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SHORT COMMUNICATION

Studies on the recently discovered crayfish, *Austropotamobius torrentium* (Shrank, 1803), in Turkey: morphological analysis and meat yield

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The only native freshwater crayfish species of Turkey is the narrow-clawed crayfish, *Astacus leptodactylus* (Esch., 1823) (Geldiay & Kocataş 1970; Erençin & Köksal 1977; Köksal 1988; Holdich 2002; Skurdal & Taugbol 2002; Harlıoğlu 2004). This species was first identified from Kayseri, Bursa and İstanbul (Bott 1950). It is naturally and widely distributed in lakes, ponds and rivers in different parts of Turkey, and some very large populations exist. According to Geldiay and Kocataş (1970) three subspecies of *Astacus* exist in Turkey. These are *A. leptodactylus leptodactylus*, *A. leptodactylus salinus* and *A. colchicus*. However, Albrecht (1983) considered *A. colchicus* to be a subspecies of *A. astacus*. Therefore, *A. astacus* may also be present in Turkey, but up to now there have been no reports of it (Holdich 2002). Starobogatov (1995) also mentioned that *A. colchicus* might be found in the vicinity of İstanbul, and it could have been introduced in eastern Turkey.

Freshwater crayfish is a popular luxury food in many West European countries. Since the domestic consumption of crayfish in Turkey was very low (Erençin & Köksal 1977), Turkey was the largest supplier of *A. leptodactylus* to Western Europe from 1970 (or possibly earlier) until 1986 (Köksal 1988; Oray 1990). The peak crayfish production was reached in the early 1980s, with over 5000 tonnes being exported in 1984. Crayfish were exported to a number of European countries, of which France and Sweden were the main buyers (Köksal 1988). After 1985, crayfish production was reduced dramatically in most Turkish lakes as a result of the crayfish plague fungus (*Aphanomyces astaci* Schikora) whose presence was reported by several authors (Rahe & Soylu 1989; Oray 1990). *Astacus leptodactylus* has been introduced to many freshwaters in Turkey after 1985 because of its commercial importance and declining catches from traditional good fisheries. Today, there are 33 important *A. leptodactylus* harvesting areas throughout Turkey (Harlıoğlu, Barım, Türkgülü & Harlıoğlu 2004). The total harvest value from these areas in 2002 was reported to be 1850 tonnes (Anonymous 2002). However, culture of this species in captivity is not practiced in Turkey.

The stone crayfish, *A. torrentium*, is indigenous to Europe and is mainly confined to central and southeastern countries. It reaches its northerly limit in Germany and the Czech Republic, westerly limit in Luxembourg, southerly limit in Greece, and easterly limit in Bulgaria (Holdich 2002). It had not been previously recorded from Turkey (Erençin & Köksal 1977; Köksal 1988; Holdich 2002; Skurdal & Taugbol 2002). However, its presence has recently been noted in the Velika River (a tributary of the Rezovska River) in European Turkey by Trontelj, Yoichi and Boris (2005). Little is known about this crayfish in European Turkey so it was decided to undertake an analysis of its morphology and abdominal meat yield in order to assess it potential for aquaculture in this study.

Materials and methods

Sixty males and 224 females of *A. torrentium* (size range: 20–45 for males and 20–40 mm carapace length (CL) for females) were caught from the Velika

River, Kırklareli, Turkey. Although a few larger crayfish (53 and 62 mm CL for males and 48 and 68 mm CL for females) were caught, these were not included in the study because of their extreme values. The specimens were sorted by their sex, washed and then frozen at $-20\,^{\circ}C$ for further processing.

Measurements of carapace width, abdomen length, abdomen width, chelae length, chelae width and cheliped length were documented and used to determine sexual dimorphism between males and females. The positions, from which the measurements were taken, based upon the techniques of Rhodes and Holdich (1979). Measurements were made to the nearest 1 mm using a flexible metal ruler. For abdominal meat yields, crayfish and tissue were weighed to the nearest 0.001 g. After opening the abdomen by slitting, the meat was carefully removed using a scalpel and forceps. Because the claws of *A. torrentium* are relatively small, economic meat recovery is probably not viable; hence, meat yield from the claws was not examined. In order to determine allometric relationship and to observe whether or not abdominal (tail) meat yield and/or body weight increased at a rate greater than the cube of the CL with growth, slopes were investigated by applying regression analysis of log transformed variables in the form: $\log y = \log(a) + \log(b)\, x$, where a value of >3.0 for the constant b was taken to indicate that the abdominal meat yield (or body weight) increased at a greater rate (positive allometry) than the cube of CL (Romaire, Forester & Avault 1977). Analysis of variance and Duncan's new multiple range test were also used for the statistical analysis of the data to show the differences between sexes in morphology and abdominal meat yield (significant difference, $\alpha = 0.05$).

Results

In both sexes, a linear relation was observed between CL and body weight ($r^2 = 0.89$ for males and $r^2 = 0.79$ for females). The formulae of regression analyses are (sample no. = 60 for males and 224 for females):

	$\log \boldsymbol{y} = \log(\boldsymbol{a}) + \log(\boldsymbol{b})\, \boldsymbol{x}$	r^2	*Slope*
log male CL versus log body weight	$y = -3.2932 + 2.8895\,x$	0.888	2.8895
log female CL versus log body weight	$y = -13.213 + 0.7299\,x$	0.7821	0.7299

The regression analysis of body weight versus CL yielded regression coefficients (slopes) lower than 3, indicating negative allometric growth in male and female *A. torrentium* (slopes: 2.89 for males and 0.73 for females).

A significant sexual dimorphism was observed in the body weight, abdomen width, chelae width, chelae length and cheliped length between male and female of *A. torrentium* of the same size. Males of *A. torrentium* had significantly heavier body weight than the females (mean body weight = 12.29 ± 5.98 g for males and 9.92 ± 3.04 g for females). Males also had significantly longer cheliped and chelae, and significantly wider chelae than those of the females ($P < 0.001$ for each case). However, females had significantly ($P < 0.001$) wider abdomen than males (mean abdomen width = 15.03 ± 2.40 mm for males and 16.73 ± 1.84 mm for females). In addition, males had wider carapace than did females (16.30 ± 2.93 mm for males and 15.95 ± 2.51 for females), and females had longer abdomen than males (36.69 ± 3.73 mm for females and 36.01 ± 4.84 mm for males).

Regression analysis of abdomen meat yield versus CL showed that the abdominal meat yield of males and females does not increase at a greater rate than the cube of the CL (slopes: 2.61 for males and 1.19 for females; $N_{♂} = 26$, $N_{♀} = 47$). The formulae for regression analyses are (abdomen meat yield versus CL) as follows:

	$\log \boldsymbol{y} = \log(\boldsymbol{a}) + \log(\boldsymbol{b})\, \boldsymbol{x}$	r^2	*Slope*
log male meat yield versus log CL	$y = -4.0579 + 2.6128\,x$	0.621	2.6128
log female meat yield versus log CL	$y = -1.8487 + 1.1857\,x$	0.073	1.1857

There was a significant difference in the abdomen meat yield between males and females ($P < 0.001$). It was 1.183 ± 0.45 g for males (mean CL = 37.60 mm) and 0.86 ± 0.32 g for females (mean CL = 31.20 mm). In addition, big sized males (37–44 mm CL) had significantly ($P < 0.001$) more abdomen meat yield than the small sized ones (30–36 mm CL) (1.45 ± 0.30 g for the big size males and 0.97 ± 0.23 g for the small size males). There was not a significant difference ($P > 0.05$) in the abdomen meat yield of males and females of the same size (30–36 mm CL). It was 0.91 ± 0.33 g for males and 0.97 ± 0.23 g for females.

However, the abdomen meat yields as percentage of body weight of males and females were 6.61% and 9.40% respectively.

Discussion and conclusion

In general, isometric and negative allometric growths have been observed for female crayfish. For example, for *Cherax destructor* (slope$_{\text{wet weigth versus CL}}$ = 2.61), *C. quadricarinatus* (slope = 2.92) and for *C. tenuimanus* (slope = 2.76) (Austin 1995); for *A. leptodactylus* (slope = 2.82) (Köksal 1988), (slope = 2.74) (Harlıoğlu 1996); for *Pacifastacus trowbridgii* (slope = 3.07) (Mason 1975); for *P. leniusculus* (slope: 2.89) (Harlıoğlu 1996). On the other hand, positive allometric and isometric growths have been observed in general for male crayfish. For example, for *A. astacus* (slope = 3.83) (Pursiainen, Saarela & Westman 1988); for *C. quadricarinatus* (slope = 3.29) and *C. destructor* (slope = 3.22) (Austin 1995); for *P. trowbridgii* (slope = 3.59) (Mason 1975); for *A. leptodactylus* (slope = 3.13) (Köksal 1988) and (slope = 3.25) (Harlıoğlu 1996); for *P. leniusculus* (slope = 2.97) (Harlıoğlu 1996). Our study indicates that both male and female *A. torrentium* exhibit negative allometric growth. This is thought to be a consequence of the heavy exoskeleton (shell) in this species. Even, body weights of small sized male and female individuals of *A. torrentium* that have heavy body skeletons do not increase faster than the cube of their CLs.

Sexual dimorphism has been observed in the abdomen size, carapace width and chelipeds (claws) in many mature crayfish species (Lowery 1988). In general, male crayfish have larger and heavier chelipeds than females, and female crayfish have a bigger and wider abdomen. In addition, males are heavier than females (Romaire *et al*. 1977; Rhodes & Holdich 1979; Harlıoğlu 1996). Our study also showed that males of *A. torrentium* had significantly heavier body weight than females. The males also had significantly bigger cheliped, chela, and wider chela than those of the females, whereas the females had significantly wider abdomen than did the males. However, meat extraction from the chelipeds appears uneconomic because of their overall relatively small size.

In the present study, the abdominal meat yield produced by male *A. torrentium* was found to be significantly higher than that of female *A. torrentium*. However, when expressed as a percentage of the body weight, that of females (9.40%) was found to be higher than that of males (6.61%). This is because the body weight of males is considerably heavier than that of females because of the greater mineralization of the shell (exoskeleton), particularly the chelipeds. In percentage terms, the amount of abdomen meat yield for several different species has been reported to be between 10% and 40% of body weight (Lee & Wickins 1992). For example, this value was found to be 19.6% for male *A. astacus* and 17.5% for female *A. astacus* (Lindqvist & Louekari 1975), 14.79% for male *P. leniusculus* and 12.34% for female *P. leniusculus*, and 12.60% for male *A. leptodactylus* and 12.45% for female *A. leptodactylus* (Harlıoğlu & Holdich 2001), 27.40% for male *A. pallipes* and 23.20% for female *A. pallipes* (Rhodes & Holdich 1984). In our study, slope values of < 3 for abdomen meat yield for male and female *A. torrentium* in the regression analysis indicated that meat content did not increase at a rate greater than the cube of CL as the crayfish grew. Negative allometry for abdomen meat yield was also observed for the males and females of *A. leptodactylus* and *P. leniusculus* (Harlıoğlu 1996). In a study, Huner (1993) studied the meat yield in some species belonging to Cambaridae and only the abdomen meat was considered. He found that meat yield ranged from 1.79 to 3.91 g for the most popular species *Procambarus clarkii* and *P. zonangulus*. Similar levels of tail meat for *P. clarkii* were also found in a different study (Harlıoğlu 1996). In a study, Harlıoğlu and Holdich (2001) found that the mean abdomen meat yield of male and female *P. leniusculus* ranged between 2.75–3.03 g for males and 2.28–2.76 g for females. Those of male and female *A. leptodactylus* were 2.32–3.26 g and 2.53–2.91 g respectively. However, Köksal (1988) found that male *A. leptodactylus* produced an average of 4.25 g of tail meat and that of females was 4.41 g. These differences in the meat yield content might be due to the state of maturity, size, condition and location as well as the way the meat was prepared for analysis. When compared with the above-mentioned species, considerably lower abdomen meat yield content was observed for *A. torrentium* (mean 1.18 g for males and 0.86 g for females). Similarly, Obradovic, Sekulic and Rac (1988) found that the abdomen meat yield was not the same for males and females, i.e. a greater increase in weight was found in the abdomen meat yield of males than in those of females.

Austropotamobius torrentium is of little commercial interest because it only reaches a maximum size of about 11 cm and a maximum weight of about 70 g (Troschel, Schulz & Berg 1995). According to Lowery (1988), some populations of *A. torrentium* are not exploited because of their small size. Therefore, it was concluded that the exploitation of *A. torrentium* can thus be considered to be negligible. On the other hand, Laurent (1988) also stated that *A. torrentium* is sympatric with the larger *A. astacus* and in the countries where they both live, fishermen do not bother with it, preferring the larger crayfish. Based on the results of this investigation, in conjunction with the fact that *A. torrentium* only reaches a maximum size of about 11 cm and maximum weight of about 70 g, it would appear that this species in Turkey would not appear to be an economically exploitable resource.

It has been suggested that there has been a reduction in the range of *A. torrentium*. Therefore, like other native European crayfish species (*A. astacus* and *A. pallipes*), *A. torrentium* is also considered to be a threatened species (Taylor 2002). Consequently, it has been listed under an 'endangered' category in the Austrian Red List of endangered species and the Annex IV of European Community Directives for the Conservation of Natural habitats and wild Flora and Fauna (97/62/EU) as a species requiring special conservation measures (Streissl & Hödl 2002).

Austropotamobius torrentium occupies the middle of Europe in the upper tributaries of the right side of the Rhine in Germany, till the confluence with the Lahn, and the left side till the confluence with the Mosel. It has been observed in the vicinity of Strasbourg and from many locations in the north-east of Switzerland in tributaries of the Rhine. It has also been caught in the Danube system from the springs to the lron Doors in Romania and from Bavaria, Austria, Bohemia, the northern part of Hungary, former Yugoslavia and Albania. More to the south, it was present in the Vardar system in Yugoslavian Macedonia (Laurent 1988). Therefore, it was stated that the distribution of *A. torrentium* extends from 50°N in Germany to 41°N in Macedonia and 8°E on the Rhine to about 24°E in Romania (Laurent 1988). However, the present study shows that the range of *A. torrentium* extends into the European part of Turkey. However, whether this is a natural extension of its range, or if it has been introduced into European Turkey by man is not known. A recent study of 13 rivers and brooks close to the Velika River has not revealed any other populations (U. Güner, personal observation, 2005).

In conclusion, because of its relatively small size, low abdominal meat yield and limited distribution in European Turkey, it is clear that *A. torrentium* is of limited exploitation interest. However, ecological research should be conducted in the area to determine the potential or actual impacts that *A. torrentium* could be having on associated ecosystems.

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