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A compilation of longevity data in decapod crustaceans

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Abstract

Longevity information was collected from 219 literature sources for 244 decapod crustaceans, representing 1.7% of species, 4.8% of genera and 30% of families. Reliable methods of age determination (laboratory rearing, mark-recapture method, growth models, lipofuscin method) revealed longevities from 0.1 to 72 years, corresponding to a 700-fold difference between the shortest and longest lived species. The mean longevity of the species included in this article is 7.1 years (SD=10.18; CV=142.9%); 61.1% of the species live less than 5 years, 29.5% live between 5 and 20 years, and 9.4% live longer than 20 years. The basal Dendrobranchiata have a mean longevity of only 2.1 years whereas the Achelata have a mean longevity of 27.2 years. The oldest decapod aged with a direct method is a hermit crab that was reared in captivity for more than 42 years. The particularly long-lived species belong to different families of the infraorders Achelata, Astacidea, Anomura and Brachyura. Average longevity is highest in semiterrestrial and terrestrial habitats (13.0 years), followed by freshwater (7.2 years) and marine and brackish waters (6.0 years). The deep sea, polar waters, freshwater caves and terrestrial environments apparently promote the evolution of high life spans.

Keywords

Decapoda, life span, environment, taxonomy, evolution.

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Introduction

Ageing and longevity in the Decapoda is still a neglected field of research. In 2012, I have published the first comprehensive review article on ageing and longevity in this ecologically and economically important animal group (Vogt, 2012). This paper summarized life span data, anti-ageing strategies and age related diseases and discussed the impacts of indeterminate growth and different environments on longevity. Since then, further review articles and book chapters with comprehensive ageing data have been published for freshwater decapods (Vogt, 2014), freshwater crayfish (McLay and van den

Brink, 2016), brachyuran crabs (McLay, 2015), cave dwelling decapods (Venarsky *et al.*, 2012), and crustaceans (Vogt, 2018). In the present article I have compiled and updated all reliable longevity data of decapods that I could find in original studies, review papers and species profiles provided by experienced carcinologists. In addition, I have compared longevities between the higher taxa of the Decapoda and between marine, freshwater and terrestrial environments.

Ageing techniques and their advantages and disadvantages

The longevity data compiled in this paper were obtained with different ageing techniques like growth models, the lipofuscin method, the mark and recapture method, and rearing in captivity. Growth models based on size-frequency and life history data were predominant. Sometimes, life spans were directly estimated from size-frequency and life history data without applying growth models. An alternative indirect ageing method was quantification of the age pigment lipofuscin. The direct methods applied were the mark-recapture method and rearing in captivity.

Rearing in captivity from hatching to death is the most exact ageing technique. However, life span data obtained with this approach are mainly available for relatively short-lived aquaculture, laboratory and pet species. This method underestimates longevity in the wild if the culture conditions are inadequate. On the other hand, it can considerably overestimate natural longevity because protection from adverse environmental conditions, predators and diseases can greatly expand life span. Thus, rearing under optimal conditions reflects the upper possible age limits of the species.

The mark and recapture method is presently the only direct ageing technique applied in the wild. In order to ensure life-long retention of the mark, the tags have to be placed underneath the cuticle. Otherwise, they are lost during moulting. There are several internal markers available for decapods, among them passive integrated transponders (microchips), coded microwire tags, visible implant alphanumeric tags and visible implant elastomeres (Hartnoll, 2001; Davis *et al.*, 2004; Buřič *et al.*, 2008). Further details on mark-recapture methods are found in Hartnoll (2001), Vogt (2012) and Kilada and Driscoll (2017). In practice, the mark-recapture method was mostly used to estimate growth increment per year, which was then used in growth models. There are only few cases where marked specimens were recaptured after more than a decade. For example, a *Procambarus erythrops* crayfish was recaptured in Sim's Sink cave, Florida, 16 years after marking (Streever, 1996).

The most widespread ageing method used in wild populations is the analysis of length-frequency distributions and reproduction parameters, often combined with growth models. Size frequency analysis depends on the identification of modes in the distribution, which can be equated with recruitment cohorts or year classes. The raw data are first grouped into length groups and then converted to age groups. Growth models such as the von Bertalanffy equation help to estimate longevity from length frequency and life history data. Further details are found in Hartnoll (2001) and Jennings *et al.* (2001). Size frequency analysis gives reliable information for short-lived species with well-defined annual reproduction periods. The approach becomes increasingly unreliable the longer a species lives because slowly growing specimens of older age may group together with fast growing specimens of younger age. Since these effects increase with age, size-frequency based growth models are imprecise in long-lived species (Sheehy *et al.*, 1999; Hartnoll, 2001). Moreover, the von Bertalanffy growth model assumes that an organism reaches a maximum size and approaches this size asymptotically. This assumption holds for the determinately growing decapods like the snow crab *Chionoecetes opilio*, which stops growing after a terminal moult but continues to live for several years (Ernst *et al.*, 2005). However, most decapods are indeterminate growers and have no fixed growth limit.

The lipofuscin method is based on the continuous, life-long deposition of lipofuscin in persistent cell types. Lipofuscin is a fluorescent, yellow-brown aggregate consisting of oxidized protein and lipid clusters (Jung *et al.*, 2007). It originates from lysosomal degradation of cytosolic proteasome-protein complexes and damaged cell organelles. Lipofuscin is insoluble, resists enzymatic degradation and is deposited in residual bodies within the cells. The neurons and neuroglia of some brain areas of decapods obviously persist throughout life and accumulate lipofuscin with age, providing ideal targets for lipofuscin-based age determination (Sheehy, 1992). The lipofuscin content is usually quantified by measurement of the lipofuscin area in histological sections and, less reliably, by spectrofluorometric analysis. The lipofuscin content is a marker of the physiological age rather than the chronological age, and therefore, calibration is required with specimens of known age and for each environment (Sheehy *et al.*, 1995b; Maxwell *et al.*, 2007). In long-lived species, the lipofuscin method is apparently superior to size or weight based ageing techniques (Belchier *et al.*, 1998).

Leland *et al.* (2011) and Kilada *et al.* (2012) suggested using cuticular growth bands of stomach ossicles and the growing edge of the eyestalks for age determination. The interpretation of cuticle bands in the ossicles as annual age marker is based on the idea that parts of the gastric mill are retained through the moult and accumulate a continuous record of age. Analyses in several species seemed to support this idea (Kilada and Driscoll, 2017; Gnanalingam *et al.*, 2019). However, Sheridan and O'Connor (2018) and Becker *et al.* (2018) revealed in several species that the zygocardiac ossicles in question are shed during moulting and wondered how the age information could be transferred to the new cuticle. Because of this unsettled controvery, I have not included growth band data in this paper.

RESULTS

Table 1 includes 282 longevity data for 244 species. These data are heterogeneous because they were obtained with different ageing methods: 108 data come from growth models (mainly von Bertalanffy equations), 61 from the analysis of size-frequency and life history data, 19 from the mark and recapture method, 20 from rearing in captivity, 9 from the lipofuscin method, 2 from shell radiometry, 62 from review articles, book chapters and the discussion sections of papers, and 33 from species profiles compiled by experienced carcinologists (some papers have used more than one ageing approach). Table 1 lists the highest longevities given by the authors. These are either minimum expected life spans, maximum life spans estimated by growth models, or recorded ages of the oldest individuals. The list represents 1.7% of the 14,335 decapod species, 4.8% of the genera, 30% of the families and 63.6% of the sub-/infraorders.

Mean longevity of the 244 decapod species is 7.12 years with 4.1% of the species living less than 1 year, 57.0% living from 1–4.9 years, 18.4% from 5–9.9 years, 11.1% from 10–19.9 years and 9.4% living beyond 20 years (Fig. 1). The oldest decapod in captivity is a 42-year old hermit crab (*Coenobita clypeatus*). This specimen was purchased by Carol Ann Ormes in summer 1976 and kept since then as a pet (Atlas Obscura, 2019). It was still alive in December 2018 (NBC2 News, 2018). The oldest marked decapod ever recaptured is a caridean freshwater shrimp (*Xiphocaris elongata)* from a headwater stream in Puerto Rico. It was recaptured after 18 years (Cross *et al.*, 2008). The highest age determined by the lipofuscin method was 72±9 years for a female of the European lobster, *Hommarus gammarus*, from the Yorkshire fishery in U.K. (Sheehy *et al.*, 1999). The maximum age estimated by growth models was 70–100 years for females and males of coconut crab, *Birgus latro*, on Christmas island (Drew *et al.*, 2013). The highest age ever estimated by growth models was 176 years in the cave-dwelling crayfish *Orconectes australis* (*cf.* Cooper, 1975). However, reinvestigation of new populations and Cooper's data with refined growth models revealed a longevity of 22 years for this species, with only a small proportion of individuals exceeding this age (Venarsky *et al.*, 2012).

Longevity differences between and within higher taxa

Longevity varies markedly between sub-/infraorders (Table 2). The plesiomorphic Dendrobrachiata have average longevities of 2.1 years. The average lifespan of the derived Pleocyemata, which include all other infraorders, is 7.8 years. Caridea live on average for 4.2 years, Brachyura for 5.6 years, Astacidea for 11.0 years, Anomura for 11.4 years and Achelata for 27.2 years (Table 2). For the Gebiidea I have found only one reliable value of 4 years, and for the Axiidea, Polychelida and Glypheidea data are apparently lacking. Kornienko (2013) estimated the longevity of the Gebiidea and Axiidea to 2–5 years but mentioned that some workers have estimated their maximum life span to 10 years and more.

Longevity can markedly differ among members of the same higher taxon. Longevity varies from 0.1–9 years (CV=75.6%) in the Dendrobranchiata, 0.5–18 years (CV=96.7%) in the Caridea, 0.7–30 years (CV=102.9%) in the Brachyura, 0.7–70 years (CV=161.2%) in the Anomura, 1.5–72 years

Table 1. Life spans of decapod crustaceans.

Sub-/Infraorder	Family	Species	Environment	Life span (yr)	Ageing method	Reference
Dendrobranchiata	Aristeidae	*Aristeus antennatus* (Risso, 1816)	M	3	SF	Sarda and Demestre, 1987
				9	GM	Orsi Relini and Relini, 1998
		Aristaeomorpha foliacea (Risso, 1827)	M	4–5^1	GM	Ragonese *et al.*, 2012
	Luciferidae	*Belzebub faxoni* (Borradaile, 1915)	M	0.1	RC	Lee *et al.*, 1992
	Penaeidae	*Atypopenaeus stenodactylus* (Stimpson, 1860)	M	1	SP	Kunju, 1969
		Metapenaeus ensis (De Haan, 1844)	M	1.3	SF	Leung, 1997
		Metapenaeopsis dalei (Rathbun, 1902)	M	1.5–1.6^1	GM	Choi *et al.*, 2005
		Metapenaeopsis sibogae (de Man, 1907)	M	2.3	GM	Rahman and Ohtomi, 2018
		Parapenaeopsis stylifera (H. Milne Edwards, 1837)	M	2	SF	Anantha *et al.*, 1997
		Parapenaeus fissuroides Crosnier, 1986	M	2–2.5^1	GM	Farhana and Ohtomi, 2017
		Penaeus aztecus Ives, 1891	M	1.1–1.3^1	GM	Chávez, 1973
		Penaeus brasiliensis Latreille, 1817	M	2	GM	Leite and Pretere, 2006
		Penaeus kerathurus (Forskål, 1775)	M	3	GM	Vitale *et al.*, 2010
		Penaeus monodon Fabricius, 1798	M	1.5–2^1	SF, RC	Motoh, 1981
				2	LM	Sheehy *et al.*, 1995a
		Penaeus paulensis (Pérez Farfante, 1967)	M	2	GM	Leite and Petrere, 2006
		Penaeus semisulcatus De Haan, 1844	M	1.3–1.7^1	GM	Niamaimandi *et al.*, 2007
		Penaeus setiferus (Linnaeus, 1767)	M, B	2	SF	Lindner and Cook, 1970
		Penaeus stylirostris Stimpson, 1871	M, B	1.7	GM	López-Martinez *et al.*, 2005
				1.7–1.9^1	GM	Palacios *et al.*,1993
		Penaeus subtilis (Pérez Farfante, 1967)	M	2.1–2.2^1	GM	Silva *et al.*, 2015
		Rimapenaeus constrictus (Stimpson, 1871)	M	0.7–1.1^1	GM	Garcia *et al.*, 2016
				1.2–1.6^1	GM	Lopes *et al.*, 2017
		Trachysalambria curvirostris (Stimpson, 1860)	M	1.2–1.3^1	GM	Cha *et al.*, 2004
				1.5	GM	Hossain and Ohtomi, 2010
		Xiphopenaeus kroyeri (Heller, 1862)	M, B	1.5–2^1	GM	Lopes *et al.*, 2014
				1.4–2.1^1	GM	Castilho *et al.*, 2015
	Sergestidae	*Acetes chinensis* Hansen, 1919	M	0.8–1^2	GM	Oh and Jeong, 2003
		Acetes indicus H. Milne Edwards, 1830	M, B	1.9–2.5^1	GM	Amin *et al.*, 2012
		Acetes japonicus Kishinouye, 1905	M	0.2	R	Lee *et al.*, 1992
		Lucensosergia lucens (Hansen, 1922)	M	1.2	R	Lee *et al.*, 1992
	Solenoceridae	*Solenocera acuminata* Pérez Farfante & Bullis, 1973	M	2	GM	Guéguen, 1998
		Solenocera choprai Nataraj, 1945	M	2.5	SF	Dineshbabu and Manissery, 2007

Table 1. Cont.

Sub-/Infraorder	Family	Species	Environment	Life span (yr)	Ageing method	Reference
		Solenocera crassicornis (H. Milne Edwards, 1837)	M	0.8–1.3^1	R	Kunju, 1969
		Solenocera melantho de Man, 1907	M	3.1	GM	Ohtomi and Irieda, 1997
Caridea	Alpheidae	*Alpheus armillatus* H. Milne Edwards, 1837	M	1.2–1.3^1	GM	Mossolin *et al.*, 2006
	Atyidae	*Atya lanipes* Holthuis, 1963	F	8	GM	Cross *et al.*, 2008
		Atyaephyra desmarestii (Millet, 1831)	F, B	1	SF	Fidalgo *et al.*, 2015
				1.1–1.3^1	SF	Dhaouadi-Hassen and Boumaiza, 2009
				2	LH	Vorstman, 1955
		Caridina cantonensis Yü, 1938	F	1.8	SF	Yam and Dudgeon, 2005
		Caridina fernandoi Arudpragasam & Costa, 1962	F	1	GM	De Silva, 1988a
		Caridina multidentata Stimpson, 1860	F	6	SP	Wirbellosen Datenbank, 2019a
		Caridina serrata Stimpson, 1860	F	1.4	SF	Yam and Dudgeon, 2005
		Caridina simoni Bouvier, 1904	F	1–1.5	GM, RC	De Silva, 1988b
		Palaemonias ganteri Hay, 1902	FC	15	RC	U.S. Fish and Wildlife Service, 2010
	Crangonidae	*Crangon crangon* (Linnaeus, 1758)	M	3.3	GM	Oh *et al.*, 1999
		Crangon franciscorum Stimpson, 1856	M	1–1.5^1	GM	Gavio *et al.*, 2006
		Notocrangon antarcticus (Pfeffer, 1887)	M	6–10^1	GM, LM	Bluhm and Brey, 2001
		Sabinea septemcarinata (Sabine, 1824)	M	4	SF	Węsławski, 1987
		Sclerocrangon boreas (Phipps, 1774)	M	9	GM	Sainte-Marie *et al.*, 2006
		Sclerocrangon ferox (Sars G.O., 1877)	M	4	SF	Węsławski, 1987
	Hippolytidae	*Chorismus antarcticus* (Pfeffer, 1887)	M	7	GM	Gorny *et al.*, 1993
		Latreutes fucorum (Fabricius, 1798)	M	0.5	R	Bauer, 2004
		Latreutes parvulus (Stimpson, 1871)	M	0.5	R	Bauer, 2004
	Lysmatidae	*Lysmata wurdemanni* (Gibbes, 1850)	M	1.6	SF	Baldwin and Bauer, 2003
	Nematocarcinidae	*Nematocarcinus lanceopes* Spence Bate, 1888	M	6	R	Bauer, 2004
	Palaemonidae	*Macrobrachium acanthurus* (Wiegmann, 1836)	F, B	2	R	Brown *et al.*, 2010
		Macrobrachium borellii (Nobili, 1896)	F	2	R	Brown *et al.*, 2010
		Macrobrachium carcinus (Linnaeus, 1758)	F, B	8	GM	Valenti *et al.*, 1994
		Macrobrachium hainanense (Parisi, 1919)	F	2.4–4^1	GM	Mantel and Dudgeon, 2005
		Macrobrachium rosenbergii (de Man, 1879)	F	3	R	Brown *et al.*, 2010
		Palaemon antennarius H. Milne Edwards, 1837	F	2	R	Wirbellosen Datenbank, 2019b
		Palaemon macrodactylus Rathbun, 1902	M, B	1	GM	Vázquez *et al.*, 2012
				2	R	Bauer, 2004
		Palaemon modestus (Heller, 1862)	F	1.1–1.3^1	GM	Oh *et al.*, 2002

Table 1. Cont.

Sub-/Infraorder	Family	Species	Environment	Life span (yr)	Ageing method	Reference
		Palaemon paludosus (Gibbes, 1850)	F	1	GM	Beck and Cowell, 1976
		Palaemon paucidens De Haan, 1844	M	1.1	GM	Kim *et al.*, 2008
		Palaemon pugio Holthuis, 1949	F, B	0.5–1.1^{3}	GM	Alon and Stancyk, 1982
		Palaemon xiphias Risso, 1816	M	1.4	GM	Guerao *et al.*, 1994
	Pandalidae	*Heterocarpus reedi* Bahamonde, 1955	M	6	GM	Roa and Ernst, 1996
		Heterocarpus woodmasoni Alcock, 1901	M	3.7–5^{1}	GM	Rajasree *et al.*, 2011
		Pandalus borealis Krøyer, 1838	M	4–8^{3}	R	Koeller, 2006
				5–7^{1}	GM	Sokholov, 2002
				11	GM	Nilssen and Aschan, 2009
		Pandalus eous Makarov, 1935	M	11	GM	Sadakata, 1999
		Plesionika edwardsii (Brandt, 1851)	M	3.5	GM	Colloca, 2002
		Plesionika izumiae Omori, 1971	M	1.5	GM	Ahamed and Ohtomi, 2012
		Plesionika semilaevis Spence Bate, 1888	M	3	GM	Ohtomi, 1997
	Thoridae	*Heptacarpus sitchensis* (Brandt, 1851)	M	1.5	R	Bauer, 2004
		Spirontocaris phippsii (Krøyer, 1841)	M	5	SF	Węsławski, 1987
		Thor manningi Chace, 1972	M	0.5	R	Bauer, 2004
	Xiphocarididae	*Xiphocaris elongata* (Guérin-Méneville, 1855)	F	5–11^{3}	GM	Cross *et al.*, 2008
				18	MR	Cross *et al.*, 2008
Astacidea	Astacidae	*Astacus astacus* (Linnaeus, 1758)	F	10	R	Skurdal and Taugbøl, 2002
				15	R	Sadykova *et al.*, 2011
		Austropotamobius fulcisianus (Ninni, 1886)	F	8	MR, GM	Scalici *et al.*, 2008a
				15–18^{1}	GM	Ghia *et al.*, 2015
		Austropotamobius pallipes (Lereboullet, 1858)	F	5-6^{3}	MR, SF	Neveu, 2000
				6	SF, LH	Pratten, 1980
				9–11^{1}	GM	Wendler *et al.*, 2015
		Austropotamobius torrentium (von Paula Schrank, 1803)	F	9	GM	Streissl and Hödl, 2002
		Pacifastacus leniusculus (Dana, 1852)	F	9.7	GM, LM	Fonseca and Sheehy, 2007
				12	MR, GM	Flint, 1975
				16.7	LM	Belchier *et al.*, 1998
		Pontastacus leptodactylus (Eschscholtz, 1823)	F	7.4	GM	Deval *et al.*, 2007
	Cambaridae	*Cambarellus patzcuarensis* Villalobos, 1943	F	1.6	SP	Wirbellosen Datenbank, 2019c
		Cambarellus puer Hobbs, 1945	F	1.2	R	Walls, 2009
		Cambarellus shufeldtii (Faxon, 1884)	F	1.5	R	Walls, 2009

Table 1. Cont.

Sub-/Infraorder	Family	Species	Environment	Life span (yr)	Ageing method	Reference
		Cambarus bartonii (Fabricius, 1798)	F	13	MR, GM	Huryn and Wallace, 1987
		Cambarus chasmodactylus James, 1966	F	3	R	Lukhaup and Pekny, 2008
		Cambarus dubius Faxon, 1884	F	7	SF, LH	Loughman, 2010
		Cambarus elkensis Jezerinac & Stocker, 1993	F	5.3	SF, LH	Jones and Eversole, 2011
		Cambarus halli Hobbs, 1968	F	2	R	McLay and van den Brink, 2016
		Cambarus hubbsi Creaser, 1931	F	3	R	McLay and van den Brink, 2016
		Cambarus robustus Girard, 1852	F	4	R	Guiaşu and Dunham, 2002
		Creaserinus fodiens (Cottle, 1863)	F	6	LH	Norrocky, 1991
		Creaserinus gordoni (Fitzpatrick, 1987)	F	3	LH	Johnston and Figiel, 1997
		Faxonella creaseri Walls, 1968	F	1.5	R	Walls, 2009
		Faxonius eupunctus (Williams, 1952)	F	2.5	SP	Lukhaup and Pekny, 2008
		Faxonius immunis (Hagen, 1870)	F	3	R	Holdich, 1993
		Faxonius limosus (Rafinesque, 1817)	F	4	R	U. S. Fish and Wildlife Service, 2015
		Faxonius ozarkae (Williams, 1952)	F	2.5	SP	Lukhaup and Pekny, 2008
		Faxonius placidus (Hagen, 1870)	F	3	R	Taylor, 2003
		Faxonius rusticus (Girard, 1852)	F	3	SP	Lukhaup and Pekny, 2008
		Faxonius virilis (Hagen, 1870)	F	3	R	Holdich, 1993
		Lacunicambarus diogenes (Girard, 1852)	F	6	RC	Walls, 2009
		Lacunicambarus ludovicianus (Faxon, 1884)	F	3	R, RC	Walls, 2009
		Orconectes australis (Rhoades, 1941)	FC	22	MR, GM	Venarsky *et al.*, 2012
		Orconectes inermis Cope, 1872	FC	10	R	Venarsky *et al.*, 2012
		Procambarus alleni (Faxon, 1884)	F	3	R	Wirbellosen Datenbank, 2019d
		Procambarus clarkii (Girard, 1852)	F	1–4[1]	R	Huner, 2002
				4	GM	Scalici and Gherardi, 2007
				6.6	GM	Chucholl, 2011
		Procambarus erythrops Relyea & Sutton, 1975	FC	16	MR, SF	Streever, 1996
		Procambarus hinei (Ortmann, 1905)	F	1.5	R	Walls, 2009
		Procambarus suttkusi Hobbs, 1953	F	3	LH	Baker *et al.*, 2008
		Procambarus viaeviridis (Faxon, 1914)	F	2	SP	Lukhaup and Pekny, 2008
		Procambarus virginalis Lyko, 2017	F	4.4	RC	Vogt, 2010
	Cambaroididae	*Cambaroides japonicus* (De Haan, 1841)	F	10–11[1]	GM	Kawai *et al.*, 1997
	Nephropidae	*Homarus americanus* H. Milne Edwards, 1837	M	33	R	Wolff, 1978
		Homarus gammarus (Linnaeus, 1758)	M	40	R	Wolff, 1978

Table 1. Cont.

Sub-/Infraorder	Family	Species	Environment	Life span (yr)	Ageing method	Reference
				42–72^{1}	LM	Sheehy *et al.*, 1999
		Nephrops norvegicus (Linnaeus, 1758)	M	12-15^{1}	R	Bell *et al.*, 2006
	Parastacidae	*Astacoides betsileoensis* Petit, 1923	F	15	MR, GM	Jones *et al.*, 2007
		Astacoides crosnieri Hobbs, 1987	F	30	MR, GM	Jones *et al.*, 2007
		Astacoides granulimanus Monod & Petit, 1929	F	25	MR, GM	Jones and Coulson, 2006
				30	MR, GM	Jones *et al.*, 2007
		Astacopsis gouldi Clark, 1936	F	26	LH, MR, LR	Hamr, 1997
				60	SP	Lukhaup and Pekny, 2008
		Cherax cuspidatus Riek, 1969	F	8	LM	Sheehy, 2002
		Cherax destructor Clark, 1936	F	6	R	Gherardi *et al.*, 2010
		Cherax quadricarinatus (von Martens, 1868)	F	5	R	Gherardi *et al.*, 2010
		Euastacus armatus (von Martens, 1866)	F	20–28^{3}	GM	Gilligan *et al.*, 2007
		Geocharax tasmanicus (Erichson, 1846)	F	10	GM	Hamr and Richardson, 1994
		Paranephrops planifrons White, 1842	F	3–5^{1}	MR, GM	Parkyn *et al.*, 2002
		Paranephrops zealandicus (White, 1847)	F	29	MR, GM	Whitmore and Huryn 1999
		Parastacus brasiliensis (von Martens, 1869)	F	6	GM	Fontura and Buckup, 1989
		Parastacus defossus Faxon, 1898	F	3.3	GM	Noro and Buckup, 2009
Gebiidea	Upogebiidae	*Upogebia pusilla* (Petagna, 1792)	M	3	GM	Kevrekidis *et al.*, 1997
				4	GM	Conides *et al.*, 2012
Achelata	Palinuridae	*Jasus lalandii* (H. Milne Edwards, 1837)	M	40	SP	FAO, 2019
		Panulirus argus (Latreille, 1804)	M	20	LM	Maxwell *et al.*, 2007
				30	MR, GM	Ehrhardt, 2008
		Panulirus cygnus George, 1962	M	27	LM	Sheehy, 2002
		Palinurus elephas (Fabricius, 1787)	M	15	R	Phillips and Melville-Smith, 2006
		Palinurus gilchristi Stebbing, 1900	M	30	R	Phillips and Melville-Smith, 2006
		Palinurus mauritanicus Gruvel, 1911	M	21	R	Phillips and Melville-Smith, 2006
Anomura	Aeglidae	*Aegla franca* Schmitt, 1942	F	2.3	R	Rocha *et al.*, 2010
		Aegla itacolomiensis Bond-Buckup & Buckup, 1994	F	2.2–2.5^{1}	GM	Silva-Gonçalves *et al.*, 2009
		Aegla jarai Bond-Buckup & Buckup, 1994	F	2	GM	Boos *et al.*, 2006
		Aegla paulensis Schmitt, 1942	F	2.8–3.3^{1}	GM	Cohen *et al.*, 2011
		Aegla strinatii Turkay, 1972	F	2.8	R	Rocha *et al.*, 2010
	Coenobitidae	*Birgus latro* (Linnaeus, 1767)	T	50	GM	Fletcher *et al.*, 1990
				70	MR, GM	Drew *et al.*, 2013

Table 1. Cont.

Sub-/Infraorder	Family	Species	Environment	Life span (yr)	Ageing method	Reference
		Coenobita clypeatus (Fabricius, 1787)	T	42	RC	NBC2 News, 2018; Atlas Obscura, 2019
		Coenobita perlatus H. Milne Edwards, 1837	T	30	R	Animal Diversity Web, 2019a
		Coenobita variabilis McCulloch, 1909	T	20	SP	Species Bank, 2019
	Diogenidae	*Clibanarius antillensis* Stimpson, 1859	M	4	GM	Turra and Leite, 2000
		Clibanarius sclopetarius (Herbst, 1796)	M	3.9	GM	Turra and Leite, 2000
		Clibanarius vittatus (Bosc, 1802)	M	3.5	GM	Turra and Leite, 2000
	Hippidae	*Emerita analoga* (Stimpson, 1857)	M	3	SF	Osório *et al.*, 1967
		Emerita brasiliensis Schmitt, 1935	M	0.6–0.7^{1}	GM	Veloso and Cardoso, 1999
		Emerita holthuisi Sankolli, 1965	M	0.7	SF	Ansell *et al.*, 1972
		Emerita portoricensis Schmitt, 1935	M	1.1–1.3^{1}	GM	Sastre, 1991
		Emerita talpoida (Say, 1817)	M	1–1.8^{1}	SF	Diaz, 1980
	Lithodidae	*Paralithodes camtschaticus* (Tilesius, 1815)	M	20	RC	Matsuura and Takeshita, 1990
	Paguridae	*Pagurus brevidactylus* (Stimpson, 1859)	M	1.5–2^{1}	GM	Mantelatto *et al.*, 2005
Brachyura	Aethridae	*Hepatus pudibundus* (Herbst, 1785)	M	1.9–2.4^{1}	GM	Miazaki *et al.*, 2019
	Camptandriidae	*Deiratonotus kaoriae* Miura, Kawane & Wada, 2007	M	1.5	SF, LH	Kawane *et al.*, 2012
	Cancridae	*Cancer irroratus* Say, 1817	M	8	LH	Hines, 1991
		Cancer pagurus Linnaeus, 1758	M	9	LM	Sheehy and Prior, 2008
				10	LH	Hines, 1991
				21	SP	BIOTIC, 2019
		Cancer productus Randall, 1840	M	4	LH	Hines, 1991
		Glebocarcinus oregonensis (Dana, 1852)	M	5	LH	Hines, 1991
		Metacarcinus anthonyi (Rathbun, 1897)	M	5	LH	Hines, 1991
		Metacarcinus gracilis (Dana, 1852)	M	4	LH	Hines, 1991
		Metacarcinus magister (Dana, 1852)	M	5	LH	Hines, 1991
				10	SP	Pauley *et al.*, 1989
		Romaleon antennarium (Stimpson, 1856)	M	7	LH	Hines, 1991
	Carcinidae	*Carcinus aestuarii* Nardo, 1847	M	3	LH	Furota et *al.*, 1999
		Carcinus maenas (Linnaeus, 1758)	M	4–7^{3}	R	Klassen and Locke, 2007
	Dorippidae	*Medorippe lanata* (Linnaeus, 1767)	M	1	GM	Rossetti *et al.*, 2006
	Gecarcinidae	*Cardisoma armatum* Herklots, 1851	ST, T	12	SP	Rademacher and Mengedoht, 2011
		Cardisoma guanhumi Latreille, 1825	T	20	R	Wolcott, 1988
		Gecarcinus lateralis (Guérin, 1832)	T	10	SP	Rademacher and Mengedoht, 2011
		Gecarcinus quadratus Saussure, 1853	T	10	SP	Rademacher and Mengedoht, 2011

Table 1. Cont.

Sub-/Infraorder	Family	Species	Environment	Life span (yr)	Ageing method	Reference
		Gecarcinus ruricola (Linnaeus, 1758)	T	15	LH	Hartnoll *et al.*, 2006
		Gecarcoidea natalis (Pocock, 1889)	T	20	R	Green, 2004
	Gecarcinucidae	*Orizothelphusa ceylonensis* (Fernando, 1960)	F	4	SP	Rademacher and Mengedoht, 2011
		Parathelphusa maculata de Man, 1879	F	5	SP	Rademacher and Mengedoht, 2011
		Parathelphusa pantherina (Schenkel, 1902)	F	10	SP	Rademacher and Mengedoht, 2011
	Geryonidae	*Chaceon chilensis* Chirino-Gálvez & Manning, 1989	M	20	GM	Canales and Arana, 2009
		Chaceon maritae (Manning & Holthuis, 1981)	M	25	GM, MR	Melville-Smith, 1989
		Chaceon quinquedens (Smith, 1879)	M	30	GM	Chute *et al.*, 2008
	Grapsidae	*Grapsus adscensionis* (Osbeck, 1765)	M	0.5–1[1]	R	Hartnoll, 2009
		Pachygrapsus crassipes Randall, 1840	M	2.7	SF, LH	Hiatt, 1948
	Hymenosomatidae	*Amarinus laevis* (Targioni-Tozzetti, 1877)	F, B	1	R	Lucas, 1980
		Amarinus lacustris (Chilton, 1882)	F, B	2	R, RC	Lucas, 1980
		Amarinus paralacustris (Lucas, 1970)	F, B	2	R, RC	Lucas, 1980
		Elamenopsis lineata A. Milne-Edwards, 1873	M	1.5	R	McLay, 2015
		Halicarcinus cookii Filhol, 1885	M	1.5	LH	Van den Brink, 2006
		Halicarcinus planatus (Fabricius, 1775)	M	1.8	LH	Vinuesa and Ferrari, 2008
				3	R	McLay, 2015
				4	SF, LH	Diez and Lovrich, 2013
		Halicarcinus quoyi (H. Milne Edwards, 1853)	M	1.5	R	McLay, 2015
		Halicarcinus varius (Dana, 1851)	M	1.5	R	McLay, 2015
		Hymenosoma orbiculare Desmarest, 1823	M	1.5	R	McLay, 2015
		Limnopilos naiyanetri Chuang & Ng, 1991	F	2	SP	Rademacher and Mengedoht, 2011
		Lucascinus coralicola (Rathbun, 1909)	M	1	RC, LH	Gao *et al.*, 1994
		Neorhynchoplax kempi (Chopra & Das, 1930)	M, B	0.5–0.9[2]	SF, LH	Ali *et al.*, 1995
		Rhynchoplax messor Stimpson, 1858	M	1	LH	Gao and Watanabe, 1998
	Inachidae	*Inachus dorsettensis* (Pennant, 1777)	M	3	RC, GM	Hartnoll and Bryant, 2001
	Inachoididae	*Pyromaia tuberculata* (Lockington, 1877)	M	0.4–0.7[2]	LH	Furota, 1996
	Macrophthalmidae	*Macrophthalmus banzai* Wada & Sakai, 1989	M	1.6–2.5[3]	SF, LH	Henmi, 1993
	Majidae	*Maja squinado* (Herbst, 1788)	M	7	GM	Le Foll, 1993
	Mithracidae	*Maguimithrax spinosissimus* (Lamarck, 1818)	M	1	R	McLay, 2015
	Ocypodidae	*Austruca lactea* (De Haan, 1835)	M, B	7	LH	Yamaguchi, 2002
		Leptuca cumulanta (Crane, 1943)	M, B	0.7	GM	Koch *et al.*, 2005
		Minuca pugnax (Smith, 1870)	M, B	4.5	R	McLay, 2015

Table 1. Cont.

Sub-/Infraorder	Family	Species	Environment	Life span (yr)	Ageing method	Reference
		Minuca rapax (Smith, 1870)	M. B	1.4	GM	Koch *et al.*, 2005
				2.5	R	Taddei *et al.*, 2010
		Minuca vocator (Herbst, 1804)	M, B	1.1	GM	Koch *et al.*, 2005
		Ocypode quadrata (Fabricius, 1787)	M, B	3	SP	Animal Diversity Web, 2019b
		Uca maracoani (Latreille, 1802)	M, B	1.2–1.5[1]	GM	Koch *et al.*, 2005
		Ucides cordatus (Linnaeus, 1763)	M, B	8.3–9.2[1]	GM	Pinheiro and Taddei, 2005
				15.7–17.6[1]	GM	Costa *et al.*, 2014
	Oregoniidae	*Chionoecetes bairdi* Rathbun, 1924	M	4.2	RS	Ernst *et al.*, 2005
				12	GM	Donaldson *et al.*, 1981
		Chionoecetes opilio (O. Fabricius, 1788)	M	6.9	RS	Ernst *et al.*, 2005
				7.7	MR	Fonseca *et al.*, 2008
		Hyas coarctatus Leach, 1815	M	1.5–2[1]	RC, LH	Hartnoll and Bryant, 2001
	Pinnotheridae	*Dissodactylus mellitae* (Rathbun, 1900)	M	1.2	SF, LH	Bell and Stancyk, 1983
		Pinnotheres pisum (Linnaeus, 1767)	M	3	RC	Berner, 1952
		Pinnotheres tsingtaoensis Shen, 1932	M	2	SF, LH	Soong, 1997
		Zaops ostreus (Say, 1817)	M	1–3[1]	RC, LH	Christensen and McDermott, 1958
	Portunidae	*Callinectes danae* Smith, 1869	M	2.4–3.3[1]	GM	Shinozaki-Mendes *et al.*, 2012
		Callinectes sapidus Rathbun, 1896	M	8	GM, MR	Rugolo *et al.*, 1998
		Charybdis bimaculata (Miers, 1886)	M	1.5	GM	Doi *et al.*, 2008
		Charybdis japonica (A. Milne-Edwards, 1861)	M	4	R	Doi *et al.*, 2008
		Charybdis smithii MacLeay, 1838	M	1	R	Doi *et al.*, 2008
		Portunus pelagicus (Linnaeus, 1758)	M	2	LH	De Lestang *et al.*, 2003
		Portunus trituberculatus (Miers, 1876)	M	2	LH, RC	Ariyama, 1992
		Scylla olivacea (Herbst, 1796)	M, B	3.5–3.9[1]	GM	Viswanathan *et al.*, 2016
	Potamidae	*Potamon fluviatile* (Herbst, 1785)	F	8.6–14.3[3]	GM	Scalici *et al.*, 2008b
	Potamonautidae	*Liberonautes latidactylus* (de Man, 1903)	F	6	R	Cumberlidge, 1999
		Potamonautes lirrangensis (Rathbun, 1904)	F	10	SP	Rademacher and Mengedoht, 2011
	Pseudothelphusidae	*Rodriguezus garmani* (Rathbun, 1898)	F	3	RC, LH	Rostant *et al.*, 2008
	Sesarmidae	*Aratus pisonii* (H. Milne Edwards, 1837)	ST	2	SF, LH	Leme (2002)
				4.5–6[3]	LH	Conde *et al.*, 2000
		Geosesarma bicolor Ng & Davie, 1995	ST	2	SP	Rademacher and Mengedoht, 2011
		Geosesarma krathing Ng & Naiyanetr, 1992	T	2	SP	Rademacher and Mengedoht, 2011
		Geosesarma notophorum Ng & Tan, 1995	T	2	SP	Rademacher and Mengedoht, 2011

Table 1. Cont.

Sub-/Infraorder	Family	Species	Environment	Life span (yr)	Ageing method	Reference
		Guinearma huzardi (Desmarest, 1825)	T	8	SP	Rademacher and Mengedoht, 2011
		Metasesarma aubryi (A. Milne-Edwards, 1869)	T	4	SP	Rademacher and Mengedoht, 2011
		Metasesarma obesum (Dana, 1851)	T	3	SP	Rademacher and Mengedoht, 2011
		Neosarmatium meinerti (de Man, 1887)	ST	7	SP	Rademacher and Mengedoht, 2011
		Parasesarma eumolpe (De Man, 1895)	ST	3	SP	Rademacher and Mengedoht, 2011
		Pseudosesarma bocourti (A. Milne-Edwards, 1869)	ST	5	SP	Rademacher and Mengedoht, 2011
		Pseudosesarma crassimanum (De Man, 1888)	ST	5	SP	Rademacher and Mengedoht, 2011
		Pseudosesarma moeschii (De Man, 1892)	ST	5	SP	Rademacher and Mengedoht, 2011
		Sesarmops intermedius (De Haan, 1835)	ST	5	SP	Rademacher and Mengedoht, 2011
		Sesarma jarvisi Rathbun, 1914	T	5	LH	Diesel and Horst 1995
	Trichodactylidae	*Dilocarcinus pagei* Stimpson, 1861	F	2.4–2.7^1	GM	Pinheiro *et al.*, 2005
				4–4.5^1	GM	Taddei and Herrera, 2010
	Varunidae	*Eriocheir japonica* (De Haan, 1835)	F, B	4.4	RC	Kobayashi, 2012
		Eriocheir sinensis H. Milne Edwards, 1853	F, B	1	LH	Jin *et al.*, 2002
				5	R	Herborg *et al.*, 2003
		Hemigrapsus crenulatus (H. Milne Edwards, 1837)	M	5	LH	Clark, 1987
		Neohelice granulata (Dana, 1851)	M, B	2	GM	Barcelos *et al.*, 2007
				4.1	GM	Luppi *et al.*, 2004
	Xanthidae	*Xantho poressa* (Olivi, 1792)	M	1–2^1	SF, LH	Spivak *et al.*, 2010

Longevity figures are maximum values given in cited references. Ranges in longevity column are differences between sexes^1, summer and winter generations^2, and habitats^3. Species names and habitats are according to the World Register of Marine Species. Some species, *e.g.*, from the Ocypodidae (Crane, 1975; Thurman *et al.*, 2013), Hymenosomatidae and Varunidae live in a broad range of salinities, which is considered in column 4 by using the abbreviations M, B and F, B. Abbreviations: B, brackish water; F, fresh water; FC, freshwater cave; GM, growth model based on size-frequency distribution and reproductive parameters; LH, life history analysis; LM, lipofuscin method; M, marine; MR, mark-recapture method; R, reviewed data; RC, rearing in captivity; RS, radiometry of shell; SF, size-frequency distribution analysis; SP, data from species profile; ST, semiterrestrial; T, terrestrial.

Table 2. Comparison of longevities between higher taxa.

	No. of species with longevity data	Longevity range (yr)*	Mean (yr) ± SD and CV (%)
Dendrobranchiata	29 of 540	0.1-9	2.13±1.61; 75.6
Caridea	43 of 3,268	0.5-18	4.19±4.05; 96.7
Astacidea	54 of 653	1.5-72	11.00±13.80; 125.5
Gebiidea	1 of 192	4-4	4.00±0.00; 0.0
Achelata	6 of 140	15-40	27.17±8.56; 31.5
Anomura	19 of 2,451	0.7-70	11.34±18.28; 161.2
Brachyura	92 of 6,559	0.7-30	5.59±5.75; 102.9
Decapoda	244 of 14,335	0.1-72	7.12±10.18; 142.9

* Based on reported maximum values of species. CV=coefficient of variation. No reliable data were found for the 69 Stenopodidea, 2 Glypheidea, 423 Axiidea and 38 Polychelida. Species numbers of decapod groups are from De Grave *et al.*, 2009

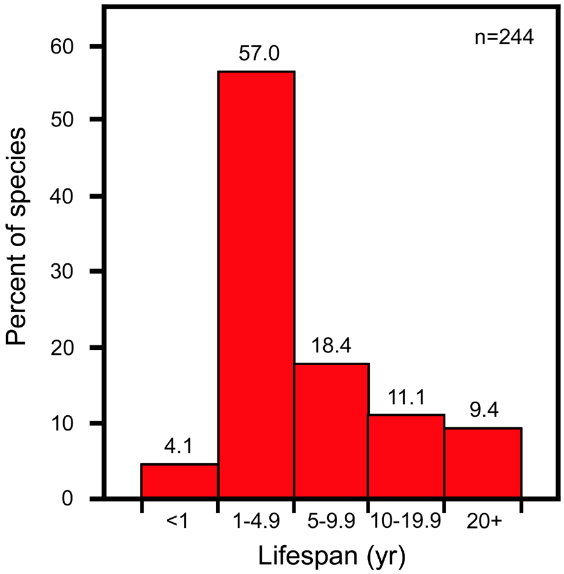

Figure 1. Longevity spectrum of the Decapoda. More than half of the 244 investigated species have life spans below 5 years. Approximately 20% of species live longer than 10 years and less than 10% reach ages above 20 years.

(CV=125.5%) in the Astacidea, and 15–40 years (CV=31.5%) in the Achelata (Table 2). There are also marked differences within the same family or genus. Examples are the Cambaridae with life spans of 1.2–22 years and the genus *Procambarus* with life spans of 1.5–16 years (Table 1). These differences may be the result of the evolution of different life histories and life styles and spreading into different environments.

Longevity differences between marine, freshwater and terrestrial environments

Longevity is on average lowest in the sea and brackish water (6.0 years, n=132), intermediate in fresh water (7.2 years, n=88) and highest in semiterrestrial and terrestrial environments (13.0 years, n=24) (Fig. 2). The difference between marine and freshwater environments is partly due to the fact that the shorter-lived Dendrobranchiata have not invaded freshwater habitats. Longevity promoting environments are obviously the deep sea, polar waters, freshwater caves and the land. For example, the deep sea shrimps *Aristeus antennatus* and *Aristaeomorpha foliacea* have the highest life spans of all investigated Dendrobranchiata and the polar caridean shrimps *Notocrangon antarcticus* and *Sclerocrangon boreas* live much longer than crangonids from warmer waters (Table 1). The cave-dwelling shrimp *Palaemonias ganteri* and crayfish *Orconectes australis* live much longer than their epigean relatives, and the terrestrial anomurans have considerably higher life spans than their marine and freshwater relatives (Table 1).

Particularly long-lived species

Species that live for several decades are found in distantly related families like the achelatan Palinuridae (spiny lobsters), astacidean Nephropidae (clawed lobsters) and Parastacidae (southern hemisphere crayfish), anomuran Coenobitidae (hermit and coconut crabs), and brachyuran Menippidae and Inachidae. Examples of the first four families are found in Table 1. Examples of the latter two families are the Tasmanian giant crab *Pseudocarcinus gigas* (Lamarck, 1818) and the giant Japanese spider crab *Macrocheira kaempferi* (Temminck, 1836). The ability of these species to live for many decades and even more than 100 years was deduced from their exceptionally large size (*e.g.*, *Homarus americanus* and *Macrocheira kaempferi*), slow growth and late onset of maturity (*e.g.*, *Pseudocarcinus gigas* and *Astacopsis gouldi*), and phases of zero and negative growth at high age (*e.g.*, *Birgus latro*) (Wolf, 1978; Hamr, 1997; Gardner *et al.*, 2002; Drew *et al.*, 2013). For example, the intermoult duration in adult *Pseudocarcinus gigas* is about 9 years (Gardner *et al.*, 2002) and the average age at maturity in the giant Tasmanian freshwater crayfish *Astacopsis gouldi* is approximately 9 years in males and 14 years in females (Hamr, 1997).

Discussion

The present list of life spans in decapod crustaceans was compiled to provide a first data base for interested carcinologists. Since longevity is an important parameter in ecology, fisheries and conservation (Hartnoll, 2001; Cailliet and Andrews, 2008) it may help researchers in these fields with information and literature. I am aware that the compiled data are quite heterogeneous since they were obtained with different ageing methods but having data of diverse quality is better than having no data. The list includes only data obtained with established methods of age determination such as rearing in captivity, mark-recapture method, growth models and the lipofuscin method (Hartnoll, 2001; Vogt, 2012). Data obtained by growth band counts of hard structures that are thought to perist during moulting were not considered because this issue is still controversially discussed (Kilada and Driscoll, 2017; Becker *et al.*, 2018). Future research must show, whether this approach will be a breakthrough in ageing of decapods or a wrong path.

The Decapoda include almost 15,000 species that differ greatly in body size, life history and ecology (De Grave *et al.*, 2009). Almost 80% live in the sea or brackish water, about 20% in freshwater and less than 1% on land. The highest percentage of longevity data is available for the terrestrial species followed by freshwater species. Analysis of the longevity data of 244 species revealed an exceptionally broad range of life spans in the Decapoda when compared to other animal groups and differences between higher taxa and environments.

Longevity in the Decapoda ranges from 0.1 to about 70 years, corresponding to a 700 fold difference. The shortest-lived decapods are planktonic shrimps and the longest-lived decapods are clawed lobsters. In insects, the closest relatives of crustaceans, life span varies from a month in fruit fly to about two decades in queens of termites (Thorne *et al.*, 2002). In bivalves, the longevity range is 1–374 years (Abele *et al.*, 2009), in fishes 1–152 years, in amphibians 1.8–55 years, in reptiles 1–153 years, in birds 1.5–73 years, and in mammals 1–122 years (Carey and Judge, 2000).

Longevity in decapods apparently depends on taxonomic affiliation. The plesiomorphic Dendrobranchiata have the smallest average live span. They usually live less than 2 years with the exception of some deep-sea representatives. The infraorder with the highest percentage of long-lived species is probably the Achelata, which include slipper lobsters and rock lobsters. However, the coefficient of variation for life spans is high in all infraorders, mostly exceeding 100%. This data indicates that longevity was subject to intense evolution in all infraorders of the Decapoda.

The present compilation of data also shows that longevity is dependent on the environment. Terrestrial species live on average longer than freshwater species, and freshwater species live longer than marine species. In an earlier paper, I have presented examples on the positive correlation of life span and latitude and examples on longevity differences between diverse habitats of the same geographical region (Vogt, 2012). The deep sea, cold polar waters and nutrient-poor cave environments seem to prolong life spans.

It was not my aim to correlate longevity with body size but there is a general tendency that bigger species have long life spans. For example, freshwater crayfish, lobsters, slipper lobsters and some large brachyuran crabs have life spans of decades, whereas small species from these groups life only for 1–2 years. However, there are also some contradictory examples like the shrimps of the genus *Penaeus* that reach sizes of more than 30 cm but live only for about 2 years.

The present database gives no information about which method of age determination is the most appropriate one, because studies that have analysed the same population with more than one ageing technique are scarce. For example, in the shrimp *Xiphocaris elongata* from a Puerto Rican headwater stream longevity was estimated to 11 years by a growth model but recapture of an earlier marked specimen revealed an age of 18 years (Cross *et al.*, 2008).

There is a certain probability that, due to indeterminate growth, some exceptionally large specimens of the long-lived species may become centenarians. However,

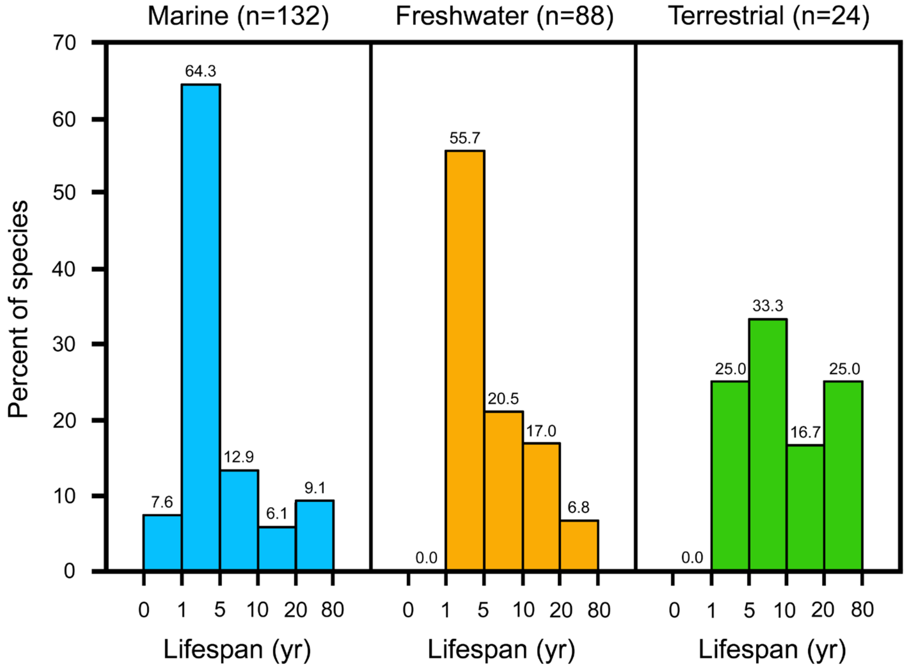

Figure 2. Comparison of longevities between marine, freshwater and terrestrial environments. The percentage of life spans ≥5 years increases markedly from marine to freshwater to terrestrial species. Brackish water species are included in the marine group.

validation would require long-term rearing in captivity over several generations of researchers or recapture of marked specimens in the distant future. Both approaches are principally possible but I doubt if there are scientists who engage in such long-term tasks.

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