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Article

The Magnitude of Global Marine Species Diversity

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Summary

Background: The question of how many marine species exist is important because it provides a metric for how much we do and do not know about life in the oceans. We have compiled the first register of the marine species of the world and used this baseline to estimate how many more species, partitioned among all major eukaryotic groups, may be discovered.
Results: There are ∼226,000 eukaryotic marine species described. More species were described in the past decade (∼20,000) than in any previous one. The number of authors describing new species has been increasing at a faster rate than the number of new species described in the past six decades. We report that there are ∼170,000 synonyms, that 58,000–72,000 species are collected but not yet described, and that 482,000–741,000 more species have yet to be sampled. Molecular methods may add tens of thousands of cryptic species. Thus, there may be 0.7–1.0 million marine species. Past rates of description of new species indicate there may be 0.5 ± 0.2 million marine species. On average 37% (median 31%) of species in over 100 recent field studies around the world might be new to science.
Conclusions: Currently, between one-third and two-thirds of marine species may be undescribed, and previous estimates of there being well over one million marine species appear highly unlikely. More species than ever before are being described annually by an increasing number of authors. If the current trend continues, most species will be discovered this century.

Introduction

The most widely used metric of biodiversity is species richness, and much has been written about how many species may exist on land and in the sea [1–3]. Recent estimates of the number of extant described marine species vary from 150,000 to 274,000, and of those that may exist from 300,000 to over 10 million [4–14] (Table 1). Most of these estimates were made without the benefit of a global inventory of known marine species. The former estimates were based on experts' polls. The latter were based on extrapolation from past rates of description of species and higher taxa, proportions of undescribed species in samples, proportions that well-known taxa may represent of regional biota, and numbers of species in samples (Table 1). Here, we report on the near completion of such an inventory. The World Register of Marine Species (WoRMS) is an open-access online database created by an editorial board of 270 taxonomists from 146 institutions in 32 countries [15]. The first goal of WoRMS has been the compilation of a list of all taxonomically accepted marine species, commonly used synonyms, and key literature sources. Beyond complete taxonomic coverage, the longer-term aim is to provide or link to data on species distributions, biology, ecology, images, and guides to their identification. An important side benefit is that it facilitates communication within and beyond the taxonomic community, which can lead to increased rates of discovery of species and synonyms and a reduced rate of creation of new synonyms (and homonyms).

This collaborative database enabled the following set of marine biodiversity metrics to be compiled for the first time: (1) the number of nominal species, i.e., all species named, including those now recognized as synonyms due to multiple descriptions of the same species, and (2) the number of taxonomically accepted species, i.e., recognized species, excluding names that have been relegated to synonymy. In addition, we estimated the number of species that (3) have been collected but not yet described, (4) are undiscovered (unsampled), and (5) are molecular cryptics, i.e., only distinguishable by molecular analysis. Finally, we applied a statistical model that predicted how many more species might be discovered based on historical rates of species description and compared it with values from the above estimates. We omitted Bacteria and Archaea from our analysis because the species concept used for eukaryotes cannot be applied to these two taxa.

Our estimates of valid and nominal species are based on the WoRMS database as of February 17, 2012 and the literature on taxa for which WoRMS was not yet complete. The figures regarding species collected but not yet described, undiscovered, and cryptic are based on our own experience and that

Table 1. An Overview of the Estimated Numbers of Marine Species Described and Those that May Exist, as Published in the Literature

	Method	Reference (Year)
Number of Species Described		
150,000	expert opinion	van der Land [4] (1994)
160,000	expert opinion	Gordon [5] (2001)
204,000	expert opinion	Gibbons et al. [6] (1999)
222,000–230,000	inventory of 214,000 and expert opinion	present study
230,000	expert opinion	Bouchet [7] (2006)
250,000	literature and expert opinion	Winston [8] (1992)
274,000	expert opinion	Reaka-Kudla [9] (1996)
Number of Existing Species		
300,000	predicted based on description rate using WoRMS 2009	Costello et al. [10] (2012)
<500,000	proportion new species in samples	May [11] (1992)
320,000–760,000	predicted based on description rate using WoRMS 2012	stats model, present study
704,000–972,000	expert opinion	experts, present study
>1,000,000	expert opinion of proportions of undescribed species in regions of the world	Winston [8] (1992)
1,500,000	extrapolation from proportion of Brachyura in Europe	Bouchet [7] (2006)
2,200,000	extrapolation from rate of discovery of higher taxa	Mora et al. [12] (2011)
5,000,000	extrapolation from benthos samples off Australia	Poore and Wilson [13] (1993)
>10,000,000	extrapolation from deep-sea benthos samples	Grassle and Maciolek [14] (1992)

of other experts, considering information on numbers of undescribed species that we observed in samples and our knowledge of particular habitats and geographic areas that remain little explored. The rationales for these estimates are provided in Table S2 available online. We each limited our estimates to groups for which we have close working knowledge. To indicate areas of uncertainty, we applied minimum and maximum estimates. The expert-opinion approach to estimating the magnitude of unknown biodiversity has been endorsed, for example, by Gaston [16] and used by many others (e.g., [7, 8]; Table 1). It complements macroecological approaches involving extrapolation from surrogate taxa, habitats, and/or geographic areas (reviewed in [2]). Our collective estimates are less likely to be biased than previous estimates made by fewer experts because we are most familiar with our particular taxa [17]. The 270 editors in WoRMS are among the world's top taxonomists. They represent ~5% of the active marine taxonomists today (based on ~4,900 marine taxonomists publishing during the last decade) and are involved in nearly one-third of new marine species descriptions in the past decade [15]. However, estimates based on expert opinion are subject to bias based on scientists' individual experiences, accuracy of their recollections and beliefs (e.g., how endemic a taxon is), and concerns about the consequences of their estimates on perceptions of the importance of their taxon [18]. For example, expert estimates tend to be optimistic [18], and they may feel it prudent to overestimate rather than underestimate the number of species in a taxon. Estimates can be substantially improved by combining empirical data with expert judgment [19]. Thus, we complemented the expert-opinion approach by fitting a statistical model with confidence limits to the species description rate for accepted species in WoRMS as of February 17, 2012 [20] (Supplemental Experimental Procedures). This model accounts for variation between years and identifies taxa whose rate of discovery is too variable for such extrapolation.

Results

Accepted Species

We recognized that 222,000–230,000 accepted eukaryotic marine species have been described. Of these, ~7,600 species belong to Plantae, ~19,500 to Chromista, ~550 to Protozoa, ~1,050 to Fungi, and nearly 200,000 to Animalia. We were unable to give a more precise number for Animalia due to the uncertainty in the total number of gastropod species (Table 2; see also Table S2).

Unaccepted Synonyms

Of ~400,000 species names established, ~170,000 (~40%) were currently not accepted, i.e., were synonyms (Table 2). This means that on average, for every five species described as new to science, at least two had already been described. The level of synonymy was greatest among the most-studied organisms, such as cetaceans, where 1,271 names existed for only 87 valid species. Taxa of which over 70% of names were considered synonyms were Cetacea, Reptilia, Sirenia, Sipuncula, Siphonophora, Zoantharia, and Bacillariophyceae. Taxa with over 50% synonymy rates included Pisces, Mollusca, Myriapoda, Scleractinia, Asteroidea, Pennatulacea, Chaetognatha, and Larvacea. Of the 170,000 synonyms we were aware of, 57,000 were entered into WoRMS. These entries indicated that the proportion of recognized synonyms has been steadily decreasing since the early 20th century (Figure 1). Of species described in the first decade of the 20th century, 25% were now synonyms, from the 1950s 15%, and the 1980s 5%. Adjusting for the fact that about 33% of synonyms were in WoRMS, and if this synonym trend was only due to the time it takes to discover synonyms, then a further 42,000 species remain to be synonymized since 1900.

Estimated Total Global Species Richness

Based on Past Rates of Species Descriptions

The marine species description rate has increased since the 1750s, with a very high discovery rate around 1900 (Figure 2). It declined during the two world wars and has recovered from 1950 to present. The curve dipped in the 1990s but has sharply increased again since 2000, with more than 20,000 marine species (9% of those currently known) described in the last decade. The number of marine species described per year reached all-time highs in the past decade, with over 2,000 species described in each of four different years (Figure 2).

The statistical model predicted a total of 540,000 marine species, with a 95% probability interval of 320,000 to 760,000. When limited to the different taxonomic groups, the estimates were comparable to or less than the experts' estimates (Table 2). For several taxonomic groups (especially where the majority of species remain to be described), the rate of discovery was still rising and the model could not make a meaningful estimate of total species numbers. This was the case for Acanthocephala, Polychaeta, Hirudinea, Oligochaeta, Cumacea, Isopoda, Tanaidacea, Copepoda, Ostracoda, Bryozoa, Cephalorhyncha, Chaetognatha, Hexacorallia, Octocorallia, Hydrozoa, Gastrotricha, Gnathostomulida, Bivalvia, Gastropoda, Cestoda, Digenea, and Porifera (Table 2).

Even in taxa of large body size or high economic value, new species continued to be discovered and described. Between 1999 and 2008, 780 new crabs, 29 lobsters, and 286 shrimps (of a total of 1,401 decapods), 1,565 marine fish, 4 sea snakes, and 3 new species and 7 subspecies of cetaceans [15] were described.

Our data also showed that the number of authors describing new species each year has been increasing, to 4,900 authors in the past decade (Figure 3). Moreover, the number of authors has been increasing faster than the number of new species. The number of valid species described per author decreased from between three to six species per year before 1900 to less than two species per author per year since the 1990s (Figure 3).

Based on Expert Opinion

Our collective estimates suggested that global marine species richness was between 704,000 and 972,000, so that only one-third to one-fourth of marine species have been described. However, this proportion varied greatly between taxa (Table 2). Of this number, 58,000–72,000 species, or 25%–30% of the known marine diversity, were already represented in specimen collections waiting to be described (Table 2). The estimated number of undiscovered molecular cryptic species was ~9,000–35,000 (Table 2) for 49 taxa that have a total of ~80,000 accepted described species—i.e., 11%–43% of their known species. Cryptic species were predicted not to occur in 9 taxa, and for 32 of the 98 remaining taxa, the experts did not have a basis on which to make an estimate. The proportion of cryptic species was highest in taxa with few externally visible diagnostic characters, such as Radiozoa, Placozoa, Hydrozoa, Zoantharia, Mesozoa,

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Table 2. Estimates of Known and Unknown Marine Species Diversity

			Total Known	Described (Accepted)	% Syn	Undescribed (Collected)	Undiscovered (Morpho)	Undiscovered (Molecular Cryptic)	Total Unknown (Experts)	Total Unknown (Model)	Total Estimated	% Known	New spp. (1999-2008)
Plantae			**7,593**							**2,500-3,600**	**22,798-22,803**	**33**	**632**
	Chlorophyta			1,300	19	?	1,200	-	1,200	-		52	
	Rhodophyta			6,150	49	?	14,000	-	14,000	-		31	
	Mangroves			75	29	?	0-5	-	0-5	-		94-100	
	Seagrasses			68	6	0	5	-	5	-		93	
Chromista			**19,444**							**3,500-4,200**	**77,930-93,923**	**21-25**	**790**
	Bigyra			76	?	?	75	-	75	-		50	
	Cercozoa			173	?	?	160	-	160	-		52	
	Ciliophora			2,615	39	?	1,058-4,648	3,173-14,526	4,231-19,174	-		12-38	
	Cryptophyta			86	?	?	150	-	150	-		36	
	Foraminifera			6,000	40	1,000	500	-	1,500	-		80	
	Haptophyta			241	?	?	100-150	-	100-150	-		62-71	
	Heliozoa			10	?	?	20	-	20	-		33	
	Myzozoa			2,686	?	?	575	-	575	-		82	
	Ochrophyta												
		Phaeophyceae		1,800	49	50	150-200	-	200-250	-		88-90	
		Bacillariophyceae		5,000	75	?	50,000	-	50,000	-		9	
		Chrysophyceae		51	-	?	1,000	-	1,000	-		5	
		Other Ochrophyta		263	?	?	160	-	160	-		62	
	Oomycota			43	?		225	-	225	-		16	
	Radiozoa			400	30	0	40	50-1,000	90-1,040	-		28-82	
Protozoa			**542**							**150-400**	**2,207**	**25**	**23**
	Amoebozoa			117	?	?	450	-	450	-		21	
	Apusozoa			3	?	?	15	-	15	-		17	
	Choanozoa			150	?	?	750	-	750	-		17	
	Euglenozoa			243	?	?	370	-	370	-		40	
	Excavata			29	?	?	80	-	80	-		27	
Fungi			**1,035**	1,035	10	200	14,800	-	15,000	**1,100-1,500**	**16,035**	**6**	**125**
Animalia													
	Acanthocephala		**450**	450	25	20	150	50-150	220-320	**	**670-770**	**58-67**	**30**
	Annelida		**13,721**								**26,011-37,096**	**37-53**	**841**
		Polychaeta		12,632	35	3,160	3,160	NB	6,320	**		67	
		Hirudinea		179	28	15-35	50-100	5-20	70-155	**		54-72	
		Oligochaeta		910	30	300	5,000-15,000	600-1,600	5,900-16,900	**		5-13	
	Arthropoda												
		Chelicerata	**2,685**							**2,700-3,000**	**5,335-7,066**	**38-50**	**340**
		Merostomata		4	-	1	0	NB	1	-		80	
		Pycnogonida		1,307	3	150-500	979-1,650	50-100	1,179-2,250	-		37-53	
		Acarina		1,218	-	100	1,220-1,830	150-200	1,470-2,130	-		36-45	
		Araneae		125	-	?	?	-	-	-		-	
		Pseudoscorpionida		31	-	?	?	-	-	-		-	
		Crustacea											
		Decapoda	**12,029**							**4,500-5,100**	**21,073-24,204**	**50-57**	**1,611**
		Dendrobranchiata		551	31	50	100	NB	150	-		79	
		Achelata		142	38	10	30-70	5-10	45-90	-		61-76	
		Chirostyloidea		206	2	250	580	10-55	840-885	-		19-20	

(*Continued on next page*)

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Table 2. *Continued*

			Total Known	Described (Accepted)	% Syn	Undescribed (Collected)	Undiscovered (Morpho)	Undiscovered (Molecular Cryptic)	Total Unknown (Experts)	Total Unknown (Model)	Total Estimated	% Known	New spp. (1999-2008)
		Galatheoidea		715	8	300	830	19-97	1,149-1,227	-		37-38	
		Hippoidea		81	19	3	10	NB	13	-		86	
		Lithodoidea		129	20	10	40	-	50	-		72	
		Lomisoidea		1	0	0	0	-	0	-		100	
		Paguroidea		1,106	17	150-200	400	NB	550-600	-		65-67	
		Enoplometopoidea		12	20	0	2-7	1-3	3-10	-		55-80	
		Glypheoidea		2	0	0	1-2	-	1-2	-		50-67	
		Nephropoidea		54	24	1	10-28	2-5	13-34	-		61-81	
		Brachyura		5,688	30	300	3,550-6,400	0	3,850-6,700	-		46-60	
		Procarididea		6	0	0	2	NB	2	-		75	
		Caridea		2,572	25	400	1,500	NB	1,900	-		58	
		Polychelida		38	27	0	7-15	1-3	8-18	-		68-83	
		Stenopodidea		68	16	10	50	NB	60	-		53	
		Gebiidea		203	10	50	100	-	150	-		58	
		Axiidea		455	10	50	200	-	250	-		65	
	Peracarida		**17,115**							**	**132,297-228,231**	**7-13**	**2,275**
		Amphipoda		6,947	-	?	20,000	-	20,000	4,000-4,300		26	
		Bochusacea		5	0	0	10	NB	10	-		33	
		Cumacea		1,444	2	45	6000	-	6,045	**		19	
		Isopoda		6,345	2	3,400	60,000-120,000	0	63,400-123,400	**		5-9	
		Lophogastrida		56	24	10	120	1-5	131-135	-		29-30	
		Mictacea		1	0	0	0	0	0	-		100	
		Mysida		1,180	32	80-100	2,000-4,000	10-20	2,090-4,120	340-450		22-36	
		Tanaidacea		1,130	6	900	22,600-56,500	NB	23,500-57,400	**		2-5	
		Thermosbaenacea		7	0	1	5	-	6	-		54	
	Other Crustacea		**21,086**								**55,604-107,594**	**20-38**	
		Branchiopoda		90	3	0	0	0	0	-		100	
		Cephalocarida		12	0	0	10	NB	10	-		55	
		Amphionidacea		1	-	0	0	0	0	-		100	
		Euphausiacea		86	42	0	0	0	0	-		100	
		Stomatopoda		468	19	52	200	-	252	-		65	
		Leptostraca		49	2	50-100	200-600	-	250-700	-		7-16	
		Branchiura		44	12	2-3	50-80	NB	52-83	-		35-46	
		Copepoda		10,000	17	1,500-2,000	28,500-48,000	125	30,125-50,125	**		17-25	
		Mystacocarida		13	0	1	10	NB	11	-		54	
		Pentastomida		10	-	?	?	-	-	-		-	
		Tantulocarida		36	0	60	1,000	NB	1,060	-		3	
		Thecostraca		1,400	7	?	100-200	NB	100-200	-		88-93	
		Ostracoda		8,853	7	1,000-2,000	1,625-32,000	NB	2,625-34,000	**		21-77	
		Remipedia		24	4	8	20-50	5-9	33-67	-		26-42	
	Hexapoda (Insecta and Collembola)		**2,037**	2,037	15	30-60	30-100	NB	60-160	110-250	**2,097-2,197**	**93-97**	**30**
	Myriapoda		**61**	61	58	?	190	-	190	-	**251**	**24**	**2**
Brachiopoda			**388**	388	-	0	?		-	65-175	**388**	**?**	**21**
Bryozoa			**5,900**	5,900	9	?	2,450-4,250	350-950	2,800-5,200	**	**8,700-11,100**	**53-68**	**599**
Cephalorhyncha			**284**							**	**2,667-3,772**	**8-11**	**47**
	Kinorhyncha			228	0	250-350	1,000-2,000	-	1,250-2,350	-		9-15	
	Loricifera			32	0	123	1,000	-	1,123	-		3	

Table 2. *Continued*

		Total Known	Described (Accepted)	% Syn	Undescribed (Collected)	Undiscovered (Morpho)	Undiscovered (Molecular Cryptic)	Total Unknown (Experts)	Total Unknown (Model)	Total Estimated	% Known	New spp. (1999-2008)
	Nematomorpha		5	0	?	10-15	NB	10-15	-		25-33	
	Priapulida		19	-	?	?	-	-	-		-	
Chaetognatha		**129**	129	54	6-9	44	0-256	50-309	**	**179-438**	**29-72**	**11**
Chordata												
	Cephalochordata	**33**	33	-	?	?	-	-	-	**33**		
	Tunicata	**3,020**							2,700-4,300	**4,600-5,100**	**59-66**	**391**
	Ascidiacea		2,874	43	500	500-1,000	500	1,500-2,000	-		59-66	
	Larvacea		67	53	4	63	NB	67	-		50	
	Thaliacea		79	0	5	8	-	13	-		86	
	Pisces (incl. Agnatha)	**16,733**	16,733	49	500	4,200-4,300	200-300	4,900-5,100	6,700-10,700	**21,633-21,833**	**77**	**1,577**
	Mammalia	**135**							0-11	**137-143**	**94-99**	**3**
	Carnivora		44	14	0	0	-	0	-		100	
	Sirenia		4	89	0	0	0	0	-		100	
	Cetacea		87	93	0	1-5	1-3	2-8	-		92-98	
	Reptilia	**110**	110	82	?	20-30	-	20-30	-	**130-140**	**79-85**	**4**
	Aves	**641**	641	-	30-50	30-50	0	60-100	0-9	**701-741**	**87-91**	**1**
Cnidaria												
	Hexacorallia	**3,152**							**	**3,976-5,105**	**62-79**	**286**
	Actiniaria		1,093	25	?	?	NB		-		-	
	Antipatharia		250	11	50-75	50-100	NB	100-175	-		59-71	
	Ceriantharia		141	12	4-6	15-25	-	19-31	-		82-88	
	Corallimorpharia		47	15	?	?	NB	0	-		-	
	Zoantharia		101	78	30	180-380	60-760	270-1,170	-		8-27	
	Scleractinia		1,520	61	93	342	0-142	435-577	-		72-78	
	Octocorallia	**3,171**							**	**4,871**	**65**	**290**
	Alcyonacea, Helioporacea		2,951	18	100	1,500	NB	1,600	-		65	
	Pennatulacea		220	51	20	80	NB	100	-		69	
	Cubozoa	**37**	37	20	10-20	20-50	-	30-70	-	**67-107**	**35-55**	
	Hydrozoa (excl. Siphonophorae)	**3,426**	3,426	27	50-100	500-1,500	1,000-2,500	1,550-4,100	**	**4,976-7,526**	**46-69**	**304**
	Siphonophorae	**176**	176	74	50-60	50-60	0	100-120	-	**276-296**	**59-64**	
	Scyphozoa	**201**	201	1	38-80	77	22-25	137-182	-	**338-383**	**52-59**	
	Staurozoa	**48**	48	24	10-12	30-50	0-3	40-65	-	**88-113**	**42-55**	
Ctenophora		**190**	190	24	25-50	100-250	0-10	125-310	7-57	**315-500**	**38-60**	3
Cycliophora		**2**	2	0	3	10-125	-	13-128	-	**15-130**	**2-13**	1
Echinodermata		**7,291**							230-300	**9,617-13,251**	**55-76**	297
	Asteroidea		1,922	65	125-200	200-500	-	325-700	-		73-86	
	Echinoidea		999	37	20-50	45-150	306-1,080	371-1,280	-		44-73	
	Ophiuroidea		2,064	34	260-300	200-400	100-150	560-850	-		71-79	
	Crinoidea		623	32	20-30	50-100	-	70-130	-		83-90	
	Holothuroidea		1,683	29	200-400	800-2,600	-	1,000-3,000	-		36-63	
Echiura		**175**	175	14	5-10	30-40	-	35-50	12-44	**210-225**	**78-83**	5
Entoprocta		**193**	193	13	30	1,000	NB	1,030	16-57	**1223**	**16**	18
Gastrotricha		**434**	434	18	310	1,000-1,500	500-1,000	1,810-2,810	**	**2,244-3,244**	**13-19**	86
Gnathostomulida		**98**	98	10	15-20	200	NB	215-220	**	**313-318**	**31**	9
Hemichordata		**118**	118	7	10	?	-	10	0-2	**128**	**?**	4

(*Continued on next page*)

Table 2. *Continued*

		Total Known	Described (Accepted)	% Syn	Undescribed (Collected)	Undiscovered (Morpho)	Undiscovered (Molecular Cryptic)	Total Unknown (Experts)	Total Unknown (Model)	Total Estimated	% Known	New spp. (1999-2008)
Mesozoa (Orthonectida, Dicyemida)		134	134	1	40-50	500-1,000	100-500	640-1,550	84-305	774-1,684	8-17	34
Mollusca		43,689-51,689							**	135,887-164,107	28-36	4,022
	Bivalvia		9,000	55	2000	3,000	-	5,000	**		64	
	Caudofoveata		133	8	?	500	-	500	-		21	
	Cephalopoda		761	-	150	500	-	650	-		54	
	Gastropoda		32,000-40,000	69-75	35,000-45,000	50,000-60,000	-	85,000-105,000	**		23-32	
	Monoplacophora		30	-	3	50	-	53	-		36	
	Polyplacophora		930	52	50	50-100	-	100-150	-		86-90	
	Scaphopoda		572	33	55	500	NB	555	-		51	
	Solenogastres		263	21	20-30	320-480	-	340-510	-		34-44	
Myxozoa		700	700	7	100-250	6,300-8,400	71-468	6,471-9,118	600-1,200	7,171-9,818	7-10	93
Nematoda		11,400							-	61,400	19	295
	Nematoda, free-living		6,900	9	?	50,000	NB	50,000	-		12	
	Nematoda, parasitic		4,500	-	?	?	-	-	-		-	
Nemertea		1,285	1,285	20	200-400	500-1,000	-	700-1,400	170-320	1,985-2,685	48-65	85
Phoronida		18	18	56	0	0	-	0	-	18	100	0
Placozoa		1	1	0	18	0	10-100	28-118	-	29-119	1-3	0
Platyhelminthes		11,690							3,000-3,900	35,296-73,441	16-33	1,142
	Cestoda		1,393	31	300	2,000	-	2,300	**		38	
	Monogenea		1,626	-	200-300	10,000-15,000	500-5,000	10,700-20,300	2,300-2,700		7-13	
	Aspidogastrea		18	25	0	6	-	6			75	
	Digenea		6,000	20	600	4,000-8,500	400-900	5,000-10,000	**		38-55	
	Catenulida		12	0	5	20	-	25	-		32	
	Rhabditophora		2,641	9	500-700	5,000-28,000	75-420	5,575-29,120	820-1,130		8-32	
Porifera		8,553	8,553	22	2,300-3,000	15,000	NB	17,300-18,000	**	25,853-26,553	32-33	621
Rotifera		114	114	-	20	?	300-2,500	320-2,520	20-140	434-2,634	4-26	17
Sipuncula		150	150	90	3-5	10-25	30-200	43-230	2-20	193-380	39-78	0
Tardigrada		183	183		?	1,120	-	1,120	40-280	1,303	14	16
Xenacoelomorpha		401							250-360	4,501	9	74
	Acoela		391	35	100	4,000	NB	4,100	-		9	
	Nemertodermatida		8	20	?	?	NB	0	-		-	
	Xenoturbellida		2	0	0	?	NB	-	-		-	
Total		222,201-230,201			58,279-72,326	415,205-633,872	8,792-35,753	482,776-741,951		704,977-972,152		

The following data are listed: number of currently described and taxonomically accepted species, percent of all nominal species names considered subjective synonyms (% Syn), undescribed species in specimen collections, unsampled and undiscovered morphospecies, undiscovered molecular cryptic species (only distinguishable by molecular methods), total species unknown (undescribed + undiscovered based on expert opinions), total species unknown based on the statistical model, total estimated number of species (expert-based), estimated percent of all existing species that are currently described (% known), and number of new species published in the last decade (1999–2008; data from WoRMS). Names of taxonomic groups for which data are broken down further by subgroups are listed in bold. The following symbols are used: ?, not estimated; -, no data; NB, no basis for judgment; **, rate of discovery still rising, so no meaningful estimate of total species numbers can be made using the statistical model.

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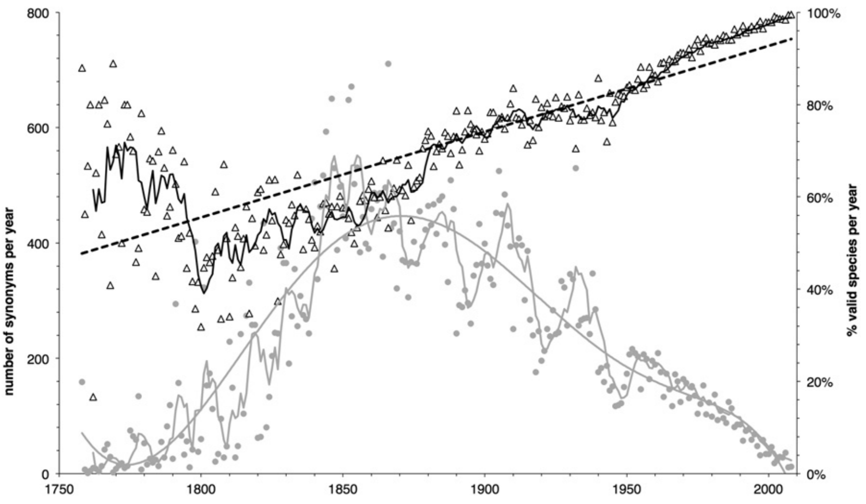

Figure 1. Number of Synonyms per Year of Original Description

The number of synonyms per year of original description (gray circles; solid gray lines: five-year moving average and sixth-order polynomial) and the percent of species that are now recognized as valid (black triangles; solid black line: five-year moving average; dashed black line: linear with $r^2 = 0.638$).

Rotifera, Sipuncula, Oligochaeta, and Remipedia. In contrast, there was no evidence that taxa such as Sirenia, Staurozoa, Siphonophora, and several Crustacea groups (including Brachyura and Isopoda, which are species rich) have any molecular cryptic species.

The Best-Known Taxonomic Groups. Based on the estimates of the authors, no new species were expected in some groups with few species already, namely marine mammals such as Sirenia (4 spp.) and Carnivora (44 spp.), Phoronida (18 spp.), and crustaceans such as Mictacea (1 sp.), Amphionidacea (1 sp.), Lomisoidea (1 sp.), Branchiopoda (90 spp.), and Euphausiacea (86 spp.). Only a few species may still be discovered in Cetacea (+2–8 spp.), Reptilia (+10 spp.), Merostomata (+1 sp.), Aspidogastrea (+6 spp.), Thaliacea (+13 spp.), and Nematomorpha (+10–15 spp.). Other well-known taxonomic groups that were >90% known but with hundreds of species were seabirds and, with over 2,000 species, marine Hexapoda (e.g., Insecta, Collembola). The marine vascular plants (mangrove species and seagrasses) were >80% known, but seaweeds and microalgae remained poorly known (Table 2).

The Least-Known Taxonomic Groups. Groups for which fewer than an estimated 20% of the species have been described included some taxa with few known species (i.e., Cycliophora, Loricifera, Placozoa, Tantulocarida, Leptostraca, Caudofoveata). However, most have hundreds (Myxozoa, Acoela, Kinorhyncha, Oligochaeta, Gastrotricha, Dicyemida, Orthonectida, and Entoprocta) to thousands (Bacillariophyceae, Ciliophora, Rhabditophora, Cumacea, Tanaidacea, Isopoda) of species. The largest numbers of undiscovered species may be in Isopoda (+63,150–123,600 spp.), Gastropoda (+85,000–105,000 spp.), Bacillariophyceae (+50,000 spp.), Nematoda (+50,000 spp.), Copepoda (+30,125–50,125 spp.), Ostracoda (+2,625–34,000 spp.), Rhabditophora (excluding Neodermata; +5,500–29,000 spp.), Tanaidacea (+21,900–24,900 spp.), Amphipoda (+20,000 spp.), Monogenea (+10,700–20,300 spp.), Porifera (+17,300–18,000 spp.), Ciliophora (+4,231–19,368 spp.), Oligochaeta (+5,900–16,900 spp.), and marine Fungi (+15,000 spp.) (Table 2).

Based on Undescribed Species in Samples Collected

Another approach to estimating how many species were undiscovered was to aggregate empirical data on the ratio of undescribed to described species in samples. Field studies on over 33,000 marine species in over 100 studies found an average of 37% (median 31%) of species were undescribed, primarily invertebrates from tropical and offshore environments (Table S1). The largest sample for which we had an estimate of unknown species was for the marine biota of New Zealand, estimated at 17,135 species of which 25% were undescribed and in specimen collections. Over all, Pisces and Echinodermata were below the median, but so were Scleractinia, Pycnogonida, Porifera, and free-living Nematoda as well. Taxa with a higher percentage of unknown species than the average included Oligochaeta, Polychaeta, Mollusca, Rhabditophora, and Peracarida (especially Tanaidacea and Isopoda). The proportion of unknown species was higher than average for studies from Australia (52%) but lower

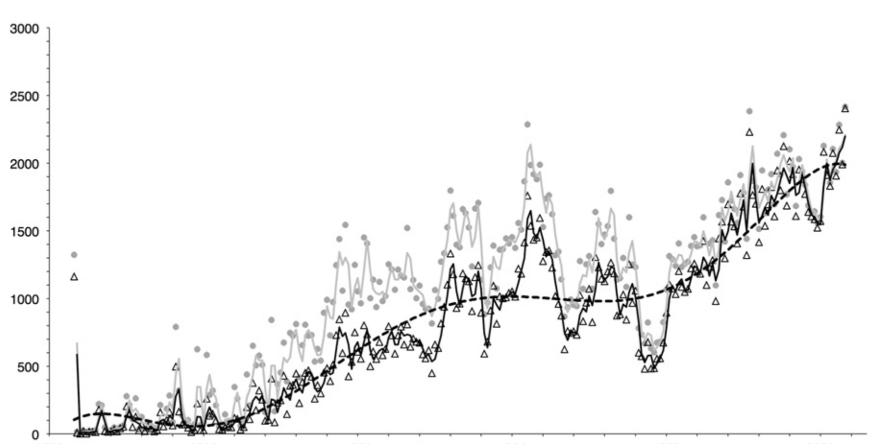

Figure 2. Number of Species Described per Year versus Number of Species Currently Recognized as Valid

The number of species described per year (gray circles, solid gray line) versus the number of species currently recognized as valid (black triangles, solid black line). Trend lines are two-year moving averages; the sixth-order polynomial for valid species ($r^2 = 0.869$, dashed black line) is also shown.

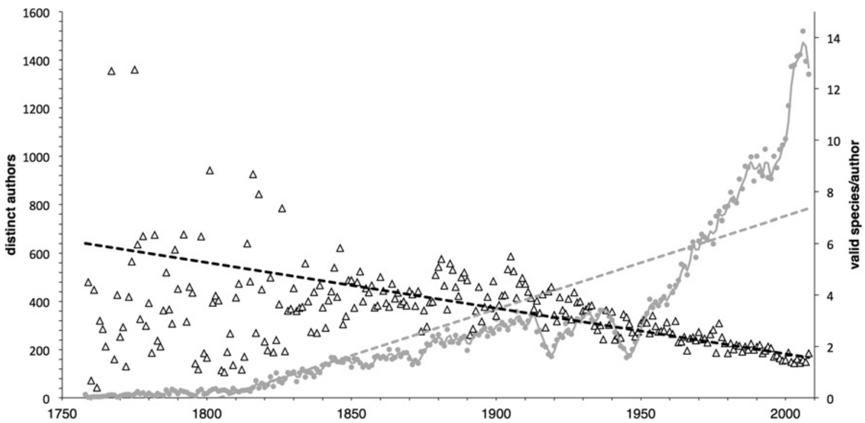

Figure 3. Number of Distinct Author Names per Year and Number of Valid Species per Author

The number of distinct author names per year (gray circles; solid gray line: two-year moving average; dashed gray line: linear with r^2 = 0.721) and the number of valid species per author (black triangles; dashed black line: linear with r^2 = 0.056).

than the median for New Zealand and the Southern Ocean (25% each). Averages for studies from Europe, deep sea, and tropics were close to the overall average (37%, 39%, and 33% respectively). These proportions can question estimates of total species richness. For example, the estimate of free-living nematode diversity reported here as 50,000 species suggests that 86% of the existing species remain to be discovered. Yet, field surveys have found only 6% to 56% undescribed species.

Discussion

Rate of Discovery

The description rate of marine species has been increasing steadily since 1955. Costello et al. [10] found a similar trend for marine and terrestrial (including freshwater) species, but the relative rate of description of marine species was higher than for terrestrial species. Evidently, the past decade has been the most productive period for marine species discovery. This may be due to more taxonomic effort, new technologies, exploration of new habitats and localities, use of molecular methods, or a combination of these factors.

Our analysis of temporal trends indicated a decreasing rate of species description (from six to two species per author per year) and an increased number of authors engaged in species descriptions. This increase in the number of taxonomists is likely to contribute to the continued high rates of species description. Other studies have similarly reported an increasing number of authors describing fossil North American mammals [21], marine fish [22], terrestrial vertebrates and plants in Brazil [23], flowering plants of the world [24, 25], cone snails, spiders, amphibians, birds, and mammals [25], as well as marine and nonmarine species globally [10].

The increasing number of authors publishing in taxonomy reflects the increasing number of scientists worldwide [26]. This has particularly been the case in Australasia and South America since the 1980s [27, 28]. The number of taxonomic publications has increased more than 8-fold from 1969 to 1996 [29]. Haas and Häuser [30] estimated there to be 5,000 professional and 35,000 amateur taxonomists worldwide. Our data suggest that this may be an underestimate. We found that 4,900 authors described marine species in the past decade alone, which accounted for about 12% of all species described. Although some of the marine taxonomists may also describe nonmarine species, this suggests that there are over 40,000 scientists involved in the taxonomic description of species. This number may be higher if the authors who could be considered taxonomists but have not recently described species are included, for example those who study taxa in well-studied geographic regions.

The change in the number of authors of species descriptions, a minimum indicator of authors involved in taxonomy, does not necessarily indicate increased taxonomic effort, because the individuals' effort may be declining. However, we found in WoRMS [15] that the proportion of authors who described only one species has been similar (42%–44%) over the past century. A previous study using WoRMS similarly found no trend in the proportion of the most prolific authors during that period [10].

The advent of scuba diving [31], deep-water tangle nets [32], submersibles, remotely operated vehicles (ROVs), and other technologies [22] has allowed sampling of previously unexplored habitats such as cold seeps, mud volcanoes, submarine canyons, and anchialine lakes and caves [33, 34] and of very fragile organisms previously unavailable to scientists [35]. For example, since 2002, the number of species of remipedes (crustaceans that live exclusively in coastal anchialine caves) has more than doubled from 11 to 24. The use of submersibles and deep diving resulted in the discovery of 30 new fish species around even such a highly studied area as the Galápagos Islands [22]. Thus, the greater number of taxonomists, the sampling of more remote geographic areas, and the use of a greater variety of sampling methods must all be contributing to the high rate of species description.

Molecular Methods and Cryptic Species

Estimating the diversity of cryptic species, i.e., species that remain unrecognized because of limitations of current morphotaxonomic methods, is a challenge because molecular surveys that most readily reveal them have been applied to only a fraction of marine diversity. For example, only 6,199 species (3% of all described) have been genetically "barcoded" by MarBOL (http://www.marinebarcoding.org, as of April 24, 2012). Furthermore, in all taxa except Placozoa (with only one species at present), these discoveries of "cryptic" species only apply to some of the presently known species, sometimes only within genera. For example, up to 18 cryptic species have been reported for parasite genera, but most (78%) only had one or two cryptic species [36]. It also needs to be considered that reports of cryptic species may be subject to sampling bias because these methods tend to be applied to taxa where positive findings are expected, and negative results may not be reported [36].

For two-thirds (in terms of described richness) of marine biota, experts were hesitant to provide, or indicated there was no good basis for, any estimate for the diversity of cryptic species, reflecting our poor understanding of this issue. For the remaining one-third, estimates ranged widely, reflecting the limited sampling and differences in the incidence of cryptic species among taxa. In some genera, molecular characters are more useful than morphological characters for distinguishing species (e.g., *Leptochonchus* gastropods [37]). In others, morphology is adequate to distinguish species, although molecular data can aid their classification. Thus in Pisces, a morphologically complex and visually communicating group of animals, the likely incidence of cryptic diversity is low, estimated here as ~1% of total diversity [38]. Most crustaceans have sufficient morphological characters to discriminate species, and so cryptic speciation may also be low (<5%) overall. Conversely, in Sipuncula, which have limited morphological complexity, cryptic species are estimated to represent between 10% and 55% of total diversity [39]. In some coral genera, molecular markers could better indicate the occurrence of cryptic species than reveal synonyms, because a lack of variation in one character does not necessarily suggest they are the same species [40]. Our knowledge is noticeably incomplete in the unicellular eukaryotes, where environmental sequencing is indicating that some of these groups may be more diverse than currently recognized based on conventional morphological taxonomy [41]. However, how this genetic diversity translates into species diversity is unknown.

Despite the uncertainty in the estimates of cryptic species, they help to illustrate the degree to which molecular methods may increase our knowledge of marine biodiversity, both in distinguishing and classifying species. Considering our numbers of cryptic species, molecular methods may add tens of thousands, rather than hundreds of thousands, of species to the currently accepted ~226,000 species. In a few cases, molecular methods have actually worked in reverse by assigning species to synonymy, though this is unlikely to have any more than a minor influence on total species numbers. Certainly, it is not valid to multiply up from examples of cryptic diversity discovered by molecular methods for a small group of species or genera to a phylum.

Synonyms

Our data showed that the proportion of described species that were later recognized to be synonyms of others was decreasing over time. This could be the result of fewer synonyms being created and/or could reflect the time it takes to discover synonyms. Taxa that had been studied more intensively tended to have more synonyms (e.g., fish, mollusks) but were also more likely to have had their taxonomy revised and thus more likely to have had such synonyms discovered. Even the same taxonomist can describe a species several times: for example, 9 of the sperm whale's 19 synonyms were by three authors, each naming the species three times [42]. With better access to publications and type specimens, improved communication among taxonomists, and the greater availability of systematic revisions, the introduction rate of synonyms should continue to decline.

Furthermore, molecular analyses complement morphological approaches and, where the latter are equivocal, have supported the raising of subspecies to species status [22]. For example, the killer whale and the common bottlenose dolphin have each been split into two or more species [43, 44]. WoRMS currently contains ~7,600 recognized infraspecific taxa (i.e., 3%). Molecular methods will also resurrect some names from synonymy. Assuming that pre-1900 names assigned to synonymy are mostly true synonyms, about 21,000 names of species described since 1900 were synonymized and another 42,000 may yet be synonymized due to the time delay in recognizing synonyms. It is highly unlikely that all 63,000 would be resurrected from synonymy by molecular methods. If all recognized subspecies and, say, 25% of synonyms were reestablished as accepted species, then the number of known species could increase by about 23,000.

The occurrence of as yet unrecognized synonyms is one of the most significant problems in estimating the true number of described species. Taxonomic revision may find more synonyms, but in some cases, often assisted by use of molecular methods, previously "sunken" species names may be found to be real. Although the significance of synonymy in biasing estimates of taxon and global species richness merits more in-depth study, action to reduce the reoccurrence of synonyms can be undertaken. This must include taxonomic revisions, rapid publication, open access to descriptions, online species identification guides, knowledge of where type specimens and genetic profiles are located, accessibility of taxonomic expertise, and continued revision of species inventories at global to local levels. An analysis of whether there is a trend of less time to discover synonyms could usefully clarify whether the creation of synonyms has been decreasing.

Global Species Richness

Both the sum of our individual estimates and the statistical analysis predicted that there were fewer than one million eukaryotic marine species on Earth. It was reassuring that the methods overlap, in contrast to most previous estimates, which have exceeded one million (Table 1). The estimates based on expert opinion were closest to ours, in the 1.0–1.5 million range. Winston [8] also considered the proportion of undescribed species in different geographic regions in her estimate of "over one million." This avoided extrapolation from one geographic area to the world, as was the case with the 5–10 million estimates. Local (α) diversity tends to overestimate regional (γ) diversity when few samples are available and thus spatial turnover (β diversity) is underestimated [45]. The relative species richness of higher taxa varies across geographic regions [46], although whether this is true or reflects variation in sampling and taxonomic effort is unclear. Further research is required before it can be assumed that the proportion that a higher taxon contributes to species richness in one region is the same as in other regions. Using the relationship of species richness in higher taxa to predict global species richness may compound several biases, including the changing proportions of species across higher taxa as classifications change, and dominance of richness by a few taxa. However, experts are not impartial [18]. They are subject to influence by such biases as the estimates of their peers and authority figures, widely reported hyperestimates, their personal experience and recollections, and not wishing to downplay the importance of their specialty. We have partly addressed this by independently eliciting experts by e-mail before exposing all experts to their peers' estimates. Experts were then asked to document their reasoning and review their numbers. This documentation was then compiled and circulated to experts, and they were asked to reconsider their estimates once again. Experts were not aware of the statistical model's predictions until a late stage in this process and thus did not consider them. By providing the rationale for our individual estimates (Table S2), we encourage them to be challenged as new data become available, as is the recommended best practice [19]. A future improvement on our approach may be to include direct discussion of all available data and opinions between experts at a workshop or video conference [17].

Recent estimates of the richness of insects and terrestrial species have also been more modest, on the order of six million, compared to the 30–100 million species proposed by some authors (reviewed in [1, 10]). The same model we used here predicted that only 0.3 million marine species may exist on Earth using an earlier version of WoRMS [10]. This model is sensitive to the period of highest species description. Because the data now show that the highest marine species description rates occurred in the past decade, the present study predicted 0.5 million species. Both estimates will be inflated by undiscovered synonyms. Future modeling may be improved by distinguishing the taxa and geographic regions that are well known and by quantifying the effects of taxonomic effort.

Some of our higher estimates of undiscovered species may be questioned. Findings of high local species diversity do not necessarily imply high global species diversity [45]. Species with life stages that are easily dispersed (e.g., due to small body size, as in microbes, Fungi, and meiofauna) and can survive conditions suboptimal for growth tend to be cosmopolitan and thus have low spatial turnover (β diversity) in species (discussed in [10, 45]). This may be the case for the high predictions of undiscovered species for Fungi and Nematoda [47]. Indeed, one analysis suggested that there were 10,000–20,000 free-living marine nematodes [48] rather than the 50,000 listed in this paper. The present estimate of undiscovered Fungi was back calculated from an estimate of 1.5 million species on Earth, suggesting that only 7% of species are described. This seems unlikely by comparison with other taxa, and if there were so many undescribed species, one might expect the current rate of description to be relatively higher than it is for other taxa, because species would be easier to discover. However, comparable easily dispersed life stages are not common in macroinvertebrate taxa such as Crustacea (especially Isopoda, Tanaidacea, Amphipoda, Cumacea, and Leptostraca) and Mollusca, where thousands of undiscovered species are predicted as well. Moreover, more cosmopolitan species also tend to be discovered first, and the remaining species of such taxa are likely to be geographically rare (i.e., endemic to small areas). Thus, a particular problem in estimating global species richness is the lack of understanding of geographic patterns. It is well known that most species are geographically rare, but whether all taxa show similar β diversity is not clear. For example, are there equal proportions of parasitic and nonparasitic copepods that are cosmopolitan, and does the spatial occurrence of parasitic and symbiotic species scale similarly with their hosts? If taxa do scale similarly, then this will aid prediction of both global species richness and sensitivity to extinction [45]. However, the present evidence suggests that taxa have contrasting geographies, with pelagic megafauna (mammals, birds, reptiles) and meiofauna being more cosmopolitan than benthic macroinvertebrates (reviewed in [10]). Consequently, taxonomic research into this spectrum of rare and endemic species is critical for scientific discovery and to inform the selection of conservation priorities.

Field studies found that most samples have less than 37% undescribed species (median 31%), suggesting that our estimate of two-thirds to three-quarters of species being undiscovered may be too high rather than too low. However, field studies document common species better than rare species, whereas undescribed species are proportionally better represented among rare species. Because of this, field studies undersample undescribed species, except when they are exhaustive at the species level, a level of sampling that has yet to be attained in species-rich localities (see e.g. [49]). Alternatively, these averages may be overestimates because (1) authors do not report when all species in samples have been described or (2) upon closer analysis, some may prove not to be new to science (but are perhaps new to the observer). Europe has probably the best-studied sea area in the world, but one-third of its biodiversity may yet be undescribed [2]. Consequently, the proportion of undiscovered species is likely between one-third and two-thirds of all described marine species. However, this is a global figure, and some taxa provide exciting opportunities for discovering many new species, notably Mollusca, Rhabditophora, Oligochaeta, Tanaidacea, and Isopoda.

If we further consider that the number of authors describing species has been increasing at a higher rate than the number of new species described, then it seems that it has become harder to find new species [10]. If the description curves for taxa have not reached an asymptote because of the increasing taxonomic effort, then the model will overpredict marine species richness as well as bias our personal estimates. Consideration of the increasing effort suggests that we should be conservative in our estimates of the number of undiscovered species.

Rates of marine species description have never been higher and are driven by the increasing number of taxonomists and their ability to sample geographic areas and habitats previously undersampled. If the rate of 2,000 new species per year can be maintained by continued taxonomic effort and focus on the least-known places, habitats, and taxa, then another 100,000 species will be described in the next 50 years, and the number of described species will be within the 95% confidence limits of our statistical predictions.

As more species are described, the skills to diagnose them will be increasingly in demand. This applies to both the large, easily identified species that may be important for food, conservation, and ecosystem functioning and the less conspicuous taxa with small body size, because they will include parasites and pathogens of other species, may become pests, and may have as yet unrealized roles in ecosystem function.

The open-access online World Register of Marine Species has set the stage for our estimates of marine diversity. Collaborative international initiatives such as WoRMS help increase our knowledge, promote standardization in taxonomy, and bring the community together in a more coordinated and, because of the shared responsibility of maintaining the database, more sustainable way. We call on other taxonomic communities to similarly collaborate to publish online databases of their species as a synthesis of current knowledge and vehicle for improved scientific collaboration. The present study provides a baseline of the diversity of marine species and higher taxa, which the taxonomic editors of WoRMS should revisit in 5 to 10 years' time in the light of future discoveries.

Supplemental Information

Supplemental Information includes two tables and Supplemental Experimental Procedures and can be found with this article online at http://dx.doi.org/10.1016/j.cub.2012.09.036.

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References

1. Hamilton, A.J., Basset, Y., Benke, K.K., Grimbacher, P.S., Miller, S.E., Novotný, V., Samuelson, G.A., Stork, N.E., Weiblen, G.D., and Yen, J.D. (2010). Quantifying uncertainty in estimation of tropical arthropod species richness. Am. Nat. *176*, 90–95.
2. Costello, M.J., and Wilson, S.P. (2011). Predicting the number of known and unknown species in European seas using rates of description. Glob. Ecol. Biogeogr. *20*, 319–330.
3. May, R.M. (2002). The future of biological diversity in a crowded world. Curr. Sci. *82*, 1325–1331.
4. van der Land, J. (1994). UNESCO-IOC Register of Marine Organisms: A common base for biodiversity inventories: Families and bibliography of keyworks, version 1.0 (DOS-formatted 3.5" floppy disk). http://www.marinespecies.org/urmo/.
5. Gordon, D.P. (2001). Marine Biodiversity (Wellington, New Zealand: The Royal Society of New Zealand).
6. Gibbons, M.J., Abiahy, B.B., Angel, M., Assuncao, C.M.L., Bartsch, I., Best, P., Biseswar, R., Bouillon, J., Bradford-Grieve, J.M., Branch, W., et al. (1999). The taxonomic richness of South Africa's marine fauna: crisis at hand. S. Afr. J. Sci. *95*, 8–12.
7. Bouchet, P. (2006). The magnitude of marine biodiversity. In The Exploration of Marine Biodiversity: Scientific and Technological Challenges, C.M. Duarte, ed. (Madrid: Fundación BBVA), pp. 31–62.
8. Winston, J.E. (1992). Systematics and marine conservation. In Systematics, Ecology, and the Biodiversity Crisis, N. Eldredge, ed. (New York: Columbia University Press).
9. Reaka-Kudla, M. (1996). The global biodiversity of coral reefs: a comparison with rain forests. In Biodiversity II: Understanding and Protecting our Biological Resources, M.L. Reaka-Kudla, D.E. Wilson, and E.O. Wilson, eds. (Washington, DC: Joseph Henry Press), pp. 83–108.
10. Costello, M.J., Wilson, S., and Houlding, B. (2012). Predicting total global species richness using rates of species description and estimates of taxonomic effort. Syst. Biol. *61*, 871–883.
11. May, R.M. (1992). Bottoms up for the oceans. Nature *357*, 278–279.
12. Mora, C., Tittensor, D.P., Adl, S., Simpson, A.G.B., and Worm, B. (2011). How many species are there on Earth and in the ocean? PLoS Biol. *9*, e1001127.
13. Poore, G.C.B., and Wilson, G.D.F. (1993). Marine species richness. Nature *361*, 597–598.
14. Grassle, J.F., and Maciolek, N.J. (1992). Deep-sea species richness: regional and local diversity estimates from quantitative bottom samples. Am. Nat. *139*, 313–341.
15. Appeltans, W., Bouchet, P., Boxshall, G.A., Fauchald, K., Gordon, D.P., Hoeksema, B.W., Poore, G.C.B., van Soest, R.W.M., Stöhr, S., Walter, T.C., and Costello, M.J., eds. (2011). World Register of Marine Species (WoRMS). http://www.marinespecies.org.
16. Gaston, K.J. (1991). The magnitude of global insect species richness. Conserv. Biol. *5*, 283–296.
17. McBride, M.F., Garnett, S.T., Szabo, J.K., Burbidge, A.H., Butchart, S.H.M., Christidis, L., Dutson, G., Ford, H.A., Loyn, R.H., Watson, D.M., and Burgman, M.A. (2012). Structured elicitation of expert judgments for threatened species assessment: a case study on a continental scale using email. Methods Ecol. Evol. *3*, 906–920.
18. Burgman, M.A. (2004). Expert frailties in conservation risk assessment and listing decisions. In Threatened Species Legislation: Is It Just an Act?, P. Hutchings, D. Lunney, and C. Dickman, eds. (Mosman, Australia: Royal Zoological Society of New South Wales), pp. 20–29.
19. Martin, T.G., Burgman, M.A., Fidler, F., Kuhnert, P.M., Low-Choy, S., McBride, M., and Mengersen, K. (2012). Eliciting expert knowledge in conservation science. Conserv. Biol. *26*, 29–38.
20. Wilson, S.P., and Costello, M.J. (2005). Predicting future discoveries of European marine species by using a non-homogeneous renewal process. Appl. Stat. *54*, 897–918.
21. Alroy, J. (2002). How many named species are valid? Proc. Natl. Acad. Sci. USA *99*, 3706–3711.
22. Eschmeyer, W.N., Fricke, R., Fong, J.D., and Polack, D. (2010). Marine fish biodiversity: A history of knowledge and discovery (Pisces). Zootaxa *2525*, 19–50.
23. Pimm, S.L., Jenkins, C.N., Joppa, L.N., Roberts, D.L., and Russell, G.J. (2010). How many endangered species remain to be discovered in Brazil? Natureza & Conservação *8*, 71–77.
24. Joppa, L.N., Roberts, D.L., and Pimm, S.L. (2011). How many species of flowering plants are there? Proc. Biol. Sci. *278*, 554–559.
25. Joppa, L.N., Roberts, D.L., and Pimm, S.L. (2011). The population ecology and social behaviour of taxonomists. Trends Ecol. Evol. *26*, 551–553.
26. Ware, M., and Mabe, M. (2009). The STM Report: An Overview of Scientific and Scholarly Journal Publishing (Oxford: International Association of Scientific, Technical and Medical Publishers).
27. Zhang, Z.-Q. (2010). Reviving descriptive taxonomy after 250 years: Promising signs from a mega-journal in taxonomy. In Systema Naturae 250: The Linnaean Ark, A. Polaszek, ed. (Boca Raton, FL: CRC Press), pp. 95–107.
28. Gaston, K.J., and May, R.J. (1992). Taxonomy of taxonomists. Nature *356*, 281–282.
29. Winston, J.E., and Metzger, K.L. (1998). Trends in taxonomy revealed by the published literature. Bioscience *48*, 125–128.
30. Haas, F., and Häuser, C.L. (2005). Taxonomists: An endangered species? In Success Stories in Implementation of the Programmes of Work on Dry and Sub-Humid Lands and the Global Taxonomy Initiative: Abstracts of Poster Presentations at the 11th Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice of the Convention on Biological Diversity, CBD Technical Series 21 (Montreal: Secretariat of the Convention on Biological Diversity), pp. 87–89.
31. Pyle, R.L. (2000). Assessing undiscovered fish biodiversity on deep coral reefs using advanced self-contained diving technology. Mar. Technol. Soc. J. *34*, 82–91.
32. Ng, P.K.L., Mendoza, J.C.E., and Manuel-Santos, M. (2009). Tangle net fishing, an indigenous method used in Balicasag Island, central Philippines. Raffles Bull. Zool. *20*(*Suppl.*), 39–46.
33. Becking, L.E., Renema, W., Santodomingo, N.K., Hoeksema, B.W., Tuti, Y., and de Voogd, N.J. (2011). Recently discovered landlocked basins in Indonesia reveal high habitat diversity in anchialine systems. Hydrobiologia *677*, 89–105.
34. Dennis, C., and Aldhous, P. (2004). Biodiversity: a tragedy with many players. Nature *430*, 396–398.
35. Haddock, S.H.D. (2004). A golden age of gelata: past and future research on planktonic cnidarians and ctenophores. Hydrobiologia *530/531*, 549–556.
36. Poulin, R. (2011). Uneven distribution of cryptic diversity among higher taxa of parasitic worms. Biol. Lett. *7*, 241–244.
37. Gittenberger, A., and Gittenberger, E. (2011). Cryptic, adaptive radiation of endoparasitic snails: sibling species of *Leptoconchus* (Gastropoda: Coralliomorphidae). Org. Divers. Evol. *11*, 21–41.
38. Ward, R.D., Zemlak, T.S., Innes, B.H., Last, P.R., and Hebert, P.D.N. (2005). DNA barcoding Australia's fish species. Philos. Trans. R. Soc. Lond. B Biol. Sci. *360*, 1847–1857.
39. Kawauchi, G.Y., and Giribet, G. (2010). Are there true cosmopolitan sipunculan worms? A genetic variation study within *Phascolosoma perlucens* (Sipuncula, Phascolosomatidae). Mar. Biol. *157*, 1417–1431.
40. McFadden, C.S., Alderslade, P., van Ofwegen, L.P., Johnsen, H., and Rusmevichientong, A. (2006). Phylogenetic relationships within the

tropical soft coral genera *Sarcophyton* and *Lobophyton* (Anthozoa, Octocorallia). Invertebr. Biol. *125*, 288–305.
41. Liu, H., Probert, I., Uitz, J., Claustre, H., Aris-Brosou, S., Frada, M., Not, F., and de Vargas, C. (2009). Extreme diversity in noncalcifying haptophytes explains a major pigment paradox in open oceans. Proc. Natl. Acad. Sci. USA *106*, 12803–12808.
42. Perrin, W.F. (2011). The World Cetacea Database. http://www.marinespecies.org/cetacea.
43. Morin, P.A., Archer, F.I., Foote, A.D., Vilstrup, J., Allen, E.E., Wade, P., Durban, J., Parsons, K., Pitman, R., Li, L., et al. (2010). Complete mitochondrial genome phylogeographic analysis of killer whales (*Orcinus orca*) indicates multiple species. Genome Res. *20*, 908–916.
44. Möller, L.M., Bilgmann, K., Charlton-Robb, K., and Beheregaray, L. (2008). Multi-gene evidence for a new bottlenose dolphin species in southern Australia. Mol. Phylogenet. Evol. *49*, 674–681.
45. Stork, N.E. (1997). Measuring global biodiversity and its decline. In Biodiversity II: Understanding and Protecting our Biological Resources, M.L. Reaka-Kudla, D.E. Wilson, and E.O. Wilson, eds. (Washington, DC: Joseph Henry Press), pp. 41–68.
46. Costello, M.J., Coll, M., Danovaro, R., Halpin, P., Ojaveer, H., and Miloslavich, P. (2010). A census of marine biodiversity knowledge, resources, and future challenges. PLoS ONE *5*, e12110.
47. Vanreusel, A., Fonseca, G., Danovaro, R., da Silva, M.C., Esteves, A.M., Ferrero, T., Gad, G., Galtsova, V., Gambi, C., da Fonse Genevois, V., et al. (2010). The contribution of deep-sea macrohabitat heterogeneity to global nematode diversity. Mar. Ecol. *31*, 6–20.
48. Mokievsky, V., and Azovsky, A. (2002). Re-evaluation of species diversity patterns of free-living marine nematodes. Mar. Ecol. Prog. Ser. *238*, 101–108.
49. Bouchet, P., Lozouet, P., Maestrati, P., and Heros, V. (2002). Assessing the magnitude of species richness in tropical marine environments: exceptionally high numbers of molluscs at a New Caledonia site. Biol. J. Linn. Soc. Lond. *75*, 421–436.

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Supplemental Information

The Magnitude of Global

Marine Species Diversity

Ward Appeltans et al.

Supplemental Inventory

Table S1
The proportions of undescribed marine species found for particular taxa and locations. This is related to the main text - section "estimated total global species richness, based on undescribed species in samples collected".

Supplemental Experimental Procedures
A non-homogeneous renewal process model based on extrapolation of the discovery curve as a logistic function. This is related to the main text section "estimated total global species richness, based on past rates of species descriptions".

Table S2
Comments on reasoning behind the data on particular taxa in Table 1.

Table S1. The proportions of undescribed marine species found for particular taxa and locations. The total estimated number of undescribed species is ~12,581 (37%) of 33,566 collected (N° of species). This is related to the main text - section "estimated total global species richness, based on undescribed species in samples collected".

undescribed	N° of species	Taxon	Location	Reference
67%	184	Peracarida	Mid-Atlantic Continental Slope, USA	Grassle & Maciolek [S1]
37%	106	Mollusca		
64%	367	Polychaeta		
95%	459	Copepoda associated with other species	Madagascar, New Caledonia, Moluccas (note that the Madagascar samples were collected over several years)	Humes [S2]
33%	372	Polychaeta	Georges Bank	Carlton [S3]
71%	158	Polychaeta	Hawaii	
42%	320	Gastropoda	Philippines	
55%	564	Gastropoda	New Guinea	
79%	29	Harpacticoida	Gulf of Mexico	
92%	134	Turbellaria	Great Barrier Reef	
80%	2,000	Mollusca	New Caledonia	Bouchet [S4]
64%	14	Hydrozoa	Seamounts, Tasmania	Koslow *et al.* [S5]
12-27%	33	Octocorallia		
0-28%	29	Annelida		
43-57%	14	Bryozoa		
30%	10	Mollusca		
35-62%	37	Decapoda		
69-88%	32	Other Crustacea		
4-9%	22	Asteroidea		
8-31%	36	Ophiuroidea		
18-45%	11	Other Echinodermata		
>14%	28	Pisces		
30-40%	>2,000	Nematoda (free-living)	European seas	Lambshead & Boucher [S6]
ca. 90%	158	Foraminifera	Deep regions of the Atlantic sector of the Southern Ocean	Brandt *et al.* [S7]
56%	57	Nematoda (free-living)		
70%	100	Ostracoda		
86%	674	Isopoda		
27%	295	Polychaeta		
22%	76	Porifera		
31%	65	Bivalvia		
5%	1,222	Pisces	Tropical eastern Pacific	Zapata & Robertson [S8]
>90%	365	Isopoda	Australia	Poore *et al.* [S9]
>30%	524	Decapoda	Australia	Poore *et al.* [S10]
83%	1,409	Turridae (molluscs)	New Caledonia	Bouchet *et al.* [S11]
61%	79	Tubificidae (oligochaetes)	Western Australia	Erséus ([S12] and references therein)
5-24% (average 14.3)		Azooxanthellate Scleractinia corals	Most of world's oceans.	Cairns [S13]
0-18% (average 6.1)		Zooxanthellate Scleractinia corals	Australia, Caribbean, Japan, Red Sea, Vietnam	
25%	450	Ciliophora (free-living)	Chinese coastal regions of the Bohai Sea and Yellow Sea	Song, Warren, Hu [S14]

64%	14	Rhabdocoel flatworms	Uruguay (July-August 2004)	Van Steenkisten *et al.* [S15]
61% 78%	71 40	Rhabdocoel flatworms	Lanzarote (October 2011) Panama (December 2011)	Artois [unpubl. data]
76% 90%	34 30	Proseriate flatworms	Lanzarote (October 2011) Pacific Panama (December 2011)	Curini-Galletti [unpubl. data]
56%	30	Octocorallia	Records of the Western Australian Museum	Alderslade [S16]
60%	50	Octocorallia	New Caledonia and adjacent islands	Grasshoff [S17]
28%	19	Octocorallia	Sinai coast and the Strait of Gubal, Red Sea	Grasshoff [S18]
64%	34	Octocorallia	Indo-Pacific	Van Ofwegen [S19]
40%	15	Octocorallia	Palau, Micronesia	Van Ofwegen [S20]
42%	59	Tubificidae (oligochaetes)	Belize	Erséus [S21]
41%	37	Tubificidae (oligochaetes)	N. T., Australia	Erséus [S22]
41%	41	Tubificidae (oligochaetes)	Western Australia	Erséus [S23]
24%	99	Ascidiacea	Guadeloupe	Monniot [S24-S27], Monniot [S28-S31]
38%	208	Ascidiacea	New Caledonia	Monniot [S32-S37], Monniot [S38-S45]
50%	211	Ascidiacea	Tropical Western Pacific	Monniot [S46], Monniot[S47-S50]
29%	180	Ascidiacea	South Africa	Michaelsen [S51], Millar [S52-53], Monniot *et al.* [S54]
19%	16	Ascidiacea	California continental shelf	Lambert [S55]
0%	11	Sipuncula	Antarctic Waters	Cutler *et al.* [S56]
0%	5	Sipuncula	The deep Angola Basin	Saiz Salinas [S57]
40%	10	Pycnogonida	Melanesia	Bamber [S58]
30%	10	Pycnogonida	Taiwan	Bamber [S59]
19%	16	Pycnogonida	Melanesia	Bamber [S60]
23%	13	Pycnogonida	Melanesia	Bamber [S61]
20%	5	Pycnogonida	Ecuador	Bamber & Takahashi [S62]
7%	15	Pycnogonida	W Australia (shallow)	Bamber [S63]
17%	12	Pycnogonida	S Australia	Staples [S64]
15%	13	Pycnogonida	Queensland	Bamber [S65]
17%	6	Pycnogonida	Azores	Bamber & Costa [S66]
14%	50	Pycnogonida	Caribbean Colombia	Muller & Krapp [S67]
24%	17	Pycnogonida	W Australia (deep)	Arango [S68]
7%	204	Ophiuroidea	New Caledonia region	O'Hara & Stöhr [S69], Stöhr [S70]
2%	130	Ophiuroidea	North Atlantic, below 200 m	Martynov & Litvinova [S71]
8%	55	Crinoidea	Bahamas (July 2009)	Messing [unpubl. data]

6%	456	Nematoda	Southern Bight of the North Sea	Vincx [S72]
12%	114	Nematoda	Strait of Magellan and Beagle Channel (South America)	Chen [S73]
27-38%	250-350	Nematoda	Manganese nodule field off Peru, southern part of East Pacific	Bussau [S74]
88%	65	Tanaidacea	SE Australia	Blazewicz-Paszkowycz and Bamber [S75]
92%	26	Tanaidacea	W Australia (shallow)	Bamber [S76]
69%	29	Tanaidacea	Queensland	Bamber [S77]
46%	266	Tanaidacea	Antarctic	Blazewicz-Paszkowycz [unpubl. data]
28%	320	Bryozoa	New Zealand deep sea >500 m (including sea mounts)	Gordon [unpubl. data]
0-100% (average 41.3)	2 to 13	Zoantharia	Galapagos, Singapore, Japan, British Columbia, Cape Verde, Taiwan	Reimer *et al.* [S78-S87]
92%	26	Leucothoidae (Amphipoda)	Japan	White and Reimer [S88-S90]
24%	17	Echinoidea	North Atlantic	Mortensen [S91-S93]
19%	16	Echinoidea	Gulf of Thailand	Mortensen [S94]
41%	17	Echinoidea	South Atlantic, Antarctic coast & deep water	Mortensen [S92,S95]
29%	14	Echinoidea	Southwest Atlantic coast, Antarctic coast	Mortensen [S92,S96]
29%	14	Echinoidea	Northwestern Australia	Mortensen [S97]
33%	18	Echinoidea	New Zealand & Auckland-Campbell Islands	Mortensen [S98]
22%	144	Echinoidea	Philippines and adjacent regions	Mortensen [S99-S102]
14%	7	Echinoidea	Caribbean deep water	Mironov [S103]
3%	36	Echinoidea	Philippines and Makassar Strait	David & de Ridder [S104]
0%	31	Echinoidea	Antarctic coast, Subantarctic shelf and Kerguelen Islands	de Ridder *et al.* [S105]
25%	17,135	All taxa	New Zealand	Gordon *et al.* [S106]
70%	259	Triphoridae (gastropods)	Vanuatu	Albano et al. [S107]

Supplemental References: Table S1

S1. Grassle, J.F., and Maciolek, N.J. (1992). Deep-sea species richness: regional and local diversity estimates from quantitative bottom samples. Am. Nat. *139*, 313–341.

S2. Humes, A.G. (1994). How many copepods? in Ecology and morphology of copepods, Ferrari, F.D., Bradley, B.P. (Eds.) Proceedings of the 5th International Conference on Copepoda. Hydrobiologia *292/293*, 1–7.

S3. Carlton, J.T. (1995). Examples of the magnitude of under-described biodiversity among marine invertebrates in familiar and easily accessible marine environments, in: Committee on biological diversity in marine systems. Understanding marine biodiversity: a research agenda for the nation (National Academic Press, Washington D.C.), 11.

S4. Bouchet, P. (1997). Inventorying the molluscan diversity of the world. What is our rate of progress? The Veliger *40*, 1–11.

S5.Koslow, J.A., Gowlett-Holmes, K., Lowry, J.K., O'Hara, T., Poore, G.C.B., and Williams, A. (2001). Seamount benthic macrofauna off southern Tasmania: community structure and impacts of trawling. Mar. Ecol. Prog. Ser. *213*, 111–125.

S6. Lambshead, P.J.D., and Boucher, G. (2003). Marine nematode deep-sea biodiversity – hyperdiverse or hype? J. Biogeogr. *30*, 475–485.

S7. Brandt, A., Gooday, A.J., Brandão, S.N., Brix, S., Brökeland, W., Cedhagen, T., Choudhury, M., Cornelius, N; Danis, B., De Mese, I., *et al.* (2007). First insights into the biodiversity and biogeography of the Southern Ocean deep sea. Nature *447*, 307–311.

S8. Zapata, F.A., and Robertson, D.R. (2007). How many species of shore fishes are there in the Tropical Eastern Pacific? *J. Biogeogr. 34*, 38–51.

S9. Poore, G.C.B., Just, J., and Cohen, B.F. (1994). Composition and diversity of Crustacea Isopoda of the southeastern Australian continental slope. Deep Sea Res. Part I. *41*, 677–693.

S10. Poore, G.C.B., McCallum, A.W., and Taylor, J. (2008). Decapod Crustacea of the continental margin of southwestern and central Western Australia: preliminary identifications of 524 species from FRV Southern Surveyor voyage SS10–2005. Museum Victoria Science Reports *11*, 1–106.

S11. Bouchet, P., Lozouet, P., and Sysoev, A. (2009). An inordinate fondness for turrids. *Deep-Sea Research II 56*, 1724–1731.

S12. Erséus, C. (1997). Marine Tubificidae (Oligochaeta) from the Montebello and Houtman Abrolhos Islands, Western Australia, with descriptions of twenty-three new species, in: Wells, F.E (Ed). The Marine Flora and Fauna of the Houtman Abrolhos, Western Australia, (Western Australian Museum, Perth), 389–458.

S13. Cairns, S.D. (1999). Species richness of recent Scleractinia. Atoll Research Bulletin *459*, 1–12.

S14. Song, W., Warren, A., and Hu, X. (2009). Free-living ciliates in the Bohai and Yellow Seas, China. Science Press, Beijing, 518 pp.

S15. Van Steenkisten, N, Volonterio, O., Schockaert, E., and Artois, T. (2008). Marine Rhabdocoela (Platyhelminthes, Rhabditophora) from Uruguay, with the description of eight new species and two new genera. Zootaxa *1914*, 1–33.

S16. Alderslade, P. (1998). Revisionary systematics in the gorgonian family Isididae, with descriptions of numerous new taxa (Coelenterata: Octocorallia). Records of the Western Australian Museum Supplement *55*, 1–359.

S17. Grasshoff, M. (1999). The shallow water gorgonians of New Caledonia and adjacent islands (Coelenterata, Octocorallia). Senckenbergiana Biologica *78*, 1–121.

S18. Grasshoff, M. (2000). The gorgonians of the Sinai coast and the Strait of Gubal, Red Sea (Coelenterata, Octocorallia). Courier Forschungsinstitut Senckenberg *224*, 1–125.

S19. van Ofwegen, L.P. (2005). A new genus of nephtheid soft corals (Octocorallia: Alcyonacea: Nephtheidae) from the Indo-Pacific. Zoologische Mededelingen *79*, 1–236.
S20. van Ofwegen, L.P. (2008). The genus *Sinularia* (Octocorallia: Alcyonacea) at Palau, Micronesia. Zoologische Mededelingen *82*, 631–735.
S21. Erséus, C. (1990). The marine Tubificidae (Oligochaeta) of the barrier reef ecosystems at Carrie Bow Cay, Belize, and other parts of the Caribbean Sea, with descriptions of twenty-seven new species and revision of Heterodrilus, Thalassodrilides and Smithsonidrilus. Zool. Scr. *19*, 243–303.
S22. Erséus, C. (1997). The marine Tubificidae (Oligochaeta) of Darwin Harbour, Northern Territory, Australia, with descriptions of fifteen new species, in: Hanley, R.H., Caswell, G., Megirian, D., Larson, H.K. (Eds). The Marine Flora and Fauna of Darwin Harbour, Northern Territory, Australia. Proceedings of the Sixth International Marine Biological Workshop, Museum and Art Galleries of the Northern Territory and the Australian Marine Sciences Association, Darwin, 99–132.
S23. Erséus, C. (1993). The marine Tubificidae (Oligochaeta) of Rottnest Island, Western Australia, in: Wells, F.E., Walker, D.I., Kirkman, H., Lethbridge, R. (Eds). The Marine Flora and Fauna of Rottnest Island, Western Australia. Proceedings of the Fifth International Marine Biological Workshop, Western Australian Museum, Perth *2*, 331–390.
S24. Monniot, C. (1983). Ascidies littorales de Guadelope 2. Phlebobranches. Bull. Mus. natn. Hist. nat., Paris, *4 ser*, *5, A*, *1*, 51–71.
S25. Monniot, C. (1983). Ascidies littorales de Guadelope 6. Pyuridae et Molgulidae. Bull. Mus. natn. Hist. nat., Paris, *4 ser, 5, A, 4,* 1021–1044.
S26. Monniot, C. (1983). Ascidies littorales de Guadelope. 4. Styelidae. Bull. Mus. natn. Hist. nat., Paris, *4 ser, 5, A, 2*, 423–456.
S27. Monniot, C., and Monniot, F. (1984). Ascidies littorales de Guadeloupe. 7. Especes nouvelles et complementaries a l'inventaire. Bull. Mus. natn. Hist. nat., Paris, *4 ser., 6, A, 3*, 567–582.
S28. Monniot, F. (1983). Ascidies littorales de Guadelope 3. Polyclinidae. Bull. Mus. natn. Hist. nat., Paris, *4 ser*, *5, A, 2,* 413–422.
S29. Monniot, F. (1983). Ascidies littorales de Guadelope. 1. Didemnidae. Bull. Mus. natn. Hist. nat., Paris, *4 ser, 5, A, 1,* 3–49.
S30. Monniot, F. (1983). Ascidies littorales de Guadeloupe 5. Polycitoridae. Bull. Mus. natn. Hist. nat., Paris, *4 ser*, *5, A, 4,* 999–1019.
S31. Monniot, F. (1984). Ascidies littorales de Guadeloupe 8. Questions de systematique evolutive prosees par les Didemnidae. Bull. Mus. natn. Hist. nat., Paris, *4 ser, 6 A, 4*, 885–905.
S32. Monniot, C. (1987). Ascidies de Nouvelle-Caledonie. 1. Phlebobranches du lagon. Bull. Mus. natn. Hist. nat., Paris, *A 9, 1,* 3–31.
S33. Monniot, C. (1987). Ascidies de Nouvelle-Caledonie. 2. Les genres *Polycarpa* et *Polyandrocarpa.* Bull. Mus. natn. Hist. nat., Paris, *A 9, 2*, 275–310.
S34. Monniot, C. (1988). Ascidies de Nouvelle-Caledonie. 4. Styelidae (suite). Bull. Mus. natn. Hist. nat., Paris, *10, 2,* 163–196.
S35. Monniot, C. (1989). Ascidies de Nouvelle-Caledonie. 6. Pyuridae et Molgulidae. Bull. Mus. natn. Hist. nat., Paris, *A 11, 3,* 475–507.
S36. Monniot, C. (1991). Ascidies de Nouvelle-Caledonie. 8. Phlebobranches (suite). Bull. Mus. natn. Hist. nat., Paris, *4 ser, 12, A, 3–4,* 491–515.
S37.. Monniot, C. (1991). Ascidies de Nouvelle-Caledonie. 10. Stolidobranches (suite). Bull. Mus. natn. Hist. nat., Paris, *13*, 3–37.

S38. Monniot, F. (1987). Ascidies de Nouvelle-Caledonie. 3. Polyclinidae du lagon. Bull. Mus. natn. Hist. nat., Paris, *A9, 3*, 499–535.
S39. Monniot, F. (1988). Ascidies de Nouvelle-Caledonie. 5. Polycitoridae du lagon. Bull. Mus. natn. Hist. nat., Paris, *10, 2*, 197–235.
S40. Monniot, F. (1989). Ascidies de Nouvelle-Caledonie. 7. Les genres *Atriolum* et *Leptoclinides* dans le lagon sud. Bull. Mus. natn. Hist. nat., Paris, *A, 11, 4*, 673–691.
S41. Monniot, F. (1990,1991). Ascidies de Nouvelle-Caledonie. 9. Le genre *Trididemnum.* Bull. Mus. natn. Hist. nat., Paris, *4 ser., 12*, 517–529.
S42. Monniot, F. (1992). Ascidies de Nouvelle-Caledonie. 12. Le genre *Lissoclinum* (Didemnidae) dans le lagon sud. Bull. Mus. natl. Hist. nat., Paris, *4 ser, 14A, 3-4*, 565–589.
S43. Monniot, F. (1993). Ascidies de Nouvelle-Caledonie. 13. Le genre *Polysyncraton* (Didemnidae). Bull. Mus. natl. Hist. nat., Paris, *4 ser, 15 A 1-4*, 3–17.
S44. Monniot, F. (1994). Ascidies de Nouvelle-Caledonie. 14. Le genre *Diplosoma* (Didemnidae). Bull. Mus. natn. Hist. nat., Paris, *4 ser, 16 A, 1*, 3–11.
S45. Monniot, F. (1995). Ascidies de Nouvelle-Caledonie. 15. Le genre *Didemnum.* Bull. Mus. natl. Hist. nat., Paris, *4 ser., 16, A, 2–4*, 299–344.
S46. Monniot, F. (2010). Some new data on tropical western Pacific Ascidians. Zootaxa *2561*, 1–29.
S47. Monniot, F., and Monniot, C. (1996). New collections of ascidians from the Western Pacific and Southeastern Asia. Micronesica *29*, 133–279.
S48. Monniot, F., and Monniot, C. (2001). Ascidians from the tropical western Pacific. Zoosystema *23*, 201–383.
S49. Monniot, F., and Monniot, C. (2004). A new species of Plurellidae (Ascidiacea: Phlebobranchia) from Papua New Guinea. Zootaxa *423*, 1–8.
S50. Monniot, F., and Monniot, C. (2008). Compléments sur la diversité des ascidies (Ascidiacea, Tunicata) de l'ouest Pacifique tropical. Zoosystema *30*, 799–872.
S51. Michaelsen, W. (1934). The ascidians of the Cape Province of South Africa. Transactions of the Royal Society of South Africa *22*, 129–164.
S52. Millar, R.H. (1955). On a collection of ascidians from South Africa. Proceedings of the Zoological Society of London *125*, 169–221.
S53. Millar, R.H. (1962). Further descriptions of South African ascidians. Annals of the South African Museum *46*, 113–221.
S54. Monniot, C., Monniot, F., Griffiths, C.L., and Schleyer, M. (2001). South African ascidians. Annals of the South African Museum *108*, 1–141.
S55. Lambert, G. (1993). Three new species of stolidobranch ascidians (Chordata: Ascidiacea) from the California continental shelf. Proc. Calif. Acad. Sci. *48*, 109–118.
S56. Cutler, E.B., Dean, H.K., and Saiz Salinas, J.I. (2001). Sipuncula from Antarctic Waters. Proceedings of the Biological Society of Washington *114*, 861–880.
S57. Saiz Salinas, J.I. (2007). Sipunculans and echiurans of the deep Angola Basin. Journal of Natural History *41*, 2789–2800.
S58. Bamber, R.N. (2000). Pycnogonida: Pycnogonids from French cruises to New Caledonia, Fiji, Tahiti and the Marquesas. New records and new species. In: A. Crosnier (ed.). Résultats des campagnes MUSORSTOM, Vol. 21. Mémoires du Muséum national d'Histoire naturelle, Paris *184*, 611–625.
S59. Bamber, R.N. (2004). Pycnogonids (Arthropoda: Pycnogonida) from Taiwan, with description of three new species. Zootaxa *458*, 1–12.
S60. Bamber, R.N. (2004). Pycnogonids (Arthropoda: Pycnogonida) from New Caledonia, Fiji and Tonga: new records and new species, in: Marshall, B., and Richer de Forges, B. (Eds).

Tropical Deep-Sea Benthos, Vol. 23. Mémoires du Muséum national d'Histoire naturelle, Paris *191*, 73–83.
S61. Bamber, R.N. (2004). Pycnogonids (Arthropoda: Pycnogonida) from French cruises to Melanesia. Zootaxa *551*, 1–27.
S62. Bamber, R.N., and Takahashi, Y. (2005). Some littoral sea spiders (Arthropoda: Pycnogonida) from Ecuador, with a new species of *Anoplodactylus* Wilson, 1878 (Phoxichilidiidae). Zootaxa *815*, 1–8.
S63. Bamber, R.N. (2005). Pycnogonids (Arthropoda: Pycnogonida) from the Recherche Archipelago, Esperance, Western Australia, Australia, in: Wells, F.E., Walker, D.J., and Kendrick, G.A. (Eds). The Marine Flora and Fauna of Esperance, Western Australia, Proceedings of the Twelfth International Marine Biological Workshop. Western Australia Museum, Perth, 325–341.
S64. Staples, D.A. (2007). Pycnogonids (Arthropoda: Pycnogonida) from the Great Australian Bight, southern Australia, with description of two new species. Memoirs of the Museum of Victoria *64*, 95–101.
S65. Bamber, R.N. (2008). Sea-spiders (Arthropoda: Pycnogonida) from Moreton Bay, Queensland, in: Davie, P.J.F., and Phillips, J.A. (Eds). The Marine Fauna and Flora of Moreton Bay, Queensland, Proceedings of the Thirteenth International Marine Biological Workshop. Memoirs of the Queensland Museum - Nature *54*, 131–142.
S66. Bamber, R.N., and Costa, A.C. (2009). The pycnogonids (Arthropoda: Pycnogonida) of São Miguel, Azores, with description of a new species of *Anoplodactylus* Wilson, 1878 (Phoxichilidiidae). Proceedings of the Third International Workshop of Malacology and Marine Biology, São Miguel, Açores, Portugal. Açoreana, Supplement *6*, 167–182.
S67. Müller, H-G., and Krapp, F. (2009). The pycnogonid fauna (Pycnogonida, Arthropoda) of the Tayrona National Park and adjoining areas on the Caribbean coast of Colombia. Zootaxa *2319*, 1–138.
S68. Arango, C.P. (2009). New species and new records of sea spiders (Arthropoda: Pycnogonida) from deep waters in Western Australia. Zootaxa *1977*, 1–20.
S69. O'Hara, T.D., and Stöhr, S. (2006). Deep water Ophiuroidea (Echinodermata) of New Caledonia: Ophiacanthidae and Hemieuryalidae. Tropical Deep Sea Benthos (Mémoires du Muséum national d'Histoire naturelle 193), *24*, 33–141.
S70. Stöhr, S. (2011). New records and new species of Ophiuroidea (Echinodermata) from Lifou, Loyalty Islands, New Caledonia. Zootaxa *3089*, 1–50.
S71. Martynov, A.V., and Litvinova, N.M. (2008). Deep-water Ophiuroidea of the northern Atlantic with descriptions of three new species and taxonomic remarks on certain genera and species. Marine Biology Research *4*, 76–111.
S72. Vincx, M. (1987). Freeliving marine nematodes from the Southern Bight of the North Sea. PhD Ghent University, 618 pp.
S73. Chen, G. (1999). Ecology and systematics of the meiofauna and nematode communities in the strait of Magellan and the Beagle Channel (Chile). PhD thesis Ghent University, 315 pp.
S74. Bussau, C. (1993). Taxonomische und ökologische Untersuchungen an Nematoden des Peru-Beckens. PhD Thesis Kiel University, 621 pp.
S75. Błażewicz-Paszkowycz, M., and Bamber, R.N. The shallow-water Tanaidacea (Arthropoda: Malacostraca: Peracarida) of the Bass Strait, Victoria, Australia (other than the Tanaidae). Memoirs of Museum Victoria. in press.
S76. Bamber, R.N. (2005). The Tanaidaceans (Arthropoda: Crustacea: Peracarida: Tanaidacea) of Esperance, Western Australia, Australia, in: Wells, F.E., Walker, D.J., and Kendrick, G.A. (Eds). The Marine Flora and Fauna of Esperance, Western Australia,

Proceedings of the Twelfth International Marine Biological Workshop. Western Australia Museum, Perth, 613–728.
S77. Bamber, R.N. (2008). Tanaidaceans (Crustacea: Peracarida: Tanaidacea) from Moreton Bay, Queensland, Australia, in: Davie, P.J.F., and Phillips, J.A. (Eds). The Marine Fauna and Flora of Moreton Bay, Queensland, Proceedings of the Thirteenth International Marine Biological Workshop. Memoirs of the Queensland Museum – Nature, 143–217.
S78. Reimer, J.D., Sinniger, F, and Hickman, C. (2008). Zoanthid diversity (Anthozoa: Hexacorallia) in the Galapagos Islands: a molecular examination. Coral Reefs *27*, 641–654.
S79. Reimer, J.D., and Hickman, C. (2009). Preliminary survey of zooxanthellate zoanthids (Cnidaria: Hexacorallia) of the Galápagos and associated symbiotic dinoflagellates (Symbiodinium spp.). Galápagos Research *66*, 14–19.
S80. Reimer, J.D., and Todd, P.A. (2009). Preliminary molecular examination of zooxanthellate zoanthid (Hexacorallia, Zoantharia) and associated zooxanthellae (Symbiodinium spp.) diversity in Singapore. Raffles Bulletin of Zoology. Supplement *22*, 103–120.
S81. Reimer, J.D. (2010). Key to field identification of shallow water brachycnemic zoanthids (Order Zoantharia: Suborder Brachycnemina) present in Okinawa. Galaxea *12*, 23–29.
S82. Reimer, J.D., and Fujii, T. (2010). Four new species and one new genus of zoanthids (Cnidaria: Hexacorallia) from the Galápagos. ZooKeys *42*, 1–36.
S83. Reimer, J.D., Hirose, M., Nishisaka, T., Sinniger, F., and Itani; G. (2010). *Epizoanthus* spp. associations revealed using DNA markers: a case study from Kochi, Japan. Zoological Science *27*, 729–734.
S84. Reimer, J.D., and Sinniger, F. (2010). Unexpected diversity in Canadian Pacific zoanthids (Cnidaria: Anthozoa: Hexacorallia): a molecular examination and description of a new species from the waters of British Columbia. Marine Biodiversity *40*, 249–260.
S85. Reimer, J.D., Hirose, M., and Wirtz, P. (2010). Zoanthids of the Cape Verde Islands and their symbionts: previously unexamined diversity in the Northeastern Atlantic. Contributions to Zoology *79*, 147–163.
S86. Reimer, J.D., Obuchi, M., Irei, Y., Fujii, T., and Nozawa, Y. (2011). Shallow water brachycnemic zoanthids (Cnidaria: Hexacorallia) from Taiwan: a preliminary survey. Zoological Studies *50*, 363–371.
S87. Reimer, J.D., Hirose, M., Yanagi, K., and Sinniger, F. (2011). Marine invertebrate diversity in the oceanic Ogasawara Islands: a molecular examination of zoanthids (Anthozoa: Hexacorallia) and their Symbiodinium (Dinophycaea). Systematics and Biodiversity *9*, 133–144.
S88. White, K.N., Reimer, J.D. (2012). Commensal Leucothoidae (Crustacea, Amphipoda) of the Ryukyu Archipelago, Japan. Part I: ascidian-dwellers. ZooKeys *163*, 13–55.
S89. White, K.N., Reimer, J.D. (2012). Commensal Leucothoidae (Crustacea, Amphipoda) of the Ryukyu Archipelago, Japan. Part II: sponge-dwellers. ZooKeys *166*, 1–58.
S90. White, K.N., Reimer, J.D. (2012). Commensal Leucothoidae (Crustacea, Amphipoda) of the Ryukyu Archipelago, Japan. Part III: coral rubble-dwellers. ZooKeys *173*, 11–50.
S91. Mortensen, T. (1903). The Danish *Ingolf*-Expedition 1895–1896. Vol. 4, No. 2. Echinoidea, pt. 1. Bianco Luno, Copenhagen, 198 pp.
S92. Mortensen, T. (1905). Some new species of Echinoidea. Videnskabelige Meddelelser fra den naturhistoriske Forening i Kjøbenhavn *7*, 241–243.
S93. Mortensen, T. (1907). The Danish *Ingolf*-Expedition 1895–1896. Vol. 4, No. 2. Echinoidea, pt. 2. Bianco Luno, Copenhagen, 200 pp.
S94. Mortensen, T. (1904). The Danish Expedition to Siam 1899–1900. III. Echinoidea (1). Kongelige Danske Videnskabelige Selskabs, Skrifter, Serie *7*, 1–124.

S95. Mortensen, T. (1909). Die Echinoiden der Deutschen Südpolar-Expedition 1901–1903. Pp. 1–114, in: Drygalski, E.v. (Ed) Deutsche Südpolar-Expedition 1901–1903 im Auftrage des Reichsamtes des Innern, XI. Band, Zoologie III. Band, Heft I Georg Reimer, Berlin.
S96. Mortensen, T. (1910). The Echinoidea of the Swedish South Polar Expedition. Pp. 1–114, in: Nordenskjöld, O. (Ed).Wissenschaftliche Ergebnisse der Schwedischen Südpolar-Expedition 1901–1903 6 (Zoologie II), 1–114.
S97. Mortensen, T. (1918). Results of Dr. Mjöbergs Swedish Scientific Expedition to Australia 1910–1913. XXI. Echinoidea. Kungelige Svenska Vetenskaps-Akademiens Handlingar *58*, 1–22.
S98. Mortensen, T. (1921). Papers from Dr. Th. Mortensen's Pacific Expedition 1914–1916. Echinoderms of New Zealand and the Auckland-Campbell Islands. I. Echinoidea. Videnskabelige Meddelelser fra Dansk Naturhistoriske Forening *73*, 139–198.
S99. Mortensen, T. (1927). Contributions to the Biology of the Philippine Archipelago and adjacent regions. Report on the Echinoidea collected by the United States fisheries streamer "Albatross" during the Philippine Expedition, 1907–1910. Part I. The Cidaridae. Bulletin of the Smithsonian Institution, U.S. National Museum *100*, 243–312.
S100. Mortensen, T. (1934). New Echinoidea. (Preliminary Notice.) . Videnskabelige Meddelelser fra Danks naturhistorisk Forening i København *98*, 161–167.
S101. Mortensen, T. (1940). Contributions to the Biology of the Philippine Archipelago and adjacent regions. Report on the Echinoidea collected by the United States fisheries streamer "Albatross" during the Philippine Expedition, 1907–1910. Part 2. The Echinothuriidae, Saleniidae, Arbaciidae, Aspidodiadematidae, Micropygidae, Diadematidae, Pedinidae, Temnopleuridae, Toxopneustidae, and Echinometridae. Smithsonian Institution, United States National Museum Bulletin Bulletin *100*, 1–52.
S102. Mortensen, T. (1948). Contributions to the Biology of the Philippine Archipelago and adjacent regions. Report on the Echinoidea collected by the United States Fisheries Steamer "Albatross" during the Philippine Expedition, 1907–1910. Part 3: The Echinoneidae, Echinolampidae, Clypeastridae, Arachnidae, Laganidae, Fibulariidae, Urechinidae, Echinocorythidae, Palaeostomatidae, Micrasteridae, Palaepneustidae, Hemiasteridae, and Spatangidae. Smithsonian Institution, United States National Museum Bulletin Bulletin *100*, 93–140.
S103. Mironov, A.N. (1975). [Deep-sea urchins (Echinodermata, Echinoidea) collected during the 14th cruise of the R/V "Akademik Kurchatov"]. Trudy Instituta Okeanologii, Akademii Nauk SSSR *100*, 205–214.
S104. David, B., and de Ridder, C. (1989). Echinodermes: Échinides irréguliers. Pp. 203–227 in Forest, J. (ed.) Résultats des Campagnes Musorstom, Volume 4. Mémoires du Muséum National d'Histoire Naturelle, Série A (Zoologie) *143*, 203–227.
S105. de Ridder, C., David, B., and Larrain, A. (1992). Antarctic and subantarctic echinoids from "Marion Dufresne" expeditions MD03, MD04, MD08, and from the "Polarstern" expedition Epos III. Bulletin du Muséum national d'Histoire naturelle, 4e série, Section A (Zoologie, Biologie et Écologie animales) *14*, 405–441.
S106. Gordon, D.P., Beaumont, J., MacDiarmid, A.B., Robertson, D.A., and Ahyong, S.T. (2010). Marine biodiversity of Aotearoa New Zealand. PLoS One *5*, 1–17.
S107. Albano, P.G., Sabelli B., Bouchet B. 2011. The challenge of small and rare species in marine biodiversity surveys: microgastropd diversity in a complex tropical coastal environment. *Biodiversity Conservation* 20, 3223-3237.

Supplemental Experimental Procedures

There is a large literature on statistical prediction of the number of species remaining to be described [S1–S2], where it is known more generally as the 'number of kinds' problem. Most methods of estimation require data in the form of a sample of individuals of known size, where each individual in the sample has been identified so that the proportional abundance of individuals among species in the sample is known.

Such samples are available for only a small portion of the biosphere, making their use difficult. However, the global rate of species description is known, allowing curve fitting and extrapolation to be used for prediction [S3–S7]. We compared the expert-based estimates on the total number of marine species to predictions generated by a non-homogeneous renewal process model based on extrapolation of the discovery curve as a logistic function. The logistic function has the form

$$\text{Number discovered by year } t = \frac{N}{1+\exp\left(-\beta(t-\alpha)\right)},$$

and takes an 'S' shape, going from 0 at t = –∞ to N at t = +∞. The logistic function is a popular choice as a model for the trend in species discovery in a given taxon, as it has the property of an initial slow rate of discovery, rising to a peak before discoveries tail off when most of the species in the taxon are described. The three parameters of the function are N, the total number of species to be discovered; α, the year of maximum rate of discovery; and β that describes the overall rate of discovery, with a larger β implying a faster rate. This has the advantage over other models of producing confidence limits based on the variation in the rate of description between years [S8]. This model is stochastic and describes the time between the discovery of species as a renewal process [S9] where the mean number discovered as a function of time follows a logistic function. Bayesian statistical inference methods are used to fit the discovery curve to this model, giving an estimate of the 3 parameters of the logistic function and in particular an estimate of N, the total number of species. This is then used to estimate the number of species in the taxon remaining to be described.

Unfortunately, predictions based on extrapolating a logistic curve are very sensitive to the fitted value of α, the date of maximum rate of discovery. That date is very difficult to estimate from the data in cases where there is no sign that it has been reached (*e.g.*, groups where the majority of species remain to be described), making the application of this model challenging. In these cases, it is only assumed that the date of maximum rate of discovery occurs between 2010 and 2450. In our analysis we focused on lower and upper bounds for the predicted numbers of species.

Supplemental References: Supplemental Experimental Procedures

S1. Bunge, J., and Fitzpatrick, M. (1993). Estimating the number of species: a review. J. Amer. Statist. Assoc. *88*, 364–373.
S2. Colwell, R.K., and Coddington, J.A. (1994). Estimating terrestrial biodiversity through extrapolation. Philos. Trans. R. Soc. London [Biol] *345*, 101–118.
S3. Frank, J.H., and Curtis, G.A. (1979). Trend lines and the number of species of Staphylinidae. Coleopt. Bull. *33*, 133–149.
S4. Zapata, F.A., and Robertson, D.R. (2007). How many species of shore fishes are there in the Tropical Eastern Pacific? J. Biogeog. *34*, 38–51.
S5. Solow, A.R., and Smith, W.K. (2005). On estimating the number of species from the discovery record. Proc. R. Soc. B. *272*, 285–287.
S6. Bebber, D.P., Marriott, F.H.C., Gaston, K.J., Harris, S.A., and Scotland, R.W. (2007). Predicting unknown species numbers using discovery curves. Proc. R. Soc. B. *274*, 1651-1658.
S7. May, R.M. (1990). How many species? Phil. Trans. R. Soc. Lond. B *330*, 293–304.
S8. Wilson, S.P., and Costello, M.J. (2005). Predicting future discoveries of European marine species by using a non-homogeneous renewal process. Appl. Statist. *54*, 897–918.
S9. Ross, S.M. (1995). Stochastic Processes, 2nd edition. New York: Wiley.

Table S2. Comments on reasoning behind the data on particular taxa in Table 1.

Chlorophyta, Rhodophyta, Cryptophyta, Haptophyta, Phaeophyceae, Bacillariophyceae, Chrysophyceae, Euglenozoa [Michael D. Guiry, Olivier De Clerck]	**Described + nominal** Data on described species and the percentage of synonyms are based on AlgaeBase (Guiry & Guiry, 2012). **Undiscovered** Several papers have previously addressed algal diversity and provided detailed estimates on the number of species, known and unknown, for various algal groups (*e.g.*, Andersen, 1992; John, 1994; Norton *et al.*, 1996; John & Maggs, 1997; Adl *et al.*, 2007). The numbers presented in these papers are the result of censusing taxonomic experts for specific groups. The total number of recognized species ranged from approximately 29.000 (Adl *et al.*, 2007; lower estimate) to 43.400 (Andersen 1992; upper estimates). Even though on average estimates of global diversity were about 2-fold higher than the currently recognized number of species, the estimates differed widely among studies and groups. Most notably, estimates of diatom richness ranged from 100.000 species to 10 million, which would indicate that 90–99% of diatom species remains unknown to date. But estimates for other groups also display large variation. The Eustigmatophyceae for example, were considered to comprise between 1000 and 10.000 species by Andersen (1992) and John (1994), while Adl *et al.* (2007) go for a more modest global estimate of 30 species. Important, the abovementioned studies address global algal diversity and hence the numbers presented refer to the combined marine, freshwater and subaerial diversity. The percentage of marine species differs widely among groups. Whereas the Chlorarachniophyta, Dinophyta, Haptophyta, Rhodophyta and Phaeophyceae are predominantly to exclusively marine, other groups are much more speciose in freshwater habitats (*e.g.*, Chlorophyta, Chrysophyceae and Euglenozoa) (Dring, 1982; Van Den Hoek et al., 1995; Edvardsen & Medlin, 2007; Ishida et al., 2007; Moestrup & Daugbjerg, 2007). The Diatoms are predominantly marine or marine/brackish (63%) (Mann, 1996), but about 25% is exclusively restricted to freshwater habitats. These differing ecologies among groups make it difficult to tease out the marine components and complicate comparison of algal species richness. The estimates of unknown diversity are those presented by Adl *et al.* (2007), except for Chlorophyta and Bacillariophyceae. Numbers have been adjusted for the fraction of marine taxa. These numbers are rough estimates that depend critically on the estimates of total richness, the percentage of marine taxa and equal taxonomic effort in freshwater and marine environments. For two groups of algae, Chlorophyta and Bacillariophyceae, extrapolation of the data by Adl *et al.* (2007) yielded unrealistically high species numbers that await description. Estimates of 1–2x10(exp 5) Chlorophyta, 13.8% of which is marine (Dring, 1982), are probably overly enthusiastic. We estimate a maximum of 2,500 marine Chlorophyta, 1,200 of which remaining to be described. Likewise, an estimate of 2x10(exp 5) Bacillariophyceae (Mann, 1999; Adl et al., 2007) with 63% of the genera being marine (Mann, 1996), would leave more than 1.2x10(exp 5) marine species to be described. We concur with Mann (1999) in that there are indeed a lot of diatom species, but extrapolation of freshwater diversity patterns to the marine environment, is likely to overestimate the marine diversity. A maximum of 50,000 is therefore suggested. **Cryptic**

With the notable exception of Adl *et al.* (2007), estimates of algal diversity largely predate the wide-scale application of molecular sequence in phycology. Sequencing of target genes in individual organisms or more recently by environmental sequencing has revolutionized algal systematics at every taxonomic level. At lower taxonomic levels, gene sequences have confronted phycologists with the notion that algal genetic diversity is in many cases inadequately reflected by the morphology of the organisms. This mismatch between genetic diversity and morphology has been the focus of a whole body of research over the past two decades. Regardless of the taxonomic group, adequately sampled datasets nearly always reveal a plethora of cryptic or in some cases pseudocryptic species. (Lajeunesse, 2002; Montresor et al., 2003; Saez et al., 2003; De Clerck et al., 2005; Saez & Lozano, 2005; Sarno et al., 2005; Saunders & Lehmkuhl, 2005; Evans et al., 2007; Lilly et al., 2007; Medlin et al., 2007; Kooistra et al., 2008; Leliaert et al., 2009; Verbruggen et al., 2009; Boo et al., 2010; Gomez et al., 2011; Piganeau et al., 2011).

Undescribed, collected

The main challenges, however, nowadays are not set by disclosing diversity, but consist of linking genetic diversity to names in the literature and ultimately to the specimens housed in herbaria. The 'low morphology' problem (Vanoppen et al., 1993) of single-celled photosynthetic eukaryotes and seaweeds does not only complicate diversity assessments of living organisms, it also makes accurate interpretation of type material and historical collections a daunting task. With our current knowledge it is therefore nearly impossible to predict how many species have been collected but await formal description. The numbers of Bebber *et al.* (2010), predicting that more than half of the undescribed flowering plant species has been discovered and stored in herbaria already, probably hold up for algae as well. If one interprets 'discovered' as being recognized as undescribed, this number is probably very low.

References

Adl, S.M., Leander, B.S., Simpson, A.G.B., Archibald, J.M., Anderson, O.R., Bass, D., Bowser, S.S., Brugerolle, G., Farmer, M.A., Karpov, S., Kolisko, M., Lane, C.E., Lodge, D.J., Mann, D.G., Meisterfeld, R., Mendoza, L., Moestrup, O., Mozley-Standridge, S.E., Smirnov, A.V., and Spiegel, F. (2007). Diversity, nomenclature, and taxonomy of protists. Systematic Biology *56*, 684–689.

Andersen, R.A. (1992). Diversity of eukaryotic algae. Biodiversity and Conservation *1*, 267–292.

Boo, S.M., Kim, H.S., Shin, W., Boo, G.H., Cho, S.M., Jo, B.Y., Kim, J.H., Yang, E.C., Siver, P.A., Wolfe, A.P., Bhattacharya, D., Andersen, R.A., and Yoon, H.S. (2010). Complex phylogeographic patterns in the freshwater alga synura provide new insights into ubiquity vs. Endemism in microbial eukaryotes. Molecular Ecology *19*, 4328–4338.

De Clerck, O., Gavio, B., Fredericq, S., Barbara, I., and Coppejans, E. (2005). Systematics of grateloupia filicina (halymeniaceae, rhodophyta), based on rbcl sequence analyses and morphological evidence, including the reinstatement of g. Minima and the description of g. Capensis sp. Nov. Journal of Phycology *41*, 391–410.

Dring, M. (1982) The biology of marine plants. Cambridge University Press, Cambridge.

	Edvardsen, B., and Medlin, L.K. (2007). Molecular systematics of haptophyta. Unravelling the algae: The past, present, and future of algal systematics (ed. by J. Brodie and J. Lewis), pp. 183–196. Taylor and Francis. Evans, K.M., Wortley, A.H., and Mann, D.G. (2007). An assessment of potential diatom "Barcode" Genes (cox1, rbcl, 18s and its rdna) and their effectiveness in determining relationships in sellaphora (bacillariophyta). Protist *158*, 349–364. Gomez, F., Lopez-Garcia, P., and Moreira, D. (2011). Molecular phylogeny of dinophysoid dinoflagellates: The systematic position of oxyphysis oxytoxoides and the dinophysis hastata group (dinophysales, dinophyceae). Journal of Phycology *47*, 393–406 Guiry, M.D., and Guiry, G.M. (2012). Algaebase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org. Ishida, K., Yabuki, A., and Ota, S. (2007). The chlorarachniophytes: Evolution and classification. Unravelling the algae: The past, present, and future of algal systematics (ed. by J. Brodie and J. Lewis), pp. 171–182. Taylor and Francis. John, D.M. (1994). Biodiversity and conservation: Algal perspective. The Phycologist *38*, 3–21. John, D.M., and Maggs, C.A. (1997). Species problems in eukaryotic algae: A modern perspective. Species: The units of biodiversity (ed. by M.F. Claridge, H.A. Dawah and M.R. Wilson). Chapman & Hall. Kooistra, W., Sarno, D., Balzano, S., Gu, H.F., Andersen, R.A., and Zingone, A. (2008). Global diversity and biogeography of skeletonema species (bacillariophyta). Protist *159*, 177–193. Lajeunesse, T.C. (2002). Diversity and community structure of symbiotic dinoflagellates from caribbean coral reefs. Marine Biology *141*, 387–400. Leliaert, F., Verbruggen, H., Wysor, B., and De Clerck, O. (2009). DNA taxonomy in morphologically plastic taxa: Algorithmic species delimitation in the boodlea complex (chlorophyta: Cladophorales). Molecular Phylogenetics and Evolution *53*, 122–133. Lilly, E.L., Halanych, K.M., and Anderson, D.M. (2007). Species boundaries and global biogeography of the alexandrium tamarense complex (dinophyceae). Journal of Phycology *43*, 1329–1338. Mann, D.G. (1996). Crossing the rubicon: The effectinveness of the marine/freshwater interface as a barrier to the migration of diatom germplasm. In: 14th Diatom Symposium (eds. Mayama, Idei and Koizumi), pp. 1–21. Koetlz Scientific Books. Mann, D.G. (1999). The species concept in diatoms. Phycologia *38*, 437–495. Medlin, L.K., Metfies, K., John, U., and Olsen, J.L. (2007). Algal molecular systematics: A review of the past and prospects for the future. Unravelling the algae: The past, present, and future of algal systematics (ed. by J. Brodie and J. Lewis), pp. 341–353. Taylor and Francis. Moestrup, O., and Daugbjerg, N. (2007). On dinoflagellate phylogeny and classification. Unravelling the algae: The past, present, and future of algal systematics (ed. by J. Brodie and J. Lewis), pp. 215–230. Taylor and Francis. Montresor, M., Sgrosso, S., Procaccini, G., and Kooistra, W. (2003). Intraspecific diversity in scrippsiella trochoidea (dinophyceae): Evidence for cryptic species. Phycologia *42*, 56–70.

	Norton, T.A., Melkonian, M. & Andersen, R.A. (1996). Algal biodiversity. Phycologia *35*, 308–326. Piganeau, G., Eyre-Walker, A., Grimsley, N., and Moreau, H. (2011). How and why DNA barcodes underestimate the diversity of microbial eukaryotes. PLoS ONE 6(2), e16342. doi:10.1371/journal.pone.0016342 Saez, A.G., and Lozano, E. (2005). Body doubles. Nature *433*, 111. Saez, A.G., Probert, I., Geisen, M., Quinn, P., Young, J.R., and Medlin, L.K. (2003). Pseudo-cryptic speciation in coccolithophores. Proceedings of the National Academy of Sciences of the United States of America *100*, 7163–7168. Sarno, D., Kooistra, W., Medlin, L.K., Percopo, I., and Zingone, A. (2005). Diversity in the genus skeletonema (bacillariophyceae). Ii. An assessment of the taxonomy of s-costatum-like species with the description of four new species. Journal of Phycology *41*, 151–176. Saunders, G.W., and Lehmkuhl, K.V. (2005). Molecular divergence and morphological diversity among four cryptic species of plocamium (plocamiales, florideophyceae) in northern europe. European Journal of Phycology *40*, 293–312. Van Den Hoek, C., Mann, D.G., and Jahns, H.M. (1995). Algae: An introduction to phycology. Cambridge University Press. Vanoppen, M.J.H., Olsen, J.L., Stam, W.T., Vandenhoek, C., and Wiencke, C. (1993).Arctic-antarctic disjunctions in the benthic seaweeds acrosiphonia-arcta (chlorophyta) and desmarestia-viridis-willii (phaeophyta) are of recent origin. Marine Biology *115*, 381–386. Verbruggen, H., Vlaeminck, C., Sauvage, T., Sherwood, A.R., Leliaert, F., and De Clerck, O. (2009). Phylogenetic analysis of pseudochlorodesmis strains reveals cryptic diversity above the family level in the siphonous green algae (bryopsidales, chlorophyta). Journal of Phycology *45*, 726–731.
Mangroves [Farid Dahdouh Guebas, Koedam Nico]	**Described + Nominal** It is important to highlight that the list of Mangrove associates is never-ending and if one refers to mangroves one should consider only the species that are either Minor or Major mangrove components. Some people who live in one part of the world argue that in their part of the world mangrove-associate or even terrestrial trees are considered mangroves, but this lead to absurd situations in which the number of mangroves "explode" at the expense of the management of true mangroves (minor + major). **Undescribed, collected** My best guestimate is that there are none, or at least they might be the same as the ones under undiscovered. **Undiscovered** My best guestimate is that in countries where congeneric species are present, there might be undiscovered hybrids. An analysis on the geographic data in the Mangrove Reference Database and Herbarium (Massó i Alemán et al, 2010) leads to the guestimate of the theoretical hybrids below. This means that the putative parents occur in the same country and may therefore have crossed. However there are 3 caveats, 2 of which I can resolve if the resolution of the other marine species that you are investigating is higher and if I have more time: (1) I did not take into account country size (more likely to have undiscovered species or hybrids in large countries with large mangrove areas), and (2) co-occurrence in a country does not necessarily

	imply co-occurrence in the same forest. Guestimate of number of totally new species : 0–5 Potential undiscovered hybrids : 54 hybrids, being Between *Acanthus ebracteatus*, *A. ilicifolius* and *A. xiamenensis* : 3 hybrids Between *Acanthus ilicifolius* and *A. volubilis* : 1 hybrid Between *Acrostichum aureum*, *A. danaeifolium* and *A. speciosum* : 3 hybrids Between *Aegiceras corniculatum* and *A. floridum* : 1 hybrid Between *Avicennia integra* and *A. marina* : 1 hybrid Between *Avicennia alba*, *A. marina*, *A. officinalis* and *A. rumphiana* : 6 hybrids Between *Avicennia germinans* and *A. schaueriana* : 1 hybrid Between *Bruguiera hainesii* on one hand and *B. cylindrica*, *B. gymnorrhiza*, *B. parviflora* or *B. sexangula* on the other : 4 hybrids Between *Bruguiera cylindrica*, *B. exaristata*, *B. gymnorrhiza*, *B. parviflora* and *B. sexangula* : 9 hybrids (excl. the ones documented already) Between *Camptostemon philippinense* and *C. schultzii* : 1 hybrid Between *Ceriops australis*, *C. decandra* and *C. tagal* : 3 hybrids Between *Excoecaria agallocha* and *E. indica* : 1 hybrid Between *Heritiera fomes*, *H. kanikensis* and *H. littoralis* : 3 hybrids Between *Heritiera globosa* and *H. littoralis* : 1 hybrid Between *Kandelia candel* and *K. obovata* : 1 hybrid Between *Rhizophora stylosa* on one hand and *R. mucronata* or *R. samoensis* on the other hand : 2 hybrids Between *Sonneratia hainanensis* on one hand and *S. alba*, *S. caseolaris* or *S. ovata* on the other hand : 3 hybrids Between *Sonneratia alba*, *S. apetala*, *S. caseolaris* and *S. griffithii* : 5 hybrids (excl. the ones documented already) Between *Sonneratia alba*, *S. caseolaris*, *S. lanceolata* and *S. ovata* : 3 hybrids (excl. the ones documented already) Between *Xylocarpus granatum* on one hand, and *X. mekongensis* or *X. moluccensis* : 2 hybrids The 3rd caveat is related to the question: if these hybrids exist wouldn't someone have noticed it by now in these well-populated coastal ecosystems? Is this theoretical analysis, even though based on occurrence data, not an overestimation? I believe it is, and if based on discovery of hybrids over the last 20 years I tend to say the guestimate should be closer to 5–10 than to 50! **References** Massó i Alemán, S., Bourgeois, C., Appeltans, W., Vanhoorne, B., De Hauwere, N., Stoffelen, P., Heughebaert, A., and Dahdouh-Guebas, F. (2010). The 'Mangrove Reference Database and Herbarium' Plant Ecol. Evol. *143*, 225–232.
Ciliophora [Alan Warren]	I made estimates based on the arguments proposed by Finlay *et al*. (1996, 1998) and Foissner *et al.* (2008), and following extensive discussions with Genoveva Esteban (co-author of Finlay *et al*., 1996, 1998). **Undiscovered** This, of course, is highly debatable, and especially difficult to estimate for parasitic or commensal forms as we know little about their host species

	specificity. Basically, the number of undiscovered species of such forms may depend on the number of unknown host species. The 'moderate endemicity' model (Foissner et al, 2008) states that the total number of ciliate species is significantly underestimated largely due to: (1) undersampling; (2) previously unrecognised morphological variation, and; (3) the existence of sibling species, a lack of understanding of the genetic species diversity, etc. When these factors are taken into account it is estimated that 83 – 89% of free-living ciliate diversity remains undiscovered (Foissner et al., 2008). Maximum bounds: (1) Habitat studies (undersampling) suggests that the number of species should be doubled: using the upper limit of described species (2,421) gives a revised total of 4,842. Using the lower limit (2,115) gives a revised total of 4,230. (2) Unrecognised morphological variation suggests that this figure should increase by a further 50%. Based on the upper limit value (4,842), the number should be increased by 2,421 giving a further revised total of 7,263. Based on the lower limit value (4,230) the number should increase by 2,115 giving a further revised total of 6,345. Minimum bounds: According to Esteban (pers. comm.) a 50% synonymy rate should be applied to the total estimated (morpho)species diversity. Thus for the lower limit value (6,345), a 50% synonymy rate results in 3,173 (morpho)species. Thus, the maximum and minimum bounds for the estimated total numbers of marine ciliate (morpho)species are: maximum 7,263; minimum 3,173. **Cryptic** According Foissner *et al.* (2008), genetic and molecular evidence suggests that the ciliate (morpho)species diversity must be doubled or trebled. Maximum bounds: Trebling the maximum number of (morpho)species (7,263) gives 21,789. Thus, if the number of (morpho)species is 7,263 then the number of cryptic molecular species is 14,526. Adding these together gives a maximum total of 21,789 marine ciliate species. Minimum bounds: According to Foissner et al.'s (2008) lower estimate, the number of cryptic molecular species is the same as the number of (morpho)species, *i.e.*,the latter value must be doubled to give the total species number. Thus, the number of (morpho)species (before applying the 50% synonymy rate) is 6,345. Doubling this gives 12,690. However, according to Esteban (pers. comm.) a 50% synonymy rate should also apply to the number of cryptic molecular species. Thus of the 12,690 cryptic species, 6,345 are redundant. Subtracting this from the 12,690 cryptic species gives a total of 6,345 marine ciliate species. Therefore, the maximum and minimum bounds for the estimated total numbers of marine ciliate species are: maximum 21,789; minimum 6,345. Note, all this assumes that the estimates derived for free-living species also apply to non-free-living species. **References**

	Finlay, B.J., Corliss, J.O., Esteban, G., and Fenchel, T. (1996). Biodiversity at the microbial level: the number of free-living ciliates in the biosphere. The Quarterly Review of Biology *71*, 221–237. Finlay, B.J., Esteban, G., and Fenchel, T. (1998). Protozoan diversity: converging estimates of the global number of free-living ciliate species. Protist *149*, 29–37. Foissner W., Chao, A., and Katz L.A. (2008). Diversity and geographic distribution of ciliates (Protista: Ciliophora). Biodiversity and Conservation *17*, 345–363.
Foraminifera [Bruce Hayward]	**Described** We have Ellis and Messina catalogue of published foram species and descriptions. There are nearly 50,000 species described and named — but that includes a majority from the fossil record. Species described from the modern are not separated out and many species described from the fossil are still extant. John Murray (2007) recently published an estimate based on the data he assembled world-wide for his book. However, I have little faith in his methodology or assumptions. His initial number is based on specimens recorded stained (ie contained protoplasm) in studies. Fewer than 20% of studies on modern forams have stained their specimens in processing. As a result fewer than 50% of the species recorded from NZ for example are in his count and even lower percentage from the deep sea. I disagree with him that only 50% have been described - I think the number is a lot higher, except for cryptic taxa that can only be identified by molecular studies. I also think far greater percentage is cosmopolitan but this is obscured by multiple descriptions and namings from different regions. I think around 5,000 species is reasonable, which is not far off Murray's maximum. Only one small family is complete — one that I monographed 20 years ago and no new species have been found since then, even in the fossil record. Clearly we will never have a precise answer to your questions but even a near accurate estimate is still some time (years?) away. **Nominal** Would be >10,000 **Undescribed, collected** Might be <1000 **Undiscovered** If molecular species are excluded then <500. I will watch these numbers change over time. **References** Ellis and Messina catalogues, New York: Micropaleontology Press, AMNH. Available from http://www.micropress.org/e_m.html
Radiozoa (polycystine) [David Lazarus]	**Described + Nominal** There are a total of ca 570 polycystine radiolarian species names collated from the plankton literature of the last ca 30 years by various people, including Demetrio Boltovskoy and Kozo Takahashi, the list provided by EOL to Jane Dolven, Annika Sanfilippo and myself, and additions by other contributors. Of these, 400 are considered by us to be valid, 160 are thought

	to be synonyms, and around 10 have not been resolved yet. This implies a synonym percentage of 29%. Note that we are explicitly excluding the many hundreds, probably >1,000, additional names for presumed living polycystine species introduced in the 19th century but not used in any of the modern literature sources. Most of these early names are either clearly artificially split species or nomen dubia, having minimal description, no illustration, and no type material. Many of these early names may not even be really from the plankton but from sub-fossil material (*e.g.*, up to a few thousand years old) present in the surface sediments, or even older fossil material reworked into younger layers. Please also note that we are discussing only the polycystine radiolarians. There are two other groups often referred to as 'radiolaria' — the Phaeodarians and the Acantharia. We do not have any useful summary data on diversity yet for either of these groups, though neither group is as diverse as the polycystines. **Undiscovered** Although I do not work with the plankton directly myself, only with the surface sediments, I can confirm the comment made earlier by Kozo. It is highly unlikely that there are more than ca 10% truly 'undiscovered' (*i.e.*,unsampled) living polycystine taxa — plankton provinces are large and have been sampled repeatedly by many workers, both directly in the water column and even more intensively from surface sediments. **Cryptic** What is still largely unknown is how many cryptic species there are. This is a major problem for protists. All genetic studies so far find very high levels of cryptic or pseudo-cryptic species. The number of biological species, to the extent this concept applies in protists, may be much higher than the morpho-species count — possibly twice as much and protists diversity may grow significantly in the future, not from unsampled material but by refined (genetic) character analyses. Based on rates of cryptic diversity seen in sister groups, *e.g.*, planktonic foraminifera, coccolithophores, total species diversity for radiozoa might be 500-1,500.
Fungi [Paul Kirk]	**Described** From the recently published Marine Fungi (E.B.G. Jones) there are 1,035 'obligately' marine species — by this I mean they occur in marine environments by 'choice' rather than by accident ... they are not 'contaminants'. **Nominal** Add heterotypic names and that figure rises to 1,156. **Undescribed, collected** I guess there are about 200 undescribed species from collection based on an estimate of the collecting activity and the number of new species described in recent years. There may be more than this from environmental sampling but this is an area where I have no information as little has been published. **Undiscovered** If we assume that there are a global total of 1.5 million fungi and we currently know 100,000 then we can apply the same ratio to marine fungi and arrive at an estimate of 1,000 x 15 = 15,000.

Acanthocephala [David Gibson]	The number of undescribed and undiscovered species are complete guesstimates. **Cryptic** There is genetic evidence, as far as I am aware, from only one 'species'. My estimates range from 50–150.
Polychaeta [Geoffrey B. Read.]	**Described and Nominal** 12,632 accepted (includes 659 unchecked, 259 yet to be entered in WoRMS), and 6696 unaccepted, including 9 homonyms, plus (another category outside 'unaccepted') 122 Nomen dubium, 13 Nomen nudum, thus a total number of nominal species of 19,463. Since 1758, the beginning year of Linnaean nomenclature, the current total of nominal species (about 19,500) has accumulated at a modest overall average of around 90 Polychaeta described per year, with the number varying from fewer than 5 (mostly back in the 18th century) to a startling peak of 685 per year (in 1866). We would hope for an increasing pace in modern times with steadily more taxonomists interested in the group and working, but as yet this trend is not pronounced. WoRMS data shows that for the last 50 year period with full figures, 1956 to 2006, the average has been 130 per year, with the most species described in this period of 248 in 1972. The most productive years for polychaete taxonomy were back in the era 1860–1880 which contained four years with over 300 species described per year. This is because major monographs by Quatrefages, Kinberg, Schmarda, etc, were published during that time. **Undescribed, collected** Glasby *et al.* (2009) reported 34 % known undescribed species documented in collections for New Zealand seas in 2000, the year of their assessment, and estimated the likely number of species was double the then total of 763. Since most of the world apart from well-explored coasts such as along the northwestern Mediterranean and North Sea, are probably less or equivalently explored for Polychaeta as New Zealand, it seems conservative to extrapolate that 80 % of worms in collections worldwide are described, making a world total undescribed in collections of an additional 3,158 species. New Zealand museums are expected to have a somewhat higher number of undescribed species than elsewhere (large offshore collections in New Zealand have not been described). A further conservative extrapolation merely doubling the total described and known undescribed gives about a world fauna of around 19,000 (18,948) Polychaeta species, but a total of 25,000 to 30,000 species would not be surprising. **Cryptic** Based on the experience in recent papers there would be between >1 to >5 molecular cryptics for every valid name, conservatively (one paper found 10), with mostly towards the lower limit applying. As usual the Polychaeta are so disparate that the proportion is likely to fluctuate wildly between families, and there simply has not been sufficient of this work done to assess the situation overall, so a more precise estimate is not possible. Noting that people tend to look for cryptics when they're already suspicious. **Reference**: Glasby, C.J., Read, G.B., *et al.* (2009). Phylum Annelida. Bristleworms,

	Earthworms, Leeches. In Gordon, D.P. (ed.) The New Zealand Inventory of Biodiversity: Volume 1. Kingdom Animalia: Radiata, Lophotrochozoa, and Deuterostomia. Christchurch, New Zealand. Canterbury University Press. p. 312–358.
Hirudinea [Jürgen B. Kolb]	**Described and nominal** The list of names as of today stands at nominal 249 and discounting synonyms at 179 valid species. **Undescribed, collected** Chances are slim to find many marine fish leech specimens in existing collections as the conventional sampling techniques leading to their existence make it nearly impossible to catch these parasites before they detach and fall of their hosts. Leeches tend to be lost off their hosts while trawling, bringing the sampling equipment to surface or on board during the subsequent handling of material. Furthermore, there is often very little time during an expedition to look at a greater number of fish host individuals, including inspection of the gill chambers, or even other temporary hosts to find the often small and inconspicuous animals. Nevertheless, sometimes leech specimens are found alongside their carrier species upon close inspection. Thus I assume a potential of 15-35 yet to be described species lie hidden in the collections around the world. **Undiscovered** The leech species living in the marine environment are elusive parasites and are very difficult to study, thus, our knowledge to their true number is very limited. In particular rough seas such as the North Atlantic and the polar regions are under-sampled due to logistical but also financial constraints. This in combination with the parasitic life strategy leads to a low success rate in discoveries and inevitably limits our knowledge of the true marine leech fauna. If one considers that only a handful of experts work on the taxonomic field of marine leeches, it is remarkable that particularly in coastal habitats there are still new species discovered with a reasonable frequency of only a few years apart. I hold at least one new species from Antarctic waters in my collection for future description. The actual number of species in the marine world could well be much greater than currently known. I therefore propose to expect a range for undiscovered morphospecies of 50-100. **Cryptic** As of today, unfortunately an estimate to the total number of cryptic species has to be an educated guess rather than based on facts as we simply lack the necessary data. The new genomic era changes this in the near future with information becoming available now from bar coding as well as whole genome sequencing projects. Assuming vast similarities in evolutionary terms for marine invertebrates on a global scale and thus genetic diversity, as far strechted as this might be, I propose adopting the generally accepted 10% margin of the known morphospecies to be cryptic. Thus, considering the severe data deficiencies for most marine habitats, I would not be surprised if future molecular work discovers 5-20 or more cryptic piscicolid species.
Oligochaeta [Christer Erséus]	**Described** The 910 currently known marine morphospecies are still a valid number, as compiled by Tarmo Timm in 2009; virtually nothing has been added since

	then. [I spend most of my time on molecular systematics these days, and never seem to get around describing all the undescribed marine worms I have.] **Undescribed, collected** My previous estimation of (roughly) 300 undescribed species (those present in my own collections) is up to date too, as I have not collected anything really new during the last 1–2 years. **Undiscovered** Based on a gut feeling, we probably have just described about a tenth of all species out there. Virtually nothing is known from the South American and African coasts, and large parts of the Polar regions, Asia and the Indo-Pacific Islands. Not to mention the deep sea, from where we only have scattered records; these latter records, however, indicate a rather high diversity). If you ask for a 95% interval, it would be between 5,000 and 15,000. **Cryptic** Although I am finding cryptic species all the time, it is extremely difficult to translate this into a general percentage (or a similar measure). Today I concentrate my research on non-marine oligochaetes, and there are probably (and totally) hundreds of cryptic species among all common freshwater and terrestrial morphospecies, including the "cosmopolitan" taxa that are so popular as model organisms in research around the world. For marine worms, I have preliminary genetic evidence of cryptic speciation in at least 15 morphospecies, which is a low percentage of the about 300 marine species that I have sampled for DNA so far. Then it should be noted, however, that for the majority of my many marine species, I have sampled only one specimen or population, and I am sure that the number of sibling species will increase with wider geographical sampling. What I dare to hypothesize is that at least 10% of all marine oligochaete morphospecies known today are each containing 2 (or in many cases >2) cryptic species. Thus 10% of total morphospecies (6,000–16,000) contains at least one extra, cryptic species = >600–1,600.
Acarina [Ilse Bartsch]	**Described** Acarina: known species (end of 2010) • Prostigmata: Halacaridae 1098 marine species (1122 valid species minus ca 25 exclusively freshwater species) • Prostigmata: Pontarachnidae 42 species • Astigmata: Hyadesiidae 48 species • Oribatida: Ameronothroidea 30 species • Not included are species of a group called Mesostigmata; I would say, they are terrestrial rather than aquatic. The sum of that, 1218 valid species. This is the number of momently valid species, synonyms are ignored **Undescribed, collected** About 100 new (undescribed) species are hanging around in collections. **Undiscovered** In recent years, I received material from parts of the world not studied before, the result; more species than described as new ones have been

	withdrawn and, also surprisingly, most of the species were known from localities far away. I expect the number of undiscovered species (on the basis of morphological characters) between 1X and 1.5X that already known, accordingly between 1320–1980 species. If you exclude the 100 species in collections it would be 1220–1830 species. **Cryptic** There are some few very widespread species, widespread mainly in a biogeographical but also ecological sense and range. One may expect the one or other cryptic species amongst these species. A lot of species are known from a single locality/sample. Less than 10 % of presently described species may not be just one but two (or more) species, though actually, there is not a single record of a cryptic species. I think there aren't many cryptic species amongst the halacarid mites. Just to give a number, 3–8 % of the described species may prove to represent a cluster of species, in all perhaps 150, max 200 new species.
Merostomata [Geoff Boxshall]	**Described and nominal** There are 4 valid species but I have seen several other invalid names at various times. The only uncertainty is about synonyms. **Undescribed and undiscovered** One species awaiting description; no unknown new species predicted, although it is always possible that molecular techniques might reveal cryptic species.
Pycnogonida [Roger Bamber]	**Decribed** 1307 species. **Nominal** 1348 species names. **Undescribed, collected** 150–500. Based on looking at material awaiting study in Museums in London, Cape Town, Wellington (NZ) and Melbourne. Then multiplying by number of Museums likely to have some material (only one museum currently has an in-house pycnogonid researcher), error margins (max min) based on estimated disparity between those four collections. **Undiscovered** 979–1650. The minimum number is based on analyzing the number of new species described per year over the last 20 years for 10 sea regions where there has been study in the last 20 years (surprisingly consistent), and assuming the same value for the other regions (where there has not been study in the last 20 years), and extrapolating for the number to be found over the next 60 years in the best studied areas (about 130 years of proper study), and allowing for the fact that those less-well-studied regions have more species awaiting to be described by assuming a similar accretion rate had they also been studied already for 130 years. [Annual “accretion” curve of new species over the last 20 years does not asymptote, so this may be an underestimate!] **Cryptic** 50–100. Based on an estimate of the number of species currently far-too-widely “distributed” for a taxon with no dispersive phase, together with the

	number of new taxa confirmed by molecular means from the few recent studies on such "widespread" species, with "range" generated by allowance for number of recent synonymies.
Shrimp-like Decapoda: Caridea, Procarididea, Stenopodidea, Dendrobranchiata [Charles Fransen, Sammy De Grave]	**Cryptic** As for cryptic genetic diversity in shrimps, there is only one study, on a subgroup of *Alpheus*. This estimates that that potential species complex comprises 20 species rather than the one currently known. I would feel uncomfortable to projecting that ratio to all shrimps, as the level of cryptic species diversity must vary amongst groups. Overall, there is no basis for judgement in terms of all the shrimps groups Charles and I provided numbers for. Given the high number of available synonyms in the genera for which there has been a suggestion of cryptic species diversity (based on very limited genetic evidence) and the lack of combined molecular-morphological-colour pattern-ecological studies, it is impossible for us to provide even an appropriate guestimate. **References** De Grave, S., and Fransen, C.H.J.M. (2011). Carideorum catalogus: the recent species of the dendrobranchiate, stenopodidean, procarididean and caridean shrimps (Crustacea: Decapoda). Zoologische Mededelingen, Leiden *85*, 195–589.
Achelata, Polychelida, Enoplometoidea, Glypheoidea, Nephropoidea (marine lobsters) [Tin-Yam Chan]	**Described, nominal, undescribed-collected** Achelata: 142 accepted species, 229 nominal species names, and 10 new species residing in collection. Polychelida: 38 accepted species, 52 nominal species names, and 2 new species residing in collection. Enoplometoidea: 12 accepted species, 15 nominal species names, and 0 new species residing in collection. Glypheoidea: 2 accepted species, 2 nominal species names, and 0 new species residing in collection. Nephropoidea: 53 accepted species, 71 nominal species names, and 2 new species residing in collection. **Undiscovered + cryptic** For a group of generally large sized animals with high economic value, surprisingly the number of new species discovered in marine lobsters is still high even very recently. For example, nearly 11.3% of marine lobsters were only described in the last decade (*i.e.*, since 2000). From the still very steep discovery curve, no extrapolation for total number of marine lobster seems possible. Even to the most common and commercially important genera such as *Palinurus* and *Panulirus*, new species have been added in the last few years. Recent employment of molecular tools in separating cryptic and very similar species has contributed to the discovery of more lobster species as in other decapod crustaceans under this modern trend. Nevertheless, the high discovery rate of lobsters is no doubt more related to the revived large scale expeditions in the Indo-West Pacific. It is believed that many more marine lobsters with novel morphological diversity (*e.g.*, the new genus living fossil *Laurentaeglyphea neocaledonica* discovered in 2006) are still

	awaiting discovery. At least 14 new lobster species have already been found and awaiting formal description. Thus, it seems reasonable to assume that there are at least half more species (*i.e.*, more than 120 species) of marine lobsters are still undiscovered, with min-max bounds of 30–70%. Genetic diversity will be responsible for 1/10 of these new discoveries. **References** Chan, T.Y. (2010). Annotated checklist of the world's marine lobsters (Crustacea: Decapoda: Astacidea, Glypheidea, Achelata, Polychelida). Raffles Bull. Zool. suppl. *23*, 153–181.
Chirostyloidea and Galatheoidea [Enrique Macphearson, Kareen E. Schnabel]	**Described, nominal, undescribed** **Galatheoidea**: 715 accepted species, 773 nominal species names, 300 new species residing in collection **Chirostyloidea**: 206 accepted species, 211 nominal species names, 250 new species residing in collection **Undiscovered + cryptic** After the rate of describing new species in the Indian and Pacific Oceans along the last decades, and considering the areas poorly known or scarcely sampled, we believe that the percentage of known species is c. 20% in Chirostyloidea and c. 35% in Galatheoidea. We are including in these estimations the species residing in collection and the undiscovered species. Therefore, the total number of unknown species would be: Chirostyloidea: 250 new species residing in collections, and 580 undiscovered; Galatheoidea: 300 new species residing in collections and 830 undiscovered. Usually, the term 'cryptic' is rather loosely applied, and usually there is some way of distinguishing the species when examined carefully after a dendrogram points to significant genetic differentiation. One problem in our group of course is that not a lot of detailed genetic datasets exist, at least not with good population sizes that may uncover true cryptic species, e.g., at extreme ends of the species range. We only have the examples from a few genera (with low number of species). In these genera the colour is also important, but it can be only used in fresh material. Considering these aspects, perhaps only 1 species per genus (less than 10%) could be nearly cryptic (alhough the colour can separate the species, but we ignore the colour in most species). Therefore, the percentage of cryptic species may be 1-5%. Nevertheless, until this percentage is not studied in rich genera, the numbers will be simple speculations. **Reference** Poore, G.C.B., Ahyong, S.T., and Taylor, J. (eds) (2011). The biology of squat lobsters. 363 pp. (CSIRO Publishing: Melbourne and CRC Press: Boca Raton).
Galatheoidea (Porcellanidae) [Masayuki Osawa]	**Described** 280 valid species and 3 species of *incerta sedis* (Osawa & McLaughlin, 2010; all data in WoRMS).

	Nominal 416 (including 133 species under synonyms of accepted species). **Undescribed, collected** I have at least 3 species to describe as new at present. My guess is about 10 species in total. **Undiscovered** My guess is at least 20 species. **Cryptic** My guess is 10–30 species. **Reference** Osawa, M., and McLaughlin, P.A. (2010). Annotated checklist of anomuran decapod crustaceans of the world (exclusive of the Kiwaoidea and families Chirostylidae and Galatheidae of the Galatheoidea) Part II – Porcellanidae. The Raffles Bulletin of Zoology. Supplement No. *23*, 109–129.
Hippoidea [Christopher B. Boyko]	**Described** 81 recent + 12 fossils. **Nominal species** 18 additional names are synonyms (all Recent species) for a total of 100 recent names + 12 fossils. **Undescribed, collected** Maximum 3. **Undiscovered** Less than 10, based on rate of discovery in last 10 years. **Cryptic** There are no molecular studies that have looked at this group beyond use of 3 exemplars (1 from each hippoid family) and no current evidence of cryptic species in this group. **Reference** Boyko, C.B., McLaughlin, P.A. (2010). Annotated checklist of anomuran decapod crustaceans of the world (exclusive of the Kiwaoidea and families Chirostylidae and Galatheidae of the Galatheoidea) part IV— Hippoidea. Raffles Bulletin of Zoology Supplement No. *23*, 139–151.
Lithodoidea [Shane Ahyong]	**Described** 129 spp. **Nominal** 161 spp. **Undescribed, collected** 10 spp. **Undiscovered** The deepwaters of the Indo-Pacific are sampled in a very patchy way in

	terms of lithodid habitat. The northern Pacific has traditionally been regarded as the centre of lithodid diversity, but this seems to more likely represent an artefact of historical sampling. When expeditions to new areas in the Indo-Pacific, sampling slope depths, capture Lithodidae, these are usually new to science. Also, abyssal depths are poorly sampled worldwide, and lithodids can be expected to be present there. About 20 new species of lithodids have been described from the Indo-West Pacific in the past 5 years, based mainly on opportunistic sampling around Australia and New Zealand. The rate of discovery remains high, so a reasonable but conservative estimate would be at least 30 more species in the Indo-Pacific, especially of small sized species of Paralomis. Sampling in the Atlantic has been much more extensive historically, but new species have been described in the last few years. It could be reasonable to expect that at least 10 more species will be discovered in the South Atlantic off the coast of South America and West Africa. Therefore, a conservative estimate would be 40 undiscovered species worldwide.
Lomisoidea [Patsy McLaughlin, Rafael Lemaitre]	This is a monotypic superfamily, family and genus, endemic to Australia. No undescribed species known to exist in any collection; no undiscovered species thought yet to be found.
Paguroidea [Patsy McLaughlin, Rafael Lemaitre]	**Described** Right now there are 1,116 valid species on the books, although those numbers will change, both up and down, as revisionary studies continue. **Nominal** There are approximately 222 primary synonyms, with a couple of homonyms thrown in for good measure. I have included in the latter count, some taxa described as varieties (old works) and subspecies, but not all when it was pretty obvious that the author simply got confused. **Undescribed, collected** The number of paguroid species in existing museum collections that have yet to be identified and studied is hard to estimate. However, even in the collections of the Muséum national d'Historie naturelle, Paris, where paguroids have been actively studied for more than 30 years, the number of species still to be described probably exceeds 50. In museums lacking paguroid taxonomic expertise, such as several in China, a count of the number of unrecognized or incorrectly identified taxa would be very considerably higher (personal observations). Add to these estimates the potential for phylogenetically recognized new taxa and the number could easily double the currently known species. So, if you take in all the other museums the number is probably closer to 150 – 200. **Undiscovered** The accuracy of extrapolations from previous estimates of species diversity can be very misleading, at least as far as species of the Paguroidea are concerned. For example, in d'Udekem d'Acoz's (1999) inventory of European decapod species, 636 were reported and he said that on average, two new species was described each year. Of those 636 decapods, only 52 were paguroids and no new species have been added since his inventory. De Grave et al's (2009) checklist of worldwide genera and species put the number of Recent genera of Paguroidea at 120 and the number of species at 1,069. Similarly, McLaughlin et al.'s checklist (2010) lists 120 genera but with 1,106 Recent species. Clearly, estimates based on European species

	diversity in hermit crabs would give woefully low numbers. The apparent "explosion" in paguroid speciation is the result of expanded exploration in various parts of the world's oceans, particularly the Indo-Pacific. In the last 20 years (1990—2010), 365 new species have been added to the paguroid inventory, the majority coming from the western Pacific and Indian Oceans: Diogenidae, 118 species; Paguridae, 213 species; Parapaguridae 28 species; Pylochelidae, 4 and the new family Pylojacquesidae with two monotypic genera. Only in the family Coenobitidae have no new species been added in the past 20 years. If exploratory efforts continue at approximately the same rate in more of the poorly known tropical and subtropical regions of the world's oceans, the number of species could easily increase to a total number of 1500. **Cryptic** Asking for a guess of genetic diversity in the superfamily Paguroidea is akin to guessing the lengths of the longest and shortest straws in a bale of hay. There is only a minuscule amount known about the genetic make-up of hermits, so any idea of that diversity is simply impossible. **References** De Grave, S., Pentcheff, N.D., Ahyong, S.T., Chan, T.-Y., Crandall, K.A., Dworschak, P.C., Felder, D.L., Feldmann, R.M., Fransen, C.H.J.M., Goulding, L.Y.D., Lemaitre, R., Low, M.E.Y., Martin, J.W., Ng, P.K.L., Schweitzer, C.E., Tan, S.H., Tshudy, D., and Wetzer, R. (2009). A classification of living and fossil genera of decapod crustaceans. Raffles Bulletin of Zoology, Supplement *21*, 1–109. McLaughlin, P.A., Komai, T., Lemaitre, R., Listyo, R., and Dwi, L. (2010). Annotated checklist of anomuran decapod crustaceans of the world (exclusive of the Kiwaoidea and families Chirostylidae and Galatheidae of the Galatheoidea) Part I – Lithodoidea, Lomisoidea and Paguroidea. The Raffles Bulletin of Zoology. Supplement No. *23*, 5–107. Udekem d'Acoz, C. d' (1999). Inventaire et distribution des crustacés décapodes de l'Atlantique nord-oriental, de la Méditerranée et des eaux continentals adjacentes au nord de 25°N. Patrimoines naturels (M.N.H.N./S.P.N.) *40*, 1–383.
Brachyura [Peter Ng, Peter Davie]	**Described** As of January 2012: Total: 1,357 valid genera with 415 synonyms; 7,063 named species with 1,890 synonyms distributed across 98 families. Marine Brachyura: 1,127 genera with 362 synonyms; 5,668 species with 1,709 synonyms over 5 families. Freshwater Brachyura: 230 genera with 53 synonyms; 1,395 species with 181 synonyms over 5 families. **Undescribed** [Peter Ng]: we easily have at least 100 plus species in our collections which remain undescribed. [Peter Davie]: I have at least 60 species I know of, and then if we work on

the estimate that there are about 50 new species discovered per year (that are not from our own groups), and make the assumption that these take 3 years from discovery to formal description (probably an underestimate), than we could add another 180 from the rest of the world. So potentially at least 310 species residing in collections awaiting publication.

Undiscovered
[Peter Ng]: the last 20 years has seen an average of 60-80 new genera and species every year (average one quarter are genera, rest are species). The number of new species recognised now versus what was recognised in the 1950s has seen a 57% increase. On these trends, and assuming we have another 40-50 years of sustained progress, an increase of another c. 3,000 can be expected.

However, over the years, we have found a fair number of cryptic species, based on molecular methods, that have subtle or good morphological characters that had been missed, dismissed or under-estimated. A grand total of 10,000 is therefore not unreasonable.

Because we rarely describe species solely on the basis of DNA, we can add the following ‘cryptic’ species numbers to the undiscovered “morpho-species” category (and not to the molecular cryptic part).

[Peter Davie] The following is the basis for a reasonable guess/estimate — Given about 5,700 marine species, if we assume 10% as being widespread, Indo-West Pacific species, then this equals 570.
Recent genetic and morphological studies on three widespread IWP crabs (Keenan *et al.*, 1998; Lai *et al*., 2010; Ragionieri *et al*., 2012) show that each includes 4 cryptic species. And this is reinforced as a more widespread decapod phenomenon, by similar results on a scyllarid lobster (5 cryptic species in the complex) (Burton & Davie, 2007).

So if we were to extrapolate as a minimum of 2 cryptic species per widespread taxon (*e.g.*, one Indian Ocean Basin and one Pacific Basin), then we would potentially have around another 570 unrecognised forms. If we were to allow each to include 4 cryptic species (which, as shown, appears to be the emerging common pattern), then this would blow out to about 1,700 extra.
So let’s say for the Brachyura:
minimum unidentified cryptic species c. 550
maximum unidentified cryptic species c. 1,700
However: 1) this is based on a simple rough guess of 10% being widespread – we haven’t had time to assemble the basic distributional data for all species yet (hopefully soon), so this is likely to be an under-estimate. 2) I don’t have any personal experience of what level of cryptic speciation is likely/possible in the Atlantic.
The take-home message is that cryptic speciation is going to be an important factor in understanding marine brachyuran biodiversity, though it will take a substantial amount of work to get an accurate assessment. However if good patterns emerge from ongoing broad biogeographic, genetic and taxonomic studies, we may be able to use these data to develop surrogate models to get much more accurate predictions than are currently possible.

[Peter Ng] Agreed. Peter Davie has taken a semi-conservative approach here which ranges from an extra 560-1,700 within the 6,000 species we

	have now. The Americans think we have much more, and that there could be as many as the same total again! Instinctively, I am more inclined to agree with Peter D's estimate as on the grounds that taxonomists generally tend to be more conservative. But the truth is probably in-between. So I would say that for operational reasons, we can take the higher estimate and double it *e.g.,* 3,400 cryptic species. I suggest this on the grounds also that many of these widespread species may have up to four "cryptics", more species are found to have wider ranges than expected with better surveys (so increasing the chance of cryptics), and we are still finding many new species at a high rate. So a higher number may be more realistic. **Cryptic** We don't know of any brachyuran species that has proved to be only definable based on molecular grounds without any morphological differences. **References** Burton, T.E., and Davie, P.J.F. (2007). A revision of the Shovel-nosed Lobsters of the genus *Thenus* (Crustacea: Decapoda: Scyllaridae), with descriptions of three new species. Zootaxa *1429*, 1–38. Keenan, C.P., Davie, P.J.F., and Mann, D.L. (1998). A revision of the genus *Scylla* De Haan, 1833 (Crustacea: Decapoda: Brachyura: Portunidae). Raffles Bulletin of Zoology *46*, 1-29. Lai, J.C.Y., Ng, P.K.L., and Davie, P.J.F. (2010). A revision of the *Portunus pelagicus* species-complex (Crustacea: Brachyura: Portunidae), with the recognition of four species. Raffles Bulletin of Zoology *58*, 199–237. Ragionieri, L., Fratini, S., and Schubart, C.D. (2012). Revision of the *Neosarmatium meinerti* species complex (Decapoda: Brachyura: Sesarmidae), with descriptions of three pseudocryptic Indo–West Pacific species. The Raffles Bulletin of Zoology *60*, 71–87.
Gebiidea [Gary Poore]	**Described** 203 species **Nominal** 203 accepted + 22 synonyms = 225 species names. **Undescribed, collected** wild guess ~50 **Undiscovered** ~100 – many areas especially deep water are unexplored, cryptic species are probable and the habitats in which these burrowers are found are hard to sample.
Axiidea [Gary Poore]	**Described** 455 species. **Nominal** 455 accepted + 51 synonyms = 506. **Undescribed, collected** A wild guess ~50.

	Undiscovered ~200 – many areas especially deep water are unexplored. Eg, Poore & Collin 2009 added 50% to the known fauna of Australia following sampling in WA and similar increments could be anticipated in other of the Pacific, the centre of diversity for this group. The probability of cryptic species in some widely applied names is high, and the habitats in which these burrowers are found are hard to sample.
Amphipoda [Jim Lowry]	**Described** Based on my checklist/catalogue there are currently 9,215 accepted species, of which 2,000 freshwater; 6,947 marine; 268 terrestrial (this includes the supralittoral beach-hoppers). **Nominal** Until we get full synonymies for all species the answer to this question is not known. **Undescribed, collected** Even in my own collection at the Australian Museum I don't know how many undescribed species are present. **Undiscovered** In a 4 year project we just finished, looking at about 30 genera in 7 families around the entire Australian coast and off-shore islands, we identified about 450 species of which about 120 were new – about 37.5%. We just got a new grant to describe those species. In the recent Great Barrier Reef project we identified about 230 species and about half were new species. However the majority of described species identified from the GBR study were new records for Australia. This was the first serious study of amphipods in tropical Australian waters and in fact the sampling was limited. In Australia we have now described about 1,150 species. If the unknown species rate is about 40% then we might expect 1,600+ species in shallow Australian waters. But if you add in new records of exotic species then it becomes less predictable and much higher. So that is kind of Australia. Probably the majority of world species come from Europe, North America, Japan, Madagascar/South Africa, New Zealand, Australia and Antarctica. If you start to look at all the places that are not well studied, including the deep sea, maybe you would double the current figure and estimate to about 20,000 species.
Cumacea [Sarah Gerken]	**Described** The number of species I have in my database at the moment is 1444. **Nominal** There are very few species name synonymies (30–40 names), but there are lots of generic revisions and generic synonymies (~150). **Undescribed, collected** I have in hand at least 45 undescribed species, 27 of which are in the process of being described at the moment. **Undiscovered** Excepting the North Atlantic and a few other relatively small well-studied regions, collections usually include 80–100% new species. If there are an

	estimated 1450 valid species, then that suggests that the number of undiscovered species, conservatively, is around 6000.
Isopoda [Gary Poore, Niel L. Bruce, Christopher B. Boyko]	**Described** 6,345 species. Figures were extracted from WoRMS and Schotte *et al.* (2008) by accumulating numbers of accepted marine species in Asellota (2114 excluding Asellidae, Stenasellidae), Phoratopodidea (1 species), Cymothoida (2,615, including crustacean symbionts [fide Boyko] and excluding freshwater species defined by NL Bruce), Microcereberidea (27 marine of 48 according to Wilson (2008a)), Limnoridea (61), Sphaeromatidea (776, excluding freshwater species according to Bruce), Valvifera (603, excluding freshwater species), Oniscidea (148 in Ligiidae, Actaeciidae and Tylidae). Phreatoicidea were excluded. **Undescribed, collected** 3,400 known but this could well be an underestimate because only some of the known collections were included: Antarctica 674*86% + 600 + 70 [Brandt, Loerz], Australia 320 SE slope, 118 WA slope, 50 SE shelf, 50 subtidal, 50 NW shelf [(Poore, et al., 1994), Poore, Bruce unpublished], NZ 300 [Brenke], some coral reefs 200 [Bruce], Gulf of Mexico 59 [(Wilson, 2008b)], Atlantic [284, DIVA, BIOZAIRE, MAUD, NODINAUT provided by CeDARMAR], MNHN, 71 [Bruce]. Family based estimates: Anthuroidea: 100; Sphaeromatidae: 100; Bopyroidea: 350, and Cryptoniscoidea: 100 [Boyko pers. comm.]; Missing data: Pacific deep-sea [Blake, Wilson], other museums. **Undiscovered** Using data from the deep sea that are largely Asellota Poore & Wilson (1993) estimated that less than 5% of species are known and recent samples in Australia suggest the figure is closer to 1% for asellotes but 17% for non-asellotes. CeDAMAR scientists believe for the Atlantic the figure is more like 10–20%. I would bias the figure more towards the lower figure to represent the larger and less sampled Pacific (5%). It could be argued that for non-asellotes in shallow water we have a better handle although many tropical species remain undescribed. Use 10% for these. So, undiscovered species, 2,114/5% + 4,231/10% = 85,000. We would give a range of 60,000 to 120,000. How realistic is this? Many surveys in new areas turn up 100–300 new species. Meaning we could get another 79,000 species with 263–790 surveys. Sounds like a lot and there is a risk of faunal overlap. But (1) the world is a big place (2) the surveys we are talking about range in sampling size from 10 to 100,000 square metres (3) all are dominated by rare species and species accumulation curves that don't asymptote. It is worth remembering that sampling in the vast deep Pacific and Indian Oceans is only just beginning and asellote isopods dominate this habitat. Sampling in temperate and tropical Asia and Australia has consistently turned up numerous new species in the few families have been covered well. And as Niel Bruce reminds us "As far as Isopoda are concerned the highly diverse area of the 'Indo-Malaysian triangle' is not collected". As endemism is high there would be a large number of undescribed species in this region, easily into the 400 to 600 range if it as diverse as the Great Barrier Reef. East African coral reefs are similarly lightly collected, and indications are that these will be as diverse as the GBR.

	The flaw in our argument is that there is bound to be overlap between so many surveys. But one third of the fauna turns over along 3,000 km of the southern coast of Australia (in one biogeographic zone, see O'Hara & Poore 2000), and 80–90% from S to N Australia and again from Australia to Japan, and probably from Australia to Africa etc. **Cryptic** One introduces interesting practical and philosophical questions when asking for an estimate of undiscovered cryptic species. In the best study of the subject on isopods, Raupach *et al.* (2007) discovered as many as 5 species within a moderately widespread deep sea asellote nominal species. One could be tempted to multiply our estimate of morphological species by 5. The reason we would not is the fact that most described (and undescribed but recognised morphospecies) species are known only from a few individuals from the type locality or nearby. And there is plenty of evidence rapid species turnover with distance for deep-sea isopods, and probably other taxa. Cases of multiple identifications over a wide geographic range are surprisingly few, relative to the number of species described. No cases like Raupach's are known from common widespread species in Europe or the US. There is some genetic variation in *Idotea balthica* but still only one species as far as is known. So what you are asking is — would I recognise a new species on the basis of morphology if I found one in a new region? Our guess is probably yes. Raupach did not re-examine the morphology of his notional species but we would be surprised if they couldn't be distinguished. Morphologists are learning to look harder. There are plenty of examples of species swarms differentiated by slight morphological differences in Australia — see the work of Poore, Just, Wilson and Bruce. Plus, there are plenty of examples of so-called widespread species being later divided on the basis of morphology. So in conclusion the number of undiscovered species which one could not distinguish morphologically is probably zero. **References** O'Hara, T.D., and Poore, G.C.B. (2000). Patterns of distribution for southern Australian marine echinoderms and decapods. Journal of Biogeography *27*, 1321–1335. Poore, G.C.B., Just, J., and Cohen, B.F. (1994). Composition and diversity of Crustacea Isopoda of the southeastern Australian continental slope. Deep-Sea Research *41*, 677–693. Poore, G.C.B., and Wilson, G.D.F. (1993). Marine species richness (with reply from R.M. May). Nature *361*, 597–598. Raupach, M.J., Malyutina, M., Brandt, A., and Wägele, J-W. (2007). Molecular data reveal a highly diverse species flock within the munnopsoid deep-sea isopod *Betamorpha fusiformis* (Barnard, 1920). (Crustacea: Isopoda: Asellota) in the Southern Ocean. Deep Sea Research Part II 54, 1820–1830. Schotte, M., Boyko, C.B, Bruce, N.L., Poore, G.C.B., Taiti, S., Wilson, G.D.F. (Eds) (2008 onwards). World List of Marine Freshwater and Terrestrial Isopod Crustaceans. Available online at

	http://www.marinespecies.org/isopoda. Wilson, G.D.F. (2008a). Global diversity of Isopod crustaceans (Crustacea; Isopoda) in freshwater. Hydrobiologia *595*, 231–240. Wilson, G.D.F. (2008b). Local and regional species diversity of benthic Isopoda (Crustacea) in the deep Gulf of Mexico. Deep Sea Research Part II: Topical Studies in Oceanography *55*, 2634–2649.
Mysida & Lophogastrida [Kenneth Meland]	**Described** 1,180 species of mysids and 56 species of Lophogastrids (data from WoRMS). **Nominal** 1,743 mysids and 74 lophogastrids (data from WoRMS). **Undescribed, collected** Considering that there are few taxonomists actively working with Mysida, and that they are regularly describing new species upon discovery, we do not expect many undescribed species laying in their "private" collections? A quick enquiry to five taxonomists suggests approximately a total of 50 undescribed species in their collections (Brattegard, Meland, Murano, Hanamura, Price, pers. com.). On the same note, pertaining to the fact that only very few researchers work with Mysida taxonomy, we expect that benthic surveys might result in collections with unidentified Mysida specimens, albeit not so many, a wild guess would therefore be 80–100 undescribed already collected Mysida. The majority of Lophogastrida species are pelagic and when captured quite conspicuous. Owing to their obvious appearance as of being neither Caridea nor Mysida they do not go unnoticed and are usually identified and verified by Crustacea taxonomists. We therefore do not expect many undescribed species to be found in collections. On the other hand, considering the magnitude of pelagic sampling being conducted worldwide one can expect unsorted material in several collections that do contain Lophogastrida new to science; a conservative estimate would be approximately 10 undescribed species. **Undiscovered** Opposed to number of "already collected" undescribed species, the number of undiscovered Mysida waiting to be found is definitely much higher. When including Lophogastrida and freshwater species previous estimates of described species are as follows; 520 (Gordan 1957), 765 (Mauchline & Murano (1977), 1076 (Wittmann 1999). When compared to the current estimate of 1180 described marine species, we can safely say we are experiencing a steady increase of new species and there is no indication of saturation. According to Wittmann (1999), we expect that only 25% of known Mysida is described. This estimate is based on the idea that, on a global scale, less than 3% of the continental shelf has been sampled for Mysida. Here one must also bear in mind that the majority of benthic sampling is conducted with a grab, which is highly insufficient for capturing Mysida and therefore suggests a high degree of undersampling. Large areas of both the South American and Africa shelves, as far as Mysida are concerned, are

	practically unknown. Not to mention the deep-sea. In comparison, species diversity in well sampled areas (Mediterranean Sea, Caribbean Sea, North Atlantic and Pacific Oceans) are 3–5 times higher than a randomly selected shelf area, which suggests 2000–4000 undiscovered marine Mysida. As the Lophogastrida are mostly found in the bathy- and mesopelagic zones of the world's oceans, they are quite often frequented in pelagic surveys. Recent sampling (MarEco project, 2005) between the Azores and Island as deep as 1000–4000 meter depths revealed an enormous biomass of five Gnathophausia and five Eucopia species. Interestingly only two of these are new to science, whereas the other eight species represent an expansion of geographical distribution from the South Atlantic, Gulf of Mexico, and Pacific Ocean. Similar results were also found in a study from the Gulf of Mexico revealing nine already described Lophogastrida species (Burghart *et al.*, 2007). In effect, regarding pelagic Lophogastrida biodiversity, their taxonomic history reveals increased distribution ranges and species synonomies resulting in an overall decrease of species numbers. On the other hand, we are discovering new species of benthic living Lophogastrida. In this regard, owing to lower sampling efforts on the ocean floor, and vast areas not yet explored, following the same line of argument as in the Mysida (see Mysida section) (Wittmann 1999), species diversity of benthic Lophogastrida in well sampled areas (Mediterranean Sea, Caribbean Sea, North Atlantic and Pacific Oceans) are expected to be 3–5 times higher than a randomly selected shelf area. In effect a conservative estimate based on approximately 30 described benthic species suggests up to 120 undescribed Lophogastrida. **Cryptic** For cryptic species estimates very little has been published on "mysids", but we do have some personal observations that are useful in giving us the possibility to sketch some very rough ideas. For Mysida, studies reveal that some species with relatively broad distributions (approximately 50 Mysida species can be considered to have a global distribution) had a genetic variation that resulted in splitting into separate species, more so for freshwater species (Audzijonyte 2005). But the opposite is also true; working with deep-sea benthic species I have found that a select few so-called cosmopolitans from the Atlantic and Pacific are remarkably identical in several genes. Also, I think we should bear in mind that although not "splitters", mysida taxonomists do have a tendency of hunting for variation resulting in establishment of new species. And taking into account that our estimates suggest that only 28% of all Mysida are currently described, this sort of limits the possibilities of finding cryptic species. For the Lophagastrida, the majority being pelagic, and with up to 15 cosmopolitans, one would expect that many of these actually are cryptic. Nothing is published on Lophogastrida, but I have a fairly good genetic sampling of *Gnathophausia* and *Eucopia* species from several water bodies. When receiving your most recent enquiry on new estimates I hurriedly compiled this genetic data. What the DNA sequences reveal, which I must admit was a bit surprising to me, is that the genetic distance between Indian Ocean, Atlantic Ocean, and Atlantic is surprisingly low. There are differences, but it takes the discussion more in the philosophical direction of

	how to define species in the context of genetic variation. In other words no clear cut geographical separation in genes on broadly distributed Lophogastrida species, which forces me, considering their distribution patterns, to give a very conservative estimate of few expected cryptic species. Again, regarding cryptic species in Mysida and Lophogastrida, we know very little. Summing up, in the marine environment, we generally expect to find more species and maybe not so much splitting of what we have already described. For freshwater and cave systems, now that's a different matter. Much more needs to be done, and for the pelagic Lophogastrida and cavernicoulos Stygiomysida, I expect more research in the near future, only time will tell. **References** Audzijonytė, A., and Väinölä, R. (2005). Diversity and distributions of circumpolar fresh- and brackish-water *Mysis* (Crustacea: Mysida): descriptions of *M. relicta* Lovén, 1862, *M. salemaai* n. sp., *M. segerstralei* n. sp. and *M. diluviana* n. sp., based on molecular and morphological characters. Hydrobiologia *544*, 89–141. Gordan, J. (1957). A bibliography of the Order Mysidacea. Bulletin of the American Museum of Natural History, *112*, 279–394. Mauchline, J., and Murano, M. (1977). World list of Mysidacea, Crustacea. Journal of the Tokyo University of Fisheries *64*, 39–88. Wittmann, K.J. (1999). Global biodiversity in Mysidacea, with notes on the effects of human impact. Pages 511–525, In: Schram, F.R., & J.C. von Vaupel Klein (eds.), Crustaceans and The Biodiversity Crisis: Proceedings of the Fourth International Crustacean Congress, July 20–24, 1998, volume I. Koninklijke Brill NV, Leiden, Netherlands. Burghart, S.E., Hopkins, T.L., and Torres, J.J. (2007). The bathypelagic Decapoda, Lophogastrida, and Mysida of the eastern Gulf of Mexico. Marine Biology *152*, 315–327.
Tanaidacea [Magda Blazewicz, Gary Anderson]	**Described** We have 1,153 species already described (data in WoRMS and Anderson, 2011). **Nominal** After going through my Peracarid database (Anderson, 2011), I have determined that there are about 70 subjective synonyms for various tanaids, and this is cross-checked with WoRMS. **Undiscovered** Based on the collections I have studied, 5% of tanaids might be known in the Antarctic and the Atlantic (relatively well studied regions). In contrast, the Pacific is less studied and probably only 2% is known. Following this there might be from 22,600 to 56,500 species of tanaids in world ocean. **Cryptic** I assume that some 10–15% might be cryptic taxa, but there is not enough

	evidence to underpin this. There is only one paper separating two species based on CO1. So there is no reliable data to let me judge how many cryptic species can be in tanaids, but in theory there should be many; otherwise how can you explain the cosmopolitan distribution of some taxa that are almost immovable, have no planktonic larvae and a short-life history? **References** Anderson, G. (2011). Tanaidacea Taxa and Literature <http://peracarida.usm.edu/>. Accessed on May 2011.
Thermosbaenacea [Damià Jaume]	**Described** Most species of this group appear in coastal oligohaline wells and caves. But these should not be considered as marine. The criterium is having been recorded in polyhaline (18–30 ppt) or euhaline waters. In that case there are 7 marine species. **Undescribed, collected** As regards numbers of marine taxa waiting in vials for a name, I have only a *Tulumella* from Caicos, and no news of others.
Copepoda [Geoff Boxshall]	**Described** 10,000 valid marine copepod species is an estimate and it is a conservative estimate because the 16,422 in WoRMS still includes so many synonyms. However, Ferrero *et al.* (2006) give an estimate of 12,000 for marine copepod species. The maximum figure I've seen for all copepods is 13,000 valid species and there are approaching 3,000 freshwater copepods. The number is obviously going to jump up when the cleaning is finished. **Undiscovered and collected but undescribed** In terms of the estimates of minimum and maximum numbers of unknown species out there, I suggest min: 30,000 and max 50,000 species. The bulk of the numbers coming from meiobenthos. The CeDAMar programme within the Census of Marine Life reported 800 different copepods from the Angola Basin (most of them new species), 300 new species from Crozex and another 300 new species from Nodinaut : http://www.isa.org.jm/files/documents/EN/Workshops/2010/Pres/CEDEMAR.pdf In shallower seas Ferrero *et al.* (2006) reported over 300 meiobenthic copepods from intertidal and subtidal sediments off Kuwait, virtually all of them new species. Outside of Europe Seas and in deeper waters, knowledge is very fragmentary. A significant number of new species will be parasitic or associated forms living symbiotically with vertebrate or invertebrate hosts. Justine *et al.* (2010) estimated that the number of described species of metazoan taxa, including copepods, parasitic on fish hosts represents about 3% of the total species richness. Currently we know over 2000 species of fish parasitic copepods, this may increase by an order of magnitude. **Cryptic** Ann Bucklin's work on near-surface pelagic copepods showed that some the so-called cosmopolitan species were hitherto unrecognized species complexes, but in other cases there really was global scale mixing and there

	was no evidence of cryptic species complexes. This applies to the surface plankton only — for virtually all benthic and parasitic copepods there are no data from which an estimate can be made. **References** Ferrero, T.J., Barnes, N., Arroyo, N.L., Bennell, G., Cornelius, P., Huys, R., Lee, C., Mustapha, M., Olaffsson, E., Sebastian, S., and Bamber, R.N. (2006). A Guide to the Meiofauna of Kuwait's Intertidal and Subtidal areas. RSKENSR Group, 73pp. Justine, J.-L., Beveridge, I., Boxshall, G.A., Bray, R.A., Moravec, F., Trilles, J.-P., and Whittington, I.D. (2010). Parasite biodiversity in coral reef fish: an annotated list of parasites (Isopoda, Copepoda, Monogenea, Digenea, Cestoda and Nematoda) collected in groupers (Serranidae, Epinephelinae) in New Caledonia. Folia Parasitologia *57*, 237–262.
Tantulocarida [Geoff Boxshall]	**Undiscovered** Tantulocaridans were only recognised in 1983 and have since been discovered as ectoparasites on a wide range of peracaridan, leptostracan, ostracod and copepod crustacean hosts. Tantulocaridans occur from the tropics to the poles and at all depths. They are easily overlooked on the host and it is the discovery of the free-living larval stages in the marine meiofauna that has given insight into true level of species richness. Mohrbeck, Martinez Arbizu & Glatzel (2010) found 30 new species in a single series of samples from Drake Passage in the Southern Ocean. In depths exceeding 5,000m in the SE Atlantic, Mohrbeck and Martinez Arbizu reported the collection of 386 tantulocaridan larvae, and a high proportion of putative species were represented by single individuals. On the basis of only two quantitative analyses it isn't possible to robustly estimate global species richness; however an estimate of 1,000 seems quite conservative. **References** Mohrbeck, I., Martínez Arbizu, P., and Glatzel, T. (2010). Tantulocarida (Crustacea) from the Southern Ocean deep sea, and the description of three new species of *Tantulacus* Huys, Andersen & Kristensen, 1992. Systematic Parasitology *77*, 131–151. Mohrbeck, I., and Martínez Arbizu, P. (2010). Biodiversity of deep-sea Tantulocarida from the Southeastern Atlantic Ocean – First results of DIVA 2. Book of Abstracts 14th International Meiofauna Conference, Ghent, Belgium. VLIZ Special Publications *44*, 57.
Euphausiacea [Siegel Volker]	**Described** 86 valid species worldwide. **Nominal** 148 species. **Undescribed, collected** None. **Undiscovered** None. Over the past 50 years only 3 new species have been described; this group of Crustacea is quite well studied and new species are hardly expected.

<table>
<tr><td></td><td></td></tr>
<tr><td>Stomatopoda
[Shane Ahyong]</td><td>Described
468 spp.

Nominal
580 spp.

Undescribed, collected
52 spp.

Undiscovered
A conservative estimate is at least 200 more. Many widespread species appear to show regional variation that will likely prove to be distinct species. Molecular data will probably help uncover species flocks. Also, many species can be expected to be discovered de novo as coral reef habitats, especially those at moderate depths in the coral triangle are explored, and deeper, level habitats are sampled. New species are present in almost every collection to new or relatively unsampled areas. Significant parts of the western Pacific remain to be sampled as do many parts of the western Indian Ocean (generally poorly sampled). Moreover, stomatopods are rarely specifically targeted in sampling programmes and existing collections are largely the result of opportunistic or general sampling. Therefore, the diversity of stomatopods is much underestimated, and in many habitats, unsampled.</td></tr>
<tr><td>Leptostraca
[Genefor Walker-Smith]</td><td>Undescribed, collected
<table>
<tr><th>Genus</th><th>Number of undescribed species</th><th>Locality</th><th>reference</th></tr>
<tr><td>Nebalia</td><td>1</td><td>Southern Australia</td><td>Walker-Smith, 1993</td></tr>
<tr><td>Nebalia</td><td>2</td><td>La Jolla Submarine Canyon, California, USA</td><td>Vetter, 1995</td></tr>
<tr><td>Nebalia</td><td>1</td><td>Zanzibar</td><td>Olesen, 1999</td></tr>
<tr><td>Nebalia</td><td>1</td><td>Guana Island, British Virgin Islands</td><td>Haney & Martin, 2004</td></tr>
<tr><td>Nebalia</td><td>2</td><td>Eastern Mediterranean</td><td>Koçak et al. 2009</td></tr>
<tr><td>Paranebalia</td><td>1</td><td>Southern Australia</td><td>Walker-Smith, 1993</td></tr>
<tr><td>Paranebalia</td><td>1</td><td>Zanzibar</td><td>Olesen, 1999</td></tr>
<tr><td>Paranebalia</td><td>1</td><td>Guana Island, British Virgin Islands</td><td>Haney & Martin, 2004</td></tr>
<tr><td>Sarsinebalia</td><td>3</td><td>Two species from Australia and one from the Red Sea</td><td>Dahl, 1985</td></tr>
<tr><td>Sarsinebalia</td><td>1</td><td>Southern Australia</td><td>Walker-Smith, 1993</td></tr>
<tr><td>New, undescribed genus</td><td>1</td><td>Locality not mentioned by Haney & Martin (2004)</td><td>Haney & Martin, 2004</td></tr>
<tr><td>“undescribed leptostracan species”</td><td>1</td><td>From the continental slope off Oregon and the Endeavor Segment of the Juan de Fuca Ridge at 2200 m</td><td>Haney & Martin, 2005</td></tr>
<tr><td>Total</td><td>16</td><td></td><td></td></tr>
</table>

In addition to the table above, the following literature refers to undescribed species held in various collections:</td></tr>
</table>

• The presence of several undescribed leptostracan taxa from Friday Harbour, Pacific coast USA (Haney & Martin, 2000)
• Various authors referring to undescribed species (*e.g.*, Thiele, 1904; Wakabara, 1965; Johnson, 1970; Vetter, 1996).

Based on this data, plus my own knowledge of the Australian collections, I estimate there are at least 50 undescribed species held in museum collections, world-wide. It is possible this is an underestimate and the number may be closer to 100.

Undiscovered
The order Leptostraca is likely to be diverse and many authors support this view, suggesting additional species await discovery and description (*e.g.*, Haney & Martin, 2000). The low number of described species is a result of limited taxonomic effort and geographically limited sampling (G. Walker-Smith pers comm.; Haney & Martin, 2004; 2005).

Koçak *et al.* (2010) note that few species of Leptostraca have been described from the Mediterranean, while Olesen (1999) reports that western Indian Ocean leptostracans remain poorly studied. Haney *et al.* (2001) suggest the east coast of the USA is an understudied region, as is north coast of Australia (G. Walker-Smith pers. comm.).

Leptostracans have been recorded world-wide, from the intertidal zone to in excess of 6000 m (Haney & Martin, 2005). Exploration within this huge depth range is likely to result in the discovery of many, many more new species.

While it is difficult to estimate the number of uncollected, undescribed, leptostracan species I believe sampling needs to be more targeted if the "true" number of taxa is ever to be uncovered. Leptostracans are known to congregate in areas of high detritus (Vetter, 1995). They are also known to be scavengers of dead and rotting animal carcasses (*e.g.*, fish and crustaceans) (J.K. Lowry pers. comm. and G. Walker-Smith pers. observ.). Therefore, if sampling targets leptostracans, either by collecting in areas where the detritus load is high, or by using baited traps (across the full distributional depth range of the Leptostraca) it is possible hundreds of undescribed species will be discovered.

References

Dahl, E. (1985). Crustacea Leptostraca, principles of taxonomy and a revision of European shelf species. Sarsia *70*, 135–165

Haney, T.A., and Martin, J.W. (2000). *Nebalia gerkenae*, a new species of leptostracan (Crustacea: Malacostraca: Phyllocarida) from the Bennett Slough region of Monterey Bay, California. Proceedings of the Biological Society of Washington *113*, 996–1014

Haney, T.A., Hessler, R.R., and Martin, J.W. (2001). *Nebalia schizophthalma*, a new species of leptostracan (Malacostraca) from deep waters off the east coast of the United States. Journal of Crustacean Biology *21*, 192–201

Haney, T.A., and Martin, J.W. (2004). A new genus and species of leptostracan (Crustacea: Malacostraca: Phyllocarida) from Guana Island, British Virgin Islands, and a review of leptostracan genera.

	Journal of Natural History *38*, 447–469 Haney, T.A., and Martin, J.W. (2005). *Nebalia kensleyi*, a new species of leptostracan (Crustacea: Phyllocarida) from Tomales Bay, California. Proceedings of the Biological Society of Washington *118*, 3–20 Johnson, D.S. (1970). Occurrence of the mud-shrimp *Nebalia* (Crustacea, Leptostraca) at Singapore. Journal of the Singapore Academy of Science *2*, 50-52 Koçak, C., Moreira, J., and Katagan, T. (2010). New records of Leptostracans (Crustacea, Phyllocarida) from the eastern Mediterranean. Turkish journal of Zoology *34*, 69–77 Olesen, J. (1999). A new species of *Nebalia* (Crustacea, Leptostraca) from Unguja Island (Zanzibar), Tanzania, East Africa, with a phylogenetic analysis of leptostracan genera. Journal of Natural History *33*, 1789–1809 Thiele, J. (1904). Die Leptostraken. Wissenschaftliche Ergebnisse der Deutschen Tiefsee-Expedition auf dem Dampfer 'Valdiva', 1898-1899 *8*, 1–26 Vetter, E.W. (1995). Detritus-based patches of high secondary production in the nearshore benthos. Marine Ecology Progress Series *120*, 251–262 Vetter, E.W. (1996). Life-history patterns of two southern Californian *Nebalia* species (Crustacea: Leptostraca): the failure of form to predict function. Marine Biology *127*, 131–141 Wakabara, Y. (1965). On *Nebalia* sp. from Brazil (Leptostraca). Crustaceana *9*, 245–248 Walker-Smith, G.K. (1993). The systematics and taxonomy of some southern Australian leptostracans. In: Department of Zoology. The University of Melbourne, Melbourne, p. 79.
Ostracoda (halocyprids) [Martin V. Angel]	**Described** I can only respond with regard to the halocyprids for which the number of accepted species is 254. **Undescribed, collected** I have on my shelves awaiting description ~60 species (of which I have made inroads into describing ~20). The majority of these are deep bathypelagic/abyssopelagic/benthopelagic. On the recent CMarZ cruises we sampled pelagically down to 5000m — we caught no novel species in the upper 2000m but 10% of the species caught below 2000m were novel (or undescribed). I would not expect to add any new species in the polar oceans in the upper 2000m, but in the Indian and Pacific Oceans novel species would be found. There was no sampling of the benthopelagic realm during CMarZ, but at the old IOS we started sampling to within 10m of the sea-bed to depths of 5500m — one sample from close to the NW African slope at 4000m caught 25 novel species. I have been looking at similar samples collected in the Southern Ocean during the AnDeep programme on the Polarstern and these contain another 10–15 novel species. No benthopelagic sampling has been carried out in the Indian Ocean or the Pacific. There seems to be a handful of benthopelagic species that occur both in the Atlantic and in the Southern Ocean, but my guess is that there is generally little in common between these communities in the major ocean basins of the World. Since I do not have a credible figure for the Atlantic where I know there are at least 50 and the total might be >100. So maybe in the

Pacific and Indian Oceans one might expect similar numbers — maybe more in the Pacific because of its much greater area. So in the benthopelagic faunas we might expect at least a further 500 species.

Undiscovered
I have just had a paper published in Deep-Sea Research ll 57 2173–2188 in which I conclude there are 153 species in the Atlantic. Almost no novel species where found at depths <1000m but from depths >3000m about 10% of the species were novel. The Atlantic has been well studied (as have the Polar oceans), but the Indo-Pacific is poorly known and almost nothing is known about the deepwater faunas. We know nothing about the scale of geographical distributions in deep sea communities — so is the Indo-Pacific one big unit or several. The distributions of the mid-water faunas tend to reflect the large scale circulation patterns (*i.e.*, water masses). So my intuition is that the deep water gyres in the Indian and Pacific Oceans will have their own assemblages of species — some of which (I guess <50%) will be shared. The Pacific is large enough for there to be and east/west divide — the Atlantic is not yet there do appear to be some small differences between east and west on either side of the mid-Atlantic Ridge. Delving into the circulation patterns is complex in the Atlantic, but more clear cut in the Pacific because of its shear scale. There are major differences in water column environments between east and west in the Pacific (there is strong oxygen depletion in the eastern tropical Pacific).
So what — I would predict that the diversity in the Pacific and Indian Ocean are similar to that in the Atlantic. In the Atlantic when the benthopelagic fauna is fully known I would expect the numbers of species to increase to 200. I would expect the diversity in the Indian Ocean to be slightly smaller (after all it has very little northern Hemisphere), but it will be greater in the Pacific — especially as there are greater north/south and east/west divides. So let us guess that the total fauna in the Indian Ocean is around 150 and that of the Pacific is 400. The latter could be a gross underestimate if seamounts have their own specific faunas (certainly true for benthic species and maybe benthopelagic species). So than what is the communality between the different oceans — total guess 50%. Then we derived a total estimate for halocyprids of 200 (Atlantic) + 75 (Indian Ocean) + 150 (Pacific — assuming there is communality between the IO and PO). The Southern Ocean adds another 50 and the Arctic 5, which gives a ball park estimate of ~480 halocyprid species — which is about double the number currently described.

Note that pelagic species have flexible boundaries to their distributions and are moved around by water currents and eddies. The ranges of benthic species will be far more restricted and the graininess of their distributions more complicated because of bottom topography. So the species richness of benthic species in both deep and shallow water can be expected to be much higher — perhaps by around an order of magnitude.

Cryptic
There is strong evidence for cryptic species in the halocyprid ostracods. In many 'species' there are differently sized populations that are segregated either geographically or bathymetrically. Recognising this segregation depends on the sampling regimes and often the bathymetric segregation goes unnoticed. Also routine processing of samples can lead to these size differences being missed. In all cases where these size differences are analysed morphologically good evidence is found to describe the different

	sizes as distinct species. Recent sequencing studies have confirmed this segregation whenever it has been possible to check them out. The situation in the Atlantic is now reasonably under control and many (?most) of these cryptic species have been separated — although there are a number of complexes that remain unresolved. Examination of species from the NW Indian Ocean shows many species look 'similar' but show variations with the Atlantic forms. There have been no sequencing checks performed yet to see if my suspicions that many of the species are indeed different. Samples from around Indonesia (Celebes Sea) again yield species that kind of look the same but I suspect that careful analysis would show them to be different. I have been looking at samples from the N.E. Pacific and these impressions are even stronger — many species look sufficiently familiar for me to attach names but again I am convinced that given time and effort I can show them to be different. **References** Angel, M.V., Blachowiak-Samolyk, K., Drapun, I., and Castillo, R. (2007). Changes in the composition of planktonic ostracod populations across a range of latitudes in the North-east Atlantic. Progress in Oceangraphy *71*, 60–78. Angel, M.V., Blachowiak-Samolyk, K., and Chavtur V.G. (2010). Atlas of Atlantic ostracods. http://www.nhm.ac.uk/research-curation/research/projects/atlantic-ostracods/atlas/index.html (accessed 4 March 2012).
Ostracoda [Simone Nunes Brandao]	**Described** In WoRMS, there is around 5800 recent, described species and a total of 5396 accepted species. Therefore, 93% of the described species are valid. Using this percentage, I estimate that from 7,000 to 9,500 described species, there are from 6,510 to 8,835 valid species described so far. **Nominal** Different previous estimations range from 7,000 to 9,500 (7,000 from Cohen & Morin, 1990; 8,000 from Horne *et al.,* 2002; 9,500 from Cohen *et al.,* 2007). **Undescribed, collected** From 1,000 to 2,000 species. **Undiscovered** Based on the data below (see Examples), from 20 to 78% of the ostracod species collected for a certain study are new to science. Using the numbers above this would mean that from 1625 to 32,000 ostracod species remain to be discovered. Examples: Machado *et al.* (2005) found 31 new species (46% of the total of 67 species) in 43 sediment samples from a small area (of 1 degree latitude, and 20’ longitude) on the continental shelf off southeastern Brazil. Even for the most sampled and best well know area of the world oceans, the North Atlantic, 32% (28 species) of all 87 species were found to be new to science (Yasuhara *et al.,* 2009). Fifteen species were found in 2 corers collected from the Southern South Atlantic, three (20%) of these species were described as new. In deep waters of the Atlantic sector of the Southern Ocean, concerning the superfamily Bairdioidea 7 new species /78% of the total 9 species) collected

	during the ANDEEP project (Brandão, 2008). The ANDEEP samples also provided 16 new species of Macrocyprididae (73% of the total of 22 species) (Brandão, 2010) In shallow waters of the Sea of Japan, a total 35 new species (59%) were found from a total of 59 species (Zenina & Schornikov, 2008). In the Polynesian islands Huahiné and Rangiroa, 8 new species (44%) were described from a total of 18 collected species (plus six species left in open nomenclature because of scarcity of the specimens). **Cryptic** Estimating the number of cryptic species of marine, benthic ostracods is very difficult, because I only know of 2 papers (Yamaguchi, 2000 and Brandao *et al.*, 2010) dealing with marine genera or species groups. I did a search in Science direct and in our literature database in Hamburg, but did not find any new paper on this topic. Most (of the few) ostracod DNA studies at this level involve freshwater taxa. I don't think we should base our estimates on the freshwater papers because most (if not all) studied last taxa show asexual and mixed (asexual+sexual) reproduction, while marine ostracods reproduce sexually only. Marine and freshwater taxa should therefore show distinct genetic patterns. One of the works comprising COI sequences of a marine genus (Yamaguchi, 2000) doesn't cite the term "cryptic species" but geographically isolated, monophyletic and highly supported clades for all 4 species they studied are found in their tree. The number of monophyletic clades was always equal to the number of localities sampled for each species (*i.e.*, varied from 2 to 7). However, distinct mitochondrial lineages may be the result of other "processes" (*e.g.*, natural selection, hybridization, incomplete lineage sorting) than speciation. Only in the case of speciation would these geographically distinct clades be cryptic species. The second study was part of my PhD and is on 1 Southern Ocean genus. There were 7 morphospecies, 6 showed no evidence of cryptic species, while 1 morphospecies (also the most morphologically variable) showed evidence for the existence of four cryptic species. But again this pattern was observed only in COI gene. I conclude that, while both papers do show some evidence for cryptic species, extrapolating the number from 2 papers (2 to 7, or 0 to 4) to the entire marine realm is too risky. I would not dare saying any number. **References** Yamaguchi, S. (2000). Phylogenetic and Biogeographical History of the Genus Ishizakiella (Ostracoda) Inferred from Mitochondrial COI Gene Sequences. Journal of Crustacean Biology *20*, 357–384. Brandão, S.N., Sauer, J., and Schön, I. (2010). Circumantarctic distribution in Southern Ocean benthos? A genetic test using the genus Macroscapha (Crustacea, Ostracoda) as a model. Molecular Phylogenetics and Evolution *55*, 1055–1069.
Remipedia [Stefan Koennemann]	**Described** 24 species. **Nominal** 25 species.

	Undescribed, collected We have 8 species awaiting description. **Undiscovered** We are describing 1–2 species per year; since I began working on the group in 2002, the number of species has more than doubled from 11 to 24 (not counting the 8 undescribed species). The exploration of new cave systems (within the main Caribbean distribution range) regularly yields new taxa, and I would expect as yet undiscovered remipedes in particular on Cuba and Jamaica, but also many other West Indian islands. However, we are also finding new species in well-explored caves. For example, we have identified three cryptic species using DNA taxonomy in more or less well-explored cave systems. Moreover, one of the enigmas concerning Remipedia is the fact that they occur sympatrically (with 4 to 6 species) in many caves. Based on a rough estimate of the number of (scientifically) unexplored caves + undiscovered occurrences of cryptic species + the possibility that remipedes may have a deep sea distribution (in addition to the "tip of the iceberg", the known anchialine caves at or slightly below sea level, as suggested by Boxshall, Iliffe and others), I could imagine that the currently known taxa might be 50% or even less of what is still out there. So this should give a min-max range of 20–50 species. **Cryptic** Circa 20% or between 5–9 species. With only 24 described species, the class Remipedia is small enough to give a fairly accurate estimate of cryptic species.
Hexapoda (insects and Collembola) [Lanna Cheng]	**Described** 2,037 species. **Nominal** 2,400 species names. **Undescribed, collected** I would hazard a guesstimate of around 30–60 undescribed species in collections around the world. **Undiscovered** It is difficult to guess how many marine insects remain to be discovered since very few entomologists work in marine environments. I guess we could use a conservative guesstimate of 30–100 species. Assuming there are some 2,000 marine insect species and some 30–60 (~2%) remain undescribed in various collections. These are likely to be 'accidentally' collected by non-entomologists. It is not unreasonable to assume that at least another 2% could be discovered as more marine habitats were to be visited by entomologists in the future. My guesstimate: 30–100 **Cryptic** I really have no idea how many cryptic species will turn up in marine insects. A recent molecular study on 3 species of Pontomyia (Chronomidae) indicated that there may be several (less than 10) cryptic species. Ditto an earlier study on 1 oceanic species of Halobates. I am not aware of any similar studies on other species of marine insects.

	References Andersen, N.M., Cheng, L., Damgaard J., and Sperling, F.A.H. (2000). Mitochondrial DNA sequence variation and phylogeography of oceanic insects Hemiptera: Gerridae: *Halobates* spp.). Marine Biology *136*, 421–430 Huang, D., and Cheng, L. (2011). The flightless marine midge Pontomyia (Diptera: Chironomidae): ecology, distribution, and molecular phylogeny. Zoological Journal of the Linnean Society *162*, 443–456 Cheng, L. (Ed.) (1976). Marine Insects. North-Holland Publishing Co., Amsterdam, 581 pages. Available for free download at escholarship.org/uc/item/1pm1485b.
Myriapoda [Anthony D. Barber]	It is often difficult to be clear as to whether myriapods found in or close to the littoral zone are, to use Silvestri's (1903) terminology myriapodi halofili genuini *i.e.,* confined to such habitats (obligate halophiles), myriapodi halofili indifferenti *i.e.,* occurring in both terrestrial and littoral habitats (facultative halophiles) or myriapodi halofili accidentali *i.e.,* chance occurrences (accidental halophiles). Such a situation may well be true of all "terrestrial" groups in which some species have invaded the littoral zone. Myriapods are essentially terrestrial groups of arthropods but representatives of all four classes from different orders, families and genera have colonised sea shore habitats and the situation is made more complex by species which appear to be genuini in one region but occur inland in another. The geophilomorph centipede *Hydroschendyla submarina*, for instance, is only ever recorded from seashores in northern Europe, the Mediterranean and Bermuda and is clearly genuini whilst *Pachymerium ferrugineum* is clearly indifferenti in much of its range. However, in many cases, where species are described from a single littoral site no such clarity is possible and the list in WoRMS may include some species which may later be considered accidentali. Class PAUROPODA About 500 species have been described altogether of which 5 seashore species are reported, all from Europe. The total number of littoral species in world must be much greater but impossible to estimate (? 40+); These are elusive animals, less than 2mm long, and are not often found by standard sampling techniques. Class SYMPHYLA About 200 species have been described in total; 4 (?5) apparently halophilic species are reported from England, Bulgaria and California. The total number of littoral species in the world must be much greater but impossible to estimate (? 30+); these are difficult animals to study and are not often identified to species level. Class DIPLOPODA Of the 10,000 or so described species of millipede four clearly halophilic species are reported from NW Europe, the Mediterranean Region, USA, Far-eastern Russia and Tasmania. In addition, two penicillate or bristly millipedes are also recorded; *Polyxenus lapidicola* by Silvestri from the Mediterranean (no subsequent definite records) and a *Chilexenus* sp. is reported from South Africa by Lawrence (1984). Total world halophilic species may be 20 or more as there are no records at all from western North America, Central & South America and the Caribbean, all of Asia and most

	of Oceania and littoral diplopods are often difficult to find. Class CHILOPODA About 3,000 species of centipedes have been described worldwide of which about 1,000 are members of the order Geophilomorpha which contains a number of littoral species. The total number of halophilic geophilomorphs recorded in a recent list (Barber, 2009) is 45. Most of these are from Europe, Western United States, the Caribbean, South America, Japan and Australia/New Zealand. There are few records from the Atlantic coast of USA or from Canada, very few African records and little from much of Asia other than Japan, Korea and Taiwan. It is highly improbable that there are no species occurring on these coasts. In addition it is possible that some species for which no habitat data is given (*e.g.,* for California / Baja California, South Africa, New Zealand) may well be halophilic and also finding littoral species in some habitats (*e.g.,* rock crevices) is not always easy. An estimate of 100 plus species from around the world seems reasonable. **References** Barber, A.D. (2009). Littoral myriapods: a review. Soil Organisms *81*, 735–760. Lawrence, R.F. (1984). The Centipedes and Millipedes of Southern Africa. Cape Town & Rotterdam, A.N.Balkema Silvestri, F. (1903). Fauna Napoletana. Myriapodi viventi sulla spiaggia del mare presso Portici (Napoli). Annuari del Museo Zoologico della R. Universita di Napoli (N.S.) *1*, 1–5.
Brachiopoda [Christian Emig]	**Described** 388 species. **Nominal species** # is not available. **Undescribed, collected** None. **Undiscovered** Not estimated. **Cryptic** Not estimated.
Bryozoa [Dennis Gordon, Phil Bock]	**Described** ~5,900 species. **Estimated undescribed and undiscovered** 2,800–5,200. Some recent (past 20 years) comprehensive studies of genera (*e.g., Bryopesanser*, *Buffonellaria*) and entire small families (*e.g.,* Eurystomellidae, Macroporidae) have yielded increases in species numbers of c. 100-650% and this level of increase appears likely to be the case as more revisionary work is done and new faunas described. A major problem is the number of species described in the 19th century that have never been revised/revisited, and no-one knows what would be the best genus for them

	now. At least they are available names. **Undiscovered + Cryptic** The bryozoan fauna for Australia is about 1,000 accepted, with another ~1,000 yet undescribed, with many areas not yet sampled. This would give 50% known. New Zealand is better known (incuding >320 known-undescribed), with better sampling density, but even shallow-water collecting is still yielding new taxa. Europe is much better known; the Caribbean would have many undescribed (in the Smithsonian), and many uncollected; the rest of the tropics are going to prove very productive when they are thoroughly sampled. Based on field experience in the past two years, coral- reef environments below 20 metres are particularly rich in Bryozoa, with sampling by SCUBA the only way to sample adequately. There has been so little done across the reefs of the world that we cannot estimate the variation between near or distant reef groups. Certainly the fauna from the northern Great Barrier Reef (Lizard Island) and the southern Great Barrier Reef (Heron Island region) show major differences. Tilbrook (2006) determined that 20-30% of bryozoan species from newly sampled areas of the tropical Indo-Pacific are new. There is a similar percentage for the New Zealand deep sea, in some cases higher, and such will be the case when other parts of the slope-to-abyssal fauna are sampled. We would estimate 2,800-5,200 undiscovered species of Bryozoa, of which the cryptic component might be 350-950, although the latter is difficult to estimate. Cryptic species discovered in the past couple of decades by genetic means (predominantly Ctenostomata like some species of *Alcyonidium*) have subsequently been discovered to have discriminating life-history or anatomical features that were previously overlooked, so that they cease to remain cryptic as defined. In this case it is a matter of failing to perceive characters. Generally bryozoans have reliable morphological characters and workers are getting better at discriminating species. We would expect the greatest proportion of cryptic species to be among the orders Ctenostomata and Cyclostomata in which there is a relative paucity of characters, confounded by homoplasy, compared to the Cheilostomata. **References** Tilbrook, K.J. (2006). Cheilostomatous Bryozoa from the Solomon Islands. Santa Barbara Museum of Natural History Monographs *4* (Studies in Biodiversity *3*), 1–385.
Cephalorhyncha Nematomorpha [Andreas Schmidt-Rhaesa]	**Undescribed, collected** Rough estimate: 70 species. **Undiscovered** From temperate regions, there are about 10% new species in samples, in tropical regions these are up to 50%. Considering which regions have been sampled I estimate that the species number is about twice as high as the known number (around 600). **Cryptic** There are no studies on cryptic species in this taxon, but sampling is highly accidental and therefore incomplete.

Kinorhyncha [Birger Neuhaus]	**Described** 180 species based on description of adult specimens + 48 species based on description of juvenile stages (valid in the sense of ICZN but usually not accepted by scientists, because many species based on the description of juveniles may/will turn out as synonyms of species based on the description of adults) **Nominal** ca. 228. **Undescribed, collected** The largest collections of undescribed kinorhynch specimens are housed by the National Museum of Natural History, Smithsonian Institution, Washington D.C., the Museum für Naturkunde Berlin, and the Zoological Museum, Natural History Museum of Denmark, Copenhagen. It is estimated that these collections include 250–350 new species. **Undiscovered** Only the coastlines of Europe and North America have been sampled for the meiobenthic Kinorhyncha in some detail with individual records from all over the world (Zelinka 1928; Higgins 1983; Adrianov & Malakhov 1999; Neuhaus & Higgins 2002). Almost every haul on the continental shelf or in the deep sea reveals new species of Kinorhyncha (Hoernle *et al.*, 2003; Neuhaus & Blasche 2006; Sørensen 2006, 2007, 2008; Sørensen *et al.*, 2000, 2007, 2009, 2010a, b ; Sørensen & Rho 2009; Sørensen & Thormar 2010; Werner *et al.*, 2009). Therefore, at least 1,000–2,000 species of Kinorhyncha can be expected to live in marine environments. **References** Adrianov, A.V., and Malakhov, V.V. (1999). Cephalorhyncha of the world ocean. KMK Scientific Press, Moscow. (in Russian and English) Higgins, R. P. (1983). The Atlantic barrier reef ecosystem at Carrie Bow Cay, Belize, 2: Kinorhyncha. Smithson. Contrib. Mar. Sci. *18*, 1–131. Hoernle, K., Mortimer, N., Werner, R., and Hauff, F. (2003). Cruise report SO168 ZEALANDIA. GEOMAR Report *113*, 1–214. Neuhaus, B., and Blasche, T. (2006). Fissuroderes, a new genus of Kinorhyncha (Cyclorhagida) from the deep sea and continental shelf of New Zealand and from the continental shelf of Costa Rica. Zool. Anz. *245*, 19–52. Neuhaus, B., and Higgins, R.P. (2002). Ultrastructure, biology, and phylogenetic relationships of Kinorhyncha. Integ. Comp. Biol *42*, 619–632. Sørensen, M.V. (2006). New kinorhynchs from Panama, with a discussion of some phylogenetically significant cuticular structures. Meiofauna Marina *15*, 51–77. Sørensen, M.V. (2007). A new species of *Antygomonas* (Kinorhyncha, Cyclorhagida) from the Atlantic coast of Florida, USA. Cah. Biol. Mar. *48*, 155–168. Sørensen, M.V. (2008). A new kinorhynch genus from the Antarctic deep sea and a new species of *Cephalorhyncha* from Hawaii (Kinorhyncha: Cyclorhagida: Echinoderidae). Org. Div. Evol. 8, 230–232. Sørensen, M.V., Heiner, I., and Hansen, J.G. (2009). A comparative morphological study of the kinorhynch genera *Antygomonas* and

	Semnoderes (Kinorhyncha: Cyclorhagida). Helgol. Mar. Res. *63*, 129–147. Sørensen, M.V., Heiner, I., Ziemer, O., and Neuhaus, B. (2007). *Tubulideres seminoli* gen. et sp. nov. and *Zelinkaderes brightae* sp. nov. (Kinorhyncha, Cyclorhagida) from Florida. Helgol. Mar. Res. *61*, 247–265. Sørensen, M.V., Jørgensen, A., and Boesgaard, T.M. (2000). A new *Echinoderes* (Kinorhyncha: Cyclorhagida) from a submarine cave in New South Wales, Australia. Cah. Biol. Mar. *41*, 167–179. Sørensen, M.V., and Rho, H.S. (2009). *Triodontoderes anulap* gen. et sp. nov. - a new cyclorhagid kinorhynch genus and species from Micronesia. J. Mar. Biol. Ass. U. K. *89*, 1269–1279. Sørensen, M.V., Rho, H. S., and Kim, D. (2010a). A new species of *Condyloderes* (Cyclorhagida, Kinorhyncha) from Korea. Zool. Sci. *27*, 234–242. Sørensen, M.V., Rho, H.S., and Kim, D. (2010b). A new species of the rare genus *Sphenoderes* (Cyclorhagida, Kinorhyncha), with differential notes on *S. indicus* Higgins, 1969. Mar. Biol. Res. *6*, 472–484. Sørensen, M.V., and Thormar, J. (2010). *Wollunquaderes majkenae* gen. et sp. nov. - a new cyclorhagid kinorhynch genus and species from the Coral Sea, Australia. Mar. Biodiv. *40*, 261–273. Werner, R., Hauff, F., and Hoernle, K. (eds) (2009). RV Sonne Fahrtbericht / Cruise Report SO199 CHRISP. IFM-GEOMAR Report *25*, 1–206. Zelinka, K. (1928). Monographie der Echinodera. Verlag W. Engelmann, Leipzig.
Loricifera [Antonio Todaro; Reinhardt Møbjerg Kristensen]	**Described** 32 species described and valid. **Nominal** 32 species names. **Undescribed, collected** 123 specimens. **Undiscovered** About 1,000 species.
Chaetognatha [Erik V. Thuesen]	**Described** 129 species described and accepted as valid in WoRMS as of July 5, 2012. **Nominal** 280 species names listed in WoRMS, including those listed as *nomen dubium*, and synonyms, including those changed due to new combinations. **Undiscovered** Total number of living chaetognath species is guesstimated to be ~180. **Cryptic** Two species of chaetognaths have been investigated for cryptic speciation, *Parasagitta setosa* (Peijnenburg et al., 2006) and *Caecosagitta macrocephala* (Miyamoto *et al.*, 2010b). Mitochondrial DNA data suggest that cryptic species exist for both of these species. Two cryptic species are inseparable from *Parasagitta setosa* based on morphology and nuclear DNA (Peijnenburg *et al*., 2006), and similarly, two cryptic species are

	inseparable from *Caecosagitta macrocephala* using morphological and nuclear DNA analyses (Miyamoto *et al.*, 2010b). If every chaetognath species displays the same amount of cryptic speciation as *P. setosa* (a neritic species from the eastern North Atlantic Ocean) and *C. macrocephala* (a cosmopolitan deepsea species), the estimated number of cryptic chaetognath species would be 256, tripling the number of total chaetognath species. This high number is based on COII and COI data for *P. setosa* and *C. macrocephala*, respectively. On the other hand, using the results of nuclear DNA analyses, a low estimate of the number of cryptic chaetognath species would be zero. Due to the extremely small mitochondrial genome size, the smallest in the Animal Kingdom (Faure and Casanova, 2006; *Miyamoto et al.*, 2010a) and the likely occurrence of ribosomal DNA allopolyploidy (Telford and Holland, 1997; Barthelemy *et al.*, 2007), much more work needs to be undertaken in order to ascertain whether or not cryptic speciation has actually taken place in the Chaetognatha. **References** Barthelemy, R.M., Grino, M., Pontarotti, P., Casanova, J. P., and Faure, E. (2007). The differential expression of ribosomal 18S RNA paralog genes from the chaetognath *Spadella cephaloptera*. Cellular & Molecular Biology Letters *12*, 573–583. Faure, E., and Casanova, J.P. (2006). Comparison of chaetognath mitochondrial genomes and phylogenetical implications. Mitochondrion *6*, 258–262. Miyamoto, H., Machida, R.J., and Nishida, S. (2010a). Complete mitochondrial genome sequences of the three pelagic chaetognaths *Sagitta nagae, Sagitta decipiens* and *Sagitta enflata*. Comparative Biochemistry and Physiology Part D: Genomics and Proteomics *5*, 65–72. Miyamoto, H., Machida, R.J, and Nishida, S. (2010b). Genetic diversity and cryptic speciation of the deep sea chaetognath *Caecosagitta macrocephala* (Fowler, 1904). Deep Sea Research Part II: Topical Studies in Oceanography *57*, 2211–2219. Peijnenburg, K.T.C.A., Fauvelot, C., Breeuwer, A.J., and Menken, S.B.J. (2006). Spatial and temporal genetic structure of the planktonic Sagitta setosa (Chaetognatha) in European seas as revealed by mitochondrial and nuclear DNA markers. Molecular Ecology *15*, 3319–3338. Telford, M.J., and Holland P.W.H. (1997). Evolution of 28S ribosomal DNA in chaetognaths: Duplicate genes and molecular phylogeny. Journal of Molecular Evolution *44*, 135–144.
Ascidiacea [Adriaan Gittenberger, Marc Rius, Billie Swalla, Noa Shenkar, Rosana Moreira da Rocha, Gretchen Lambert, Xavier Turon]	**Described** 2,874 species (Shenkar & Swalla, 2011; Shenkar *et al.*, 2012). **Nominal** Estimate = 5,000 (based on WoRMS). **Undescribed, collected** Estimate = ~ 500. Many collections from different places in the world held in museums and research institutions remain to be studied. The most recent ones include alcohol preserved vouchers amenable to genetic analysis, though most museum samples were first preserved in formalin and then transferred to

	ethanol. Thus, a substantial number of species presently undescribed are likely to surface from the study of these collections. If DNA analyses protocols can be optimized to also include formalin preserved tunicate material (as was successfully done in other marine taxa; Palero *et al.*, 2010) we expect that this will greatly nuance studies of the Ascidiacea. **Undiscovered** Rosana Moreira da Rocha conducted a review of 37 articles on ascidian fauna published between 1980 and 2009: "8 articles with less than 10% of new species, 15 with 10–30% of new species, 10 with 30–50 % and only 4 with more than 50%". Based on these numbers, we all agree that projecting 100% of increment beyond the known species is too much. Since there are almost 3000 valid species, 4000–4500 is a better estimate of the number of ascidian species. Examples per region Africa (Marc Rius): The ascidians inhabiting African waters are poorly studied. This is demonstrated by the fact that every time a taxonomist studies a particular region in Africa, a number of new species are described. For example, 10 and 17 new species were described by Millar (1955) and Millar (1962) respectively when he studied samples from South Africa. The same trend has been found when different taxonomists revise a particular region — Monniot *et al.* (2001) described 22 new species from South Africa. This is not region-exclusive and taxonomic studies conducted in different parts of Africa have shown similar trajectories (*e.g.,* Monniot & Monniot 1994 described two new species from the central west African coast; Pérez-Portela & Turon 2008 found a new species inhabiting waters of Kenya, Tasmania and Madagascar; etc.). Australia (Williams *et al.*, 2010: table 1): About 33% of the ascidians found during a recent inventory of species in Australia, were found to be unknown to science. Central & South America (Rosana Moreira da Rocha): We still have many species to be discovered in the Caribbean, since most of the islands were never surveyed and we see that we have at least 1–2 endemic species each every time we start collecting. So, we may have a very conservative guess calculating 2 new species per island or country. Panama: There are 80 spp. In the Bocas del Toro region (Caribbean side) among which more than15 species (20%) are to be described (2 *Pyura*, 1 *Symplegma*, 1 *Eudistoma*, 1 *Ecteinascidia*, 10 didemnids, 1 Clavelinidae, 1 *Eusynstyela*). Venezuela: In only one site surveyed in April 2009 we found 29 species among which 1 or 2 new *Styela*, 1 new Botryllid, 1 new *Lissoclinum* (but it is the same species in Panamá) (~14% new sp). Brazil: We have around 110 registered and more than 20 species in our collections to be described that we already know are new species (~15%) (2 *Aplidium*, 10 didemnids, 1 *Distaplia*, 2–3 Botryllids, 1 *Rhopalaea*, 3–4 *Eudistoma*). Ecuador: We also have material from Galapagos with lots of new species to be described: 3–4 *Eudistoma* , 5–6 *Aplidium*, 4 *Ascidia*, 2 Botrylids, 2–3

	didemnids). California, U.S.A. Continental Shelf: (Gretchen Lambert) A U.S.A. Department of the Interior Minerals Management Service 1983–89 conducted an assessment of long-term changes in the biological communities of the California Continental Shelf from the Santa Maria Basin and western Santa Barbara Channel. It was the only sampling of these areas since 1904 in which ascidians were identified. Of the 20 species collected, 16 were identified to species, the other 4 only to genus, 3 were new species (Lambert, 1993). Six of the 16 identified to species were the same as collected in 1904 from these areas (Ritter, 1907). Of the 14 species collected in 1904, 4 were abyssal and not found in the present study. Thus only 4 of Ritter's (1907) 14 described ascidian species were ones that he found but were not collected at similar depths about 90 years later (Lambert, 1993). Mediterranean (Xavier Turon): The number of new species described or recorded in the Mediterranean sea has leveled off during the last couple of decades (Coll *et al.*, 2010 Fig 13D), but is still increasing, particularly due to the application of new molecular techniques to unsolved taxonomic problems. So, even in the "well-known" Mediterranean, with 229 species described (Coll *et al.*, 2010, Appendix S2), we estimate that 30–50 species remain to be discovered. Red Sea and Mediterranean (Noa Shenkar): There still are quite a few new species to be discovered. Tel Aviv University includes ~500 specimens from the Red Sea and Mediterranean coasts of Israel. There are 2 recently described new species (Shenkar 2012). Brunetti published last year a new *Botryllus* sp. from the Mediterranean coast of Israel, and there are 2 new species from the Red Sea of *Rhopalaea* and *Ascidia* that still need to be described. General (Gretchen Lambert): Most of us have estimated that there are about 3,000 extant spp., with several hundred in this number yet to be discovered/described. The ascidian fauna of the tropical West Pacific is however still very poorly known, with recent works featuring overall ~50% of species being new to science (*e.g.*, Monniot & Monniot 1996, 2001, 2008). Just as Rosana Moreira da Rocha is finding new spp. around each island in the Caribbean, so this is true in the W. Pacific only on a much more gigantic scale. Therefore, we asked the opinion of Françoise Monniot, in France. She said "In my opinion (with approximate information from my own data base) about 4,000 species may be valuable ones. It is impossible to evaluate the number of unknown species, many are described every year and so many parts of the world have never been investigated!". **Cryptic** We discussed the number of species that may be discovered in the future with molecular techniques. We all agree that molecular techniques have shown that cryptic speciation is frequent in ascidians, and that they are excellent tools to discover new species. However, molecular techniques should not be considered without also considering the morphology of the species. Recent studies on ascidians revealed that the coupling of genetic and morphological approaches is fruitful and that there are always morphological characters that can distinguish among the species (*e.g.*, Perez-Portela *et al.*, 2007).

	We believe that there should not be a distinction between a "morphological perspective" versus a "molecular perspective", as both methods contribute to taxonomy. Adding 500 species that may be discovered based on molecular techniques sums up our estimation to 4000–5000 species. **References** Coll, M., Piroddi, C., Steenbeck, J., Kaschner, K., Ben Rais Lasram, F., Aguzzi, J., Ballesteros, E., Niké Bianchi, C., Corbera, J., Dailianis, T., Danovaro, R., Estrada, M., Froglia, C., Galil, B.S., Gasol, J.M., Gertwagen, R., Gil, J., Guilhaumon, F., Kesner-Reyes, K., Kitsos, M.S., Koukouras, A., Lampadariou, N., Laxamana, E., López-Fé de la Cuadra, C.M., Lotze, H.K., Martin, D., Mouillot, D., Oro, D., Raicevich, S., Rius-Barile, J., Saiz-Salinas, J.I., San Vicente, C., Somos, S., Templado, J., Turon, X., Vafidis, D., Villanueva, R., and Voultsiadou, E. (2010). The biodiversity of the Mediterranean Sea: Estimates, patterns and threats. PLoS One *5*, e11842 (36 pp). doi:10.1371/journal.pone.0011842. Lambert, G. (1993). Three new species of stolidobranch ascidians (Chordata: Ascidiacea) from the California continental shelf. Proc. Calif. Acad. Sci. *48*, 109–118. Pérez-Portela, R., Duran, S., Palacín, C., and Turon, X. (2007). The genus *Pycnoclavella* (Ascidiacea) in the Atlanto-Mediterranean region: a combined molecular and morphological approach. Invertebrate Systematics *21*, 187–205. Pérez-Portela, R., and Turon, X. (2008). Phylogenetic relationships of the Clavelinidae and Pycnoclavellidae (Ascidiacea) inferred from mtDNA data. Invertebrate Biology *127*, 108–120. Millar, R.H. (1955). On a collection of ascidians from South Africa. Proceedings of the Zoological Society of London *125*, 169–221. Millar, R.H. (1962). Further descriptions of South African ascidians. Annals of the South African Museum *46*, 113–221. Monniot, C., and Monniot, F. (1994). Additions to the inventory of eastern tropical atlantic ascidians: arrival of cosmopolitan species. Bulletin of Marine Science *54*, 71–93. Monniot, C, and Monniot, F. (1996). New collections of ascidians form the Western Pacific and Southeastern Asia. Micronesica *29*, 133–279 Monniot, C., and Monniot, F. (2001). Ascidians from the tropical western Pacific. Zoosystema *23*, 201–383. Monniot, C., and Monniot, F. (2008). Compléments sur la diversité des ascidies (Ascidiacea, Tunicata) de l'ouest Pacifique tropical. Zoosystema *30*, 799–872. Monniot, C., Monniot, F., Griffiths, C.L., and Schleyer, M. (2001). South African ascidians. Annals of the South African Museum *108*, 1–141. Palero, F., Hall, S. Clark, P., Johnston, D., Mackenzie-Dodds, J., and Thatje, S. (2010). DNA extration from formalin-fixed tissue: new light from the deep sea. Scientia Marina *74*, 465–470. Ritter, W.E. (1907). The ascidians collected by the United States Fisheries Bureau steamer Albatross on the coast of California during the summer of 1904. U.C. Publ. Zool. *4*, 1–52. Shenkar, N. (2012). Ascidian (Phylum: Chordata, Class: Ascidiacea) diversity in the Red Sea. Submitted to Marine Biodiversity. Shenkar, N., Gittenberger, A., Lambert, G., Rius, M., Moreira Da Rocha, R., Swalla, B.J., and Turon, X. (2012). World Ascidiacea Database. Available online at http://www.marinespecies.org/ascidiacea.

	Consulted on 2012–01–29. Shenkar, N., and Swalla, B.J. (2011). Global Diversity of Ascidiacea. PLoS ONE *6*, e20657., available online at http://dx.doi.org/10.1371/journal.pone.0020657.
Larvacea [Russ Hopcroft]	**Described** 67 valid species (all in WoRMS). **Nominal** 75 subjective synonyms (all in WoRMS). **Undescribed, collected** I have 2, I know of 2 others at MBARI (California) from ROV video records. Most new ones are deep-water and require collection by an ROV. There are probably less than 5 other people capable of knowing if they have discovered something new! **Undiscovered** 63, based on Hopcroft (2005). I stick with those numbers — especially when one considers they do not include cryptic species that would show up based on genetic work. **Cryptic** There is likely to be high cryptic diversity in the larvaceans, because many species have very broad distributions, with occurrences in multiple oceans. Thus far, no one has been able to find a COI primer that works for this group, so there is no information on how extensive cryptic species might be! Based on what I've seen for other groups this could be in the order of 2–5 folds. **References** Hopcroft, R.R. (2005). Diversity in larvaceans: How many species?, in: Gorsky, G. *et al.* (2005). Response of marine ecosystems to global change: ecological impact of appendicularians. pp. 45–57.
Thaliacea [Laurence P. Madin]	**Described** 79 species in 27 genera: Doliolids: 10 genera, 26 spp, Salps: 14 genera, 45 spp. Pyrosomes: 3 genera, 8 spp. **Nominal** Same as described. **Undescribed, collected** I’m not aware of any undescribed species already collected, but would guess not more than 5. **Undiscovered** I doubt there are more than another 10% of the current thaliacean species yet to be discovered, or about 8.
Pisces [William Eschmeyer]	**Described + nominal + Undiscovered** See Eschmeyer *et al.* (2010). New values of described and valid genera and species can be found online via Google (Catalog of Fishes) or at

	http://research.calacademy.org/ichthyology/catalog. New taxa in 2011 were 340 new species and 25 new genera. New online versions of the Catalog of Fishes are posted online about every 6–8 weeks. **Undescribed, collected** I would estimate that the number might be 500 (10% of the 5,000). Some would be in combination with new discoveries — find new species from new specimens, then reinforce with museum specimens. **Cryptic** The number of cryptic species in fishes is probably small and mostly among reef species. Recent papers reveal a few, maybe 15 in the last 5 years. There will be more, but not too many. Let's say less than 200–300. Fish have many characters, and most are fairly easy to define as so-far known. **Reference** Eschmeyer, W.N., Fricke, R., Fong, J.D., and Polack, D. (2010). Marine fish biodiversity: A history of knowledge and discovery (Pisces). Zootaxa *2525*, 19–50.
Sirenia [Caryn Self-Sullivan, Daryl Domning]	**Described** 4 recent marine Sirenia spp. *Trichechus inunguis* is only found in fresh water and in that sense is not a "marine" species. However, it is found along the seaward edge of the Amazon River's delta and is thus "marine" in the geographic sense, even though that coastline is always bathed in fresh water due to the Amazon's enormous discharge. **Nominal** 35 nominal species names, data from WoRMS. **Undescribed, collected** None. **Undiscovered** None. **Cryptic** For Sirenia (Mammalia), there are 4 recognized living species, and I would estimate zero cryptic species, based on the fact that a fair amount of work has been done on phylogeography of the 3 manatee species using mtDNA (and some work on the dugong), and no signs of cryptic species have turned up that I know of. Also, large mammals in general are not known to be prone to a lot of cryptic speciation, so a priori I wouldn't expect it in sirenians.
Cetacea [William Perrin]	**Described** The number of accepted species is 87. **Nominal** There are 1,271 species names of Cetacea in WoRMS. **Undescribed, collected** No new species at present. **Undiscovered + Cryptic**

	Based on the description of four new species in the last two decades, there may be a couple more out there. It has been suggested that the killer whale and the common bottlenose dolphin should each perhaps be split into two or more species. To give a number: 1–5 species for undiscovered/unknown for Cetacea, and 1–3 cryptic species.
Reptilia [Peter Uetz]	**Described** ~ 110 marine reptiles. **Nominal** ~ 600 (including misspellings). **Undescribed, collected** Just out of experience, I am sure that there are undescribed species, but it is almost impossible to guess that number. **Undiscovered** The rate of new reptile species described/discovered has been steady for over a hundred years, in fact, accelerating, so it is pretty much impossible to predict how long this trend will last. Of the 100+ marine reptiles, about 4% (4) have been described during the past 10 years. However, during the 20 years before that, only 6 new species were described but all of them by the same author (Kharin). That is, someone just made an effort and found single-handedly all new species described in 20 years. There may be up to another dozen truly marine species and another dozen undiscovered species occurring in coastal/brackish/mangrove habitats, but probably not more than that. The longer I think about it — maybe you should put 20–30 undiscovered species down, instead of 10. It is a long shot, but it sounds unlikely that the huge oceans harbor only 10 new species. Again, it is really unpredictable.
Aves [Mark Tasker]	**Described** 641 species (based on WoRMS). **Nominal** My guess is quite a low number of synonyms, though seabirds tend to be large and reasonably well described. **Undescribed, collected** My guess is 30–50 species, but many taxa have been described in the collections, just not at species level. **Undiscovered** My guess is also 30–50 species. One or two of these may presently be known from specimens but assumed extinct. **Cryptic** Only very few bird species seem to be discovered by genetic analysis; more often these are found by plumage or song variation, which may then be backed up by genetics. So I would say on the basis of current track record that there are very few extra cryptic species to be discovered using genetics.
Antipatharia [Dennis M. Opresko,	**Described** There are about 250 valid described species.

Tina Molodtsova]	**Nominal** If we include synonyms, and taxa that cannot be identified — about 280 species. **Undescribed, collected** From our examination of collections yet to be published on, we are estimating that there are 50 to 75 new taxa. **Undiscovered** We think that there may be as many as 50 to 100 still to be collected. **Cryptic** Concerning the Antipatharian corals, genetic diversity estimates would be very difficult at this time because most of the genetic studies to date have been conducted on mitochondrial markers which, for anthozoan cnidarians, do not provide an adequate level of variation to identify cryptic species.
Actiniaria [Daphne G. Fautin]	**Described** 1,093 currently considered valid species. **Nominal** 1,454. **Undiscovered** I have no basis for providing a number for this. Although new species are being described, synonyms are also being proposed, so the number is not climbing rapidly. **Reference** Fautin, D.G. (2011). Hexacorallians of the World. http://geoportal.kgs.ku.edu/hexacoral/anemone2/index.cfm.
Corallimorpharia [Daphne G. Fautin]	**Described** 47 currently considered valid species. **Nominal** 55. **Undiscovered** I have no basis for providing a number for this. Recently described species are largely from the deep sea. There is a lot of diversity in the shallow tropics; names are not easily assigned to all types but many names have been proposed that are now of uncertain application, so names may exist for most organisms, and the real work lies in figuring out what name belongs to what species. **Reference** Fautin, D.G. (2011). Hexacorallians of the World. http://geoportal.kgs.ku.edu/hexacoral/anemone2/index.cfm
Ceriantharia [Tina N. Molodtsova]	**Described** 137 species. **Nominal**

	160 species names. **Undescribed, collected** 4–6 species. **Undiscovered** 15–25 species.
Zoantharia [James Davis Reimer]	**Described** 101 species. Likely low but on the safe side, the reason this is lower than currently in WoRMS is I am certain *Palythoa* and *Zoanthus* have many synonymous names. **Nominal** 453. Total from WoRMS plus Hexacorallians of the World (Fautin, 2011) databases. There are likely a few more names out there in obscure literature, but this is a good estimate. **Undescribed, collected** 30. Undoubtedly more than this in reality, but only based on my firsthand knowledge of specimens. This number includes species that will likely have to be placed within new genera and families – based on our DNA analyses of some undescribed specimens the higher (>generic) level diversity of this order is much higher than is now known (*e.g.*, Fujii and Reimer, 2011). **Undiscovered** 180–380, based on the rates at which we are finding new species, total derived from estimated and conservative numbers of undiscovered species for each genus. Thus, the total minimal number of species in this order looks to be (101+30+180) around 300 species, with conservative estimates, but could be up to 500 based on what happens with putative synonyms, etc. The biggest problem facing zoanthid taxonomy is the very large number of potential synonyms. Thus, for many species, we really have no idea if they are valid or not, particularly in the genera *Palythoa*, *Zoanthus*, and *Epizoanthus*. Still, based on observations of *Zoanthus* and *Palythoa*, I think it is very likely there are many synonymous species in this order. Sorting this out will take many years of examination. Also, there appear to be many species still undiscovered, from the deep sea, or other unexamined localities and ecosystems (*e.g.*, Reimer and Sinniger 2010). So, the taxonomy of this order can be characterized as: a. chaotic (see Burnett *et al.*, 1994; 1997; Ryland and Lancaster, 2003), b. much synonymy, specimens redescribed from different localities, etc. (see numerous papers by Carlgren and Pax), c. much diversity remaining to be discovered (*e.g.*, Reimer and Fujii, 2010; Fujii and Reimer, 2011). **Cryptic** The ratios for zoanthids is 1.2–2.5 per morpho-species; but we have only limited molecular evidence for this. So if total morpho-species = 311–511, than 1.2–2.5 means the number of add-on cryptic species is (311*0.2)=62 and (511*1.5)=766 (rounded to 60 and 760).

	References Burnett, W.J., Benzie, J.A.H., Beardmore, J.A., and Ryland, J.S. (1994). High genetic variability and patchiness in a common Great Barrier Reef zoanthid (*Palythoa caesia*). Marine Biology *121*, 153–160 Burnett, W.J., Benzie, J.A.H., Beardmore, J.A., and Ryland, J.S. (1997). Zoanthids (Anthozoa, Hexacorallia) from the Great Barrier Reef and Torres Strait, Australia: systematics, evolution and a key to species. Coral Reefs *16*, 55–68. Fautin, D.G. (2011). Hexacorallians of the world. http://geoportal.kgs.ku.edu/hexacoral/anemone2/index.cfm. Fujii T., and Reimer, J.D. (2011). Phylogeny of the highly divergent family Microzoanthidae (Anthozoa, Hexacorallia) from the Pacific. Zoologica Scripta *40*, 418–431. Reimer, J.D., and Fujii, T. (2010). Four new species and one new genus of zoanthids (Cnidaria: Hexacorallia) from the Galápagos. ZooKeys *42*, 1–36. Reimer, J.D., and Sinniger, F. (2010). Discovery and description of a new species of *Abyssoanthus* (Zoantharia: Hexacorallia) at the Japan Trench: the world's deepest known zoanthid. Cahiers de Biologie Marine *51*, 451–457. Ryland, J.S., and Lancaster, J.E. (2003). Revision for methods separating species of *Protopalythoa* (Hexacorallia: Zoanthidea) in the tropical west Pacific. Invertebrate Systematics *17*, 407–428.
Scleractinia [Bert Hoeksema; Stephen Cairns]	**Described** Azooxanthellate: 720. The number at the end of 1999 (Cairns et al., 1999) was 669. Since then, 48 51 species have been described, 7 synonymized, and 10 added from previously forgotten sources, for a net gain of 51–54. The actual rate of growth is 48–51/110.5, or 4.6 species per year. This is down from an annual rate of 7.03 based on 30 years: 1968–1998 (Cairns, 1999) and 6.9 based on 7 years: 2000–2007 (Cairns 2007), consistent with a projected decline in the growth rate predicted by Cairns in 1999. But, the growth rate is highly dependent on how many people are actively engaged in the study of zooxanthellate taxonomy, which today is one (Marcelo Kitahara). Nonetheless, I persist that the growth rate will continue to decline and the species accumulation curve will become more horizontal. During the same time, 4 new genera were described and one synonymized, for a net gain of 3: 117 to 120. Zooxanthellate: 860 (minus ca. 60 that are likely to be synonymized again) = 800. Many taxonomic changes at family and genus level are foreseen to take place in the near future as a result of molecular methods (*e.g.*, Benzoni *et al.*, 2007, 2011; Fukami *et al.*, 2008; Nunes *et al.*, 2008; Huang *et al.*, 2009, 2011; Budd *et al.*, 2010; Kitahara *et al.*, 2010; Gittenberger *et al.*, 2011). **Nominal** Azooxanthellate: 720 + 365 junior subject synonyms (and a few junior homonyms), or 1,085 names. The synonymy rate is thus 365/1085, or 33.6%, a similar percentage (34.1%) reported by Cairns (2001). Zooxanthellate: 800 x 3.5 = 2,800 (based on 2 taxonomic revisions (Hoeksema 1989, Wallace 1999) I come to an average of 3.5 names per species. Note the difference in synonyms between deepwater corals and the easily accessible reef corals.

	Undescribed, collected Azooxanthellate: Number of undescribed new species based on collections in hand: Marseille (6), James Cook/Paris Museum (9), NMNH (73), or a total of about 88, some of which were published as species A, B, C, etc (see Cairns in Roberts, *et al.*, 2009). Zooxanthellate: 5 that I need to describe. (There are 10 categorized as nomen nudum but I do not know whether they are present in collections, and that is why they are still nomen nudum). **Undiscovered** Azooxanthelate: In my 1999 paper I used three methods to estimate this number, which I have now re-evaluated. A. Partial Inventory Method, based on percentage of new species occurring in large unworked collections: In 1999 this method estimated a total of 781 species; now the estimate based on this method is 768. (I think this occurred because many of the undescribed species are singletons or just confusing, so they are put aside and did not contribute to a higher percentage of new taxa in a previous revision.) B. Method of Hammond (1992), which is based on the yearly growth over the last decade compared to the overall growth rate since 1758, and then some rather subjective guesses. These numbers suggest 800–1,440 total species, or an additional 80–720 species. C. Intuitive: having worked with the group for 35 years I feel as though there are about 1,050 total species, or another 330 to describe. Zooxanthellate: 100. Since 1999, 142 species have been described as new. Several of these are to become synonymized. New species are sibling species (discovered by DNA analysis), strict endemics, or based on old-fashionedstandard collection revision work. Most are the result of increasing fieldwork activities worldwide, including remote places, and more an increasing number of observer's people (divers, photographers) are being aware of 'strange-looking' species thanks to field-guides. We cannot say that the last decade can be seen as is part / start of a trend, because the majority (103) of the new species has been published by Veron (2002) and they are the result of many field trips sponsored by nature conservation organizations or they are material donated to the taxonomist by other scientists. Because of the anticipated synonyms I cannot give a good rationale but only a rough guess. Another problem is that fewer taxonomists will be around to verify whether a newly collected strange-looking coral is a real new discovery. **Cryptic** 0–142. My guess is that the number of cryptic scleractinian species to be discovered through molecular analyses is practically zero. It is still difficult to get markers that work at species level (for some families easier than for others). If we do have them, we use them for phylogenetic research mostly. Deep sea corals are difficult to obtain for molecular research (counting appr. 50% of the total). I do not expect that we find sibling species easily. Mostly we check for species by molecular support if we find morphological indications. In contrast to Bert Hoeksema's view, Stephen believes that for the deep water coral species, this is 20% of the known deep water species: 0.2 x 711 = about 142.

	References

Benzoni, F., Stefani, F., Stolarski, J., Pichon, M., Mitta, G., and Galli, P. (2007). Debating phylogenetic relationships of the scleractinian *Psammocora*: molecular and morphological evidences. Contr. Zool. *76*, 35–54.

Benzoni, F., Arrigoni, R., Stefani, F., and Pichon, M. (2011). Phylogeny of the coral genus Plesiastrea (Cnidaria, Scleractinia). Contr. Zool. *80*, 231–249.

Budd, A.F., Romano, S.L., Smith, N.D., and Barbeitos, M.S. (2010). Rethinking the phylogeny of Scleractinian corals: a review of morphological and molecular data. Integr. Comp. Biol. *50*, 411–427.

Cairns, S.D. (1999). Species richness of Recent Scleractinia. Atoll Res. Bull. *459*, 1–12.

Cairns, S.D. (2001). A brief history of taxonomic research on azooxanthellate Scleractinia (Cnidaria: Anthozoa). Bull. Biol. Soc. Wash. *10*, 191–203.

Cairns, S.D. (2007). Deep-water corals: an overview with special reference to diversity and distribution of deep-water scleractinian corals. Bull. Mar. Sci. *81*, 311–322.

Cairns, S.D. (2009). Cold-water Corals, Online Appendix: Phylogenetic list of 711 valid recent azooxanthellate scleractinian species, with their junior synonyms and depth ranges. On line supplement to Cold-water Corals, Roberts, J.M., Wheeler, A., Freiwald, A., and Cairns, S.D. Cambridge University Press, London (www.lophelia.org/coldwatercoralsbook).

Cairns, S.D., Hoeksema, B.W., and van der Land, J. (1999). List of extant stony corals. Atoll Res. Bull. *459*, 13–46.

Fukami, H., Chen, C.A., Budd, A.F., Collins, A., Wallace, C., Chuang, Y.Y., Chen, C., Dai, C.F., Iwao, K., Sheppard, C., and Knowlton, N. (2008). Mitochondrial and nuclear genes suggest that stony corals are monophyletic but most families of stony corals are not (order Scleractinia, class Anthozoa, phylum Cnidaria). PLoS ONE *3*, e3222.

Gittenberger, A., Reijnen, B.T., and Hoeksema, B.W. (2011). A molecularly based phylogeny reconstruction of mushroom corals (Scleractinia: Fungiidae) with taxonomic consequences and evolutionary implications for life history traits. Contr. Zool. *80*, 107–132.

Hammond, P.M. (1992). Species inventory. Pp. 17–39 In: Broombridge, B. (ed.) Global Diversity: Status of the Earth’s Living Resources. Chapman & Hall, London.

Hoeksema, B.W. (1989). Taxonomy, phylogeny and biogeography of mushroom corals (Scleractinia: Fungiidae). Zool. Verh. *254*, 1–295.

Huang, D., Meier, R., Todd, P.A., and Chou, L.M. (2009). More evidence for pervasive paraphyly in scleractinian corals: systematic study of Southeast Asian Faviidae (Cnidaria; Scleractinia) based on molecular and morphological data. Mol. Phyl. Evol. *50*, 102–116.

Huang, D., Licuanan, W.Y., Baird, A.H., and Fukami, H. (2011). Cleaning up the ‘Bigmessidae’: Molecular phylogeny of scleractinian corals from Faviidae, Merulinidae, Pectiniidae and Trachyphylliidae. BMC Evol. Biol. *11*, 37.

Kitahara, M.V., Cairns, S.D., Stolarski, J., Blair, D., and Miller, D.J. (2010). A comprehensive phylogenetic analysis of the Scleractinia (Cnidaria, Anthozoa) based on mitochondrial CO1 sequence data. PLoS One *5*, e11490.

	Nunes, F., Fukami, H., Vollmer, S.V., Norris, R.D., and Knowlton, N. (2008). Re-evaluation of the systematics of the endemic corals of Brazil by molecular data. Coral Reefs *27*, 423–432. Veron, J.E.N. (2002). Corals of the World. Australian Institute of Marine Science**,** Townsville. Wallace, C.C. (1999). Staghorn Corals of the World. CSIRO Publishing, Collingwood.
Octocorallia (exclusive of the Pennatulacea) [Leen P. van Ofwegen]	**Described** 2,951 species. **Nominal** 3,577 species names. **Undescribed, collected** 100. **Undiscovered** Recent five largest papers dealing with alcyonaceans of the Indo-Pacific and deep water, which together house about 90% of all alcyonaceans, had 50% of the species new to science. Therefore I estimate another 1,500 species await description. **Cryptic** Our octocoral research is not yet advanced enough that we can reveal cryptic species only on the basis of DNA. So currently nothing is known about cryptic species in octocorals.
Pennatulacea [Gary C. Williams]	**Described** 220 accepted species. **Nominal** 450 species names. **Undescribed, collected** One that I know of in the past 25 years, but I estimate perhaps 20 species await recognition as undescribed. **Undiscovered** An average of one new species per year is discovered in the field resulting from new findings and improved technology regarding deep-water collecting. I estimate perhaps 80 new species await discovery. **Cryptic** No basis for judgement at this time. **References** Williams, G.C. (2011). The global diversity of sea pens (Cnidaria: Octocorallia: Pennatulacea). PLoS ONE *6*, 1–11.
Cubozoa [Allen Collins]	**Described** 37 species. **Nominal** 46 species names. These numbers come from recent updates I have made to

	the cubozoan entries in WoRMS. There might be a couple of other nominal species, but this should be quite close to correct (at present). **Undescribed, collected** I am aware of 9 additional species of cubozoans, whose descriptions are in progress (3 as part of submitted manuscripts), as well as one case where a nominal species will be synonymized. I would think that 10–20 would serve the purposes of our analyses. **Undiscovered** This is quite difficult to estimate, but I would not be surprised if we have perhaps 20–50 additional species to discover in this group. This would be my guess, but it is not based on any sort of analysis.
Hydrozoa [Peter Schuchert]	**Described** 3,521 marine species (Schuchert, 2011). **Nominal** Unaccepted species of Hydrozoa in WoRMS (1,000) multiplied with about 1.5 (very rough estimate!). **Undescribed, collected** This is almost impossible to say as it is not known what collection are available, though not many I guess, new species are more likely discovered by studying living material (esp. in medusae). I guess 50–100 species. **Undiscovered** Difficult to answer, see my paper of 1998, my feeling is that about 20% more are to be discovered based on morphology, many more with molecular methods (perhaps 100%) ⇨ morphospecies to be discovered: 500–1500 species. **Cryptic** ⇨ 1000–2500 species. **References** Schuchert, P. (2011). World Hydrozoa database. Available online at http://www.marinespecies.org/hydrozoa. Consulted on 2012–01–12 Schuchert, P. (1998). How many hydrozoan species are there? Zool. Verh. Leiden *323*, 209–219.
Siphonophorae [Phil Pugh, Gill Mapstone]	**Described** There are c. 176 valid species of siphonophore, with c. 8 species inquirendae. **Nominal** The number of synonyms for these species is at least 510, making an average of 3 synonyms per species; but the distribution is very uneven as, for instance, the Portuguese Man O'War, *Physalia physalis*, has about 50 junior synonyms. **Undescribed, collected** The number of known but undescribed species lies in the region of 50–60. **Undiscovered**

	Between the 1810s and the 1990s the increase in new species descriptions is almost linear, but in the last decade there has been an upturn, which probably will continue as the c. 50 known new species are described. We would estimate that the number of as yet undiscovered species lies within a similar range. The average number of species described per year, since 1758 is 0.68 (max 12 min 0), or 6.8 per decade (max 20 min 0). Many, but not all, of the early researchers used dip nets or buckets to collect their material from superficial waters, so that before 1900 4 cystonect, 22 physonect, and 35 calycophoran species had been described. However, most of the 20th century authorities relied on material collected by nets. Because of their fragility, and the fact that they are comprised of a myriad number of individuals, physonect siphonophores are often destroyed by or extruded through the netting, and the pieces that remain are often difficult to identify. Many calycophoran species, however, have relatively small nectophores that are fairly robust, and each colony is comprised of only one or two of them, and in the latter case they have different morphologies. These differences between the physonects and calycophorans are exemplified in the breakdown of the 73 siphonophore species described between 1900 and 1982; 1 cystonect, 19 physonects, and 54 calycophorans. With the advent of in situ collecting methods, SCUBA, submersibles, ROVs it was now possible to collect complete specimens of the fragile physonect species; while on the other hand the collection of the smaller calycophoran species depended greatly on the visual acuity of the collector. Thus, particularly in deeper waters, one tends to observe more physonect specimens that calycophorans, and this is, again, reflected in the number of new species described in recent years, namely 21 physonects and 17 calycophorans. The fact that, with an increasing rate of publication of descriptions of new siphonophore species, 80% of the estimated number of known but undescribed species is physonects indicates that we have only just begun to appreciate the significance of this group of siphonophores. It should also be noted that the deeper living populations of siphonophores have only been investigated, using in situ techniques, in a limited number of areas. In our case this is The Bahamas, the Cape Cod region, and Monterey Bay. In addition Dhugal Lindsay has been investigating the seas around Japan. **Cryptic** As far as we are aware there are no cryptic species.
Scyphozoa [Michael N Dawson, Liza Gómez-Daglio]	**Described** 201 accepted described marine species. Based on the summary of species listed on The Scyphozoan website (archived ca. 2007) appended with more recent species descriptions found by querying the Zoological Record database for TITLEsearch “Scyphozoa AND new AND species” ==> zero additional TITLEsearch “jellyfish* AND new AND species” ==> zero additional TITLEsearch “Scyphozoa AND sp. AND nov.” ==> 1 additional TITLEsearch “jellyfish* AND new” ==> 1 additional, 1 cryptic TITLEsearch “scyphozoa* AND new” ==> 4 additional ANYWHEREsearch “scyphozoa* AND new AND species” ==> 0 Also appended with one publication not yet in ZR.

	Nominal 204 nominal marine species. Preliminary molecular analyses suggest *Phyllorhiza peronleseuri is* same as *P. punctata*. Morandini & Marques (2010) – suggest several nomen dubium, species inquirenda from Gershwin & Zeidler (2008). **Undescribed, collected** = (a) 80, to (b) 38 (a) We calculated the number of taxa in published papers that were not identified to species but were stated in the publication as being a distinct taxon or awaiting description (*e.g.,* Gershwin 2003; Holland *et al.,* 2004; Dawson *et al.,* 2005; Bayha & Dawson 2010; Bayha *et al.,* 2010; and taxa listed as “sp.” in Kramp (1961) and Segura-Puertas (1984, 2003) [N.B. spp. classed as single sp.]). (b) Enumerated lots that are identified (and unidentified) in several natural history collections (CAS, CRRF, MCZ, NMNH, ZMB). Enumerated identified species. From these numbers we estimate how many species may be in the unidentified lots assuming new species are randomly distributed among all lots, but that lots from the same region and time likely contained similar medusae. N.B. We consider this likely an overestimate because the most interesting lots will have been worked on first, leaving replicates, poorly preserved specimens, etc as the majority of unidentified lots, especially in well-visited museums. More obscure collections may have higher proportions of undescribed species. To try to offset the potential overestimate by counting lots, we asked Allen Collins to look in SI collection for unidentified lots earmarked for description of new species by one person or another. Allen returned his best estimate as 3 (three) undescribed species compared with 91 described species at NMNH, *i.e.,* 96.7% of species in collections are described (from a well-known, well-visited museum). These six estimates were averaged (19%) and multiplied by the accepted current number of described species to give our estimate of 38 undescribed species in collections. **Undiscovered** 77 undiscovered marine species not yet collected. In the last two years, Liza has conducted extensive collections from Mexico to Panama, a previously moderately-to-poorly studied region. Segura-Puertas (1984) and Segura-Puertas *et al.* (2003, 2010) recorded 6 species of scyphozoan from the Tropical Eastern Pacific and Alvariño (1969) reported *Stomolophus* from Gulf of California. Liza found 14 species (excluding 2 invasives) of which 7 are previously unknown records and likely species. This indicates in moderately sampled regions currently described species may represent ~50% of all species present. Assuming fewer species (tending toward zero) remain to be found in well-sampled regions, and more species remain to be found in poorly-sampled regions (tending toward 65%), and that these regions are more-or-less evenly sized and distributed around the world w.r.t. biodiversity, we use 38% as our estimate of the number of species remaining to be collected. **Cryptic** Our estimated percentage of morphospecies that are cryptic is 7%.

	This figure was calculated as (number of taxa known to be highly divergent on the basis of only molecular data) / (number of valid species) * 100, and does include multiple cryptic species within a single morphospecies in some cases. This means we'd expect to find an additional 7% * 316–358 cryptic taxa (bringing the total count to 338–383 species of scyphozoans). We do think the 7% figure is a little low, but our guesstimate developed over the years was that the number of scyphozoan species might double (*i.e.*, to ~400; *e.g.*, Dawson 2004; Hamner & Dawson 2009), so we were reasonably comfortable with these numbers calculated various ways. Please also note that the estimated percentage of morphospecies that are cryptic (7%) is much less than the number of species that we expect will be discovered by applying molecular techniques. This is because by focusing on species that are morphologically different, we've shunted a good proportion of species that were originally discovered using genetics and subsequently distinguished morphometrically from the "cryptic" to the "undescribed" categories. Ultimately, the total estimate of species richness is about the same, but the way we get there different. **References** Alvariño, A. (1969). Zoogeografía del Mar de Cortés: quetognatos, sifonóforos y medusas. Anales de Biología Instituto de Biología, Universidad Nacional Autónoma de México *40*, 11–53. Bayha, K.M., and Dawson, M.N. (2010). A new family of allomorphic jellyfish, Drymonematidae (Scyphozoa, Discomedusae), emphasizes evolution in the functional morphology and trophic ecology of gelatinous zooplankton. Biological Bulletin *219*, 249–267. Bayha, K.M., Dawson, M.N, Collins, A.G., Barbeitos, M.S., and Haddock, S.H.D. (2010). Evolutionary relationships among scyphozoan jellyfish families based on complete taxon sampling and phylogenetic analyses of 18S and 28S ribosomal DNA. Integrative & Comparative Biology *50*, 436–455. Dawson, M.N, Gupta, A.S., and England, M.H. (2005). Coupled biophysical global ocean model and molecular genetic analyses identify multiple introductions of cryptogenic species. Proceedings of the National Academy of Sciences of the USA *102*, 11968–11973. Dawson, M.N. (2004). Some implications of molecular phylogenetics for understanding biodiversity in jellyfishes, with an emphasis on Scyphozoa. Hydrobiologia *530/531*, 249–260. Gershwin, L.-A. (2003). Scyphozoa and Cubozoa of Guam. Micronesica *35/36*, 156–158. Gershwin, L.-A., and Zeidler, W. (2008). Some new and previously unrecorded Scyphomedusae (Cnidaria: Scyphozoa) from southern Australian coastal waters. Zootaxa *1744*, 1–18. Hamner, W.M., and Dawson, M.N. (2009). A review and synthesis on the systematics and evolution of jellyfish blooms: advantageous aggregations and adaptive assemblages. Hydrobiologia *616*, 161–191. Holland, B.S., Dawson, M.N, Crow, G.L ., and Hofmann, D.K. (2004). Global phylogeography of *Cassiopea* (Scyphozoa: Rhizostomae): Molecular evidence for cryptic species and multiple Hawaiian invasions. Marine Biology *145*, 1119–1128. Kramp, P.L. (1961). Synopsis of the medusae of the world. Journal of the Marine Biological Association of the U.K. *40*, 1–469. Morandini, A.C., and Marques, A.C. (2010). Revision of the genus

	Chrysaora Péron & Lesueur, 1810 (Cnidaria: Scyphozoa). Zootaxa *2464*, 1–97. Segura-Puertas, L. (1984). Morfología, sistemática y zoogeografía de las medusas (Cnidaria: Hydrozoa y Scyphozoa) del Pacífico Tropical Oriental. Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México Publicación Especial *8*, 1–11. Segura-Puertas, L., Suárez-Morales, E., and Celis, L. (2003). A checklist of the medusae (Hydrozoa, Scyphozoa, and Cubozoa) of Mexico. Zootaxa *194*, 1–15. Segura-Puertas, L., Franco-Gordo, C., Suaréz-Morales, E., Gasca, R., and Godínez-Domínguez, E. (2010). Summer composition and distribution of the jellyfish (Cnidaria: Medusozoa) in the shelf area off the central Mexican Pacific. Revista Mexicana de Biodiversidad *81*, 103–112.
Staurozoa [Claudia Mills, Allen Collins]	**Described** Total described: 48 species **Nominal** 63 (as reflected in recent updates to WoRMS). **Undescribed, collected** Min-max: 10–12 species. **Undiscovered** Min-max: 30–50 species. It seems to me a fair estimate of undiscovered Stauromedusae is to double the present "about 50" to about 100 to be expected in the course of science as we know it. Certainly the last decade has indicated that new Stauromedusae just aren't that hard to find yet. **Cryptic** Min-max: 0–3 based on preliminary data from six species showing no indication for any cryptic species.
Ctenophora [Claudia Mills, Allen Collins]	**Described** 190, although I doubt if they are all good, but no one has revisited most of the described species. **Nominal** ~250 (255 including fossil species). **Undescribed, collected** Min-max undescribed: 25–50. Those of us who know the deep sea undescribed species continue to talk about writing descriptions, but we haven't done any yet. Steve Haddock is doing a molecular phylogeny as he gets the opportunity — many of his "species" for this phylogeny are undescribed. There remain perhaps one-third of the described species (a wild guess) that we don't know whether or not they are real and I've seen a manuscript this week that will extinguish one of those. Ctenophore taxonomy is not a very active field, although there are a few of us on the sidelines thinking about it. **Undiscovered** The amount of open ocean that has been searched amounts to some small "pencil lines" of transects, and we continue to easily find undescribed

	species. So I would ballpark the estimate of undiscovered new species of Ctenophores, as I did with the Stauromedusae, as about double what we know now, which translates to about 100–250 undiscovered morphospecies. **Cryptic** Min-max cryptic: 0–10 species (a wild guess that it is low).
Cycliophora [Reinhardt Møbjerg Kristensen]	**Described** 2 species. **Nominal** 2 species. **Undescribed, collected** 3 species. **Undiscovered** 10–125 if all clawed lobsters have Cycliophora?
Asteroidea [Christopher Mah]	**Described** 1,922 species (based on WoRMS). I find this pretty reasonable **Nominal** 5,549 species (based on WoRMS). **Undescribed, collected** Based on my museum sampling over the last few years approximately 125–200 specimens are undescribed new species. Especially in the Goniasteridae. **Undiscovered** 20–25% of Goniasteridae species were described in the last 10 years. 25% of the genus level diversity. Based on this and estimates from the new species in collections, approximately 10 to 25% may remain to be discovered. This estimate is much higher if you factor in considerations of cryptic species uncovered by DNA population studies. The monotypic Acanthaster planci has been interpreted as being composed of up to 3 or 4 species based on recent phylogeography studies. Other widely discovered taxa may show similar hidden diversity.
Echinoidea [Andreas Kroh, Rich Mooi]	**Described** 999 valid extant species (Kroh & Mooi, 2011). Estimating the number of known echinoid species was relatively straightforward, it is based on the number of species considered valid by Mortensen (1928–1950), plus those described after completion of the last volume of his Monograph. The latter were based on data taken from Kier & Lawson (1978) for period of 1951–1970, and Kroh (2010) for the years 1971–2008. Additionally, online and offline resources were scanned for extant echinoid species described in 2009 and 2010. For the purpose of the present estimate, subspecies were excluded, thus possibly underestimating true echinoid biodiversity. An up-to-date classification of the Echinoidea and a list of currently accepted genera can be found in Kroh & Smith (2010). **Nominal** Currently 1598 extant nominal echinoid taxa (accepted + unaccepted) are

	recorded in our database (Kroh & Mooi, 2011). Although additional disused 19th century species continue to be occasionally found, most are now included. Please note that this differs from the number of different names under which echinoids have been cited (*i.e.*, different combinations), which amount to about 3,000 names. **Undescribed, collected** This may range from 20 to 50. Based on a survey of a number of recent papers describing new extant echinoid taxa, it seems likely that up to 30 % of the taxa yet to be described are already present in the collections. **Undiscovered** This may range from 45 to 150. To estimate the number of species yet to be discovered is fraught with difficulties. Here the discovery rate of extant echinoid species during the last 60 years was calculated by polling the number of species established in each decade and comparing subsequent decades with each other. This results in a mean discovery rate of 0.92, indicating that a lot of extant echinoids are still being discovered. Using this rate to model future taxon discovery results in 110 species of extant echinoids still to be discovered, 90% of which are expected to be described till the year 2250. It has to be cautioned, however, that the variance of the discovery rate during the last 60 years is high for extant echinoids and that these figures are only crude estimates. Additionally, being a small group, both in terms of species and research community, any intense single person effort is bound to drastically affect future discovery rates, much like Mortensen's work on the Monograph of Echinoidea (1928–51) strongly increased discovery rates and accounted for about 60 % of all newly discovered species during that period. Mortensen alone described about one fifth of all accepted extant echinoid species. **Cryptic species** Investigation on this issue is just starting in echinoids and the estimates presented below thus poorly constrained. About a third of the extant echinoid species examined hold complexes (pers. comm. Gustav Paulay, 24.1.2011). In the studies on *Echinometra*, the only taxon investigated in relation to cryptic speciation in echinoids, three cryptic species were discovered, out of 8 morpho-species in that taxon. Based on this I would estimate importance of cryptic speciation as low to moderate in echinoids, *i.e.*, 1 to 3 cryptic species per morph-species holding species complexes. Calculation used to estimate number of cryptic species: Min. cryptic species = 1135 (min. morpho-species) * 0.3 (percentage of echinoid species supposed to harbor complexes) * 1 (min. est. no. of cryptic species per morph-species holding species complexes) = 306 Max. cryptic species = 1270 (max. morpho-species) * 0.3 (percentage of echinoid species supposed to harbor complexes) * 3 (max. est. no. of cryptic species per morph-species holding species complexes) = 1,080 (Basis: No. of morpho-species (min-max): 1020–1200 [known + unknown]) **References** Kier, P.M., and Lawson, M.H. (1978). Index of living and fossil echinoids 1924–1970. Smithsonian Contributions to Paleobiology *34*, 1–182. Kroh, A. (2010). Index of Living and Fossil Echinoids 1971–2008. Annalen des Naturhistorischen Museums in Wien, Serie A *112*, 195–470.

	Kroh, A., and Mooi, R. (2011). The World Echinoidea Database – Version 2.0. Available online at http://www.marinespecies.org/echinoidea [accessed 2012–01–22]. Kroh, A., and Smith, A.B. (2010). The phylogeny and classification of post-Palaeozoic echinoids. Journal of Systematic Palaeontology *8*, 147–212. Mortensen, T. (1928). A Monograph of the Echinoidea. I. Cidaroidea. C. A. Reitzel & Oxford University Press, Copenhagen & London, 551 pp. Mortensen, T. (1935). A Monograph of the Echinoidea. II. Bothriocidaroida, Melonechinoida, Lepidocentroida, and Stirodonta. C. A. Reitzel & Oxford University Press, Copenhagen & London , 647 pp. Mortensen, T. (1940). A Monograph of the Echinoidea. III, 1. Aulodonta, with Additions to Vol. II (Lepidocentroida and Stirodonta). C. A. Reitzel, Copenhagen, 370 pp. Mortensen, T. (1943). A Monograph of the Echinoidea. III, 2. Camarodonta. I. Orthopsidæ, Glyphocyphidæ, Temnopleuridæ and Toxopneustidæ. C. A. Reitzel, Copenhagen, vii+553 pp. Mortensen, T. (1943). A Monograph of the Echinoidea. III, 3. Camarodonta. II. Echinidæ, Strongylocentrotidæ, Parasaleniidæ, Echinometridæ. C. A. Reitzel, Copenhagen, 446 pp. Mortensen, T. (1948). A Monograph of the Echinoidea. IV, 1 Holectypoida, Cassiduloida. C. A. Reitzel, Copenhagen, 371 pp. Mortensen, T. (1948). A Monograph of the Echinoidea. IV, 2. Clypeasteroida. Clypeasteridæ, Arachnoidæ, Fibulariidæ, Laganidæ and Scutellidæ. C. A. Reitzel, Copenhagen, 471 pp. Mortensen, T. (1950). A Monograph of the Echinoidea. V, 1. Spatangoida I. Protosternata, Meridosternata, Amphisternata I. Palæopneustidæ, Palæostomatidæ, Aëropsidæ, Toxasteridæ, Micrasteridæ, Hemiasteridæ. C. A. Reitzel, Copenhagen, 432 pp. Mortensen, T. (1951). A Monograph of the Echinoidea. V, 2. Spatangoida II. Amphisternata II. Spatangidæ, Loveniidæ, Pericosmidæ, Schizasteridæ, Brissidæ. C. A. Reitzel, Copenhagen, 593 pp.
Ophiuroidea [Sabine Stöhr]	**Described** 2,064 species (Stöhr, O'Hara & Thuy, 2012). **Nominal** >3,100 species names (Stöhr & O'Hara, 2011). **Undescribed, collected** 260–300 species have been putatively identified as undescribed by the leading experts. **Undiscovered** 200–400 species. The rate of species descriptions has been about 10 per year in the last decade, compared to twice that many during the most prolific time (1870–1940) of ophiuroid description. Description rates do however not decrease linearly over time as the number of species to discover declines. They also strongly depend on opportunity and personal interest of the respective researchers. In addition, species definitions change over time and any estimate of undiscovered species numbers can only be an indication of magnitude, rather than absolute numbers. **Cryptic**

	100–150. My estimate may be more conservative than what geneticists expect. Ophiuroids are less well studied than echinoids, with currently a small fraction of the number of sequences in GenBank than there are for echinoids. Published and still undergoing genetic studies suggest that some species are complexes of two or more species (Boissin *et al.*, 2011). However, there may be a selection bias, because certain groups are much more variable and difficult to understand than others and molecular studies tend to focus on these. Extrapolating from those groups will overestimate diversity. There is also a problem with definitions of cryptic species. Often, morphological (and other) differences are recognized when molecular data indicate separate lineages in a morpho-species, resulting in the delimitation of two morpho-species (Stöhr & Muths, 2010). These are then no longer cryptic and probably never where, just understudied and unrecognized. Therefore the terms undiscovered and cryptic species overlap and should be viewed together. **References** Boissin, E., Stöhr, S., and Chenuil, A. (2011). Did vicariance and adaptation drive cryptic speciation and evolution of brooding in *Ophioderma longicauda* (Echinodermata: Ophiuroidea), a common Atlanto-Mediterranean ophiuroid? Molecular Ecology *22*, 4737–4755. Stöhr, S., and Muths, D. (2010). Morphological diagnosis of the two genetic lineages of *Acrocnida brachiata* (Echinodermata: Ophiuroidea) with description of a new species. Journal of the Marine Biology Association U.K. *90*, 831–843. Stöhr, S., and O'Hara, T. (2011). World Ophiuroidea database. Available online at http://www.marinespecies.org/ophiuroidea Stöhr S., O'Hara T.D., and Thuy, B. (2012). Global diversity of brittle stars (Echinodermata: Ophiuroidea). PLoS ONE *7*, e31940. doi:10.1371/journal.pone.0031940.
Crinoidea [Charles Messing]	**Described** My best estimate of the number of living crinoids is 623, although I expect quite a number to be synonymized and at least a few to be separated from within named taxa. **Nominal** I estimate around 300 synonyms exist (not including nomina nuda and misspellings). **Undescribed, collected** I currently have 5 undescribed species in my possession, but I have no good idea what might be lying about in museum collections (especially in Paris). **Undiscovered** I expect between at least 50 and 100 crinoid species remain to be discovered. New species and genera continue to be found on a regular basis, particularly from deep water. The known crinoid fauna of the tropical western Atlantic numbers approximately 55 species (the status of a few subspecies remains uncertain), with the great majority described before 1950. However, during a 10-day submersible cruise to the Bahamas in 2009, I found what appear to be four new crinoid species chiefly in ~600 m depth, which increases the regional fauna by 7%.
Holothuroidea	**Described**

[Gustav Paulay]	Number of accepted species: Bit fuzzy, as synonymies vary and some are old. In the database I have there are ~1710–1740 accepted names depending on how you cut it (and considering some unchecked things). I suspect this is an overestimate and once I trace the fate of a number of these the real number will be closer to 1,600. Data from WoRMS: 1,683 valid marine holothuroid species. **Nominal** 2,347 available names at present and this is probably pretty close. Does not include nomina nuda, suppressed names, or any not-available name. **Undescribed, collected** No good estimate possible. Cryptic species are a huge issue, collections are full of them, but they need to be tested genetically as often there are no discernible morphological differences in preserved specimens. This is presently difficult at best for old specimens. In terms of morphologically recognizable species, I would guess about 200–400 are in collections, but I have not seen some of the largest collections, so this is a bit of a wild guess. **Undiscovered** We are finding cryptic species to be a huge issue, especially in deep sea material. I would guess at least as many species remain undiscovered as have been described, but this estimate is very poorly constrained.
Echiura [John Pilger]	**Described** Presently the number of described and accepted echiuran morphospecies is 175. However, many descriptions are incomplete or ambiguous so the number could vary considerably after a thorough review of types. **Nominal** I estimate 29 synonyms and 7 as *incertae sedis*. **Undescribed, collected** Based on my personal collection and discussions with others I estimate that there are 5–10 collected but undescribed species. **Undiscovered** I estimate that roughly 70–80% of the species have discovered. Based on the number of described and accepted species, 175, there could be 35–50 species that are undiscovered. In the past, when there were more people studying echiurans, specific collecting expeditions were conducted. More recently echiurans are discovered incidental to regional and site-specific benthic surveys.
Entoprocta [Claus Nielsen, Tohru Iseto]	**Described** There are 143 valid names in the Loxosomatidae. Colonial forms: about 50 valid names. **Nominal** About 5 Loxosomatidae are synonyms and about half of the colonial forms are probably synonyms. **Undescribed, collected** Tohru has about 30 undescribed species in his collection.

	Undiscovered Our conservative guess is 1,000 undiscovered species (but the number may well be higher). **Cryptic** There is no evidence (no basis for judgment) for cryptic speciation in the Entoprocta.
Gastrotricha [Antonio Todaro; William Hummon	**Undescribed, collected** About 310 (this number includes information from Antonio Todaro (96 spp), William Hummon (180 spp) and other 5 colleagues active on marine Gastrotricha (collectively 36 spp). **Undiscovered** These estimates (based on morphology) come out considering: a) several new species are still found in areas quite well sampled (Mediterranean-Italy and northern Europe); b) 200 undescribed species are known from areas that have barely been sampled: Middle Atlantic, Hawaii, North Carolina, New England, the Pacific Coast of US and the Middle East. In this areas the number of present species can be doubled easily *e.g.,* sampling different habitats; c) there are many other places on the earth that have not been sampled at all. From my experience (Brazil and Kuwait) 80% of species collected in new areas are new to science. **Cryptic** Cryptic genetic diversity (in known species) may range from 56 to 81%. These last estimates come from the following reasoning: (1) so far there are only two studies in this regard, both carried out by me and co-workers. (2) The first study (based on the mitochondrial COI and RFLPs analysis) indicated that 3 populations of the transatlantic *Xenotrichula intermedia* may in fact be four cryptic species. The other very recent study, based on comparisons of sequences of the mitochondrial COI, indicated that four putative populations of *Turbanella cornuta* from the North Sea, Tyrrhenian sea, Adriatic sea and Persian Gulf are in fact four different species (p-distance: intrapopulation < 2%, inter-population >15%). The take home message from these studies is: species known to have a wide geographic range are in fact species complexes; the number of species of these complexes varies depending on taxon and amplitude of its putative range. Considering that about 15–20% of the known marine gastrotrich species are anphiatlantic and/or regional cosmopolitans, and estimating that each of these taxa may be composed in average of 4 species (a different species for each basin) we'll get the following number of cryptic species added to the total unknown figure: 1,310 * 0.15 * 3= ~500 1,810 * 0.20 * 3= ~1,000 **References** Todaro, M.A., Fleeger, J.W., Hu, Y.P., Hrincevich, A.W., and Foltz, D.W. (1996). Are meiofauna species cosmopolitan? Morphological and molecular analysis of *Xenotrichula intermedia* (Gastrotricha:

	Chaetonotida). Marine Biology *125*, 735–742. Dal Zotto, M., Ghiviriga, S., Kånneby, T., Jondelius, U., and Todaro, M.A. (2010). Probing Gastrotricha taxonomy with DNA barcoding. Proc. XIV International Meiofauna Conference, Gent 12/15 July 2010.
Gnathostomulida [Wolfgang Sterrer]	**Described** 98 species (latest addition by Sterrer 2011). **Nominal** 98+11=109 species names. **Undescribed, collected** 15–20 species. **Undiscovered** 200 species. Over the past decade, my collecting (Sterrer, in prep.) on Indo-Pacific coasts (from S. Africa to Red Sea, Hong Kong, Japan, NW America and Galapagos) will bring the total number of species known from the Indo-Pacific from 38 to 74 species, including 18 species new to science. **Cryptic** No basis for judgement. **References** Sterrer, W. (2011). Two species (one new) of Gnathostomulida (Bursovaginoidea: Conophoralia) from Barbados. Proc. Biol. Soc. Washington *124*, 141–146.
Hemichordata [Billie Swalla, Noa Shenkar, Chris Cameron]	**Described** The final number of Hemichordate species described now is 118 species. However, this number represents only a small portion of the true richness of hemichordate species, and reflects the low sampling effort invested in this group (Cannon *et al.*, 2009). The number of undiscovered and undescribed species is high, probably at least 500, if not over 1,000. Recent deep sea expeditions have found a number of new species in the recently described family Torquaratoridae (Osborn *et al.*, 2011) and many more species are being described from the extensive Bullock collections by Chris Cameron and colleagues (Cameron *et al.*, 2010; Deland *et al.*, 2010). Interesting points from mapping the biogeography of hemichordates: 1) The striking low numbers of hemichordates from tropical waters, an environment that represents the highest marine biodiversity suggest that many new species remain to be discovered, and 2) The high number of species described based on a single specimen and a single site. **Nominal** In the Hemichordata there are only few cases of synonymy in comparison to other marine groups (less than %10). More cases of synonym may be revealed in the future by combining molecular methods with classic morphological parameters (*e.g.*, the case of *Saccoglossus kowalevskii* and *S. bromophenolosus*, King *et al.*, 1994). **Undescribed, collected** Dr. Chris Cameron from the University of Montreal in Canada is describing the extensive enteropneust collection from the deceased Dr. Theodore

	Bullock at Scripps Institute (Cameron *et al.*, 2010; Deland *et al.*, 2010). Osborn *et al.* (2011) described 4 new genera (A-D) of the deep sea family Torquaratoridae, that is a sister clade to the Ptychoderidae. They also reported 18 undescribed enteropneust species from their recent expeditions, suggesting that there is a large diversity of deep sea hemichordates. Noa Shenkar reports a collection stored at the National Collections of Natural History at Tel Aviv University, Israel. This collection includes a wide variety of samples from different Red Sea expeditions and Mediterranean coasts surveys. The few hemichordate specimens (<10 jars) are not identified to species levels. Dr. Billie Swalla at the University of Washington has a collection of several undescribed enteropneust worms and also a collection of tornaria larvae that are being sequenced and described morphologically. **References** Cameron, C., Deland, C., and Bullock, T. (2010). A revision of the genus *Saccoglossus* (Hemichordata: Enteropneusta: Harrimaniidae) with taxonomic descriptions of five new species from the Eastern Pacific. Zootaxa *2483*, 1–22. Cannon, J.T., Rychel, A.L., Blasczyk, H., Halanych, K.M., and Swalla, B.J. (2009). Molecular phylogeny of Hemichordata. Mol. Phylo. Evolution *52*, 17–24. Deland, C., Cameron, C., Rao, K., Ritter, W., and Bullock, T. (2010). A taxonomic revision of the family Harrimaniidae (Hemichordata: Enteropneusta) with descriptions of seven species from the Eastern Pacific. Zootaxa *2408*, 1–30. King, G.M., Giray, C., and Kornfield, I. (1994). A new hemichordate, *Saccoglossus bromophenolosus* (Hemichordata: Enteropneusta: Harrimaniidae) from North America. Proceedings of the Biological Society of Washington *107*, 383–390. Osborn, K.J., Kuhnz, L.A., Priede, I.G., Urata, M., Gebruk, A.V., Holland, N.D. (2011). Diversification of acorn worms (Hemichordata, Enteropneusta) revealed in the deep sea. Proc R. Soc. Biol. 279, 1646-1654.
Mesozoa (Orthonectida, Dicyemida) [Hidetaka Furuya]	**Described** 134, data based on WoRMS **Nominal** Only 1%. **Undescribed, collected** We have at least 40 and maximum 50 undescribed species in our collections now. **Undiscovered** Roughly estimated, there are at least 1,000, maximum 1,500 species in total. In Japanese waters, we may find the maximum of 100 species. Similar waters are counted from 10 to 15 in the world. **Cryptic** May count for 100–500 species.
Bivalvia	**Described**

[Gary Rosenberg]	At the moment WoRMS has 8,081 accepted species of bivalves. From this should be subtracted 27 fossil only and 35 freshwater only, and at least 100 duplicates (judging from remaining non-checked items that have Chemnitz as author or lack authority altogether). So we take 7,900 valid species in WoRMS as the basis for estimating number of bivalve species. Regarding how many Tellinidae and Galeommatidae are missing: galeommatids comprise 11.5% of the New Caledonian bivalve fauna in Bouchet *et al.* (2002) and tellinids 9.8%. The ratio of those two groups to other bivalves is 111/408 = 27%. WoRMS already has 301 accepted tellinids and 409 accepted galeommatoids. If we subtract those from 7,900 we get about 7,200 bivalve species. If we then add 27%, we get an estimate of 9,144 species. However, the New Caledonia figures include undescribed species, which for galeommatoids in particular biases the result to be too high. In the Japanese fauna, based on Higo, Callomon & Goto (1999), galeommatoids are 4.8% and tellinids 6.7%, or 168/1304 = 13%. This gives an estimate of 8,136 species. In the Eastern Pacific fauna using Keen 1971 gives 116/676 = 17%, which estimates 8,424 species. If we allow for a generous 10% missing in the latter figure, the estimate would be 9,266. Given the uncertainties involved, the estimate should have only one significant digit, so the choice is between 9,000 or 10,000. The evidence we have suggests that 9,000 is closer to the mark. **Reference** Bouchet, P., Lozouet, P., Maestrati, P., and Heros, V. (2002). Assessing the magnitude of species richness in tropical marine environments: exceptionally high numbers of molluscs at a New Caledonia site Biol. J. Linn. Soc. *75*, 421–436. Higo, S., Callomon, P., and Goto, Y. (1999). Catalogue and Bibliography of the Marine Shell-bearing. Mollusca of Japan. 749 pp.
Caudofoveata [Oscar Garcia-Alvarez, Philippe Bouchet]	**Described** 133 species (data in WoRMS). **Nominal** 145 species (data in WoRMS). **Undescribed, collected** We have 5 unstudied new species. It is difficult to say but at least another 10–15 more species (Philippe Bouchet prefers to put a question mark). **Undiscovered** Oscar believes approximately 65% is still not known of Caudofoveata. However, Philippe estimates 500 undiscovered spp.
Gastropoda [Serge Gofas, Gary	**Described** A complete list of gastropod species is not yet available, and estimates are

Rosenberg]	based on a gastropod/bivalve ratio. In Bouchet *et al.* (2002), the ratio was found to be 4.2:1. With 9,000 bivalves, there would be 37,800 gastropods. For estimates for all taxa, it would probably better to give a range than a single number, *e.g.*, 36,000 +/- 4,000. Note that there are thousands of names listed as valid even though no one has studied them for 100 years. Many of them could have been marked as species inquirenda. **Undiscovered** Based on the following "hard" data: • Bouchet, Heros, Lozouet & Maestrati (2008): All deep-water papers in the MNHN cruises, 743 new species representing half of total studied (in "large" families *e.g.*, Muricidae, Tonnoideans...) • Peñas & Rolán (2010): Pyramidellidae (Turbonillini) 239 identified species, 209 new to science (87%) in a size range < 10 mm • Peñas & Rolán (submitted): Pyramidellidae (Chrysallidini) 235 identified species, 214 new to science (91%) in a size range < 10 mm • Bouchet, Heros, Lozouet & Maestrati (2002): 51,91% (about half) of species are less than 8.7 mm so same size-range as Pyramidellidae (their figure 4). This can be extrapolated to some extent. To be refined, we would need to know the ratio of "deep" versus shelf/shore species but to start with we could assume equivalent numbers. We also have to assume that the size ratios nearshore are equivalent to those in the deep. Next, to assume that the ratio of undescribed depends on size. Then, considering 40,000 known Gastropods, this would give: In the "deep" realm: 20,000 known species of which 10,000 "large" known by 50% and 10,000 "small" known by 10% so (20,000 total known + 10,000 unknown "large" + 90,000 unknown "small"): total estimated 120,000. In the "shallow" realm, the "unknown number could be anything between 0 and 50% so the most conservative estimate (assuming everything known) would give 120,000 to 140,000 gastropod species overall. **References** Bouchet, P., Lozouet, P., Maestrati, P., and Heros, V. (2002). Assessing the magnitude of species richness in tropical marine environments: exceptionally high numbers of molluscs at a New Caledonia site Biol. J. Linn. Soc. *75*, 421–436. Bouchet, P., Héros, V., Lozouet, P., and Maestrati, P. (2008). A quater-century of deep-sea malacological exploration in the South and West Pacific: Where do we stand? How far to go? In: Héros V., Cowier, R.H. & Bouchet, P. (eds.), Tropical Deep-Sea Benthos 25.- Mémoires du Muséum National d'Histoire Naturelle, Paris 196, 9–

	40. Peñas, A., and Rolán, E. (2010). Deep water Pyramidelloidea of the tropical South Pacific: Turbonilla and related genera. Mémoires du Muséum national d'Histoire naturelle (1993), 200. Publications Scientifiques du Muséum: Paris. ISBN 978-2-85653-642-1. 436 pp.
Polyplacophora [Enrico Schwabe]	**Described** Should be 930. **Nominal** c. 1,950. **Undescribed, collected** I may only estimate this roughly from what I saw. It's difficult as I do not know all institutions. I guess there might be additional 50 species (also taken species into account, which occur in my database as Genus sp.) **Undiscovered** This is even more difficult, as usually no quantitative sampling efforts were undertaken to collect chitons. Fact is that intensive collection in different regions (even well examined) often yield new species, but depending on the environment the number may differ considerably. Unexplored deep-water regions may provide a higher number, than shallow water regions. Having a quick look on what was ongoing during the last decade, I guess we speak also of about 50–100 new species, but as explained before is more a belly-feeling rather a statistic base.
Scaphopoda [Victor Scarabino]	**Described** 572 species (data: WoRMS up to 2012–1–20, http://www.marinespecies.org/aphia.php?p=taxdetails&id=104) **Nominal** Steiner & Kabat (2004) consider 517 (recent) valid species, 311 synonyms and other combinations. Studies carried on after 2004 (2, 3, 4, 5, 6, 7, 8) new combinations and synonyms were submitted, and 63 new spp. were described, reaching to 572 valid species. **Undescribed, collected** 55 species, most at the care in the collections of the MNHN and in the NMNH are identified as new (12 Dentaliida and Gadilida 43, (VS mid-2011). **Undiscovered** Even that sounds ambitious, in my opinion, 500 species is a coherent number. This assumption is based on the lack of updated records from large ocean areas, such as the western and central Indian Ocean, the tropical eastern Pacific and in deep-water realms around the world (most of the Scaphopoda distributes in the slope to abyssal environments, ± 66%, based on live records confirmed in several institutional collections (VS pers obs). **Cryptic** I prefer to state "no evidence / lack of information." Evidence could be available after processing of materials ready for barcode studies (mainly at the care of MNHN).

	References Caetano, C.H.S., Scarabino, V., and Absalao, R. (2006). Scaphopoda (Mollusca) from the Brazilian continental shelf and upper slope (13º to 21ºS) with descriptions of two new species of the genus *Cadulus* Philippi, 1844. Zootaxa *1267*, 1–47. Caetano, C.H.S., Scarabino,V., Absalao, R.S. (2010). Redescoberta de *Gadila elongata* comb. nov. (Mollusca, Scaphopoda, Gadilidae) e morfometria da concha para as espécies do gênero *Gadila* ocorrentes no Brasil. Zoologia *27*, 305–308. Scarabino, V. (2008). New species and new records of scaphopods from New Caledonia, in Héros, V., Cowie R. H. & P. Bouchet (eds), Tropical Deep-Sea Benthos 25. Mémoires du Muséum national d'Histoire naturelle *196*, 215–268. Scarabino, V., and Caetano, C.H.S. (2008). On the genus *Heteroschismoides* Ludbrook, 1960 (Scaphopoda: Gadilida: Entalinidae), with descriptions of two new species. The Nautilus *122*, 171–177. Scarabino, V., and Scarabino, F. (2010). A new genus and thirteen new species of Scaphopoda (Mollusca) from the tropical Pacific Ocean. Zoosystema *32*, 409–423. Scarabino, V., and Scarabino, F. (2011). Ten new bathyal and abyssal species of Scaphopoda from the Atlantic Ocean. The Nautilus *125*, 127–136. Scarabino, V., Caetano, C.H.S., and Carranza, A. (2011). Three new species of the deep-water genus *Bathycadulus* (Mollusca, Scaphopoda, Gadilidae). Zootaxa *3096*, 59–63. Steiner, G., and Kabat, A.R. (2004). Catalog the names of the groups of fossil and recent species Scaphopoda (Mollusca) Zoosystema *26*, 549–726.
Solenogastres [Oscar Garcia-Alvarez]	**Described** 263 species (7 with doubts). **Nominal** 335 species names (263 accepted species + 72 synonyms). **Undescribed, collected** I know directly 18 species; it is difficult to say but at least another 20–30 more species. **Undiscovered** If we suppose, as is indicated in the literature, that still around 60% of the diversity in solenogastres is not known, than we would have 320–480 species unknown.
Myxozoa [Stephen W. Feist, Matt Longshaw	**Described** The most recent review of myxozoan genera was compiled by Lom & Dyková (2006). To that date a total of 2,180 myxosporean species, belonging to 62 genera were recognized. Of these 37 genera were regarded as exclusively marine with a further 8 genera containing species infecting marine and freshwater fish species, the remainder being exclusively freshwater. Since 2006, several new myxosporean genera have been erected following the discovery of previously undescribed species (at least 4) but each genus contains only the single type species. The current estimated

	number of described marine myxosporeans is 700. **Nominal** For several myxosporean genera, for example *Myxobolus* (approximately 800 species reported in the literature), there is increasing evidence of widespread synonomy between species. For this predominantly freshwater genus this appears to be particularly prevalent but there have been insufficient molecular studies to confirm. However, most genera of marine myxosporeans contain fewer than 60 species with several genera containing a single type species. Including synonyms it is estimated that there are approximately 750 marine myxosporeans. **Undescribed, collected** There are few collections of marine myxosporeans awaiting descriptions although several researchers around the world will have obtained material of a few species. Estimates for these based on contacts from scientific networks such as http://www.myxozoa.org/ suggest that there are relatively few undescribed species already collected, perhaps fewer than 100 with a maximum of 250. **Undiscovered** The number of undiscovered species is certain to be substantial. Only a small percentage of the available hosts, *i.e.*, all fish species and potentially marine reptiles, have been investigated and many geographic areas such as the polar regions, deep sea environments, Middle East are practically uninvestigated for myxosporean species. It is reasonable to suggest that on the basis of numbers of fish hosts alone at least 30–40% are likely to harbor species new to science. This could equate to between 6,300 to 8,400 species (assuming 21,000 known and unknown marine fish species). **Cryptic** As for 'cryptic diversity', we estimate this as being low, between 1 and 5%. **References** Lom, J., and Dyková, I. (2006). Myxozoan genera: definition and notes on taxonomy, life-cycle terminology and pathogenic species. Folia Parasitologica *53*, 1–36.
Nematoda (free-living) [Jan Vanaverbeke]	**Described & nominal** 6,900 and 710 synonyms based on NeMYS (Deprez *et al*., 2005). **Undescribed, collected** Unknown. **Undiscovered** The most recent estimates of marine nematode species numbers very between 10,000–20,000 species (Mokievsky & Azovsky, 2002) and 10^5 – 10^6 (Lambshead & Boucher, 2003). The method in Mokievsky & Azovsky (2002) is a rough calculation based on extrapolating alpha-diversity within relatively small plots (by species-specimen relations or rarefaction procedures), taking into account the effects of area, biotope and historical-geographical processes). Lambshead & Boucher's (2003) estimate is based on 21 cores of five stations along a N-S transect in the Pacific. When the species-accumulation curve up from north to south, they come to 10 million, and from south to north to 100, 000. This is caused by a productivity

	gradient, which affects the shape of the curve. In addition, Lambshead & Boucher (2003) mention that about 30–40% of the nematode species encountered in European waters are new to science. On the very well studied Belgian Part of the North Sea (surface: 3600 km², 74 sampling stations), 443 species were identified and 52 new species were recorded. (Vanaverbeke, pers. comm.). In less investigated coastal areas, the amount of undiscovered species is even higher. In a recently finished PhD on Vietnamese mangrove systems, Nguyen (2009) found 115 species; about 40% could not be fully identified and are probably new to science. In Cuban coastal waters, a recent survey resulted in 4 nematode genera new to science, on a total of about 80 genera recorded during the survey (Armenteros, 2009). In addition to this, it is well accepted that nematode diversity in the deep sea is far from known due to lack of basic taxonomic studies (Fonseca *et al.*, 2006). In conclusion, 10–20,000 seems too conservative, and >1,000,000 too high. Considering the high dispersal and survival of nematodes in poor conditions, 50,000 could well be right. Anyway, all this suggests that the actual number of described free-living marine species does not at all cover the amount of species that can be encountered in marine sediments. **Cryptic** Besides Derycke *et al.* (2008) almost nothing is known on cryptic diversity in nematodes. This paper discovered many cryptic species in *Pelioditis marina* in the Westerscheldt, but it is impossible to scale this up to all the remaining (cosmopolitan) species. **References** Deprez, T. *et al.* (2005). NeMys. World Wide Web electronic publication. www.nemys.ugent.be, version (12/2011). Nguyen, D.T. (2009). Seasonal and spatial patterns in meiofauna community structure of the Can Gio mangrove forest (Vietnam) with a focus on nematoda and their role as bioindicator. PhD thesis, Ghent University, 242 pp. Armenteros, M. (2009). Ecology and taxonomy of free-living marine nematodes from Cienfuegos Bay, Caribbean Sea. PhD thesis, Ghent University, 204 pp. Mokievskey, V., and Azovsky, A.I. (2002). Re-evaluation of species diversity patterns of free-living marine nematodes. Mar. Ecol. Prog. Ser. *238*, 101–108. Fonseca, G., Decraemer, W., and Vanreusel, A. (2006). Taxonomy and species distribution of the genus *Manganonema* Bussau, 1993 (Nematoda: Monhysterida). Cah. Biol. Mar. *47*, 189–203. Lambshead, P.J.D., and Boucher, G. (2003). Marine nematode deep-sea biodiversity – hyperdiverse or hype? Journal of Biogeography *30*, 475–485. Derycke, S., Fonseca, G., Vierstraete, A., Vanfleteren, J., Vincx, M., and Moens, T. (2008). Disentangling taxonomy within the *Rhabditis* (*Pellioditis*) *marina* (Nematoda, Rhabditidae) species complex using molecular and morphological tools. Zool. J. Linn. Soc. *152*, 1–15.
Nemertea [Jon Norenburg]	**Described** 1,275 species as of Kajihara *et al.* (2008). About 1,285 now. **Nominal**

	My best estimate is 1,600 marine species (actual count is 1,604 but the margin of error could be as much as 25, or more). **Undescribed, collected** Min-max: 200/400. **Undiscovered** Min-max: 500/1000. **References** Kajihara, H., Chernyshev, A.V., Sun, S.-C., Sundberg, P., and Crandall, F.B. (2008). Checklist of nemertean genera and species published between 1995 and 2007. Spec. Diver. *13*, 245–274.
Phoronida [Christian Emig]	**Described** 18 species, of which 10 adults and 8 larval species. **Nominal** 41 species names, of which 25 adults and 16 larval species. **Undescribed, collected** None. **Undiscovered** Probably none.
Placozoa [Bernd Schierwater]	**Described** 1 species. **Nominal** 1, *Trichoplax adhaerens* (but see below for different view). **Undescribed, collected** Genetic data, particularly from the mitochondrial 16S gene (published) as well as from ND1, CO1, and ITS1–2 (unpublished), suggests substantial diversification is present within Placozoa. The number of distinct haplotypes reported for this marker has risen to 18. The relationship between these divergences and species differences is still unknown, primarily due to a lack of documented morphological divergences, but a conservative estimate would be that at least 18 species corresponding to 8 well-supported relatively deeply diverging clades exist within Placozoa. A reasonable estimate for the maximum number of known undescribed species would be 18, the number of distinct 16S haplotypes known. This is because whole genome sequencing and ultra-morphology studies have revealed distinct differences even between the two most closely related known 16S haplotypes. The first identified morphological differences between *Trichoplax adhaerens* and the closely related haplotype H2 (Guidi *et al.*, 2010) will soon lead to a description of a second placozoan species. A formerly reported species, *Trichoplax reptans*, was insufficiently described, never found again and its existence must be doubted. **Undiscovered** Considerable uncertainty would exist about the total species richness of Placozoa, but Eitel and Schierwater (2010) estimate that the number of 16S haplotypes could total anywhere from several dozen to “in the hundreds”,

	based on the relationship between sampling sites and haplotypes uncovered. Keeping in mind that the relationship between 16S haplotypes and species is still unknown, one might roughly guess that the number of undiscovered species could range anywhere from perhaps 10 to more than 100. Differences between the genomes and the ultrastructures of epithelia cells of the most closely related 16S haplotypes suggest that all currently known haplotypes represent different species. Unfortunately, sharp ecological differences between different haplotypes and clades hinder straightforward culturing and examination of the different lineages and make resolving placozoan systematics a burdensome and slow process. **Cryptic** For Placozoa all new species are "cryptic species" and they can yet only be identified by genetics. **Reference** Eitel, M., and Schierwater, B. (2010). The phylogeography of the Placozoa suggests a taxon rich phylum in tropical and subtropical waters. Molecular Ecology *19*, 2315–2327.
Monogenea [David Gibson]	These estimates are, judging from the published estimates in local areas, based on the number of fish species still unexamined and the average number of parasites on each examined fish species. **Cryptic** Any evidence comes from freshwater taxa. On the marine side, lots of new species are currently being described based on minuscule differences in the copulatory and other hardparts. Such work, which usually occurs after genetic differentiation, likely reduces the number cryptic species. So a complete guess on my part would be 500–5,000.
Digenea [Thomas Cribb]	**Described** There are probably in the vicinity of 6,000 species described. I know of over 4,000 from marine (or brackish) fishes and my records are not complete. So to allow for the species I do not have and those from other host groups (all much less important than fishes), I think 6,000 species would be reasonable. **Nominal** I would add 1500 species for synonyms. **Undescribed, collected** Perhaps 600 species. **Undiscovered** 4000–8500 species. I think that undiscovered species can double the present number. Even well-studied places like the Mediterranean still produce new species regularly and there are still very large numbers in my part of the world. **Cryptic** 400–900 undiscovered, not collected molecular cryptic species. I think 5–10% cryptic is a reasonable stab in the dark. The problem is not huge, but not insignificant either.
Catenulida	**Undiscovered**

[Tom Artois, Wolfgang Sterrer]	As to the number of undiscovered species, I think the number given by Wolfgang is realistic. I based myself on a personal communication with Karolina Larsson, who was unable to find a single specimen of marine catenulids during several years of sampling at the Swedish and the Belgian Coast. The number of undiscovered species of Catenulida is probably very few. Wolfgang estimates there are probably 20 species undiscovered.
Rhabditophora (excl. Neodermata) [Tom Artois, Marco Curini-Galletti]	**Described** Up to now, 2,641 valid species have been described. Counts are based on Tyler *et al.* (2006–2011) and a comprehensive literature survey. **Nominal** There are 261 subjective synonyms. The number of nominal species is, therefore, 2,902. The percentage of synonyms is 9%. **Undescribed, collected** The total number of already collected but yet undescribed rhabditophoran species lies between 500 and 700. **Undiscovered** For the estimate of the number of undiscovered species, we have used the division of the world's coastal areas into ecoregions as was proposed by Spalding *et al.* (2007). They recognise 232 ecoregions, and only from 80 of these localities, rhabditophorans are described. This means that species are known from 34% of the regions. In our experience, samplings in new regions, almost always result in a species list with between 80 and 100% of new species. So it is safe to suppose that 90% of the species found in a randomly chosen ecoregion which has never been sampled before is new to science. 2,641 species are known. Therefore, simple calculation leads to an estimate of 4,597 species still to be discovered. However, here we have taken the assumption that in the 80 ecoregions from which flatworm are known, all species that occur there are known (*i.e.,* that we know the entire turbellarian fauna from that ecoregion). We know this is absurd. Most of these ecoregions are very poorly sampled, most only once or twice, and then mostly only a limited amount of taxa were described (*e.g.,* only polyclads) and even in many very-well known regions as *e.g.,* the Western Mediterranean, up to 60% of the species collected are new to science. Furthermore, even in comparatively well known areas, samples have mostly, if not exclusively, been taken in shallow water habitats. The few records from deeper waters, or from marine caves, revealed species not present at shallower depths, casting doubts of the representativity of present, local census of rhabditophoran diversity. Thus, with the exception of the North Sea coast, the Baltic and the Swedish Coast, which are adequately known, for most of the already sampled ecoregions we think an (even conservative) estimate of 75% of undiscovered species in a random sampling campaign is a reasonable estimate. Following this assumption about sampled ecoregions and the 90% rule for unsampled regions explained above, this brings us to an estimate of 28,321species still to be described, which in our view is much more realistic then the 4,597 species of the first calculation. **Cryptic** Integrative taxonomy approach, combining morphological, molecular, karyological information, as well as cross-breeding experiments, has recently revealed that genera in the morphologically simple

	Monocelidinae(Proseriata: Monocelididae) include previously undected complexes of cryptic species – as in the cases of the *Pseudomonocelis ophiocephala* and *P. agilis* species complexes (Casu & Curini-Galletti, 2006; Casu *et al.*, 2009). The phenomenon may occur in other taxa of Proseriata, lacking or with 'simple' sclerotised structures of the copulatory organ. Such taxa, however, are comparatively few, and most proseriates have complex copulatory structures, which usually aid species discrimination. As to rhabdocoels, data are even less available than in proseriates. In the "species" *Gyratrix hermaphroditus* real cryptic speciation seems rampant (according to a large amount of molecular data we collected from populations worldwide), although we still have to see to which extent they cannot be distinguished morphologically. For freshwater rhabdocoels, we have (only incomplete) data, that show that the same rule applies as given above: in taxa with few species-level diagnostic characters, there are species that can be identified on molecular grounds only. We, therefore, propose that the number of really cryptic species in Proseriates is limited, less than 1.5 % of morphologically recognised species. Should this be extended to all the other rhabditophorans, it would give a range of cryptic species between 75 and 420 (if the multiplication value is minus or equal to 1.5%). **References** Casu, M., and Curini-Galletti, M. (2006). Genetic evidence for the existence of cryptic species in the mesopsammic flatworm *Pseudomonocelis ophiocephala* (Rhabditophora: Proseriata). Biological Journal of the Linnean Society *87*, 553–576. Casu, M., Lai, T., Sanna, D., Cossu, P., Curini-Galletti, M. (2009). An integrative approach to the taxonomy of the pigmented European *Pseudomonocelis* Meixner, 1943 (Platyhelminthes: Proseriata). Biological Journal of the Linnean Society *98*, 907–922. Tyler, S., Schilling, S., Hooge, M., and Bush, L.F. (2006–2011). Turbellarian taxonomic database. Version 1.7. http://turbellaria.umaine.edu.
Porifera [Rob van Soest, Nicole de Voogd]	**Described** 8,553 accepted species (mind you, these include those that have not been listed as synonym in any taxonomic study). **Nominal** 10,967 species names. **Undescribed, collected** Based on our collections (assuming they are representative of the world's museum collections) we estimate 25–35% undescribed, so that would amount to approx. 2,300–3,000 new species still hiding in the museum collections. **Undiscovered** An 'old' guess of John Hooper from 1994 is 15,000 species of sponges in world's oceans. We have no reason to adjust this number, but it remains a guess. With on average 50 species described this will be described in 100–150 years. **Cryptic**

	There are a few studies on cryptic genetic diversity in some widespread Porifera species, but unfortunately the knowledge base is far too small to extrapolate this into an educated guess of overall cryptic diversity in the phylum. I think that naming a figure (*e.g.*, based on the occurrence of approx. 15% of 'widespread species' you could argue that these are the most likely taxa to contain cryptic diversity and you could arrive in that way at several thousand cryptic species) is not a scientifically responsible action at this moment in time. We need more cases and more elaborate studies of what the genetic clades that appear in the investigated cases really represent: cryptic 'species' are usually based on percentage of sequence diversity observed among investigated individuals and translating these into biological entities that may be recognized morphologically is usually omitted. **References** Van Soest, R.W.M., Boury-Esnault, N., Vacelet, J., Dohrmann, M., Erpenbeck, D., De Voogd, N.J., Santodomingo, N., Vanhoorne, B., Kelly, M., and Hooper, J.N.A. Global diversity of sponges (Porifera). Submitted to PLoSONE.
Rotifera [Hendrik Segers]	**Described** 114 marine and brackish water species (Segers, 2007). **Nominal** 3,570 species names (Segers *et al.*, 2012). **Undescribed, collected** c. 20 species. **Undiscovered** Undefined. However, cryptic speciation is very important; can amount to a factor 10, see Segers & De Smet (2008). **Cryptic** My guesstimate of cryptic diversity in rotifers, based on available studies, is between 3 to 20 times that of currently known diversity. **References** Segers, H. (2007). Annotated checklist of the rotifers (Phylum Rotifera), with notes on nomenclature, taxonomy and distribution. Zootaxa *1564*, 104 pp. Segers, H., De Smet, W.H., Fisher, C., Fontaneto, D., Michaloudi, E., Wallace, R.L., and Jersabek, C.D. (2012). Towards a List of Available Names in Zoology, partim Phylum Rotifera. Zootaxa *3179*, 61–68. Segers, H., and De Smet, W.H. (2008). Diversity and endemism in Rotifera: a review, and *Keratella* Bory de St Vincent. Biodivers Conserv. *17*, 303–316.
Sipuncula [José Ignacio Saiz-Salinas]	**Described** 150 species (all in WoRMS). **Nominal** 150 valid + 1,366 synonyms = 1,516 species names.

	Undescribed, collected Very roughly between 3–5 new species. In the period 2000–2010 only 2 new species have been proposed (+ 1 new subspecies). If we take into account the existence of about 5 active taxonomists, we could calculate an average number of 5 new species in a short term of 10 years. Anyway, this last number is quite optimistic in my opinion. **Undiscovered** This is difficult to say. Sipunculans, as many other non-polychaete 'worms', are lacking many anatomical characters to split species. We can say sipunculans are quite cryptic species by the simplicity of their anatomy. Just soft invertebrates without parapodia, nor chaeta. On the other hand, we should admit the existence of large areas in the oceans not well sampled, which could give further new taxa. By forcing us to estimate numbers: I would say from 10 to 25 species still undiscovered based on classical methods in identification (dissection + microscope). Based on this classical method, the rate of new species would remain strikingly low. **Cryptic** However, by using DNA analysis, some species ('= cosmopolits' + eurybaths + circumtropical + or present in several oceans at the same time) could be splitted into several new clades. There are about 30–50 species with very wide horizontal + vertical distribution. If we assume a range of 2–5 clades as average, we can guess around 60–250 new clades by molecular methods. From this range: 60–250 minus 30–50 = 30–200 additional species by using genetics. Note that Kawauchi & Giribet (2010) published on a single species of Sipuncula, in which they identified 4 cryptic species with wide distribution. **References** Kawauchi, G.Y., and Giribet, G. (2010). Are there true cosmopolitan sipunculan worms? A genetic variation study within *Phascolosoma perlucens* (Sipuncula, Phascolosomatidae). Mar Biol *157*, 1417–1431.
Tardigrada [Reinhardt Møbjerg Kristensen]	**Described** There are 973 species of tardigrades of which only 183 species (and subspecies) are marine, however on genus level the marine tardigrades are more diverse than the terrestric/limnic tardigrades. Arthrotardigrada are all marine except for one species, *Styraconyx hallasi* — which is found in a salt spring in Westgreenland. There are 5 families in Arthrotardigrada. I have 158 accepted species; some of them were described as subspecies. Echiniscoidea are most terrestric — however 1 family is tidal/marine. 18 species have been described. Eutardigrada are all terrestric/limnic except for one genus, *Halobiotus* which contains 6 species. Furthermore one species of *Isohypsibius* has been recorded from a marine beach! I know two more species of *Halobiotus*. **Undescribed/undiscovered** We know about 500 undescribed Arthrotardigrada species — I estimate about 1,000 undescribed Arthrotardigrada will exist. I estimate the family Echiniscoididae has about 100 undescribed species, we already know 20 undescribed species of the genus *Echiniscoides* and I will not expect more than 20 undescribed species of Eutardigrada.

Acoela [Tom Artois, Seth Tyler]	**Described** 391 species. **Nominal** 605 species names. **Undescribed, collected** 100 species. **Undiscovered** 4,000 species. Same rationale as for the Rhabditophora. [Seth] I fully concur with Tom and Marco. I expect similar estimates could be applied to the Acoela, but with them, the number of ecoregions sampled is probably far fewer than 81 — on the order of 20, I would guess; and again, except for those famous regions such as the Baltic, North Sea, Western Mediterranean, and Southeastern Brazil, the sampling has been haphazard at best. So the number of undiscovered species may be even proportionally higher in Acoela than Rhabditophora, but I am not prepared to hazard a guess. **Cryptic** We haven't seen any evidence for cryptic species in the acoels; in fact, we've seen evidence to the contrary (Matthew Hooge, pers comm.). We would suspect that cosmopolitan species (*e.g.*, *Childia groenlandica*), and those found over a wide geographical area (*e.g.*, *Hofstenia miamia*) might actually be species complexes, [but] molecular studies have supported the monophyly of these species. It also seems relevant to note that the acoel species usually have limited geographic distribution.
Nemertodermatida [Tom Artois, Wolfgang Sterrer]	**Described** 8 species. **Nominal** 10 species names. **Undescribed, collected** See undiscovered. **Undiscovered** As to the Nemertodermatida, I think the number of undiscovered species is much higher than 10. In a recent sampling campaign with Ulf Jondelius in North Sardinia (only 8 days), Ulf found 5 species of Nemertodermatida, 4 of which he thinks(!) are new to science. To have certainty about that, molecular data should back this up, and this research has just been started. The number of undiscovered species is difficult to estimate. These species are extremely difficult to distinguish morphologically. Molecular techniques probably will reveal a much larger biodiversity, which I think is kind of illustrated by this recent sampling campaign with Ulf. That's why we propose to keep the number of undescribed and undiscovered species for Nemertodermatida in the table with a question mark.
Xenoturbellida [Serge Gofas]	Xenoturbellida is now part of the new phylum Xenacoelomorpha.

	There are only two species in this group. For a taxon with such a low number, it is not reasonable to venture a guess about undescribed/undiscovered species.