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Global catches, exploitation rates, and rebuilding options for sharks

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ABSTRACT

Adequate conservation and management of shark populations is becoming increasingly important on a global scale, especially because many species are exceptionally vulnerable to overfishing. Yet, reported catch statistics for sharks are incomplete, and mortality estimates have not been available for sharks as a group. Here, the global catch and mortality of sharks from reported and unreported landings, discards, and shark finning are being estimated at 1.44 million metric tons for the year 2000, and at only slightly less in 2010 (1.41 million tons). Based on an analysis of average shark weights, this translates into a total annual mortality estimate of about 100 million sharks in 2000, and about 97 million sharks in 2010, with a total range of possible values between 63 and 273 million sharks per year. Further, the exploitation rate for sharks as a group was calculated by dividing two independent mortality estimates by an estimate of total global biomass. As an alternative approach, exploitation rates for individual shark populations were compiled and averaged from stock assessments and other published sources. The resulting three independent estimates of the average exploitation rate ranged between 6.4% and 7.9% of sharks killed per year. This exceeds the average rebound rate for many shark populations, estimated from the life history information on 62 shark species (rebound rates averaged 4.9% per year), and explains the ongoing declines in most populations for which data exist. The consequences of these unsustainable catch and mortality rates for marine ecosystems could be substantial. Global total shark mortality, therefore, needs to be reduced drastically in order to rebuild depleted populations and restore marine ecosystems with functional top predators.

1. Introduction

Sharks, skates, rays and chimaeras together comprise the chondrichthyan fishes (Class *Chondrichthyes*), a group of about 1000 species that has persisted for at least 400 million years, rendering them one of the oldest extant vertebrate groups on the planet. Recently, however, the global growth of fishing, coupled with *Chondrichthyes*' relatively slow growth and reproductive rates, have resulted in the progressive depletion of populations around the world. This trend has been particularly pronounced for sharks, largely due to their inherent vulnerability, and an increasing demand, particularly for their fins, in the Asian market [1–4]. As such, many shark species are comparable to great whales, which also have late maturity, slow growth and low reproductive rates, and experienced escalating global fishing pressure until a global whaling moratorium came into effect in 1986 [5]. Similar to whales, quantifying the precise extent of sharks' decline, the risk of species extinction, and the consequences for marine ecosystems have been challenging and controversial, mostly due to data limitations [4,6–8].

A key problem is the incomplete reporting of shark catches to the United Nations Food and Agriculture Organization (FAO), which tracks the status of fisheries worldwide. Caught sharks are often not landed and are instead discarded at sea [7,9], with such discards not usually reported to national or international management agencies unless there are trained observers on board. Compounding this problem is the practice of shark finning, where the animal's fins are removed prior to the body being discarded at sea [9]. Due to the high value of the fins in Asian markets this practice is globally widespread. Some jurisdictions, such as Canada, the United States, Australia, and Europe have gradually introduced anti-finning legislation over the last 10 years, yet the practice continues in most other parts of the world [2]. Therefore it is very likely that reported catches represent only a fraction of total shark mortality. For example, Clarke et al. [9] used

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trade auction records from Hong Kong to estimate that the total mass of sharks caught for the fin trade. Estimates ranged between 1.21 and 2.29 Mt (million metric tons) yr^{-1} with a median estimate of 1.70 Mt yr^{-1} in the year 2000. This amounted to more than four times the reported shark catch from FAO at that time [9].

Notwithstanding these problems, the FAO, among other management bodies, has long recognized the conservation challenges associated with sharks and their relatives, and it launched an International Plan of Action for Sharks in 1999 (IPOA-Sharks, which also includes skates, rays, and chimaeras). This plan aims to enhance the conservation and management of sharks and their sustainable use, while improving data collection and the monitoring and management of shark fisheries [10]. The IPOA-Sharks further recommends that all states contributing to fishing mortality on sharks should participate in its management, and should have developed a National Shark Plan by 2001. However, progress remains disappointing so far, with limited adoption and implementation of IPOA goals at the national level [2,11].

The objective of this paper is to provide an up-to-date assessment of the current status of shark populations including estimated global catches, current exploitation rates (herein defined as the total catch divided by the estimated biomass), and potential extinction risks at current levels of exploitation. Based on this review, possible management solutions for conserving and rebuilding shark populations are discussed. The authors intend to provide critical baseline information for the further development of national and international action plans that help ensure the conservation of sharks and their relatives.

2. Methods

Available information to estimate total shark fishing mortality, including reported landings, dead discards, and illegal, unregulated and unreported (IUU) landings were compiled for this paper. Caught sharks are either landed (reported or IUU) or discarded (alive or dead). Discarded sharks that are finned suffer 100% mortality, and those that are not finned suffer a lower post-release mortality [12]. These components (reported and IUU landings, dead discards) are estimated here from published data. In some cases it was necessary to convert shark numbers to weights or vice versa. To this end published estimates of average shark weights for species belonging to four major species groups were extracted from the available peer-reviewed literature: pelagic (e.g. *Prionace glauca*, *Isurus oxyrinchus*), large coastal (e.g. *Galeocerdo cuvier, Carcharhinus leucas*), small coastal (e.g. *Squalidae, Squatina spp.*), and deep water sharks (e.g. *Centrophorus granulosus, Apristurus profundorum*). Published weights from each study were averaged by species group in each study (e.g. all pelagic species weights were combined into one estimate), and then the median weight was computed across studies.

Reported catches were derived from the 'Fishstat' FAO online landings database [13]. FAO results were also compared with the 'Sea Around Us Project' (SAUP) database at the University of British Columbia, which is based on the FAO data and additional sources [14]. Since results were similar (<10% difference in catches), and temporal coverage was more complete (1950–2010) for the FAO data, the latter was used for analysis. Chondrichthyan catches included the following categories: large coastal and pelagic sharks, small coastal sharks, deep-water sharks, undifferentiated sharks, rays and chimaeras (mixed group), rays, skates, chimaeras (separate groups) and undifferentiated skates and rays. To estimate the total take of sharks, the proportion of sharks relative to other chondrichthyan catch from the differentiated groups was determined, and it was assumed that it was the same as in the undifferentiated (mixed species) group. Global trade data for shark fins were extracted and summarized from the same data base. For regional comparison, we also analyzed trade data from the Government of Hong Kong Department of Aquaculture and Fisheries Census and Statistics Reports.

The extent of illegal, unregulated and unreported (IUU) catch was estimated from the peer-reviewed literature [15] by taking the average of the low (11 Mt yr^{-1}) and high estimates (26 Mt yr^{-1}) for global IUU fishing, equivalent to 18.5 Mt yr^{-1}. Since the proportion of chondrichthyans in the IUU catches is unknown, it was assumed that chondrichthyans comprise the same proportion in the IUU catch as they do in the reported catch (1.2% on average). This is likely conservative because shark catches are often unreported, for example in artisanal or bycatch fisheries. When converting IUU catches to numbers of individuals it was also assumed that the proportional representation of major species groups was similar to the reported catch.

The amount of discarded sharks was estimated from published data, where scientifically trained observers had determined the overall catch rates for sharks in commercial fisheries. This analysis was performed comprehensively for the global longline fleet, a major fishery that operates worldwide and is well-known for its high proportion of shark bycatch and discards [3]. First the rate of shark catch was estimated from published sources for each major ocean basin, then this was scaled up by using the reported global longline effort, estimated at 1.4 billion hooks for the year 2000 [16]. Global effort and catch rate data were not available for other fishing gears that catch sharks (e.g. gillnet, purse-seine, troll, and trawl). Hence it was assumed that the proportion of longline shark catch in the total global shark catch would be the same as the proportion of large pelagic sharks in the total reported catch, which averaged at 52%. This assumption is based on the rationale that more than 80% of pelagic sharks caught every year are estimated to be caught on longlines [17]. Furthermore, the proportion of sharks that are finned before being discarded was estimated, along with the proportion of sharks that die post-release from other injuries, by compiling and averaging estimates of shark finning and post-release mortality from peer-reviewed published sources.

Furthermore, an average global exploitation rate for sharks was estimated. The exploitation rate is commonly defined as the total catch divided by the total biomass. Only one published estimate of total biomass was available, which amounts to 86.3 Mt for all elasmobranchs (sharks, rays, skates) combined [18]. It was assumed that half of this biomass (43.2 Mt) is comprised of sharks. The rationale for this assumption is that about half of all elasmobranch species are sharks and about half of the reported elasmobranch landings by weight are sharks. The overall biomass estimate was derived by macro-ecological scaling laws, and as such represents unexploited biomass which does not account for the effects of fishing (methodological details can be found in [18]). Here, it was assumed that half of the original biomass has been depleted due to fishing (21.6 Mt). The rationale for this number is that exploited fish stocks globally are estimated to be at $\sim$30%–45% of their original biomass [19], and 50% is therefore a conservative assumption for a highly exploited group, where many populations have declined 80% or more [20]. The resulting estimate of global shark biomass (21.6 Mt) was used as a basis for estimating global exploitation rate.

Two more independent estimates of exploitation rate were computed here. Published estimates of instantaneous fishing mortality (F) for assessed shark populations were extracted from the global RAM Legacy database of stock assessments [21] and other peer-reviewed sources. These estimates were converted to exploitation rates (U) as follows:

$$U = 1 - \exp(-F), \tag{1}$$

and then averaged across all populations. The second independent estimate of exploitation rate was derived by using the published median estimate of total shark catches for the fin trade, or 1.7 Mt [9], and dividing this by the total biomass estimate