Marine Policy ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Keeping the lead: How to strengthen shark conservation and management policies in Canada

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ARTICLE INFO

Article history:
Received 21 January 2010
Received in revised form
13 February 2010
Accepted 13 February 2010

Keywords:
Biodiversity conservation
Bycatch
Canada
Fisheries management
Sharks
Threatened species

ABSTRACT

Internationally, shark conservation is now being recognized as a major environmental challenge, but management efforts to halt the overexploitation of sharks have lagged behind. This review examines the state of knowledge for shark species in Canadian waters and analyzes the role of existing management and legislation in ensuring shark conservation. Despite Canada's early leadership, the present management framework reveals major shortcomings with regard to legal protection, bycatch and finning regulations. These problems are not unique to Canada but illustrate broader issues pertaining to the global management of endangered fish species. To strengthen the conservation and management of sharks, this paper recommends a set of key policies and management priorities, which exemplify proper precautionary management of endangered shark species in Canada and could serve as a blueprint for improving conservation efforts internationally. A structured approach for grading progress in shark conservation efforts against best practices is also presented and could be used as a goalpost elsewhere.

1. Introduction

In recent years the management of shark species has emerged as a new priority in marine conservation. Worldwide catches of sharks and other elasmobranches have increased steadily in the past two decades [1], driven largely by the rising demand for fins on the Asian market and the decline in yields in some traditional fisheries which have resulted in a shift toward species that were formerly discarded [2]. Today, an estimated 26–73 million sharks are traded annually for their fins, a number that exceeds the reported catch by three to four times [3].

Sharks have long been recognized as vulnerable to increased mortality because of their life-history characteristics (relatively slow growth, late age of maturity, long life, and low reproductive rate) [4]. In a number of regions, such as the northwest Atlantic, Gulf of Mexico, and the Mediterranean, numerous species, particularly large coastal and pelagic sharks, have shown severe declines in recent decades, and many are estimated to be less than 10 percent of former abundance [5–8]. According to the IUCN, sharks along with skates and rays are among the most threatened marine vertebrates, most notably pelagic sharks, of which 60 percent are currently threatened with extinction [9–10]. Many of these species are apex predators and changes in their abundance can have far-reaching consequences for the structure, function and resilience of marine ecosystems; which rises important ecological, socio-economic, and management concerns [11–13].

Canada is not a major shark fishing nation, but is considered one of the leading nations with regard to shark management, as it was one of the first countries in the world to develop and implement a management plan for sharks. The 1995 plan for Atlantic pelagic shark fisheries, established quotas for porbeagle (*Lamna nasus*), blue (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus)* sharks, limited the number of fishing licenses available, and imposed fishing gear restrictions [14]. Following widespread concern over the increase of shark fishing, its negative consequences on shark populations, and a lack of management, the Food and Agriculture Organization of the United Nations (FAO) developed, in 1999, an International Plan of Action for the Conservation and Management of Sharks (*IPOA-Sharks*) [15]. This plan is a voluntary instrument within the framework of the Code of Conduct for Responsible Fisheries, which encompasses both target and non-target species and is guided by the principle that total fishing mortality for each stock be kept within sustainable levels [15]. Canada is one of only 12 states out of the 130 states reporting shark landings to the FAO that participates in the *IPOA-Sharks.* Although the Canadian National Plan of Action for sharks provides useful details on commercial shark stocks, it does not specify actions to assess or mitigate threats to non-commercial or threatened shark species [16]. This review analyzes

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doi:10.1016/j.marpol.2010.02.006

to what extent the existing management framework protects shark species (Superorder *Selachimorpha*) in Canada. Our goals in this study were to evaluate the current state of knowledge, the role of existing legislation for sharks in Canada, discuss success and limitations, and highlight priorities for the management of sharks in Canada, and internationally.

2. Canadian shark species, conservation status, and the *Species at Risk Act*

Twenty-eight species of sharks representing 13 families have been reported in Canadian waters (Table 1). Few shark species are the subject of directed commercial fisheries in Canadian waters, whereas the majority are caught as bycatch and then discarded. The species, which are of primary commercial interest, include the spiny dogfish (*Squalus acanthias*), exploited on both coasts, and to a lesser extent the porbeagle and shortfin mako shark in the Atlantic [16].

According to IUCN assessments, close to half of Canadian shark species are considered globally threatened with extinction (i.e. classified as vulnerable, endangered, or critically endangered) (Table 1). In Canada, the *Species at Risk Act* (Bill C-5, or SARA 2002) was created to protect threatened species and their habitats, in order to avoid extirpation. If species are listed as threatened or endangered, no person can kill, harm, harass, capture or take any individual of this species and a recovery strategy must be developed [19]. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) provides the scientific assessment on the status of individual species, and after the socio-economic impacts are reviewed, the Minister makes the final decision of which species are to be protected under SARA. To date, 10 shark populations representing 8 species have been evaluated by COSEWIC, 3 of these as endangered, and 1 as threatened (Table 1). So far, only the bluntnose six-gill (*Hexanchus griseus*) and the tope shark (*Galeorhinus galeus*) have been legally listed under SARA (in 2007, as special concern), but their recovery plans are still pending.

All remaining species, with the exception of porbeagle, are currently being considered for listing under SARA. The porbeagle shark for which a small directed fishery exists in Atlantic waters was rejected under SARA in 2006, despite being assessed as endangered [20]. The primary reasons for the rejection were (1) the economic costs to fishers and associated industries (constituting a loss of eight jobs and an economic reduction of 2 percent to a single community), and (2) the loss of biological information from fisheries, which was the only source of information for monitoring population recovery at the time [21,22].

The process of listing endangered species under SARA has been criticized in the past; marine species, especially if commercially harvested, have rarely been afforded legal protection [23]. Currently, the Pacific population of basking sharks and the Atlantic populations of blue, shortfin mako, and great white sharks are being considered for listing under SARA. Blue sharks and shortfin makos may prove contentious, as these sharks are frequently caught in pelagic longlines fisheries directed at tuna

Table 1
List of all shark species occurring in Canadian waters with their conservation status according to the global IUCN red list and Canada's COSEWIC classification with their assessment year.

Family	Species	Common name	CAN	IUCN/COSEWIC status[a]	IUCN/COSEWIC year
Species of commercial interest					
LAMNIDAE	*Lamna nasus*	Porbeagle Shark	A	VU[b]/EN	2006/2004
LAMNIDAE	*Isurus oxyrinchus*	Shortfin Mako Shark	A, P	VU/TR (A)	2008/2006
SQUALIDAE	*Squalus acanthias*	Spiny Dogfish	A, P	VU	2006
Species that are common or occasional bycatch					
ALOPIIDAE	*Alopias vulpinus*	Thresher Shark	A, P	VU	2008
CARCHARHINIDAE	*Prionace glauca*	Blue Shark	A, P	NT/SC (A), DD (P)	2000/2006
CARCHARHINIDAE	*Galeocerdo cuvie*	Tiger Shark	A	NT	2000
CETORHINIDAE	*Cetorhinus maximus*	Basking Shark	A, P	VU/EN (P)	2000/2006
DALATIIDAE	*Somniosus pacificus*	Pacific sleeper Shark	P	N/A	–
ETMOPTERIDAE	*Centroscyllium fabricii*	Black Dogfish	A	LC	2008
HEXANCHIDAE	*Notorynchus cepedianus*	Broadnose Sevengill shark	P	DD	2000
HEXANCHIDAE	*Hexanchus griseus*	Bluntnose sixgill shark	P	NT/SC	2000/2007
LAMNIDAE	*Lamna ditropis*	Salmon Shark	P	LC	2008
SCYLIORHINIDAE	*Apristurus brunneus*	Brown Cat Shark	P	DD/DD	2004/2007
SOMNIOSIDAE	*Somniosus microcephalus*	Greenland Shark	A, Arc	NT	2006
TRIAKIDAE	*Galeorhinus galeus*	Tope Shark	P	VU/SC	2006/2007
Species that are rare bycatch					
ALOPIIDAE	*Alopias superciliosus*	Bigeye Thresher Shark	P	VU	2008
CARCHARHINIDAE	*Rhizoprionodon terraenovae*	Atlantic sharpnose shark	A	LC	2000
CARCHARHINIDAE	*Carcharhinus longimanus*	Oceanic Whitetip Shark	A	VU	2006
CARCHARHINIDAE	*Carcharhinus obscurus*	Dusky Shark	A	VU	2009
ETMOPTERIDAE	*Etmopterus spp.*	Lanternshark spp[c]	P	–	–
ETMOPTERIDAE	*Etmopterus princeps*	Great Lanternshark	A	DD	2006
LAMNIDAE	*Isurus paucus*	Longfin Mako Shark	A	VU	2006
LAMNIDAE	*Carcharodon carcharias*	White Shark	A, P	VU/EN (A), DD (P)	2000/2006
ODONTASPIDIDAE	*Odontaspis Taurus*	Sand Tiger Shark	A	VU	2000
SCYLIORHINIDAE	*Apristurus profundorum*	Deepwater catshark	A	DD	2004
SOMNIOSIDAE	*Centroscymnus coelolepis*	Portuguese Dogfish	A	NT	2003
SPHYRNIDAE	*Sphyrna zygaena*	Smooth Hammerhead	A	NT	2000
TRIAKIDAE	*Mustelus canis*	Smooth dogfish	A	NT	2000

CAN: Canadian occurrence, A: Atlantic waters, Arc: Arctic waters, P: Pacific waters; VU: vulnerable, NT: near threatened, LC: least concern, DD: data deficient, TR: threatened, SC: special concern, N/A: not assessed.

[a] Designable unit indicated in parentheses for COSEWIC status.
[b] Northwest Atlantic population is classified as endangered (2006).
[c] Possibly Hawaiian Lanternshark (*E. villosus*) [17].

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and swordfish in Atlantic waters. On the other hand, Atlantic great white sharks and Pacific basking sharks are currently very rare and consequently their listing may have little apparent cost. There are only 32 confirmed observations of great white sharks in Atlantic Canada, with 15 of these observed as bycatch in commercial fishing gear [24]. Pacific basking sharks used to be seen in large aggregations off the Canadian west coast, but were deliberately eradicated in the 1950s. Only 10 sightings of basking sharks in Pacific waters have been confirmed since 1973, of which 4 were from trawl observer records [25]. It is estimated that this population has declined by over 90 percent over the last 60 years [25].

In conclusion, whereas SARA came into effect in 2002, it has yet to be applied to protect endangered shark populations in Canadian waters. Nonetheless, shark populations receive some degree of protection through fisheries regulations under Integrated Fisheries Management Plan (IFMP). These IFMPs have been amended using the legislative tools of the Fisheries Act to achieve certain conservation goals.

3. Shark fisheries and shark bycatch management

3.1. Pelagic shark fisheries management

Due to their life history and low productivity, sharks require a particularly conservative approach to fisheries management [26]. Worldwide, only few countries have developed management plans for their shark fisheries [27]. The first Atlantic Canadian pelagic shark IFMP in 1995 was implemented with the intentions of limiting the growth of these emerging shark fisheries and collecting biological information for stock assessments [14]. In the absence of stock assessments at that time, the plan established allowable catch levels for porbeagle, shortfin mako and blue sharks, based simply on average reported landings for these 3 species [14]. Since then, management measures have included fishing seasons, area limits, licensing, quota allocations for porbeagle, blue, and shortfin mako sharks, bycatch (landings) limits, finning regulations, and monitoring of fishing activity [18]. Currently, porbeagle and blue sharks are subject to directed fisheries while shortfin makos are only retained as a bycatch species [18]. A blue shark fishery is rarely pursued because of its low market value and reported landings, primarily taken as bycatch in pelagic longlines or during shark derbies have averaged less than 55 metric tons (t) annually [28], which is much smaller than the established 250 t non-restrictive allowable quota (Table 2). The porbeagle shark is the only species managed with comprehensive stock assessments; the current recovery plan allows a catch quota of 185 t, a level below the estimated maximum sustainable yield of 250 t [34]. Notwithstanding the ethical question of targeting a species that has been assessed as regionally endangered by both the IUCN and COSEWIC (Table 1), the Canadian porbeagle fishery may be among the best-studied, controlled and monitored shark fisheries. The most recent population assessment suggests the stock is stable, but at low biomass: mature females are estimated between 83 and 103 percent of their number in 2001, or 12–16 percent of virgin stock size [30]. Under current fishing mortality the population is expected to recover slowly, but unknown and unregulated catches in the high seas might jeopardize this recovery [30]. Similar to blue sharks, shortfin makos are managed under non-restrictive quotas [18]. Since 1998, landings of shortfin makos have averaged 60–80 t annually which is thought to have little effect on the overall Atlantic population [31]. Since 2006, live release of shortfin makos and a maximum annual landings limit of 100 t (previously 250 t [14]) have been adopted as precautionary measures [31] (Table 2).

The Atlantic Pelagic Shark IFMP provides three provisions with regard to all shark bycatches, with the notable exception of spiny dogfish. First, in the swordfish and tuna longline fleets, the groundfish fixed gear fleets and the Gulf region's mackerel fleet, shark bycatch is not restricted. Second, in all other fisheries, providing the vessel has a license authorizing the landings of sharks, incidental catch of sharks is limited to the lesser of 10 percent or 500 kg by weight on board the vessel per trip. Third, in the porbeagle fisheries, landings of other shark species are allowed, with a maximum weight of less than 50 percent of the total weight of porbeagle sharks landed [18].

On the Pacific coast, there is no direct exploitation of pelagic sharks. Landings of sharks taken as bycatch in commercial

Table 2
Summary of management measures, average landings and discards in Canadian waters, and population trend for shark species managed under Canadian integrated fisheries management plans (IFMPs).

Common name *Species name*	Population	Quota ($mt\,yr^{-1}$)	Average landings ($mt\,yr^{-1}$)	Average total discards/dead discards ($mt\,yr^{-1}$)	Other measures	Canadian mortality compared to overall mortality	Population trend	References
Blue Shark *Prionace glauca*	North Atlantic	250	< 55 since 1990	2000/1000 since 2002	None	~2%	60% decline 1992–2000	[28,29,5]
Porbeagle Shark *Lamna nasus*	Northwest Atlantic	185	< 100 since 2004	27/? Since 2000	Closed area to the directed fishery to protect mating females	majority	Stable since 2002	[30]
Shortfin Mako Shark *Isurus oxyrinchus*	North Atlantic	100	60–80 since 1998	Minimal?	Encourage live release	~2–3%	40% or greater decline 1992–2000	[31,5]
Spiny Dogfish *Squalus acanthias*	Northwest Atlantic	2500	2500 since 2000	2000–3000/850 since 1986	None	Majority; some movement (10–20%) between Canadian and US waters	Stable, but the decline in the American component may have significant implications	[32]
Spiny Dogfish *Squalus acanthias*	Northeast Pacific	14,940	5000–7000 since 1996	Included in landings	None	? Majority	Stable	[33]

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fisheries are prohibited in all fisheries with the exception of trawl and hook and line fisheries.

3.2. Spiny dogfish management

Spiny dogfish are subject to a different management plan, as they are considered groundfish under the Atlantic and Pacific Groundfish IFMP [35,36]. On both coasts, spiny dogfish quotas reflect past numerical catches rather than scientifically established catch limits. On the Atlantic coast, discards of dogfish are substantial, in both mobile and fixed gear fisheries (Table 2). Anecdotally, they are deliberately discarded dead in some fisheries as they are considered pests that damage fishing gear and compete for catches [37]. In 2003, DFO, in cooperation with the dogfish fishing industry, initiated a five-year research program in order to better advise the management of this fishery [32]; new regulations are pending.

On the Pacific coast, the present fishing effort (Table 2) is not considered threatening for the population [33] and the Pacific dogfish fishery in British Columbia is currently undergoing assessment for the Marine Stewardship Council (MSC) certification.

4. Shark finning regulations

The wasteful and increasingly illegal practice of finning refers to the removal and retention of shark fins and the discard of the remainder of the carcass at sea. Finning utilizes only 2–5 percent of the shark, makes species identification challenging, and significantly contributes to the overexploitation of sharks worldwide [38]. In response, since 2000, a number of fishing states and Regional Fisheries Management Organizations (RFMOs) have adopted protective shark finning policies [27]. Worldwide, the most widely adopted management measure is a 5 percent ratio rule, allowing the landings of a maximum of 5 percent fins relative to the weight of landed carcasses. In Canada, this practice was adopted in 1994 and extended to all Canadian-licensed fishing vessels outside of the 200 mile Exclusive Economic Zone (EEZ) [16].

5. Recreational shark fisheries management

Canada is not a major game fishing nation; nonetheless, derby tournaments in the Atlantic Maritime region have grown in popularity since their beginnings in 1993 [28]. In Atlantic Canada, recreational shark fishing entails hook and release angling and shark derbies. Sharks can only be landed in shark derbies; these events are authorized by DFO and scientific staff collects data from every shark landed. The recreational fishery is mainly for blue sharks (99 percent), but porbeagle, shortfin mako and thresher (*Alopias vulpinus*) sharks are occasionally reported [28]. Shark derbies are held 5–6 times per year between late July and mid-September, solely in Nova Scotia, and landings total 10–20 t of blue sharks per year [28]. Recent precautionary measures include the live release of sharks less than 240 cm and all porbeagle sharks, as well as voluntary tagging programs (Campana, S. pers. comm.).

On the Pacific coast, recreational shark fishing is managed under the finfish recreational fisheries. Primary targets are spiny dogfish and, sometimes, salmon sharks (*Lamna ditropis*), but anglers occasionally catch other shark species such as six-gill (*Hexanchus griseus*) and blue sharks. Daily bag limits are set at 20 individuals with six-gill shark landings prohibited [39].

6. Success and limitations of the Canadian management status quo

6.1. State of knowledge

Ideally, effective management options are derived from comprehensive stock assessments using both fishery-dependent (catches, fishing effort) and fishery-independent data sources (scientific surveys, tagging programs) [40]. In Canada, only the porbeagle population is currently managed under comprehensive stock assessments. In fact, worldwide, few shark stocks are subject to complete stock assessment, usually due to a lack of quality data [1,41]. Overall, with the exception of porbeagle sharks, current population size and the relationship between abundance trends observed in Canadian waters and overall population abundance is not well known. In Canada, for the majority of shark species, fishing appears as the only known proximate threat. Based on observer data, bycatch rates for all species are available, but total actual bycatch or more importantly, total bycatch mortality is largely unknown with the exception of blue sharks in Atlantic waters. In addition, where information exists, there is still considerable uncertainty about the impacts of fishing mortality on potential recovery targets.

6.2. Monitoring

Monitoring is a key element in the effective management of fisheries. Collecting fishers' logbook information is the most widely used practice to record and monitor target species; however, recorded bycatch data are often unreliable [41]. Consequently, worldwide shark bycatch information is still very limited and rarely species-specific [41]. Scientific observer programmes provide the most reliable data on catch composition, bycatch, fishing effort and fishing practices, but their implementation is still very sporadic. Ideally, fishery-independent shark surveys offer the best information for stock assessment.

Overall, in Canada, monitoring of shark catches is well established, but observer coverage is variable (Fig. 1). Recently, two fishery-independent shark surveys have been conducted on the Atlantic coast by DFO, but results are not yet available (Campana, S. pers. comm.). In Pacific Canadian waters, groundfish fisheries in particular are subject to 100 percent electronic monitoring or at-sea observers in addition to fishing logbooks, offering accountable and reliable information on shark bycatch. However, recently gathered observer information has yet to be comprehensively evaluated with regard to sharks, and current levels of shark discards remain mostly unknown in Pacific waters. Observer coverage of domestic fisheries is still low in Atlantic Canada; for example, pelagic longline license holders require only 5 percent observer coverage (a percentage of days at sea fished). These fisheries have one of the highest incidental shark catch of any Canadian fishery; according to current information, sharks comprise on average 40 percent of the total catch by weight of which blue sharks represent over 85 percent [42]. Others fisheries, such as inshore gill nets and cod traps, receive less than 1 percent observer coverage. Bycatch is often ignored or underestimated for rare and smaller demersal species, especially in fisheries that cannot land sharks by condition of licenses. For example, the black dogfish (*Centroscyllium fabricii*) is a common bathydemersal species in Atlantic waters, which is occasionally reported in bottom trawls, but is not consistently recorded; hence no rigorous estimates of discards exist for this species.

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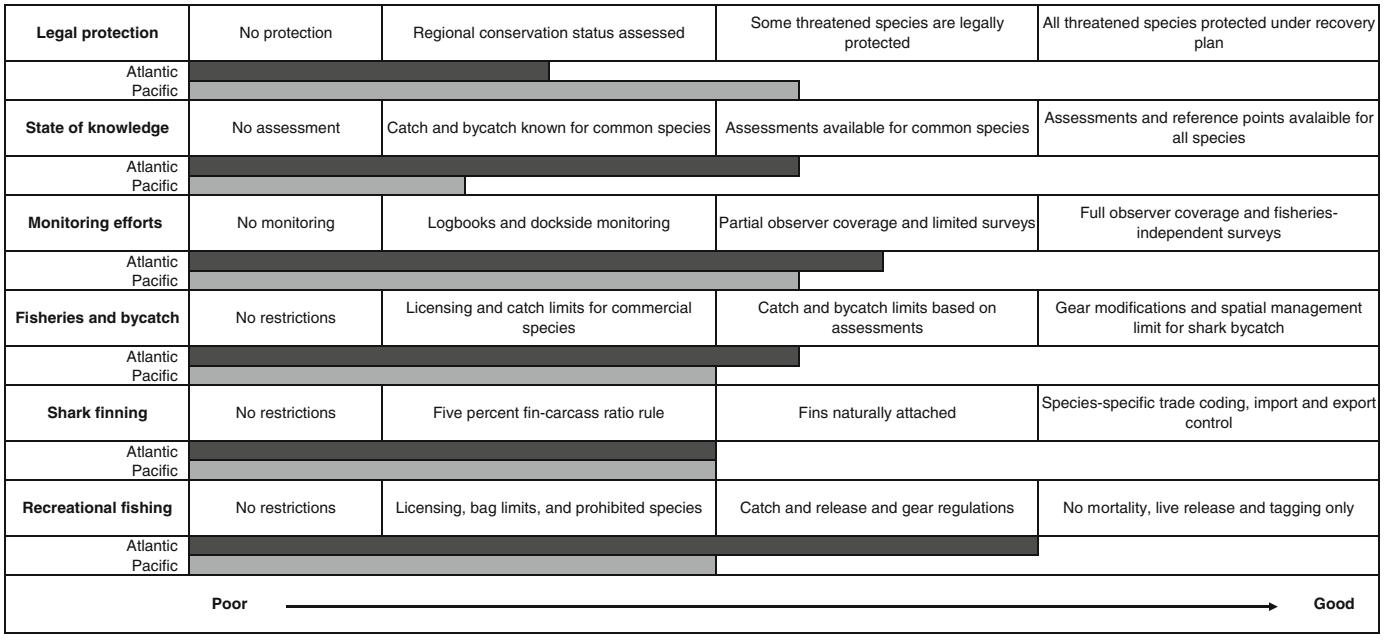

Fig. 1. The path towards improved shark management and conservation. Grey bars indicate current status in Canada relative to best practises.

6.3. Fisheries and bycatch regulations

The full range of fisheries management tools (reviewed in [43]) can be applied to the management of shark fisheries. In Canada, IFMPs provide a suite of regulations limiting the exploitation of species of commercial interest. However, several flaws persist, notably high discard rates for some species including blue sharks and spiny dogfish that result in high mortality; these can be up to 100 times higher than reported landings (Table 2). Discard mortality is currently not accounted for in their management. Likewise, other states with bycatch regulations, such as the US, South Africa or Australia have adopted landing limits, but these provisions do not limit total mortality, which presents a very serious problem in the management of sharks. Also, in Canada, with the exception of porbeagles, quotas are not scientifically defined and the total mortality across jurisdictions and in international waters is uncertain. Bycatch rates of basking and Greenland sharks in Canadian waters are significant, and have to be taken seriously given the very low productivity and poor resilience to exploitation in these species. In Pacific waters, basking sharks have already been reduced by over 90 percent of their former abundance because of overfishing and eradication programs [44]. In Atlantic Canada, since 1986, total reported discards of basking sharks have averaged 164 individuals per year and survival rates are unknown [44]. Current population models suggest a 23 percent probability that the population is decreasing, but the available index of abundance is highly uncertain [44]. Similarly, the Greenland shark is a very common bycatch species in trawl fisheries, especially in the Greenland Halibut bottom trawl fishery, yet very little is known about this species, which is endemic to Arctic and Subarctic waters.

In conclusion, unknown and unregulated discard mortality represents a primary management challenge in Canada and elsewhere. Best management practices require the implementation of total mortality limits from both catches and discards that are based on scientific assessments of species' recovery potential; this could be aided by research into gear modifications and spatial management aimed at minimizing shark bycatch rates and total mortality (Fig. 1).

6.4. Finning policy

Current finning policies are enforced with 100 percent dock-side monitoring. Notwithstanding some anecdotal reports of illegal finning in the Atlantic region, enforcement is thought to be reasonably effective overall. Nonetheless, the 5 percent ratio rule is problematic, because the fin-to-carcass weight ratio varies with species, the choices of fin set, finning procedure, and the state of the shark carcass (dressed or round). This rule contains loopholes that allow for practices such as highgrading (mixing carcasses and fins from different species), or retaining more fins for every carcass onboard [45,46]. A 'fins-attached' policy, whereas all sharks have to be landed with their fins naturally attached (or only partially detached to permit efficient storage) is the only guaranteed method to avoid such practices and has been recommended repeatedly by the IUCN World Conservation Congress. More countries are adopting this regulation, including the US, which recently passed in the House of Representatives to this effect (Shark Conservation Act of 2009) [47]. Other countries with similar regulations include much of Australia (Victoria, New South Wales, Western Australia and Tasmania), Colombia (2007), Oman (prior 1999), and El Salvador (since 2006, fins must be attached by at least one-quarter) [27]. Export and import regulations can be further strengthened by ensuring that all trading of shark fins is recorded and tracked at the species level (Fig. 1). The strongest anti-finning measures were taken by Ecuador, which faced intense illegal finning in its waters; since 2004 that country prohibited the sale and export of fins completely [27].

6.5. Recreational shark fishery

Recreational fisheries are often not well documented by governmental agencies nor are they considered a priority for management, yet they can have serious effects on rare or vulnerable species [48]. In Atlantic Canada (with the notable exception of derby tournaments), the adoption of a catch and release policy in addition to voluntary tagging programs

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demonstrates a conservative and precautionary approach to the management of sharks. Other countries with significant recreational fisheries, such as Australia, New Zealand, the US and the United Kingdom have not yet adopted such a policy, despite the fact that an increasing number of anglers voluntarily use catch and release practices [49]. In general, as in the case of Canadian Pacific regulations (Fig. 1), recreational fisheries for sharks are managed under finfish recreational regulations, with bag limitations, license, and gear restrictions.

7. Conclusion and recommendations

The current Canadian management framework for shark populations is fairly well developed, but still presents major shortcomings when gauged again best practices (Fig. 1). Currently, the SARA listing process has not yet yielded any meaningful protection measures for sharks, the state of knowledge is low for non-commercial species, and regulations governing shark bycatch in Canada do not limit total mortality. In addition, lethal shark derbies in the Maritimes, the growing interest for these events, and the message conveyed to the public, raise serious concerns, despite the fact that shark mortality associated with these tournaments is low compared to commercial fishing activities. These regional problems may illustrate broader issues pertaining to the global management of shark species. Shark conservation is challenging, as many species are highly migratory and several countries share the management of single stocks. Although many species of oceanic sharks are defined as highly migratory species under the United Nations Convention on the Law of the Sea (UNCLOS) and fall under the mandate of RFMOs and Conventions, to date, very few actions to conserve sharks have been undertaken by these organizations. Measures are primarily related to the control of shark finning (5 percent ratio rule) and encouraging the reporting of shark catches, yet there are still no limitations for the harvesting of sharks or direct measures to protect vulnerable species in international waters (reviewed in [50]). In order to achieve effective international cooperation, strong national commitment and leadership are needed. Through appropriate management actions, exploitation rates can be reduced in order to allow sensitive species to recover from overexploitation [43]. We acknowledge that any success in management relies heavily on the regional context, and the dynamic of the fisheries, ecosystem, and governance regimes. Nonetheless, in order to strengthen established shark conservation goals, this paper identifies new policies for Canada, which apply broadly to the management of sharks by other shark fishing nations, and potentially the high seas. Many shark populations have been dramatically reduced, and stringent management measures are required to ensure their persistence and recovery.

1. *Proactive protection*: Even prior to listing species under endangered species law and developing species recovery plans, species of known conservation concern could be readily protected by mandating that all live individuals should be released unharmed under current fisheries management rules. This precautionary measure would reduce total mortality immediately, considering that compliance, monitoring and enforcement are adequate.

2. *Strengthening monitoring, increasing knowledge*: Scientific knowledge is greatly dependant on monitoring efforts. Achieving 100 percent observer coverage in fisheries with high incidental catch of sharks (possibly augmented by electronic monitoring), would decisively improve estimates of shark bycatch, abundance, and distribution. Likewise independent-fishery shark surveys are important in the assessment of shark populations, and the monitoring of their recovery. These measures will result in substantial and more accurate data, which could be used to develop initial population status reports for all common shark species, including those that are not commercially fished.

3. *Innovations*: *reducing unnecessary mortality*: Further measures are needed to mitigate incidental mortality. Implementation of specific gear modifications or spatial management should be investigated further to either reduce the likelihood of shark interactions or discard mortality. Examples of such practices include the Australian and South African tuna and billfish fisheries, which have prohibited the use of wire trace; known to be associated with higher shark, catch rates [51,52]. The use of circle hooks has been shown to reduce the likelihood of blue shark mortality by decreasing chances of deep-hooking in Canadian waters [42]. In addition, on pelagic longlines, blue shark mortality varies significantly between individual vessels, reflecting different practices [42]. Ripping the hook out of the fish, which sometimes removes the jaw, and body-gaffing are two common practices on Canadian vessels, and probably elsewhere [42]. These practices produce severe trauma in sharks and decrease significantly their chance of post-hooking survival [42]. The development and enforcement of handling and release practices in cooperation with fishermen could substantially minimize such injuries. Other factors such as the use of fish instead of squid bait, or reducing the soak time of pelagic longline gear, tend to result in lower shark catch rates while maintaining high yield, yet their effect may vary among species and regions [51]. Improved gear technology could potentially reduce incidental catches and discard mortality of sharks, but further investigation and testing of such practices are required. Ultimately, total allowable catches need to fully account for all sources of discard mortality, and incentives could be developed to minimize these sources of mortality [53].

4. *Adopt 'fins-attached' policy*: Finning regulations, although effective in the Canadian context could easily be changed to adopt a more precautionary policy and reaffirming Canada's engagement in support of shark conservation. Advantages of a fins-attached policy go beyond catch reduction; fins can be cut carefully once landed, in order to get the highest fin quality and market price as well as facilitating species identification and reducing enforcement burden, as fins do not need to be weighed separately [46,50].

5. *Recreational shark fisheries*: *catch and release only*: Across Canada, recreational fisheries regulations should adopt catch-and-release policies for all sharks, without exception. Prohibiting lethal shark derbies and replacing them with tag and release programmes that promote shark education, conservation, and scientific research would demonstrate a precautionary approach to shark management and support other efforts for the conservation of shark species in Canada, and elsewhere.

Acknowledgments

The authors wish to acknowledge funding from the National Science and Engineering Research Council of Canada, the Lenfest Oceans Program, and World Wildlife Fund, Canada. For helpful comments we wish to thank S. Campana, T. Wimmer, B. Saier, and C. Muir.

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Please cite this article as: Godin AC, Worm B. Keeping the lead: How to strengthen shark conservation and management policies in Canada. Marine Policy (2010), doi:10.1016/j.marpol.2010.02.006

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Please cite this article as: Godin AC, Worm B. Keeping the lead: How to strengthen shark conservation and management policies in Canada. Marine Policy (2010), doi:10.1016/j.marpol.2010.02.006