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The state of chondrichthyan taxonomy and systematics

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The state of play

Taxonomic and systematic studies of chondrichthyan fishes are presently going through a renaissance. Exploratory fishing surveys in previously unexplored regions have led to the discovery of many new taxa. Almost 1170 species are known to occur worldwide, of which slightly more than 1000 have been formally described since the first chondrichthyans were described by Linnaeus in 1758 (Fig. 1). About 370 species, or more than a third of the world's known chondrichthyan fauna, have been described or discovered in the last 30 years.

An increasing awareness of the role of chondrichthyan fishes as apical predators in marine ecosystems, serious conservation concerns for these fishes, which are now widely considered to be amongst the most vulnerable of all marine animals, and a need to understand and manage marine biodiversity, has greatly elevated their profile in recent times. Results from the IUCN Shark Specialist Group's Red List assessments indicate that commercially exploited species of deep sea sharks have amongst the highest risk of extinction of any marine taxa (IUCN 2006). In the public eye, many sharks have gone rapidly from marine monsters to charismatic species that need protection.

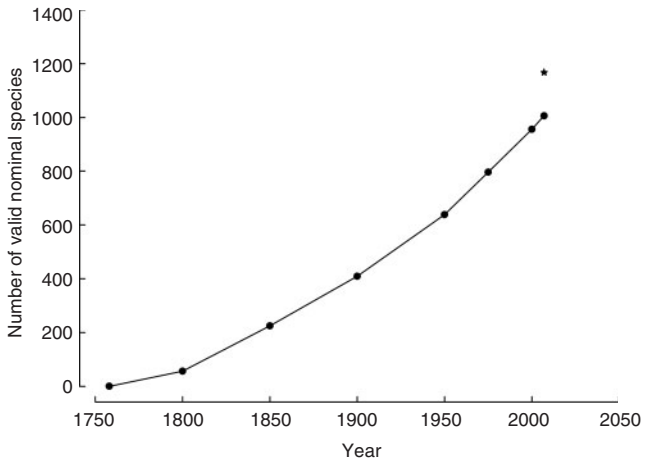

Fig. 1. Chronological representation of the number of valid chondrichthyan species dating from the description of the first species by Linnaeus in 1758 to 2007. Values (shown as black dots) are provided at 50-year intervals up until 1950 as well as 1975 and 2007; the total number of known species (valid nominal and undescribed) in 2007 is represented by a black star.

Is the fauna well known?

The rate of description of new species has increased slowly each half-decade over the past 250 years (Fig. 1), suggesting that our knowledge of the group is largely incomplete. Apart from the need to identify species complexes and determine structure within genera, there is also a need to provide better inventory coverage of the oceans' faunas. Large sectors of the species rich continental slopes of the world have never been surveyed. Chondrichthyan taxa found in deepwater are usually different to those found inshore. Hence, our knowledge of most diverse deepwater genera (e.g. *Apristurus*, *Centrophorus*, *Dipturus* and *Squalus*) is far from complete. As an example, a detailed examination of museum material and specimens obtained from recent trawl surveys along the continental margin of Australia, have led to the discovery of more than 100 new or previously unrecorded chondrichthyan fishes from the region, about two-thirds of the previously known fauna (Last and Stevens 1994). Large expanses of the Indian and Pacific Oceans remain unexplored, and based on past experience (i.e. the NORFANZ voyage, Williams *et al*. 2006), each of the major submarine ridges and plateaus are likely to have faunas well represented by narrow-ranging endemic species. Some groups, such as the skates (Family Rajidae), which rarely disperse across deep ocean barriers, are highly valuable indicators of micro-endemism.

The faunal knowledge gap is not restricted to the deep sea. Recent surveys of markets of eastern Indonesia identified 137 chondrichthyan species of which at least 20 are new to science, and at least another 40 were newly recorded from the region (White *et al*. 2006). Several of these species have been fished intensively to the point of concern prior to their taxonomic recognition. In most cases, no one has looked carefully at the species composition of the catches. Some of these species are not small or obscure. Some newly discovered rays have a body width of almost a metre and exceed 3 m in length.

Important issues that need to be addressed

Taxonomy provides a critical baseline that underpins all other forms of biological research. Without a sound taxonomic

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knowledge of a region's fauna, all other levels of research are seriously compromised. We cannot expect to understand and soundly manage chondrichthyan faunas unless they have been unambiguously defined and described. However, this message is often lost on those reliant on this information. For example, rays (batoids) are amongst the most seriously threatened marine groups on the planet with ~32% of the species assessed having been listed in threatened categories of the *IUCN Red List of Threatened Animals* (IUCN 2006). Understanding their biology and knowing how to recognise these species is fundamental to their conservation. Species are often similar and identification tools are needed to enable non-specialists to obtain accurate identifications. However, despite more than a decade of attempts by senior taxonomists to educate fellow biologists, managers, and bureaucrats, of the need for a scientifically up-to-date identification guide to the world's ray fauna, such a comprehensive guide is yet to be endorsed.

The taxonomy of chondrichthyan fishes has a long history dating back to Linnaeus in the mid 1700s with an impressive 56 species (~5%) of the world's species described by 1800 (P. R. Last and L. J. V. Compagno, unpublished data). However, the task of defining and naming the world's species has proven to be very difficult indeed. Descriptions of many of the early species are brief and do not provide an adequate diagnosis of the species. The large size of many of the species has created a problem for museums and other repositories. Large specimens are difficult to store in preservative and type specimens are often in very poor condition, stuffed or incomplete, or existing only as skins, heads or jaws. Curators are reluctant to loan bulky and often-delicate holotypes, so taxonomists can rarely assemble all important material in one location for side-by-side comparison of nominal species. Similarly, few collections hold large multiple lots of each species so that intraspecific variations can be described. This scenario has led to forms from different biogeographic regions being erroneously regarded as conspecific, resulting in serious nomenclatural problems in many groups.

Nomenclatural instability is also strongly evident at supraspecific levels. In the last decade, multiple schemes have been proposed, even above family levels (de Carvalho 1996). Contemporary taxonomic specialists are largely unconsolidated in their views on chondrichthyan classification. Once again, molecular research has both confused and added weight to these debates so it will be some time before stability is attained.

Many chondrichthyans are considered to be very widespread, but in many cases these taxa belong to species complexes. Members of some genera are often cryptic and populations need to be compared carefully across the perceived range of the component species. Morphological differences often exist but these can be very subtle. Molecular tools have proven to be invaluable for corroborating the non-conspecificity of taxa, or detecting cognitive species not previously identified using classical methods.

Our ichthyological research capacity is declining worldwide as an ageing research group retires and their roles are not being fully replaced. Without adequate succession planning, their knowledge and skills will be lost to the detriment of other fields of biological science. Chondrichthyan taxonomy and systematics are not immune. Further complicating matters is the policy of some scientific journals that have ceased to accept taxonomic papers.

What research directions are needed to fill the gaps?

A strategic plan is needed to fill major knowledge and collection gaps. Poorly surveyed regions need to be identified. Biogeographic frameworks can be used to prioritise these regions to flag likely hotspots of undiscovered endemism. Feedback should be provided to international research forums to enable gaps to be filled on a priority/opportunistic basis. There are good recent examples of where cooperative multi-national approaches have been very successful in achieving these goals e.g. NORFANZ (Williams *et al*. 2006). Improved survey methods, particularly the use of side-scan sonar to provide detailed benthic maps to assess habitat (e.g. Beaman *et al*. 2005), have enabled more strategic survey approaches to be adopted. However, dedicated deepwater surveys from large oceanic trawlers are expensive and few vessels have the capability of surveying the deep continental slopes and ocean basins. Hence, surveys need to be carefully planned and commercial vessels used opportunistically to obtain material from remote or inaccessible zones. Regional faunas also need to be investigated using current knowledge of large-scale biogeography. 'Widespread' taxa that do not conform to 'normal' faunal distribution patterns need to be investigated further using more thorough morphological examination and, where possible, molecular approaches.

What is good about chondrichthyan research, what could be done better?

An increased community interest in chondrichthyans has led to the wider and more sincere support for their survival. The quality of contemporary taxonomy, supplemented by molecular approaches, has improved our understanding of these fishes despite resource limitations. However, this work has raised as many questions as it has answered. Solving these problems is retarded, to some extent, by the perennial issue of procuring quality comparative material for investigation. Another fundamental problem with the current research environment is the need to properly inform and educate stakeholder groups of the need for scientific rigour. Similar species are often managed together either for 'simplicity' or because cognates are considered too difficult to distinguish. Poor quality assurance in the form of species misidentification often leads to poor management approaches for these species, some of which are vulnerable. Stakeholders need to know how to identify closely related sympatric species because these taxa are likely to be isolated ecologically and may need to be managed differently. However, stakeholders cannot be held accountable for employing poor procedures if the tools needed to identify taxa are unavailable. Good regional guides, or comprehensive faunal treatments such as the FAO publications (e.g. Compagno 1984), serve to educate stakeholders and eventually improve the quality of data obtained on species, leading to better decision-making and management. These references need to be user friendly but should be comprehensive in their coverage. We need to avoid 'quick and dirty' approaches and direct our efforts towards improving scientific rigour and attaining nomenclatural stability. This will involve re-examining old types and making better use of fresh contemporary material. This research is not inexpensive but if done properly will need to be done only once.

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