

Age Structure and Growth Characteristics of the Endemic Fish *Oxynoemacheilus anatolicus* (Nemacheilidae) in Düğer Creek, Mediterranean region of Turkey

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ABSTRACT

The present study reports the age and growth properties of Burdur Loach, *Oxynoemacheilus anatolicus* Erk'akan, Özeren & Nalbant, 2008 caught from the Düğer Spring Creek (Burdur-Turkey) and is currently listed as an endangered species. 100 specimens of *O. anatolicus*, which ranged in size between 2.5 and 8.6 cm in total length, 0.14 and 5.90 g in total weight, were collected during the study period. Of all the *O. anatolicus* examined, 5 were immature, 50 were female, and 45 were male. The overall sex ratio in the populations matches the expected value of 1:1 in a normal population. The otolith readings indicated the presence of five age classes (I-V). Length–weight relationships were fitted by the equation $W = 0.0082L^{3.0402}$ ($p < 0.05$) for both sexes combined and this indicated that growth was positive allometric. The condition factor values were calculated and ranged from 0.64 to 1.19. The obtained data was compared with available results from close species. This study provided first baseline data related to length-weight relationship, age, sex ratio and condition factor for *O. anatolicus* – a species whose populations have been threatened due to various ecological changes in its habitats, leading to increased concern and the need for conservation.

Keywords: Freshwater, Endemic, Burdur Loach, Karstic spring

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INTRODUCTION

Anatolia is characterized by high levels of biodiversity and a high density of endemic species, its geological history has played a key role in the diversification of freshwater fish species (Demirsoy, 2002; Kuru, Yerli, Mangit, Ünlü, & Alp, 2014; Çiçek, Sungur Birecikligil, & Fricke, 2015; Çiçek, Fricke, Sungur, & Eagderi, 2018). The loach genus *Oxynoemacheilus* has undergone major diversification in Anatolia, where more than 30 species have been reported (Froese and Pauly, 2019).

Members of the genus *Oxynoemacheilus*, commonly known as stone loaches, are small fish living in the fresh waters of Asia and its islands,

Europe, and northeast Africa. They inhabit a variety of water bodies ranging from mountain streams to salty rivers in dry lowlands (Jouladeh-Roudbar, Eagderi, & Hosseinpour, 2016). Most of them are very rare and have a limited distribution area. Despite the high diversity and endemism of *Oxynoemacheilus* genus in Turkey, knowledge about its biology and population dynamics are still limited. Most of the available studies have focused mainly on length-weight relationships (Gaygusuz et al., 2012; Erk'akan, İnnal, & Özdemir, 2013, 2014; İnnal, Özdemir, & Dogangil, 2015; Birecikligil, Çiçek, Öztürk, Seçer, & Celepoğlu, 2016; Özcan & Altun, 2016; Yazıcıoğlu & Yazıcı, 2016).

The Burdur Endorheic Basin has a great diversity of natural ecosystems including wetlands, warm and hot springs, and saline and freshwater lakes. Because of the introduction of alien or translocated fish species and building of dams for agricultural purposes, many endemic fishes have become rare and endangered here (Küçük, Gülle, Innal, & Güçlü, 2016; personal observation, Deniz Innal). The Burdur Endorheic basin provides an essential spawning and rearing habitat for many loach species, including the Burdur loach (Küçük et al., 2016). Burdur loach has been reported at input locations in Karamanlı Dam Lake (Erk'akan, Özeren, & Nalbant, 2008), Başpınar Creek (Küçük et al., 2016), Düğer Spring (Freyhof, Erk'akan, Özeren & Perdices, 2011; Innal et al., 2017) and Pınarbaşı Creek (Innal & Giannetto, 2017).

While the subject's populations have been threatened due to various ecological changes in its habitats, leading to increased concern and the need for conservation, there is not sufficient information available about its biological features. This study provided first baseline data related to length-weight relationship, age, sex ratio and condition factor for *O. anatolicus*.

MATERIALS AND METHODS

The study was carried out in Düğer Creek between March 2014 and December 2014 (6 sampling events). Düğer Creek is a small, karst system in the southwest of Turkey, situated in the Düğer Village (37°34'31.53"N 30°01'13.64"E-37°34'37.04" N 30°01'28.38"E) close to the city of Burdur (Burdur Endorheic Basin). Water quality parameters were measured at the surface at the start of each field trip. Temperature (°C), salinity, pH and dissolved oxygen (mg/l) concentration were measured using a YSI water meter (Professional Plus). A total of 100 *O. anatolicus* specimens were collected using electroshock equipment.

After being caught, the fish samples were transported to the laboratory where their size (total length; cm, referred to as L in the text and weight; g, referred to as W in the text) were measured and weighed to the nearest 1.0 mm and 0.01 g, respectively. The otoliths of individuals were used for age determination (The roman numerals indicate a subjective classification of ages). Length-weight relationships were estimated for the total sample and separated by sex, according to the equations suggested by Ricker (1975), $W=aL^b$. Where W = mass in grams; L = total length in centimeters. a=constant; b=constant described as isometric or allometric growth type. The value of Condition factor, K was calculated following Froese (2006), $K = 100 * W/ L^3$. The slopes of length-weight regressions were compared to 3 using Student's t-test to ascertain if the species grew isometrically. Size-frequency distributions between sexes were conducted using the t-test and Kolmogorov-Smirnov two-sample test. A Chi-square test was used to identify the sex-ratio divergence from the expected value of 1:1 (male:female).

RESULTS AND DISCUSSION

Düğer Creek is a natural karst spring system leading to Lake Burdur. The bottom is generally muddy or made up of small gravel. A range of water quality parameters of Düğer Creek were measured (Figure 1).

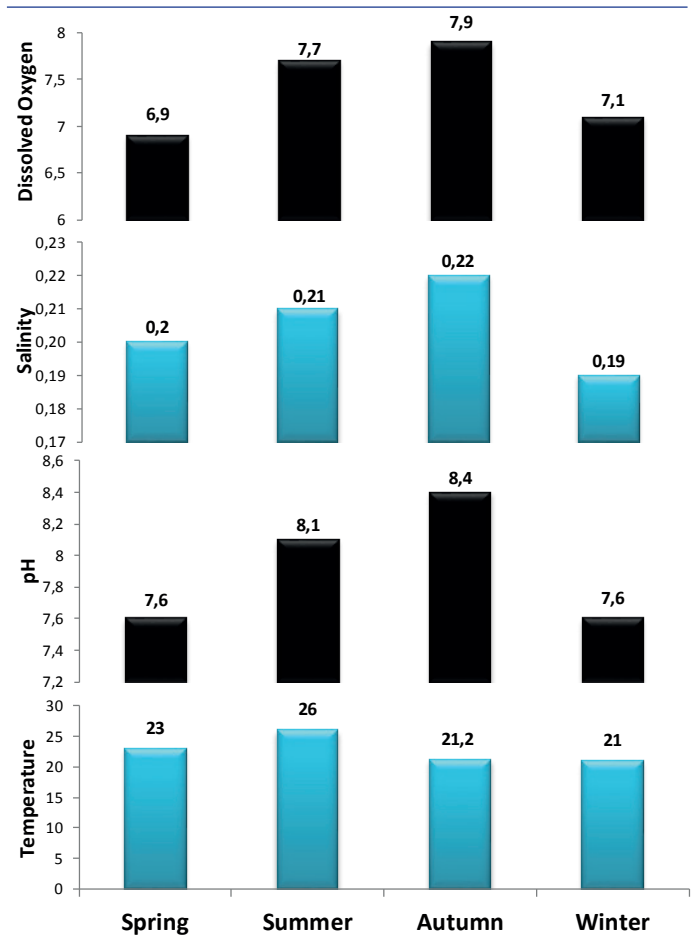


Figure 1. Water quality parameters of Düğer Creek.

O. anatolicus was observed in slow-flowing waters where the vegetation zone was dense. *Pseudophoxinus burduricus*, *Gambusia holbrooki*, *Oxyngoemacheilus theophilii* and *Oxyngoemacheilus anatolicus* were reported from Düğer Spring (Innal et al., 2015; Innal et al., 2017). Within the sample area, bottom salinity ranged from 0.19–0.22 ppt, surface temperature ranged from 21°C–26°C, pH ranged from 7.6–8.4 and dissolved oxygen (mg/L) ranged from 6.9–7.9. This species is well adapted to the warm-water spring zone of Düğer Creek.

Although a high species diversity of Genus *Oxyngoemacheilus* exists in Turkey, little is known about their life history. The ecology of *O. anatolicus* has been reported in aquatic systems in terms of systematics (Erk'akan et al., 2008), distribution (Freyhof et al., 2011; Küçük et al., 2016; Innal & Giannetto, 2017) and parasites (Innal et al., 2017). This work, however, is the first study on age and growth for Burdur Loach in Turkey, so no comparison is possible with other studies of this species.

The sex and age compositions of *O. anatolicus* are shown in Table 1.

The 100 individuals of *O. anatolicus* used for the age determination consisted of 45 (45%) males, 50 females (50%) and 5 (5%) juveniles. The female–male ratio for all fish combined was 1.11:1

Table 1. The sex and age compositions of *O. anaticus*

Age	Juvenile		Female		Male		Total	
	N	%	N	%	N	%	N	%
I	5	5	2	2	3	3	10	10
II			21	21	29	29	50	50
III			11	11	7	7	18	18
IV			15	15	4	4	19	19
V			1	1	2	2	3	3
Total	5	5	50	50	45	45	100	100

Table 2. Length frequency distribution of *O. anaticus*

Length intervals (cm)	Age groups (in years)					Total
	I	II	III	IV	V	
2-2.9	3					3
3-3.9	7	13				20
4-4.9		20				20
5-5.9		17	6			23
6-6.9			12	3		15
7-7.9				16		16
8-8.9					3	3
Total	10	50	18	19	3	100
Range TL	2.50 - 3.40	3.20 - 5.60	5.20 - 6.80	6.20 - 7.90	8.40 - 8.60	2.5 - 8.6
Mean TL±SD	2.98 ± 0.25	4.49 ± 0.64	6.01 ± 0.48	7.24 ± 0.48	8.47 ± 0.12	5.26 ± 1.55
Range W	0.14 - 0.31	0.29 - 1.53	1.07 - 3.11	2.02 - 5.31	5.45 - 5.90	0.14 - 5.90
Mean W±SD	0.23 ± 0.06	0.86 ± 0.37	1.94 ± 0.55	3.36 ± 0.81	5.65 ± 0.23	1.61 ± 1.40

Table 3. Estimated length weight parameters of *Oxynoemacheilus* species

Species	Locality	b	a	r ²	TL(Min-Max)	W(Min-Max)	N	Reference
<i>O. mesudae</i>	Küfe Creek	2.628	0.0161	0.95	6.6 - 8.9	2.2 - 5.2	14	Erk'akan et al., 2014
<i>O. evreni</i>	Çayır Creek	2.788	0.0128	0.92	5.4 - 9.4	1.4 - 6.7	27	Erk'akan et al., 2014
<i>O. theophilii</i>	Bozçay Creek	2.898	0.01	0.94	3.1-5.6	0.25-1.18	10	Innal et al., 2015
<i>O. samanticus</i>	Karaboğaz Creek	2.919	0.00851	0.92	4.5 - 8.6	0.6 - 4.3	40	Erk'akan et al., 2014
<i>O. angorae</i>	Kılıçözü Stream	2.929	0.0098	0.96	3.5-9.8	0.38-6.58	103	Yazıcıoğlu & Yazıcı, 2016
<i>O. theophilii</i>	Dalaman Stream	2.989	0.011	0.93	6.4-7.9	2.51-4.88	10	Innal et al., 2015
<i>O. anaticus</i>	Düğer Creek	3.04	0.0082	0.98	2.5-8.6	0.14-5.90	100	PRESENT STUDY
<i>O. theophilii</i>	Cüneyt Creek	3.07	0.007	0.96	6.6-10.5	2.3-11	17	Innal et al., 2015
<i>O. angorae</i>	Kızılırmak River Basin	3.102	0.008	0.94	2.8-8.6	0.22-6.18	127	Birecikligil et al., 2016
<i>O. theophilii</i>	Düğer Spring	3.188	0.007	0.94	3.9-5.8	0.56-2.09	13	Innal et al., 2015
<i>O. eregliensis</i>	Melendiz Creek	3.196	0.005	0.98	1.65-10.3	0.1-7.3	76	Erk'akan et al., 2013
<i>O. angorae</i>	Sögütözü Beynam	3.228	0.00622	0.99	4.4 - 8.3	0.8 - 6.6	24	Erk'akan et al., 2014
<i>O. angorae</i>	Balıkli Stream	3.237	0.006	0.88	4.7-7.3	0.86-3.56	30	Gaygusuz et al., 2012
<i>O. simavicus</i>	Karaçaltı Creek	3.261	0.0044	0.95	4.6-7.1	0.6-2.5	17	Erk'akan et al., 2014
<i>O. theophilii</i>	Yiğitler Creek	3.293	0.004	0.98	5.5-8.9	1.1-5.4	9	Innal et al., 2015
<i>O. hamwii</i>	Gölbaşı Lake	3.52	0.0021	0.96	5.0-8.8	0.6-3.65	28	Özcan and Altun, 2016

and Chi square test analysis conducted on sex ratio showed that the difference was not statistically significant ($P > 0.05$). The ages of the captured specimens ranged from I to V years and the second group was dominant in the population, followed by age IV (19%), III (18%), I (10%), and V (3%) age groups.

Females were caught in higher numbers in this study. A higher proportion of females has also been reported for other members of the Nemacheilidae family, for species such as 1.0/0.63 (f/m) for *O. angorae* in Kılıçözü Stream (Yazıcıoğlu & Yazıcı, 2016). 1/0.81 (f/m) for *O. tigris* from Murat River (Koyun, Ulupınar, Mart, & Tepe, 2016).

Length frequency distribution of *O. anatolicus* is given in Table 2

The specimens of *O. anatolicus* ranged from 2.5 to 8.6 cm in total length and from 0.14 to 5.9 g in total weight. Total length ranged from 3.1 to 8.4 cm in males, from 3.1 to 8.6 cm in females and from 2.5 to 3 cm in juveniles. Weight ranged from 0.208 to 5.9 g in males, from 0.203 to 5.6 g in females and from 0.14 to 0.285 g in juveniles. The mean total length and weight of females were higher than males. No significant difference was observed in mean length and weight between sexes ($P > 0.05$).

The total length of *O. anatolicus* ranged from 2.5 to 8.6 cm, which fits well within the known values (Table 3) while the minimum length observed in this study was close to the value reported for *Oxynoemacheilus angorae* from the Kızılırmak River Basin (Birekcikliğil et al., 2016). The maximum length was closer to known reported values for some species; *Oxynoemacheilus angorae* from the Kızılırmak River Basin (Birekcikliğil et al., 2016) and Sögütözü Beynam (Erk'akan et al., 2014), for *Oxynoemacheilus hamwii* from Gölbaşı Lake (Özcan & Altun, 2016), for *Oxynoemacheilus mesudae* from Küfe Creek (Erk'akan et al., 2014), for *Oxynoemacheilus samanticus* from Karaboğaz Creek (Erk'akan et al., 2014), for *Oxynoemacheilus theophilii* from Yiğitler Creek (Innal et al., 2015). In population structure, female individuals of *O. anatolicus* showed wider length range, mean length and weight than males.

Length and weight frequency distributions and length-weight relationships $W = aTL^b$ (in g and cm) for *O. anatolicus* from Düğer Creek are given in Figure 2.

Among all the individuals, dominance was in the total length range of 3-6 cm and dominance was in the weight range of 0.14-2 g (Figure 2). The length frequency distributions of males and females were not significantly different. Length-weight relationships were calculated using the data of 100 *O. anatolicus* specimens. This was found to be $W = 0.0082L^{3.0402}$ ($R^2 = 0.98$) ($p < 0.05$; 95% CI of b: 3.022-3.054) for all individuals. The calculated value of (b) exponent for female, male and combined sexes was 3.0286 ($p < 0.05$), 3.0498 ($p < 0.05$) and 3.0402 ($p < 0.05$), respectively. These values indicate that the fish had positive allometric growth. "b" values of *O. anatolicus* were not significantly different between the sexes. The regression models in the study showed no differences in terms of growth patterns between males and females of *O. anatolicus*. The r value of 0.98 indicates a high correlation degree of length and weight.

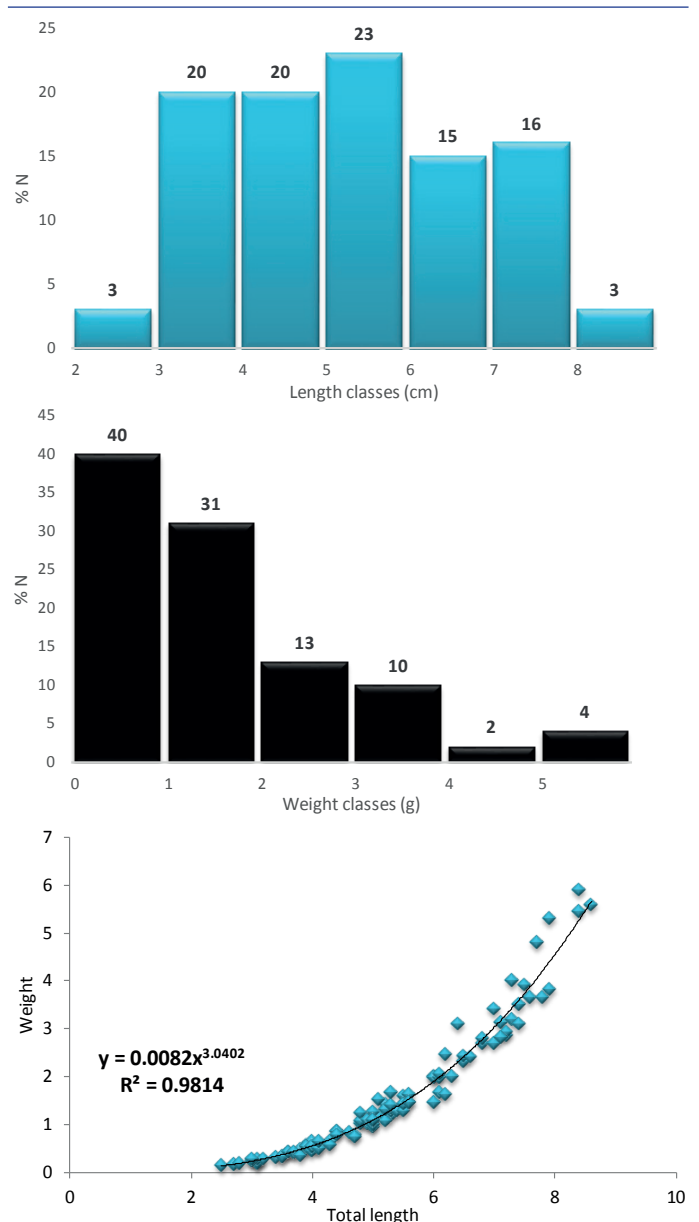


Figure 2. Length and weight frequency distributions and length-weight relationships for *O. anatolicus* from Düğer Creek.

Length-weight relationship (LWR) parameters have basic uses in fish stock assessment and fisheries management (Froese, 2006). This paper provides the first published reference of the length-weight for *O. anatolicus*. Relationships between length and weight for species of *Oxynoemacheilus* genus have been described by several authors, and both isometric and allometric growth from various water bodies have been reported for species of *Oxynoemacheilus* genus (Table 3). The b value of *Oxynoemacheilus* species in Turkey has been shown to range from 2.63 to 3.52 (Table 3).

Allometric growth of *Oxynoemacheilus* genus determined in this study was in accordance with results reported in earlier studies

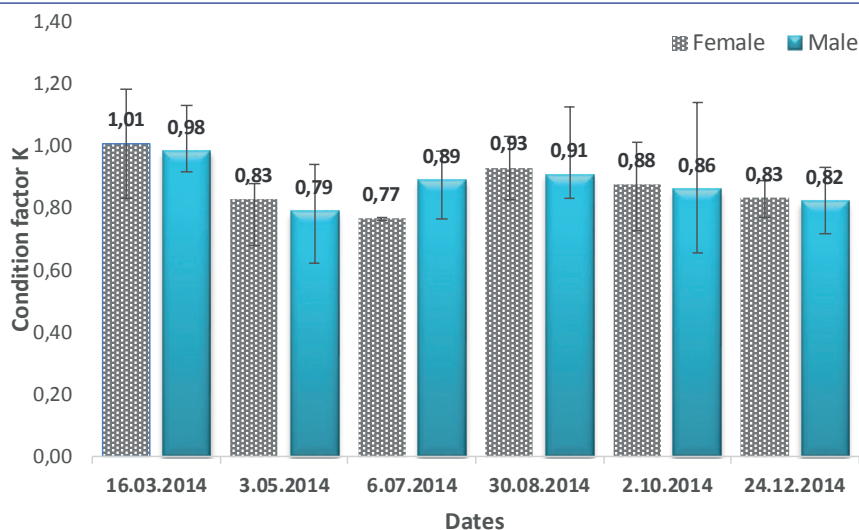


Figure 3. Seasonally condition factor of *O. anatolicus*.

(Gaygusuz et al., 2012; Erk'akan et al., 2013; Erk'akan et al., 2014; Innal et al., 2015; Birecikligil et al., 2016; Özcan & Altun, 2016). The factors affecting the b value have been reported by various authors (Tesch, 1971; Moutopoulos & Stergiou, 2002; Froese, 2006). Variations in growth type and b values from different areas may be attributed to one or more factors, including different physico-chemical parameters of systems, flora and fauna compositions of systems, sampling designs, sampling properties and characters of species (sex, length range, diet, parasites).

Graphical presentations of the seasonal condition factor for *O. anatolicus* studied are shown in Figure 3.

Condition factor (K) values for female samples were generally higher than those of the males. The mean K values for female, male and combined sexes were 0.90, 0.86 and 0.88 respectively (Fig. 3). The results showed that there were no variations in condition factors between sexes of the *O. anatolicus* collected from Düğer Creek. The condition factor of *O. anatolicus* showed seasonal variation - it was noticed that K was higher when fish entered into the maturation phase during the month of March, while for rest of the seasons K showed lower values.

The mean condition factor which is a measure of the suitability of the environmental factor for growth of the species obtained for this study was 0.88 and ranged from 0.64 to 1.19. Mean condition factor value was close to the value (0.86) documented by Yazıcıoğlu & Yazıcı, (2016) for *Oxynoemacheilus angorae* from the Kılıçözü Stream and also relatively lower than the value (0.94) reported by Birecikligil et al. (2016) for *Oxynoemacheilus angorae* from the Kızılırmak River Basin (Birecikligil et al., 2016). Differences in mean condition factors of males and females in this study were not statistically significant.

The Burdur Loach was listed as endangered as a result of dam construction and pollution (Freyhof, 2014). The species is sympatric with 3 native species; *Pseudophoxinus burduricus*, *Cobitis battalgili*, *O. theophili*, of which the first two are endemic to Ana-

tolia. During the study period in Düğer Creek, one alien species, *Gambusia holbrooki* was caught. An increasing population of *G. holbrooki* may threaten the population of *O. anatolicus*.

Anthropogenic water pollution is another important disturbance factor. The anthropogenic water pollution sources include human waste, ruminant animal farming and chicken egg industry discharges. Chemical pesticides, often used in agriculture, may constitute a high risk to *O. anatolicus*. In addition, the construction of roads for Marble Mining affects the habitat quality of Düğer Creek. A minor threat is excessive water abstraction that alters the normal creek flow and may restrict the movement of the fish along the creek channel.

CONCLUSIONS

This study highlights that growth characteristics for Burdur Loach are not much different from species in the same genus (Table 3). Length-weight relationship exhibited positive allometric growth patterns in the *O. anatolicus* collected from Düğer Creek. The overall sex ratio in the populations matched the expected value of 1:1 in a normal population. Condition factor values of *O. anatolicus* in Düğer Creek were close to the reported values for other species of the same genus. The best conditions for the fish were recorded during the month of March.

Because of the threat to *O. anatolicus* populations by loss of suitable habitats, conservation efforts are required. Data on length-weight relationship, age, sex ratio and condition factor for Burdur Loach inhabiting Düğer Creek have been presented in this paper for the first time.

It could be concluded that the findings of this study will contribute to the knowledge of bioecology of *O. anatolicus*. Further studies on the reproductive biology and conservation practices are urgently required for this endangered species.

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Ethics Committee Approval: This study was carried out in accordance with animal welfare and trial ethics. All procedures were performed in accordance with the Law on Veterinary and Medical Activities and National Animal Welfare Act.

Conflict of Interest: Author has no conflict of interest to report.

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