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Overview

The evolution of chondrichthyan research through a metadata analysis of dedicated international conferences between 1991 and 2014§

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Science is continually evolving, with recent developments in some fields, such as conservation biology, leading to shifts in priorities and needs. Recent international conferences focused on chondrichthyan research provide an opportunity to assess how the research environment of chondrichthyan science has evolved through time. We compiled metadata from Sharks Down Under (1991) and the two Sharks International conferences (2010 and 2014), spanning 23 years. Analysis of the data highlighted taxonomic biases towards charismatic species, a declining number of studies in fundamental science such as those related to taxonomy and basic life history, and the emergence of new research fields or tools such as social science and stable isotope analysis. Although there are limitations associated with our study, which are discussed, it lays the foundation for continued assessment of the progression of chondrichthyan research as future chondrichthyan-focused international conferences are organised. Considering the research biases that our metadata analysis identifies, we suggest that: (i) greater attention should be given to species or species groups that are of particular conservation concern but that may not necessarily be charismatic (e.g. batoids); (ii) increased support should be given to scientists from low-income countries; (iii) new research areas should continue to be developed and included within broad integrated research programmes; and (iv) concurrent with this, foundational research should not be neglected.

Keywords: rays, research priority, sharks, taxonomic bias

Introduction

Science is continually evolving through the development of more powerful methods of data analysis, advances in technology and equipment, and a greater breadth and depth of scientific knowledge. Some research areas can also be influenced by national or international strategy, or by changing priorities (Fazey et al. 2005a). For example, to effectively inform policy and management, conservation biology must address the most pressing problems and the most threatened systems or organisms. As threats change over time, conservation biologists should be addressing new and shifting priorities (Lawler et al. 2006).

Review of published literature has traditionally been used to provide snapshots (Clark and May 2002; Fazey et al. 2005a; Milner-Gulland et al. 2009) and reveal trends in science (Holmgren and Schnitzer 2004; Lawler et al. 2006; Griffiths and Dos Santas 2012). Such studies of publication patterns in conservation biology have, for example, identified biases towards research on vertebrates and research conducted in developed countries, with shortfalls in research from developing countries that have relatively high levels of biodiversity (Griffiths and Dos Santas 2012). Professional conferences can also provide a snapshot or reveal trends in research focus. Conference attendance is often described as benefitting professional development (Harrisson 2010), with the main benefits including professional rejuvenation, discussions among delegates leading to the strengthening of established networks or development of new collaborations, and keeping up with the advancement of knowledge through presentations and posters (Bauer et al. 2008; Harrisson 2010). Managers aim to stay up-to-date with the latest scientific advances, to remain in contact with current research providers, and to seek potential new ones. For this reason, scientific conferences are viewed as one of the most crucial activities pursued by academics and managers. Conferences also provide insights to undergraduate and postgraduate (MSc or PhD) students whose main reason for attendance is the advancement of knowledge provided by presentations and the enhancement of career prospects provided by exposing their research to the scientific community.

§ This is an editorial contribution to a special issue 'Advances in Shark Research', edited by DA Ebert, C Huveneers and SFJ Dudley, that contains articles based on papers presented at the 'Sharks International 2014' conference, held 2–6 June 2014, Durban, South Africa

Students also benefit from conferences through meeting and networking with research groups, potentially leading to post-doctorate or other employment opportunities.

Recent international conferences focused on chondrichthyan research provide an opportunity to assess how the research environment of chondrichthyan science has evolved through time. This lays the foundation for continued assessment of the progression of chondrichthyan research as future chondrichthyan-focused international conferences are organised. By means of a metadata analysis, we examined temporal trends in the content and delegate representation at three such international conferences held in 1991, 2010, and 2014. Specifically, we described: (i) the number of delegates and contributions at the conference; (ii) the types of delegate attending the conference (e.g. student, professional); (iii) the country of their affiliation; (iv) the species or groups of species most-studied; and (v) the broad topics of the presentations and posters presented. The results of the analysis allowed us to identify potential taxonomic, research field or geographic biases in contributions, as well as differences in the proportion of contributions between professionals and students, and whether such biases or differences have changed through time.

We recognise that a metadata analysis based on conference programmes and delegate lists can be affected by a range of biases. Travelling internationally has become more accessible since 1991, increasing the likelihood of attracting international delegates. The contribution from scientists based in the host country or in countries nearby is also likely to be inflated due to reduced travel costs. The level of support provided by the conference organising committee and by sponsors to delegates from developing countries and to students may differ between conferences. Also, the conferences analysed in this study were not the only international conferences during which chondrichthyan-related research was a focus. Annual conferences organised by regional professional societies such as the American Elasmobranch Society (AES), European Elasmobranch Association (EEA), and Oceania Chondrichthyan Society (OCS) have repeatedly attracted international delegates. The Indo-Pacific Fish Biology Conference (IPFC) was initiated in 1981 and has frequently hosted chondrichthyan-related symposiums. These conferences have an intrinsic regional bias, however, unlike the three conferences we investigated. The present analysis provides an assessment of chondrichthyan-focused international conferences over the last 23 years, beginning with Sharks Down Under in 1991. It is anticipated that, with Sharks International conferences having been held in 2010 and 2014, they will continue to be held every four years and hence this study will form the foundation for the investigation of trends during future conferences, such as the next one that is scheduled to take place in Brazil in 2018.

Methods

We compiled data from three chondrichthyan-focused international conferences spanning 23 years: (1) Sharks Down Under (SDU), held in Sydney, Australia, in 1991; (2) Sharks International 2010 (SI-2010) in Cairns, Australia; and (3) Sharks International 2014 (SI-2014) in Durban, South Africa. Lists of delegates, presentations and posters were obtained from the respective conference organisers and used to perform a metadata analysis. This resulted in a total sample of 314 presentations, 89 posters and 672 delegates from 40 countries across the three conferences.

For each of the conferences, we used the list of delegates to categorise the type of delegates based on their status (i.e. Student, Professional – university, or Professional – other, or Other) and record the country of their affiliation. The list of presentations and posters was combined into a list of contributions. The title and abstract of each contribution was examined to identify the focus species or group of species, as well as the broad topic. In some instances, a contribution was assigned to more than one topic. As a result, the sum of the contributions across topics was higher than the actual number of contributions. Similarly, many contributions were about more than one species and the sum of the contributions across species was higher than the number of contributions. We also listed the main method where a number of methods were used, or when a new technique had been developed.

Plenaries were not included in the analysis as the invited speakers at SI-2010 were chosen from SDU delegates, and those selected for SI-2014 specifically had prior association with South African research. As a result, plenaries might not reflect the evolution of chondrichthyan research consistently with the rest of the presentations and posters.

Results and discussion

Number of contributions

The total number of contributions at the three conferences increased from 37 in 1991 to 225 in 2014 (Table 1). The proportion of posters was the same between the two Sharks International conferences (24%), but SDU only had oral presentations and discussions (Pepperell 1992; Pepperell et al. 1993).

The increased number of contributions from the first to the second Sharks International conference is difficult to interpret because they occurred in Australia and South Africa, respectively, and accessibility to these countries is different. The increase, however, could be attributed partly to building on the success of SI-2010. Sharks Down Under and SI-2010 were both located in Australia and the number of contributions almost quadrupled between the two conferences. This corresponds with the increased interest in both chondrichthyan research and conservation effort reported in the last decade (White et al. 2012; Momigliano and Harcourt 2014), as shown by the greatest peak in new species descriptions since 1758 taking place in the 2000s, when 180 new chondrichthyan species were described (White and Last 2012). It is also possible that television documentary channels, such as Discovery, National Geographic, and Animal Planet, have raised the public fascination with sharks, potentially leading to more postgraduate students being attracted to shark-related projects. The founding of various bodies that bring together scientists focusing on chondrichthyans also illustrates the increased interest in chondrichthyan-related research since SDU. For example, the Oceania Chondrichthyan Society was founded in 2005 as a result of the increased number

Table 1: Number of countries from which delegates originated, number of delegate types, and number of contributions for each conference. Numbers in brackets are percentages across each conference; 'no data' indicated by a dash

Conference	Countries	Delegates					Papers		
		Students	Professional university	Professional other	Other	Total	Presentations	Posters	Total
Sharks Down Under (1991)	9	–	–	–	–	140	37	0	37
Sharks International 2010	22	84 (39)	36 (17)	90 (42)	4 (2)	214	107 (76)	34 (24)	141
Sharks International 2014	37	118 (37)	53 (17)	147 (46)	0 (0)	318	170 (76)	55 (24)	225

of scientists and PhD students working on chondrichthyan-related projects. It has more than 100 members and has held a conference or joint-conference annually since its inception (http://oceaniasharks.org.au). In addition, and although not a research organisation, the IUCN Species Survival Commission established the IUCN Shark Specialist Group (SSG) in 1991 in response to growing awareness and concern about the severe impact of fisheries on chondrichthyan populations around the world (C Simpfendorfer, IUCN SSG Co-Chair, pers. comm.). The SSG now brings together the knowledge of 170 members, most of them elasmobranch researchers, from 55 countries.

Number of delegates and originating countries

The number of conference delegates increased from 140 during SDU to 318 during SI-2014 (Table 1). Sharks Down Under did not record whether delegates were students or professionals, but the student proportion was similar between the two Sharks International conferences (~38%). The proportion of professional delegates from universities during the two Sharks International conferences was 17%. The remaining delegates were either from private companies or from governmental organisations, such as those undertaking marine research or fisheries management, and represented ~45% of the delegates at both Sharks International conferences. The number of nationalities quadrupled from nine during SDU to 37 during SI-2014, in accordance with the number of delegates.

Throughout the three conferences, Australia and the United States of America (USA) were among the three countries with the most delegates (21–76% and 11–15% for Australia and the USA, respectively) (Figure 1). The strong representation by delegates from Australia at both SDU and SI-2010 was due in part to these conferences being located in Australia. SI-2014 was held in South Africa, leading to 34% of delegates being from that country. Although it is expected that the highest number of delegates will originate from the host country of the conference, the distribution of nationalities attending the conference was similar to that of the locations where chondrichthyan studies have been performed between 1992 and 2012, and is consistent with the geographic biases in chondrichthyan studies and researchers reported by Momigliano and Harcourt (2014).

Previous snapshot surveys of the literature have highlighted the relatively low number of papers from developing or low-income countries that have local researchers as primary authors (Fazey et al. 2005b; Griffiths and Dos Santas 2012). There is evidence, however, that the number of scientific publications from developing countries is increasing at a higher rate than it is in developed countries (Holmgren and Schnitzer 2004). The bias between developing and developed countries is likely due to less funding being available for research in developing countries, combined with the additional difficulties of writing manuscripts in English of adequate standard. Similar to published literature, attendance at international conferences also suffers from a relatively low number of contributions from developing countries, which can partly be attributed to the costs associated with international travel and unfavourable exchange rates. Conference organisers are increasingly aware of this issue, with some conferences, such as both Sharks International conferences, providing travel funds to scientists from developing countries in an attempt to reduce this under-representation. However, the number of delegates from developing countries, aside from South Africa, remained small, despite the proximity of South Africa to a number of such countries and despite efforts by the SI-2014 organisers to attract delegates from the rest of Africa by advertising through the Western Indian Ocean Marine Science Association and by contacting individual researchers. This may partially be explained by a lack of research capacity or experts in chondrichthyan-related issues. Developing countries often have high biodiversity, and building research capacity within those countries is frequently highlighted as a global conservation priority (Barnard 1995; Brito and Oprea 2009). Central elements of capacity building are collaborative research, knowledge exchange and training (Smith et al. 2009; Sutherland 2009), highlighting the importance of ensuring attendance at conferences.

Key taxa represented in contributions

During all conferences, members of the Carcharhiniformes were the focus of most contributions, accounting for 51%, 33%, and 38% of all contributions at SDU, SI-2010, and SI-2014, respectively (Table 2). This is not surprising considering that this is the most diverse chondrichthyan order, with 285 currently described species (Ebert and van Hees 2015), and that the order includes many coastal and therefore highly accessible species, which are important in fisheries and coastal ecosystems. The decline in relative representation from SDU to the two Sharks International conferences was largely the result of a decreased number of contributions related to *Galeorhinus galeus* and *Mustelus antarcticus*. The focus on these two species during SDU might have been due to the availability of data and samples from Australia's southern shark fishery, whereas, in the late 1980s to early 1990s, sampling opportunities with regard to other species were limited by logistical constraints. This, in part, is also reflected in the topics of the contributions at

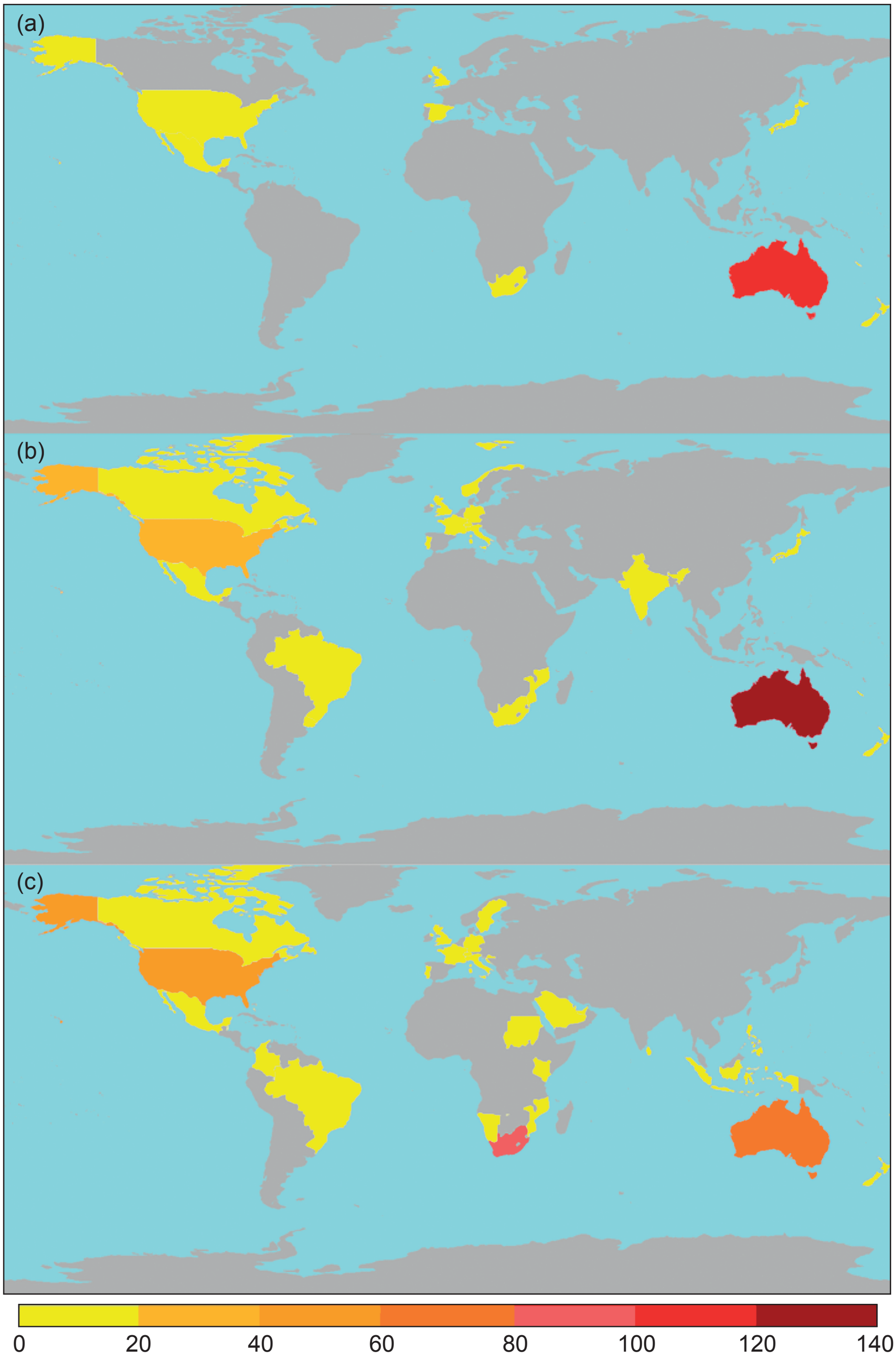

Figure 1: Number of delegates per country at (a) Sharks Down Under (1991; Sydney, Australia), (b) Sharks International 2010 (Cairns, Australia), and (c) Sharks International 2014 (Durban, South Africa)

SDU, which mostly related to large fisheries, or to shark bite mitigation programmes. This is supported by the six species that received the greatest focus during SDU, being *M. antarcticus*, *G. galeus*, *Isurus* sp., *Prionace glauca*, *Carcharodon carcharias*, and *Galeocerdo cuvier.*

Since that time, the diversity of species forming the subject of presentations increased by factors of nearly four and nearly five, respectively, from 16 species during SDU to 60 during SI-2010, and 72 during SI-2014. This could be explained partly by the overall increase in number of contributions (from 37 to 225), but might also reflect the focus of scientists on species that might logistically be less easy to study and sample, and also an impetus to understand the lesser-known species. Regardless of the increased species diversity over time, taxonomic biases remain apparent, with the four most-frequently studied species across

Table 2: Number and percentage of contributions that focused on each species or group of species at each conference. SDU = Sharks Down Under; SI-2010 = Sharks International 2010; SI-2014 = Sharks International 2014

Order	Family	Species	Number			Percentage		
			SDU	SI-2010	SI-2014	SDU	SI-2010	SI-2014
Hexanchiformes			1	2	0	2.70	1.42	0.00
	Hexanchidae		1	2	0	2.70	1.42	0.00
		Notorynchus cepedianus	1	2		2.70	1.42	
Squaliformes			0	9	4	0.00	6.38	1.78
	Squalidae		0	2	2	0.00	1.42	0.88
		Squalus acanthias		2	1		1.42	0.44
		Squalus sp.			1			0.44
	Centrophoridae		0	2	1	0.00	1.42	0.44
		Centrophorus		2	1		1.42	0.44
	Etmopteridae		0	2	0	0.00	1.42	0.00
		Etmopterus lucifer		1			0.71	
		Etmopterus princeps		1			0.71	
	Somniosidae		0	1	1	0.00	0.71	0.44
		Somniosus microcephalus		1	1		0.71	0.44
	Oxynotidae		0	1	0	0.00	0.71	0.00
		Oxynotidae sp.		1			0.71	
	Squaliformes sp.		0	1	0	0.00	0.71	0.00
Heterodontiformes			0	2	4	0.00	1.42	1.78
	Heterontidae		0	2	4	0.00	1.42	1.78
		Heterodontus portusjacksoni		2	4		1.42	1.78
Orectolobiformes			0	16	23	0.00	11.35	10.22
	Brachaeluridae		0	1	2	0.00	0.71	0.89
		Brachaelurus waddi			2		0.00	0.89
		Heteroscyllium colcloughi		1			0.71	
	Orectolobidae		0	3	1	0.00	2.13	0.44
		Orectolobus sp.		3	1		2.13	0.44
	Hemiscylliidae		0	0	1	0.00	0.00	0.44
		Chiloscyllium punctatus			1			0.44
	Ginglymostomatidae		0	1	0	0.00	0.71	0.00
		Ginglymostoma cirratum		1			0.71	
	Stegostomatidae		0	1	0	0.00	0.71	0.00
		Stegostoma fasciatum		1			0.71	
	Rhincodontidae		0	10	19	0.00	7.09	8.44
		Rhincodon typus		10	19		7.09	8.44
Lamniformes			7	16	37	18.92	11.35	16.44
	Odontaspididae		1	4	7	2.70	2.84	3.11
		Carcharias taurus	1	4	7	2.70	2.84	3.11
	Alopiidae		1	3	3	2.70	2.13	1.33
		Alopias pelagicus			1			0.44
		Alopias superciliosus	1	2	1	2.70	1.42	0.44
		Alopias vulpinus		1	1		0.71	0.44
	Cetorhinidae		0	2	2	0.00	1.42	0.89
		Cetorhinus maximus		2	2		1.42	0.89
	Lamnidae		5	7	25	13.51	4.96	11.11
		Carcharodon carcharias	2	6	19	5.41	4.26	8.44
		Isurus sp.	3	1	5	8.11	0.71	2.22
		Lamna nasus			1			0.44
Carcharhiniformes			19	47	86	51.35	33.33	38.22
	Scyliorhinidae		0	3	2	0.00	2.13	0.89
		Apristurus sp.			1			0.44
		Cephaloscyllium laticeps		1			0.71	
		Cephaloscyllium ventriosum		1			0.71	
		Haploblepharus edwardsii			1			0.44
		Scyliorhinidae sp.		1			0.71	
	Triakidae		10	3	6	27.03	2.13	2.67
		Galeorhinus galeus	4		1	10.81	0.00	0.44
		Mustelus antarcticus	5	1		13.51	0.71	
		Mustelus canis		1			0.71	
		Mustelus henlei			1			0.44
		Mustelus mustelus			2			0.89

Table 2: (cont.)

Order	Family	Species	Number			Percentage		
			SDU	SI-2010	SI-2014	SDU	SI-2010	SI-2014
Carchariniformes (cont.)	Triakidae (cont.)	*Mustelus* sp.		1			0.71	
		Triakis megalopterus			1			0.44
		Triakis semifasciata	1		1	2.70		0.44
	Hemigaleidae		0	0	1	0.00	0.00	0.44
		Hemipristis elongata			1			0.44
	Carcharhinidae		8	35	67	21.62	24.82	29.78
		Carcharhinus albimarginatus		1	1		0.71	0.44
		Carcharhinus amblyrhynchos		3	2		2.13	0.89
		Carcharhinus amboinensis		2			1.42	
		Carcharhinus brachyurus			4			1.78
		Carcharhinus falciformis		2	4		1.42	2.22
		Carcharhinus galapagensis			3			1.33
		Carcharhinus leiodon		1			0.71	
		Carcharhinus leucas	1	4	11	2.70	2.84	4.89
		Carcharhinus limbatus/C. tilstoni		2	2		1.42	0.89
		Carcharhinus longimanus			1			0.44
		Carcharhinus melanopterus		2	1		1.42	0.44
		Carcharhinus obscurus			4			1.78
		Carcharhinus perezi		1			0.71	
		Carcharhinus plumbeus	1	1	2	2.70	0.71	0.89
		Carcharhinus signatus			1			0.44
		Galeocerdo cuvier	2	3	12	5.41	2.13	5.33
		Glyphis sp.			1			0.44
		Loxodon macrorhinus		1			0.71	
		Negaprion acutidens		1			0.71	
		Negaprion brevirostris	1	1	2	2.70	0.71	0.89
		Prionace glauca	2	2	6	5.41	1.42	2.67
		Rhizoprionodon acutus		1			0.71	
		Rhizoprionodon taylori	1	1	3	2.70	0.71	1.33
		Triaenodon obesus		2			1.42	
		Various *Carcharhinus* spp.		4	6		2.84	2.67
	Sphyrnidae		1	6	10	2.70	4.26	4.44
		Sphyrna lewini	1	2	5	2.70	1.42	2.22
		Sphyrna mokarran		2	2		1.42	0.89
		Sphyrna zygaena		1	3		0.71	1.33
		Sphyrna sp.		1			0.71	
Squatiniformes			0	0	1	0.00	0.00	0.44
	Squatinidae		0	0	1	0.00	0.00	0.44
		Squatina australis			1			0.44
Pristiformes			0	4	12	0.00	2.84	5.33
	Pristidae			4	12	0.00	2.84	5.33
		Anoxypristis cuspidata		2			1.42	
		Pristis sp.		2	12		1.42	5.33
Narcinidaes			0	0	1	0.00	0.00	0.44
	Narcinidae		0	0	1	0.00	0.00	0.44
		Narcine brasiliensis			1			0.44
Rajiformes			1	5	8	2.70	3.55	3.56
	Rhinidae		1	0	0	2.70	0.00	0.00
		Rhina ancylostomus	1			2.70		
	Rhynchobatidae		0	1	0	0.00	0.71	0.00
		Rhynchobatus australiae		1			0.71	
	Rhinobatidae		0	3	4	0.00	2.13	1.78
		Aptychotrema rostrata		1			0.71	
		Glaucostegus typus		1			0.71	
		Rhinobatos productus		1	1		0.71	0.44
		Trygonoptera testacea			1			0.44
		Trygonorrhina dumerilii			1			0.44
		Trygonorrhina fasciata			1			0.44
	Arynchobatidae		0	1	1	0.00	0.71	0.44
		Psammobatis extenta			1			0.44
		Rhinoraja interrupta		1			0.71	

Table 2: (cont.)

Order	Family	Species	Number			Percentage		
			SDU	SI-2010	SI-2014	SDU	SI-2010	SI-2014
Rajiformes (cont.)	Rajidae		0	0	3	0.00	0.00	1.33
		Dipturus trachyderma			1			0.44
		Raja binoculata			1			0.44
		Raja velezi			1			0.44
Myliobatiformes			0	7	22	0.00	4.96	9.78
	Potamotrygonidae		0	3	3	0.00	2.13	1.33
		Paratrygon aiereba		1	1		0.71	0.44
		Potamotrygonidae sp.		2	2		1.42	0.89
	Dasyatidae		0	2	6	0.00	1.42	2.67
		Dasyatis americana			2			0.89
		Dasyatis fluviorum			1			0.44
		Dasyatis laosensis			1			0.44
		Himantura dalyensis		2			1.42	
		Urogymnus asperrimus			1			0.44
		Dasyatidae sp.			1			0.44
	Gymnuridae		0	0	1	0.00	0.00	0.44
		Gymnura marmorata			1			0.44
	Myliobatidae		0	0	1	0.00	0.00	0.44
		Myliobatis sp.			1			0.44
	Mobulidae		0	2	11	0.00	1.42	4.89
		Manta sp.		2	7		1.42	3.11
		Mobula tarapacana			1			0.44
		Mobulidae sp.			3			1.33
Multiple batoids				1	1		0.71	0.44
Chimaeriformes			0	1	2	0.00	0.71	0.89
	Callorhinchidae		0	1	0	0.00	0.71	0.00
	Chimaeroidae		0	0	2	0.00	0.00	0.89
		Chimaera sp.			1			0.44
		Hydrolagus africanus			1			0.44
Various chondrichthyans			13	39	56	35.14	27.66	24.89

Sharks International conferences being *Rhincodon typus*, *C. carcharias*, *Carcharhinus leucas*, and *Galeocerdo cuvier*. In addition, *Manta* species were also over-represented during SI-2014 (Table 2). Taxonomic biases are widespread within the ecological and conservation literature (Bonnet et al. 2000; Clark and May 2002; Stein et al. 2002; Baldi and McCollen 2003; Trimble and van Aarde 2010), and from a conservation viewpoint, it is of particular concern where there is a disproportionate focus on non-threatened taxa (Bonnet et al. 2000). Apart from key charismatic species that are also the focus of lucrative tourism industries, batoids were largely under-represented (9% of contributions, excluding Mobulidae) and chimaeras were virtually unrepresented (<2% of contributions).

Some of the species receiving the greatest research attention, however, are considered threatened and are protected in various countries and through international treaties (e.g. *C. carcharias, R. typus*), although it is notable that these are also charismatic species. There was also a bias towards species responsible for most shark bites on humans (*C. carcharias, G. cuvier, C. leucas*). Although these three species were already amongst those mentioned most during SI-2010, they also represented the largest increase in the proportion of contributions between SI-2010 and SI-2014, after *Pristis* spp. (see below). This is likely related to the number of shark bites that occurred within a short time-frame between 2011 and 2013 in several parts of the world, e.g. Western Australia, Egypt, and Reunion Island, increasing the focus on potentially dangerous species, and suggesting that chondrichthyan research has responded to the need to study these species as a result of the 2011–2013 attacks.

The SI-2014 conference also included 12 contributions about sawfishes, which have recently been identified as the group of chondrichthyan species at the highest risk of extinction (Dulvy et al. 2014). This increased representation of contributions on the subject of sawfishes was related to these talks being solicited to support and reinforce the launch of the IUCN SSG sawfish global conservation strategy (Harrison and Dulvy 2014) during the conference. A plenary speaker (C Simpfendorfer, James Cook University, Australia) highlighted the general research bias towards sharks, emphasising that rays are considered at higher risk than sharks (Dulvy et al. 2014). As a result of the plenary speaker's comment, and through the use of a newly created hashtag (#Raysneedlove2) on the social medium Twitter, many delegates reiterated the threatened status of rays during their presentations and through social media, with #Raysneedlove2 attracting 46 tweets (not including retweets) in the two conference days following the plenary in question. It is unknown, however, to what extent the tweets generated during SI-2014 will influence managers and policy-makers, and whether these tweets will be followed up by an increased interest in rays. With the vulnerability of batoids frequently emphasised during the conference and through recent publications (e.g. Dulvy et al. 2014), the proportion of presentations on batoids during future Sharks International conferences should be recorded and compared to SI-2010 and SI-2014.

Topics and methods

The 'Fisheries' topic was one of the top three across all conferences, contributing 22%, 14%, and 11% at SDU, SI-2010, and SI-2014, respectively (Table 3). The other important topics across all conferences, but not always found in the top three, were 'General biology and ecology', 'Movement ecology', and 'Conservation and management'. The percentage of certain other topics was high for one conference, but not for all three. For example, 'Shark bite and mitigation measures' and 'Taxonomy' were listed as main topics for over 10% of the contributions during SDU, 'Feeding ecology' was a relatively important topic during SI-2010, whereas 'Physiology' and 'Population ecology' ranked fourth and fifth during SI-2014, and had nearly tripled since SDU.

The proportion of contributions related to 'Movement ecology' more than doubled between SDU and the Sharks International conferences (Table 3). Advances in the technology available to scientists have provided opportunities to study the movement and residency of species that logistically were not feasible before. Scientists can now investigate the movement of teleosts and chondrichthyans beyond a simple description of where they go and for how long (Heupel and Webber 2012), leading to the development of questions relating to the ecological or evolutionary significance of observed movements (e.g. Thums et al. 2013). Technological advancements are illustrated by the change of methods used to study movement ecology (Table 4), with the use of acoustic telemetry doubling between SDU and the Sharks International conferences, and the sole use of conventional identification tags declining from 2.7% to 0.4%. Acoustic telemetry has continued to evolve, with new tags providing additional information, such as changes in the pH of the stomach contents of the tagged individual, which can reflect feeding events (Papastamatiou et al. 2007), or an acceleration vector that reflects activity level, which is used to infer physiological processes influencing movements (Gannon et al. 2014). The benefits of using acoustic telemetry are accentuated by global monitoring networks, such as the Australian Animal Tagging and Monitoring System (AATAMS) and the international equivalent, the Ocean Tracking Network (OTN) (O'Dor et al. 2008), which have led to an increase in acoustic coverage and the ability to gather movement data over much larger spatial scales than independent studies can cover. Methods used in 'Movement ecology' now also include photo-identification and satellite tagging (including the use of pop-up satellite archival tags, or PSAT), which were not represented in any studies presented during SDU but were used in about 7% of the studies presented at the Sharks International conferences (Table 4).

The topics 'Population structure' and 'Sensory biology' were represented only at the Sharks International conferences (Table 3). Although there are various phenotypic methods to study stock structure (Begg et al. 1999), and it can also be investigated using conventional identification tags, advances in genetic analysis have created new assessment opportunities. This approach was not used frequently at the time of SDU, but was used in ~10% of the contributions during the Sharks International conferences (Table 4). There had been many studies in the field of chondrichthyan sensory biology prior to SDU (Hodgson and Mathewson 1978; Gardiner et al. 2012). Following that intensive work, this field was then under-represented until technological improvements created new study opportunities, as seen by the appearance of contributions in this field during both Sharks International conferences. The field of 'Feeding ecology' also changed between the early 1990s and the 2010s. The only technique used to assess the diet of chondrichthyans in studies presented during SDU was the examination of prey items obtained from stomach contents (Table 4). Through the 2000s, stable isotope analysis became a standard method to determine the trophic position of chondrichthyans (Hussey et al. 2012) and was used more often than stomach content analysis in studies presented during SI-2010 and SI-2014 (3.5% vs 2.1%, and 5.8% vs 0.4%, respectively). By 2014, only one study used stomach content analysis, compared with 13 using stable isotopes, as well as a plenary presentation. The use of fatty acid profiles as a method to investigate chondrichthyan trophic ecology also appeared during the Sharks International conferences (e.g. a presentation at SI-2010, subsequently published by Beckmann et al. [2013]).

Sharks are often considered as charismatic megafauna or iconic species, and have captivated human imagination through cultural significance and media exposure (Heupel and Simpfendorfer 2011). Yet, relatively few studies have focused on the human perception of sharks, i.e. the field of social science (Simpfendorfer et al. 2011). More social science studies are now starting to emerge, with 2.1% and 5.3% of the contributions during SI-2010 and SI-2014, respectively, being based on human opinions of sharks (Table 4).

The proportion of contributions related to 'Shark bite and mitigation measures' and 'Taxonomy' decreased between SDU and SI-2010 by about 75% and 55%, respectively (Table 3). Although the proportion of contributions related to 'Taxonomy' remained low during SI-2014, an increased number of shark bites between 2011 and 2013 led to many studies on shark bite mitigation measures, as supported by the 50% increase in the number of contributions about this topic from SI-2010 to SI-2014. Nevertheless, the proportion of contributions about shark bites and mitigation measures during SI-2014 was still lower than during SDU. This might be linked to shark mitigation measures, such as beach meshing, being an important source of biological samples and abundance data (Dudley and Cliff 2010), leading to being over-represented during SDU. Sharks Down Under was also partly organised as a workshop to discuss shark mitigation measures and likely biased the number of contributions on the topic.

A decrease in the proportion of contributions related to taxonomy is mirrored by a decline in the 'General biology and ecology' topic by more than 50% between SDU and

Table 3: Number of contributions per topic at each conference. Numbers in brackets are percentages across each conference

Topic	Sharks Down Under (1991)	Sharks International 2010	Sharks International 2014
Fisheries	8 (21.62)	20 (14.19)	25 (11.11)
Movement ecology	3 (8.11)	25 (17.73)	40 (17.78)
General biology and ecology	7 (18.92)	18 (12.77)	16 (7.11)
Conservation and management	4 (10.81)	11 (7.80)	21 (9.33)
Shark bite and mitigation measures	6 (16.22)	6 (4.26)	15 (6.67)
Taxonomy	4 (10.81)	7 (4.96)	9 (4.00)
Biodiversity and abundance	1 (2.70)	6 (4.26)	15 (6.67)
Feeding ecology	1 (2.70)	10 (7.09)	14 (6.22)
Physiology	1 (2.70)	8 (5.67)	17 (7.56)
Population ecology	1 (2.70)	6 (4.26)	16 (7.11)
Husbandry	1 (2.70)		
Population structure		8 (5.67)	11 (4.89)
Sensory biology		7 (4.96)	9 (4.00)
Behaviour		7 (4.96)	4 (1.78)
Tourism		3 (2.13)	4 (1.78)
Methods		3 (2.13)	4 (1.78)
Economics		1 (0.71)	
Trophic interactions		2 (1.42)	2 (0.89)
Evolution		1 (0.71)	
Bacterial/microbial profile			2 (0.89)
Palaeontology			2 (0.89)

Table 4: Number of contributions that use a specific (main) method. Numbers in brackets are percentages across each conference

Methods	Sharks Down Under (1991)	Sharks International 2010	Sharks International 2014
Conventional tag (only)*	1 (2.7)	1 (0.7)	1 (0.4)
Acoustic telemetry	2 (5.4)	16 (11.3)	31 (13.8)
Photo-identification		10 (7.1)	18 (8.0)
Satellite tag		3 (2.1)	10 (4.4)
Pop-up tag		9 (6.4)	7 (3.1)
Various (physical/electronic)			1 (0.4)
Tags (combined)	**3 (8.1)**	**39 (27.7)**	**68 (30.2)**
Stomach contents	2 (5.4)	3 (2.1)	1 (0.4)
Stable isotopes		5 (3.5)	13 (5.8)
Fatty acid		2 (1.4)	3 (1.3)
Feeding (combined)	**2 (5.4)**	**10 (7.1)**	**17 (7.6)**
Baited remote underwater video		1 (0.7)	7 (3.1)
Genetics	1 (2.7)	18 (12.8)	19 (8.4)
Social science		3 (2.1)	12 (5.3)
Citizen science			4 (1.8)

* The use of conventional tags in conjunction with another tagging method may not be documented in contribution abstract

SI-2014. Several studies have highlighted the need for basic or fundamental research such as taxonomy or the estimation of life-history parameters (Last 2007; Simpfendorfer et al. 2011; White et al. 2012). Indeed, taxonomy has been identified as 'the foundation of all other biological sciences' as it would be difficult to place research in context without a valid species name (Simpfendorfer et al. 2011). Similarly, the estimation of life-history parameters is critical for stock assessment and to determine anthropogenic effects on chondrichthyan populations. Unfortunately, journals that publish research are important drivers of the direction that biology takes, through their editorial policies and practices. Organisations relying on governmental funding can also be at the mercy of the political climate, with the potential for funding to be reduced or cut completely. Although relevance to conservation practice is a goal that many chondrichthyan scientists aspire to, funding bodies are increasingly favouring innovative research proposals, making it more difficult to secure funds for fundamental science such as taxonomy and basic life history. With careers depending on publications in top-tier journals with high prestige and impact factors, the best researchers may lack incentives to carry out fundamental research. This can lead to research that is cutting-edge and of wide general interest to other scientists, but that is not necessarily relevant to practical conservation and management. Conversely, there may be species that are threatened but non-charismatic and habitats that urgently require basic research to underpin conservation and management, but such research may lack the novelty and general interest to warrant publication in an international journal, or presentation at a conference.

Conclusion

Inferences that can be drawn from this metadata analysis of delegate representation and contributions to international chondrichthyan-focused conferences are limited by the small number (three) of such conferences held so far. Also, the first international conference, SDU, had a relatively small number of contributions, potentially biasing some results, as a small difference in the number of contributions within a topic can lead to large differences in the percentage contribution of that topic. In addition, the time-period between conferences was not consistent, with 20 years separating the first two conferences and only four years the two Sharks International conferences. Nevertheless, the analysis can be used as a baseline from which to develop further analysis of the evolution of chondrichthyan science through future Sharks International conferences. The analysis also provides an initial quantification of trends in research topics, highlights the emergence of new areas, and identifies the declining number of studies in fundamental science, such as taxonomy and basic life history, presented at international conferences. Considering the biases identified in our metadata analysis, we suggest that: (i) greater attention should be given to species or species groups that are of particular conservation concern but that may not necessarily be charismatic (e.g. batoids); (ii) increased support should be given to scientists from low-income countries; (iii) new research areas should continue to be developed and included within broad, integrated research programmes; but (iv) foundational research (e.g. estimation of life-history parameters, taxonomy) should not be neglected.

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