Biologia, Bratislava, **59**/2: 173—179, 2004

The occurrence of *Potamon* species (Decapoda, Brachyura) relative to lotic stream factors in Greece

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Maurakis, E. G., Grimes, D. V., Mcgovern, L. & Hogarth, P. J., Occurrence of *Potamon* species (Decapoda, Brachyura) relative to lotic stream factors in Greece. Biologia, Bratislava, **59:** 173—179, 2004; ISSN 0006-3088.

This paper shows the current distributions of species of *Potamon* in Greece, and evaluates the effects of stream order and distance from the mouth of the river on the distributions of the species in river drainages. We present new records of *Potamon fluviatile* (Herbst, 1785) in the Kalamas, Aheron, and Arachthos river drainages in southwestern mainland Greece; and in the Pinios, Piros-Tethreas, Pamisos, and Evrotas drainages in Peloponnesos, Greece. Our collections of *Potamon ibericum* (Bieberstein, 1808) in the Strymon-Aggitis drainage indicates the presence of its populations in these river systems since previous studies. The average crab occurrence (average = 0.26) at lower river km (range = 0–150 km) was significantly greater than that (0) at higher river km (range = 151–450 km). Likewise, average crab occurrence (average = 0.26) in lower stream orders (1^{st} and 2^{nd}) was significantly greater than that (0) at lower stream orders (4^{th} and 5^{th}). Water temperature may be involved in limiting crab distributions in rivers as lower temperatures were correlated with greater distances from the river mouth where fewer crabs were encountered.

Key words: *Potamon*, biogeography, Greece.

Introduction

Four species of *Potamon*, representing local varieties, are extant in Greece: *Potamon fluviatile* (Herbst, 1785), *Potamon potamios* (Olivier, 1804), *Potamon ibericum* (Bieberstein, 1808), and *Potamon rhodium* (Parisi, 1913) (Brandis et al., 2000; Pretzmann, 1980; Hogarth, 1989). *Potamon fluviatile* is considered to be widely distributed in mainland Greece south and west of the Axios river in the Macedonian Prefecture; *P. ibericum* occurs in Greece from the Axios river east to Evros river at the Greek-Turkish border; *P. potamios* is endemic to selected Greek islands (e.g. Crete and Karpathos); and *P. rhodium* is restricted to the islands of Ikaria, Kos, Samos, and Rhodes (Brandis et al., 2000; Hogarth, 1989).

The European Environmental Agency (EEA) recently started a biodiversity initiative to inventory, identify and describe aquatic and terrestrial species in European Union (EU) countries. In Greece, there have been no comprehensive studies of distributions of *Potamon* species, nor have there been investigations to examine physical stream factors (elevation, distance from river mouth, stream order, stream width, stream depth, gradient, pH, and water temperature, ℃) associated with intra-drainage occurrences of the species. Likewise, river drainages in Greece have not been sampled adequately to gather baseline distributional data for the country's other aquatic invertebrate and vertebrate species (Bobori et al., 2001). Baseline distributional data are requisite in biodiversity inventories, water quality assessment, environmental impact statements, a host of ecological studies, and testing vicariant and dispersal biogeographic hypotheses. Our objectives are to present current distributions of species of *Potamon* in Greece, and evaluate the effects of stream variables (elevation, distance from the river mouth, stream order, stream width, stream depth, stream gradient, pH, and water temperature (℃) on distributions of the species in river drainages.

Material and methods

Seventy-one collections were made in 20 river drainages in Greece in 1993, 2000 and 2001 (9 in 1993; 35 in 2000, 27 in 2001, and 36 in 2002). Specimens of *Potamon* species were collected by hand from riparian habitats, and during collections of fishes with a DC backpack electroshocker and common nylon seine (1.2 × 3.1 m) with 0.64 cm stretch mesh. Specimens were preserved in 10% formalin, and transferred to 70% ethanol for storage at the University of Richmond. Collection sites containing *Potamon* species are shown by drainage, collection number (EGM = E. G. Maurakis), site, and date (Appendix 1). Location data of collecting sites where no *Potamon* species were collected are available upon request.

Methods of calculating stream order, elevation (m), stream width and depth (m), gradient (m km^{-1}), water temperature (℃), and river km (distance between a collecting site and mouth of its parent river) follow those in Gretes & Maurakis (2001); and pH was measured with a portable handheld pH meter. Other distributional data of *Potamon* species in Greece were obtained from Pretzmann (1980) and Hogarth (1989) (Appendix 1, Fig. 1).

Two characters, terminal and subterminal segments of 1st pleopod in males presented in Brandis et al. (2000) and Pretzmann (1983, 1962) were used to identify male *Potamon* spp.: 1. *P. fluviatile*: flexible zone of male gonopod V-shaped, and subterminal segment of Pl.I S-shaped with inner lobe of terminal segment buldging strongly in a regular curve from base to just before tip; 2. *P. ibericum*: flexible zone of male godopod broadened in its mesial part, and subterminal segment of Pl.I extended straight, length of terminal segment of Pl.I at most 0.4 x length of subterminal segment, greatest width at base, approximately spherical; 3. *P. potamios*: flexible zone of male gonopod symmetrically bilobed; subterminal segment of Pl.I extended straight, length of terminal segment of Pl.I rather less than 0.33 of length of subterminal segment, segment very seldom somewhat greater than 0.33, greatest width about middle, or distal to middle; and 4. *P. rhodium*: flexible zone of male gonopod distinctly V-shaped where top of "V" is situated directly on the subterminal median bulge.

Correlation analysis (SAS, 1996) was performed to determine significant relationships among stream factors (stream order, elevation, stream width, stream depth, water temperature, pH and river kilometer) and occurrence of crabs from individual and combined drainages. Stepwise regression (SAS, 1996) was used to determine the most important factors accounting for significant variation in species diversity. A General Linear Model followed by *t*-test and Duncan's multiple range test (SAS, 1996) was used to determine significant differences among the average occurrence of crabs in combined drainages per significant factors identified in correlation analysis.

Results and discussion

Approximately one in five collections contained freshwater crabs: *P. fluviatile* (23.9% of 92 collections) and *P. ibericum* (21.4% of 14 collections). With our collections, the distribution of *P. fluviatile* extended to the Kalamas, Aheron, and Arachthos river drainages in SW mainland Greece; and to the Pinios, Piros-Tethreas, Pamisos, and Evrotas drainages in Peloponnesos, Greece (Appendix 1, Fig. 1). Our 1993–2001 collections of *P. ibericum* in the Strymon-Aggitis drainage indicate that populations continue to exist since collections of the species by Hogarth (1989) and Pretzmann (1980) (Fig. 1). Biogeographically, the Axios river drainage separates *P. ibericum* (distributed in Greece from the Axios river eastward to Evros river) from *P. fluviatile*, which occurs in the Aliakmon river drainage to the W and S of the Axios river (Hogarth, 1989; Pretzmann, 1980; Starobogatov & Vassilenko, 1979). We designate the location records of *P. fluviatile* in Bulgaria listed by Bechev (2000) to *P. ibericum*, consistent with distribution of the species discussed in Hogarth (1989), Pretzmann (1980) and Starobogatov & Vassilenko (1979). The presence of *P. ibericum* in the Axios suggests a biogeographical dispersal mechanism (e.g. transterrestrial movement, Gherardi & Vannini, 1989) in freshwater crabs in the Balkan Peninsula different from that for freshwater fishes in the region. In a cladistic analysis of relationships among river drainages in the southern Balkan Peninsula based on distributions of cyprinid fishes, Maurakis et al. (2001) indicated that the Axios, Loudias, Aliakmon, and Pinios rivers form a

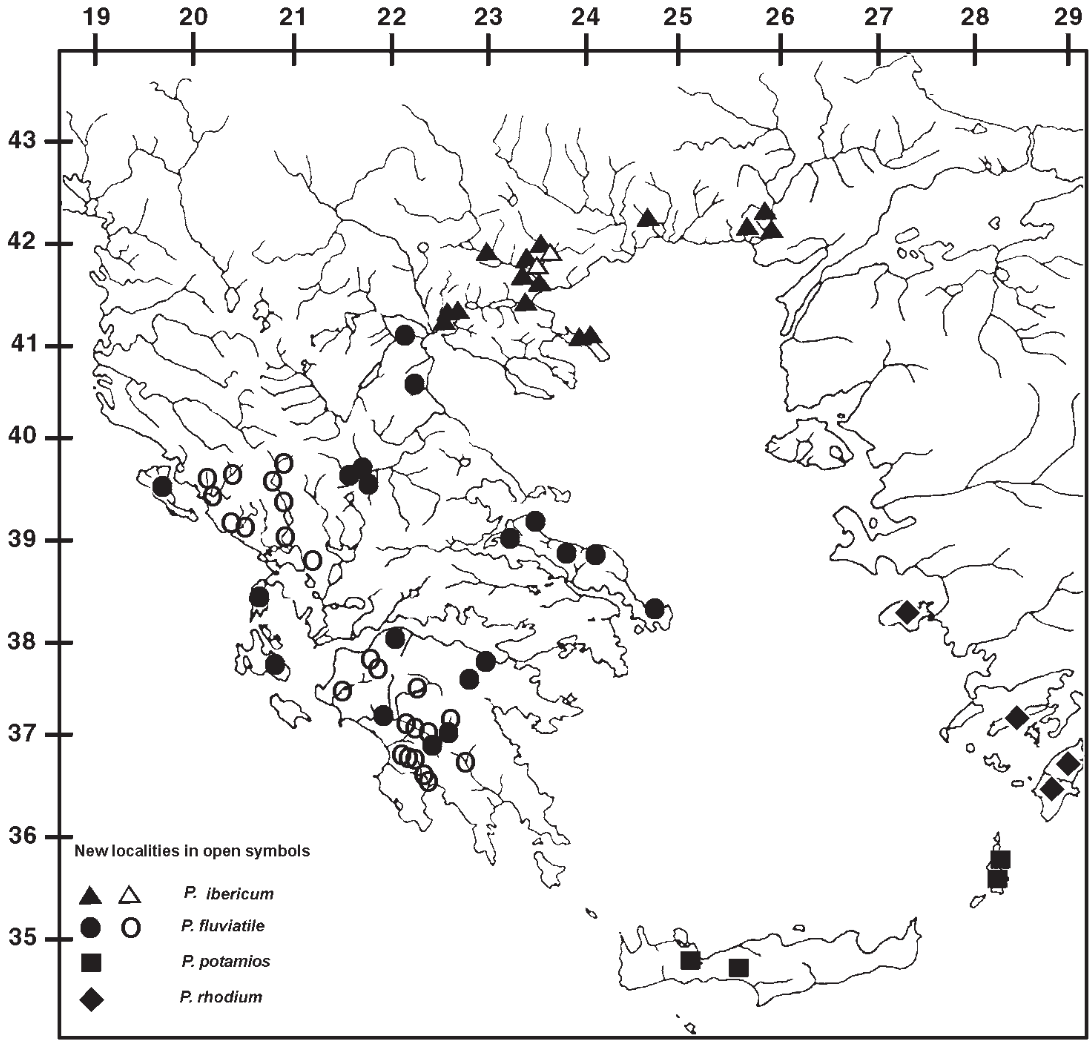

Fig. 1. Distribution of *Potamon fluviatile*, *P. potamios*, *P. ibericum*, and *P. rhodium* in Greece.

monophyletic group (i.e., *Macedonia-Thessaly* division) of the *Ponto-Aegean* division in the southern Balkan Peninsula. Additional collections to delimit distributions, and phylogenetic analysis of relationships among *Potamon* species in Greece are required prior to creating biogeographic hypotheses of freshwater crabs in the area.

In our study of *Potamon* collections, stream order was significantly correlated with stream width, depth, pH, and negatively correlated with elevation and gradient (Tabs 1, 2). Occurrence of crabs was significantly correlated negatively with river km and order (Tab. 2). Average crab occurrence (avg. = 0.26) at lower river km (range = 0–150 km) was significantly greater than that (0) at higher river km (range = 151–450; $T = 5.55$; $P > 0.001$) (Tab. 3). Likewise, average crab occurrence (avg. = 0.34) at stream orders 1 and 2 were significantly greater than that (0) at stream orders 4 and 5; $F = 2.48$, $P > 0.048$) (Tab. 3). Gherardi et al. (1987, 1988, 1989), Hogarth (1989), Micheli (1991) and Micheli et al. (1990) investigated aspects of life history and biology (including gonad history, morphology, reproduction, and feeding behavior and prey selection), ecology, and ecoethology of *P. fluviatile* in Italy and Greece; however, none related distributions of this species or other *Potamon* species to physical and chemical factors in the streams they studied. Elevation data [170 m in Micheli et al., 1990; 148 m in FYROM,

Table 1. Average values of stream variables where *Potamon ibericum* and *Potamon fluviatile* were absent or present at collecting sites in river drainages of Greece from 1993–2002.

Variable	N	Mean	SD	Min.	Max.
Potamon spp. absent					
Stream order	85	2.33	1.13	1.00	5.0
Elevation (m)	54	317.37	289.62	0	963.0
Stream width (m)	75	11.04	16.48	0.50	99.9
Stream depth (m)	68	0.30	0.22	0.02	1.0
pH	43	7.87	0.39	6.40	8.5
Gradient (m km^{-1})	84	23.03	42.42	0	178.6
Water temp. (℃)	71	19.09	4.74	6.70	31.0
River km	84	95.55	93.45	4.20	319.5
Potamon spp. present					
Stream Order	23	1.83	0.83	1.00	3.0
Elevation (m)	23	216.21	196.86	0.60	665.1
Stream width (m)	23	8.3	10.30	0.50	50.0
Stream depth (m)	23	0.28	0.23	0.04	1.1
pH	18	7.77	0.37	7.10	8.6
Gradient (m km^{-1})	23	6.06	11.29	0	57.1
Water temp. (℃)	23	19.78	3.57	11.70	27.2
River km	23	52.53	32.28	3.60	107.4

Key: N – number of samples; SD – standard deviation.

Table 2. Results of Spearman correlation analyses of occurrence of *Potamon fluviatile* and *Potamon ibericum* and stream factors of river drainages in Greece, 1993–2002.

	Order	Elevation	Width	Depth	pH	Gradient	Temp	Stream length	Crab
Order	1.000	–0.399	0.465	0.406	0.262	–0.231	0.185	–0.169	–0.190
		<.0001	<.0001	<.0001	0.041	0.017	0.075	0.082	0.049
		107	98	91	61	107	94	107	108
Elevation		1.000	–0.210	–0.105	–0.133	0.618	–0.403	0.827	–0.152
			0.039	0.322	0.308	<.0001	<.0001	<.0001	0.118
			97	91	61	107	94	107	107
Width			1.000	0.546	0.194	–0.135	0.073	–0.125	–0.077
				<.0001	0.147	0.186	0.496	0.222	0.453
				91	57	97	90	97	98
Depth				1.000	–0.073	–0.038	–0.080	0.025	–0.034
					0.588	0.722	0.455	0.815	0.750
					57	91	90	91	91
pH					1.000	–0.034	–0.065	0.032	–0.114
						0.794	0.621	0.807	0.381
						61	61	61	61
Gradient						1.000	–0.118	0.775	–0.182
							0.255	<.0001	0.061
							94	107	107
Water temperature							1.000	–0.278	0.067
								0.007	0.523
								94	94
Stream length								1.000	–0.207
									0.033
									107
									1.000

Key: Order – stream order; Width – stream width; Depth – stream depth; Temp. – water temperature; and Stream length — distance from mouth of river to collection point.

Table 3. Results of General Linear Model and Duncan's multiple range test for occurrence of *Potamon* spp. by stream order and T-test for occurrence of *Potamon* spp. by river km. Underscored means do not differ significantly at $P = 0.05$.

Order	1^{st} and 2^{nd}	3^{rd}	4^{th} and 5^{th}
avg. # crabs	0.34	0.20	0.00
$F = 3.92$;			
$P > F = 0.0484$			
df = 105			
river km	0–150	151–450	
avg. # crabs	0.26	0.00	
$t = 5.55$			
$P > T = 0.0001$			
df = 88			

2001; 150, 170, 300, and 500 m in BECHEV (2000) and pers. commun.] for their study locations of *Potamon* species are consistent with our analyses of relationships of elevation to distributions of *Potamon* populations in Greece (i.e. significantly fewer crabs in stream orders at elevations greater than 601 m and river km greater than 151 km). We suspect water temperature may be involved in limiting crab distributions in the cooler portions of rivers in the mountains as lower temperatures were correlated with greater distances from river mouth ($P = 0.0066$; Tab. 2) where fewer crabs were encountered. Our analyses, however, do not negate that abiotic and anthropogenic factors (e.g. habitat, food availability, and habitat alteration) may also be involved in limiting crab populations at higher elevations and greater distances upstream from river mouths, hypotheses that can be tested in future studies.

Distributional data of aquatic organisms, particularly indicator and keystone species, collected by scientists and the general public, can be applied to assess water quality and environmental impacts. For example, *Potamon dehaani* has been demonstrated to be a good indicator of water quality of streams in an effective, simple and inexpensive way in Japan where 59,000 individuals of the general public surveyed over 4,600 sites in rivers in the country with the added benefit of heightening environmental consciousness (Anonymous, 2000). In Greece, population declines and extinction of aquatic organisms and their habitats have been related to dam construction and operation, stream channelization, canalization, pollution, and stream desiccation, a result of water abstraction for crop irrigation and diversion of river and stream waters (e.g. Evinos and Mornos rivers) for potable water supplies of Athens and other cities and towns (e.g. BOBORI, 1996; HADJIBIROS et al., 1998; ECONOMIDIS et al., 2000; ECONOMOU et al., 2000; pers. obs.). Most development in Greece is occurring at lower elevations near coastal areas (OECD, 2000) where *Potamon* populations are prevalent in small to medium size streams. We plan to test the efficacy of using *Potamon* species as indicators of both water quality and environmental impact in freshwater environs of Greece in future investigations.

Acknowledgements

Funded by the T. F. JEFFRESS and K. MILLER JEFFRESS Memorial Trust, Science Museum of Virginia, and University of Richmond. We thank Mrs. D. BOBORI for her assistance in the field, D. N. BECHEV, who made us privy to his distributional information for *Potamon* species in Bulgaria, A. KOUKOURAS for critically reviewing the manuscript, and two anonymous reviewers whose suggestions improved the manuscript.

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Received November 8, 2002
Accepted April 10, 2003

Appendix 1. Site data where *Potamon* spp. were collected in river drainages in Greece in 1993 and 2000–2002 and those reported in BRANDIS et al. (2000), HOGARTH (1989), and PRETZMANN (1980).

Potamon ibericum: **Evros**: Avandas and Alexandroupoli (HOGARTH, 1989). **Samothraki**: Samothraki (HOGARTH, 1989). **Thasos**: no locality given (PRETZMANN, 1980). **Lesvos**: Mitilini (HOGARTH, 1989); Amebliko and Agiassos (PRETZMANN, 1980). **Xanthis**: Xanthi (HOGARTH, 1989). **Strymon-Aggitis**: EGM-Greece-340, 23.VII.1993, Aggitis river (1st order) at Strymonas, 30 km SW of Drama and 39 km E of Seres. EGM-Greece-455, Aggitis River (1st order) at Stathmos Aggitis, 1 km S of Rt. 12, 14.VI.2000. EGM-Greece-457, unnamed 1st order tributary of Strymonas River, about 5 km NE of Sidirokastro, 15.VI.2000. Vlahika, Nevrokopi, Paleochori, Sidirochori, Milopotamos, Mesoropi, Agios Gianis, Philippi, and Antiphilippi (HOGARTH, 1989). **Lake Koronea**: Liti (HOGARTH, 1989). **Lake Volvi**: Rendina (HOGARTH, 1989). **Halkidiki**: Mazmazi (HOGARTH, 1989). **Gallikos**: Neo Kilkis, Gallikos, and Gorgopi (HOGARTH, 1989).

***Potamon fluviatile*: Kalamas**: EGM-Greece-494, unnamed 2nd order tributary of Kalamas river, 8.5 km NW of Lefkothea, 25 km west NW of Ioannina, Epiros, 13.VI.2001. EGM-Greece-499, unnamed 1st order tributary of Kalamas river, 0.5 km N of Pigadoulia, about 12 air km NE of Igoumenitsa, Epiros, 13.VI.2001. **Aheron**: EGM-Greece-500, 14.VI.2001, unnamed 1st order tributary of Kokitas river, about 1.5 km NW of Themelo, about 10 air km SE of Parga, Epiros. **Arachthos**: EGM-Greece-484, 24.VI.2000, Arachthos river drainage, unnamed tributary (2nd order) of Arachthos River, 1 km SW of Potamia, about 20 km NE of Metsovo. EGM-Greece-485, 24.VI.2000, Arachthos river drainage,unnamed tributary (1st order) of Arachthos river, 2 km NW of Ambelos, about

20 km SW of Metsovo. EGM-Greece-486, 24.VI.2000, Arachthos river drainage, unnamed tributary (2^{nd} order) of Arachthos River, 4.5 km N of Potamia, 0.5 km N of Ambelos, and 19 km W of Metsovo. EGM-Greece-503, 15.VI.2001, unnamed tributary to Lake Pournariou, 0.l km N of Melates, about 15 air km NE of Arta, Epiros. **Piros-Tethreas**: EGM-Greece-510, 18.VI.2001, Tethreas river, 0.25 km East of Hai Kali, about 30 km SW of Patras, Peloponnesos. EGM-Greece-512, 18.VI.2001, unnamed tributary of Piros river, 1 km SE of Prevedos about 18 air km S of Patras, Peloponnesos. **Pinios (Peloponnesos)**: EGM-Greece-515, 19.VI.2001, Pinios river, 4 km SW of Karpeta, about 40 air km E of Amalidia, Peloponnesos. **Alphios (Peloponnesos)**: EGM-Greece-327, 5.VII.1993, Arkodis creek at Ladonas, 20 km NW of Panayitsa, about 35 km NW of Tripoli. EGM-Greece-329, 5.VII.1993, unnamed tributary of Alphios river between Vlahena and Kalivia, 53 km NW of Tripoli. EGM-Greece-536, 24.VI.2002, Alphios river (3^{rd} order), 2 km NE of Dafnoula, about 50 km ESE of Pyrgos. EGM-Greece-537, 24.VI.2002, Alphios river (3^{rd} order), 1 km NE of Kiparissia, about 8 km NW of Megalopoli. EGM-Greece-540, 24.VI.2002, headwater spring (1^{st} order) of Alphios River, 1.5 km ENE of K. Asea, 11 km E of Megalopoli and 13 km W of Tripolis. EGM-Greece-545, 25.VI.2002, unnamed 1^{st} order tributary of Alphios river, 1.5 km NW of Routsi, about 9 km SE of Megalopoli. Issari (HOGARTH, 1989). **Korinthos**: Egio (HOGARTH, 1989). **Pamisos**: EGM-Greece-547, 25.VI.2002, unnamed 2^{nd} order tributary of Pamisos river, 0.5 km E of Zevgolatio, about 26 km E of Kiparissia. EGM-Greece-549, 25.VI.2002, unnamed 1^{st} order tributary of Pamisos river, 4 km S of Koklas, about 1.5 km NE of Malthi and 15 km E of Kiparissia. EGM-Greece-550, 25.VI.2002, unnamed 1^{st} order tributary of Pamisos river, 0.5 km N of Koklas, about 18.5 km E of Kiparissia. EGM-Greece-551, 26.VI.2002, unnamed 2^{nd} order tributary of Pamisos river, 0.5 km E of Koklas, about 18 km E of Kiparissia. EGM-Greece-552, 26.VI.2002, Pamisos river (3^{rd} order), 1 km S of Neochori, about 25 km N of Kalamata. EGM-Greece-556, 26.VI.2002, Pamisos river (3^{rd} order) at bridge in Kalamata. **Evrotas**: EGM-Greece-559, 27.VI.2002, unnamed 1^{st} order tributary of Evrotas river, 1 km SE of Verdonia, about 10 km NW of Sparti. **Evia**: Katheni, Edipsos, and Steni (HOGARTH, 1989). **Andros**: Petrophos (PRETZMANN, 1980). **Pinios** (Thessaly): Asprochoma (HOGARTH, 1989). **Aliakmon**: Mesimeri (HOGARTH, 1989). **Lake Stymphalia (**PRETZMANN, 1980). **Kafalonia**: Neo Charaktion, Kulurata and Pastra (PRETZMANN, 1980). **Lefkas**: Neo Vasoliki (PRETZMANN, 1980). **Korfu**: Kapsocholades and Mesaria (PRETZMANN, 1980).

***Potamon potamios*: Crete**: Pharagi Samarias and Lohria-Amazias (HOGARTH, 1989); Lassithi, Kakopetros, Festos, Gerakari, Moni Vaniu, Amnatos and Muskatos Aligi (PRETZMANN, 1980). **Karpathos**: Volade (BRANDIS et al., 2000).

***Potamon rhodium*: Rhodes**: Rhodos (HOGARTH, 1989; PRETZMANN, 1980); Archiopolis and Kalithie (PRETZMANN, 1980). **Samos**: Marathokambou (BRANDIS et al., 2000). **Ikaria**: no locality available (BRANDIS et al., 2000). **Kos**: Antimachia (BRANDIS et al., 2000).