli, 7: Çardak, 8: Çivril. Darker circles are Lakes District populations).

Discussion and Conclusions

The limits of the range of *caralitana* have steadily expanded from Lake Beyşehir, its type locality, west to Çivril and east to eastern Konya Plain (8-11). This study confirms the presence of *caralitana* in those areas using methods that were not applied to these populations before, and increases the range boundaries further west to Çardak in Denizli province. Morphologically, all specimens from Çivril and the majority of specimens from Çardak are classified as *caralitana*. The presence of an orange venter, distinct morphometrics, and correct classification by discriminant function analysis all support this conclusion. In discriminant function analyses, all Lakes District specimens (including Konya and Denizli) cluster together and are clearly separated from specimens from other localities. The only exceptions are three individuals (two from Çardak and one from Akşehir), which are classified as the nominate form. Two of these individuals had whitish venters and all had typical *bedriagae* proportions. The slight overlap observed between Çardak populations and Antalya (and Bodrum) populations may stem from these individuals, which we classify as the form *bedriagae*.

Çardak is thought to be at the edge of the range of this taxon. On the other hand, Çivril (just next to Büyük Menderes river and with a population of pure *caralitana*) is inside the range boundaries as also reported by Budak et al. (11). Therefore, more intensive sampling from a larger area is needed to find the exact distribution of this form.

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The validity of the taxon *caralitana* was not generally accepted at first and was questioned until very recently (23, 17). The main criticism was that the coloration of the ventral surface is a common polymorphism in amphibians and that the description of a new subspecies cannot be based only upon that character. However, the form *caralitana* has been shown to be morphologically, karyologically, genetically and bioacoustically different from the nominate form (18, 19, 24). Anıkan et al. (9) had previously suggested that the Sultan Mountains form a natural barrier for the form *caralitana*. Our two specimens from Lake Akşehir, just northeast of this barrier, were intermediate in ventral color. However, following discriminant function analysis (both with all characters and with only metric characters), one specimen was consistently classified as "*caralitana*" and the other as nominate "*bedriagae*". Similarly, in Çardak, individuals resembling the nominate form existed syntopically with typical *caralitana*. This situation may be interpreted as evidence for the non-mixing of these forms, and may indicate separate species status for *caralitana*.

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