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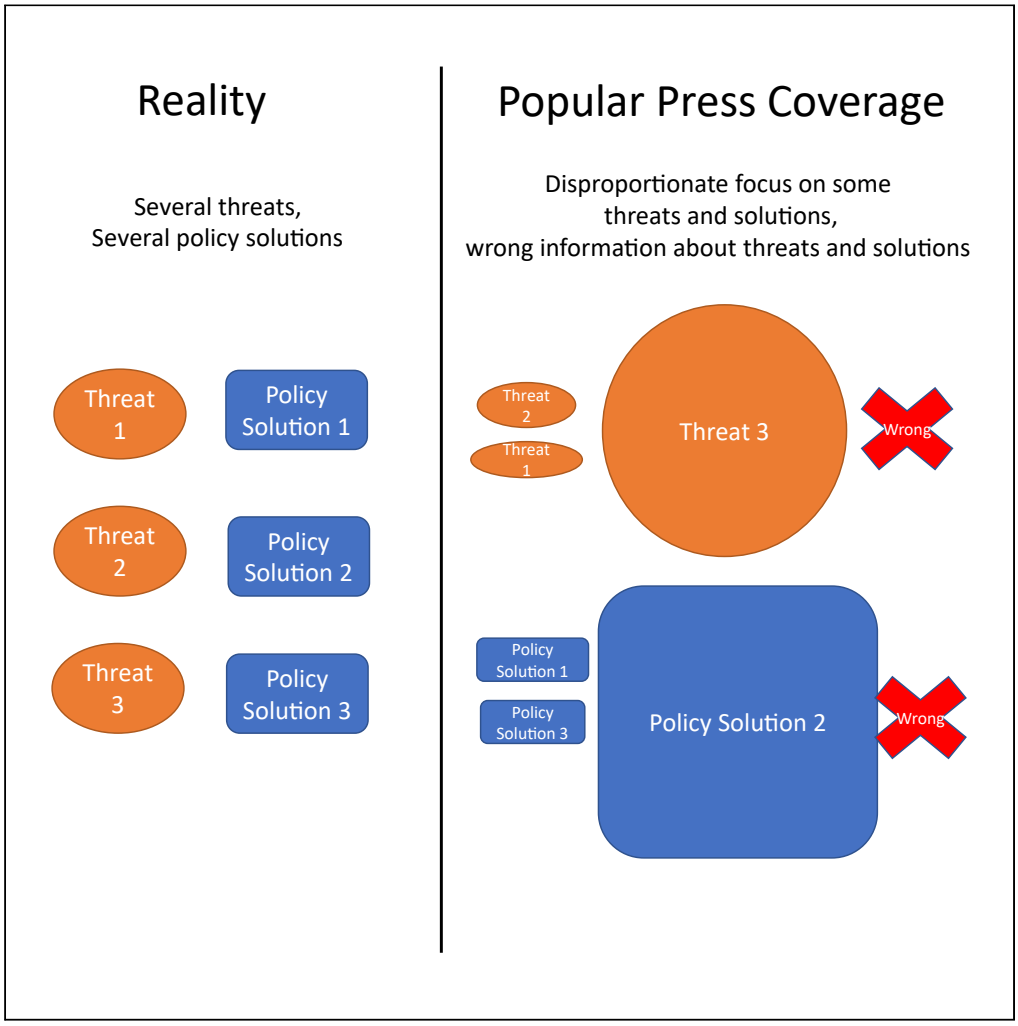

David S. Shiffman, Sarah Joy Bittick, Madeline S. Cashion, ..., Riley A. Pollom, Jennifer Provencher, Nicholas K. Dulvy

david.shiffman@gmail.com

HIGHLIGHTS

The popular press plays a role in public understanding of environmental issues

Many members of the public are misinformed about shark conservation

We analyzed popular press coverage of shark conservation topics

Topics were frequently covered in a biased, misleading, or incorrect way

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Inaccurate and Biased Global Media Coverage Underlies Public Misunderstanding of Shark Conservation Threats and Solutions

David S. Shiffman,[1,11,12,*] Sarah Joy Bittick,[2] Madeline S. Cashion,[3] Sheila R. Colla,[4] Laura E. Coristine,[5] Danielle H. Derrick,[1] Elizabeth A. Gow,[6] Catherine C. Macdonald,[7,8] Mikayla More O'Ferrall,[1] Melissa Orobko,[1] Riley A. Pollom,[1,9] Jennifer Provencher,[10] and Nicholas K. Dulvy[1]

SUMMARY

Sharks are a taxon of significant conservation concern and associated public interest. The scientific community largely supports management policies focusing on sustainable fisheries exploitation of sharks, but many concerned members of the public and some environmental advocates believe that sustainable shark fisheries cannot and do not exist and therefore support total bans on all shark fisheries and/or trade in shark products. The belief that sustainable shark fisheries cannot and do not exist persists despite scientific evidence showing that they can and do, and are important to livelihoods. Additionally, many concerned members of the public are only aware of one threat to sharks and are unaware of other threats—or of most available policy solutions. Here we assess whether the popular press plays a role in spreading misinformation and misunderstanding about these issues via the agenda-setting, priming, and cultivation roles of the media, with the goal of better understanding the causes and consequences of public confusion.

INTRODUCTION

Shark Conservation

Sharks are a taxon containing many species of conservation concern (Dulvy et al., 2014), and there is intense and rapidly growing public interest in the conservation and management of this charismatic group of fishes (Simpfendorfer et al., 2011). Many possible policy approaches to shark conservation exist, (Table 1) and these can be broadly divided into policies that promote effective management with a goal of sustainable exploitation and trade ("target-based," e.g., fishing quotas) and those that promote total bans on all exploitation and trade ("limit-based," e.g., nationwide bans on any commercial shark fishing termed "Shark Sanctuaries") (Shiffman and Hammerschlag, 2016a). Although unsustainable fishing of sharks is common historically and currently, there is no scientific doubt that sustainable shark fisheries can and do exist (Walker, 1998; Simpfendorfer and Dulvy, 2017; Shiffman and Hueter, 2017) and are preferred over bans by an overwhelming majority of scientific experts (Shiffman and Hammerschlag, 2016a). Scientists have raised concerns that limit-based tools may not only be ineffective at protecting sharks (Davidson, 2012; Dulvy, 2013) but may even undermine existing target-based efforts that have been shown to be successful in conserving and recovering shark species (Shiffman and Hueter, 2017). Limit-based tools of course have their place in some situations, especially those focused on protecting an especially vulnerable species (Davidson and Dulvy, 2017, Mizrahi et al., 2019), and a science-based network of marine protected areas can coexist with sustainable fisheries in adjacent waters.

Despite increasing scientific evidence that target-based solutions are effective at preventing shark population declines or even recovering once-overfished populations (e.g., Peterson et al., 2017) and relatively limited evidence that limit-based policy solutions are effective, limit-based policy solutions have gained popularity in recent years (Shiffman and Hammerschlag, 2016a). This may be partially explained by some stakeholders inaccurately believing that sustainable fisheries management tools cannot possibly work on sharks and that more severe measures are needed (i.e., a belief that sustainable shark fisheries cannot and do not exist and therefore we have to ban all fishing). Additionally, there is significant

[1]Earth to Ocean Group, Department of Biological Sciences, Simon Fraser University, 8888 University Drive, Burnaby, BC V5A 1S6, Canada

[2]University of British Columbia, Department of Zoology, Biodiversity Research Centre, 2212 Main Mall, Vancouver, BC V6T 1Z4, Canada

[3]Hemmera, 4730 Kingsway, 18th Floor, Burnaby, BC, V5H 0C6, Canada

[4]Faculty of Environmental Studies, York University, Toronto, ON M3J 1P3, Canada

[5]Department of Biology, The University of British Columbia - Okanagan Campus, 1177 Research Road, Kelowna, BC V1V 1V7, Canada

[6]Department of Integrative Biology, University of Guelph, Guelph, ON N1G 2W1, Canada

[7]Field School, Miami, FL, USA

[8]University of Miami Rosenstiel School of Marine and Atmospheric Sciences, 4600 Rickenbacker Causeway, Miami, FL 33149, USA

[9]Wildlife Conservation Society Canada, 344 Bloor Street West, Toronto, Ontario M5S 3A7, Canada

[10]Acadia University, Department of Biology, 15 University Drive, Wolfville, Nova Scotia B4P 2R6, Canada

[11]Present address: Arizona State University New College of Interdisciplinary Arts and Sciences

[12]Lead Contact

*Correspondence: david.shiffman@gmail.com

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Threat	
Shark finning	The removal of a shark's fins at sea and the discarding of the shark's carcass at sea. (NB: if a shark's carcass is brought to shore, that shark has not been "finned" even if the fins are later removed and sold.)
Overfishing	Removing fish from a population at a rate that cannot be replaced by reproduction (i.e., unsustainable fishing)
Shark fin trade	Selling shark fins, which may or may not come from shark finning. (NOTE: if a shark's carcass has been landed and that shark's fins are later removed and sold, that is an example of shark fin trade that did not result from shark finning. This is common in the USA and also happens elsewhere.)
Shark meat trade	Selling shark meat, which may or may not come from sharks whose fins were also sold
Shark liver oil trade	Selling shark liver oil, used in some cosmetics and pharmaceuticals
Bycatch	Catching a species unintentionally while targeting a different species (aka "non-target catch")
Recreational fishing	Fishing for sharks for fun, as opposed to commercial shark fishing. Can be but does not have to be in the form of tournaments/derbies
Pollution	Human-made waste in the ocean, including but not limited to plastics
Climate change/ocean acidification	Anthropogenic changes to the climate and associated changes in ocean pH
Policy Solution	
Fishing quota/sustainable fisheries management	Any mention of any of a suite of policies designed to limit the catch of sharks to a level deemed sustainable by scientists and managers, not banning all fishing
Finning ban	A ban on removing the fins of a shark at sea and discarding the carcass at sea, distinct from a ban on selling fins
Bycatch reduction	Regulations designed to decrease the catch of sharks as non-target species in a fishery that targets other fish
No-take MPA	A total ban on all fishing (for sharks and for other species) in an area
Shark sanctuary	A ban on commercial fishing for sharks, but not other fish, in an area
Shark fin trade ban	Banning the sale of shark fins, distinct from a finning ban
Consumer boycott/corporate response	Refers to activists who criticize a company for involvement (often peripheral) with the shark fin trade, as well as how those companies respond to that criticism

Table 1. Definitions of Threats and Policy Solutions

misunderstanding among concerned members of the public about the threats facing sharks, with many examples of the specific and technical term "shark finning" being misused to refer to any threat to sharks (Shiffman and Hammerschlag, 2016a). There are also many examples of environmental activists (primarily those unaffiliated with larger science-based non-profits) focusing exclusively on shark finning, wrongly implying that shark finning is the only threat sharks face and the only significant source of shark mortality; focusing on only part of the problem means that significant sources of mortality remain unaddressed (Shiffman and Hueter, 2017). Although some shark species in some parts of the world are indeed targeted by fisheries primarily for their fins, an increasing number have their meat traded as well—and policy solutions focusing exclusively on fins ignore this significant and growing source of mortality.

It is important to assess the causes and consequences of this misunderstanding, as members of the public who misunderstand current threats and available solutions are more likely to support solutions that are not supported by the scientific data (e.g., Loomis et al., 2001 found that members of the public held

misconceptions about prescribed burning but were more likely to support this science-based solution after they had been educated about it). Such suboptimal solutions potentially come at the expense of solutions that *are* supported by the scientific data, which may in turn lead to alienation of key stakeholder groups like fishers and further exacerbate conservation challenges.

The Role of the Popular Press in Informing the Public and Shaping Public Support for Environmental Policy

The way that scientific information reaches the public and eventually influences policy change can be conceptualized through diagrams of the science/policy interface, which allow us to model pathways of information flow as information moves from scientific experts to stakeholder groups to decisionmakers (see Phillis et al., 2013 for a simplified reactionary pathway of this process). One important mechanism by which scientific information spreads across the science/policy interface is through media coverage from the popular press, which plays a role in public understanding and interpretation of scientific and environmental issues (Hansen, 2011).

Popular press coverage not only reflects current public opinion on a topic but has the ability to shape and influence current public opinion (Scheufele and Tewksbury, 2007), with potentially large implications for public policy change (McCombs and Shaw, 1972). This can take several forms, including agenda-setting (i.e., popular press repeatedly covering a topic causing readers to believe that the topic is important when they might not otherwise believe that), priming (i.e., getting people to view a given issue or policy solution as good or bad, important or unimportant, feasible or impractical through repetition alone), or cultivation (i.e., repeated exposure to one side of a policy debate resulting in people becoming more sympathetic to that side of the debate, Scheufele and Tewksbury, 2007). Such media influence has mostly been studied in areas of geopolitics and foreign policy, including the 9/11 terror attacks and the US response (Entman, 2004) and acceptance of European Union expansion (De Vreese and Boomgaarden, 2003). However, these same principles apply to media coverage influencing public understanding of environmental problems and public support for a particular set of policy solutions (Muter et al., 2013; Johns and Jacquet, 2018).

Many people who do not directly interact with a given wildlife issue (i.e., people who do not live within an area where human-wildlife conflict is common) may hear about that issue primarily from media coverage (Messmer et al., 2001). How popular press coverage frames an environmental issue can have effects on how the public understands the problem and the possible solutions to it (e.g., in the case of habitat protections for threatened shorebirds influencing coastal construction projects, Dayer et al., 2017). Coverage of wolf-human interactions with a negative valence (tone/focus) limited the political feasibility of certain conservation policy options (Houston et al., 2010), whereas coverage of big cat-human interactions with a positive valence led to increased support for cougar conservation efforts (Jacobson et al., 2012) and panther conservation (Wolch et al., 1997).

Repeatedly hearing about a problem through one frame presenting one particular solution causes people to assume that this is the only way to understand the problem and the only solution (or the most effective solution, or the obvious solution); when new ways of understanding or solving the problem are presented, they can be dismissed as incongruous without being considered (Entman, 2004). Presenting two possible policy solutions as equally useful, effective, or supported by experts when they are not (i.e., "false balance") can result in public confusion and support for less effective, less expert-supported policy solutions (Boykoff and Boykoff, 2004).

In the world of shark conservation, one set of policy solutions (limit-based total bans on fisheries and trade) are often supported by people who wrongly believe that shark populations have declined by more than they actually have, that the consequences of those declines will be worse than the evidence suggests they will be, and that sustainable shark fisheries cannot and do not exist (Shiffman and Hammerschlag, 2016a). Such a pessimistic "doom and gloom" approach (Johns and Jacquet, 2018) has been applied throughout the world of ocean conservation, especially with respect to fisheries management—some believe there is no such thing as a sustainable fishery and that total bans on all fishing are the only genuine conservation option. This approach, based on misrepresenting or exaggerating the data to get people to pay attention, risks "crying wolf," or creating a situation where people do not believe you even when you later try to accurately describe a problem (Ladle et al., 2004). The increasingly widespread (and

demonstrably false) belief that there is no such thing as a sustainable fishery makes it much harder to gain the public support necessary for effective sustainable fisheries management (Hilborn, 2010).

Technical information presented in the popular press can be demonstrably false or simply misleading. Misleading information can include a problem we term here "aggregate coverage bias" (i.e., even if an individual article is accurate, there is disproportionate focus on one topic at the expense of another topic among all articles combined). Aggregate coverage bias falsely suggests that one aspect of a problem is more important than other aspects of that problem, whereas demonstrably false and misleading statements misinform readers in more direct ways. This is especially problematic if the aggregate coverage is biased toward a threat that is not the largest threat, or a solution that is not the most effective solution; this goes farther than "false balance" (presenting two options as equally valid when one is overwhelmingly supported by experts and the other is not, as with climate change in Boykoff and Boykoff, 2007).

When concerned non-experts wrongly believe that a problem is worse than it really is, or when they are misinformed about which policy solutions exists, they may be more likely to support more extreme solutions that are less supported by scientific evidence. This is distinct from the widely discredited "knowledge deficit model" (Sturgis and Allum, 2004), which suggests that, if everyone only knew what the experts know, they would agree with the experts on what the best solution is. Human psychology is obviously more complex than that. However, although the deficit model does not work, if people are only presented with a limited and inaccurate subset of the available information, they would not even get the chance to blend accurate facts with their personal values and form their own opinions and policy preferences that might have aligned with expert-backed policy preferences. Data suggest that policy-relevant facts have a significant impact on public policy preferences (Gilens, 2001) and that information exchanged between scientists and the public can lead to changes in the opinions including in discussions of emotionally charged environmental issues (e.g., flood mitigation in Europe; Slinger et al., 2009). In short, having access to accurate information is a necessary, but not sufficient, step in gaining public support for evidence-backed policy solutions supported by experts.

Media Content Analysis

Media content analysis is a scientific approach to measuring the relative focus and factual accuracy of how an issue is covered in the popular press. This method is important because sensationalist science media coverage has been found to drive future research goals and funding (e.g., Hilborn, 2006; Branch, 2013). This method has been applied to environmental issues like climate change (e.g., Boykoff and Boykoff, 2007, which found that lots of media coverage of climate change was misleading or wrong) and overfishing (e.g., Johns and Jacquet, 2018, which focused on the tone of coverage and found that optimism was more common than pessimism in coverage of ocean conservation), as well as wildlife conservation and human-wildlife conflict (e.g., Dayer et al., 2017, which found that most articles framed an environmental problem as being caused by a threatened species rather than by government policies). Media content analysis focuses on the tone, factual accuracy, and framing of stories, as well as who the messengers (experts interviewed and quoted) are.

A past media content analysis (Muter et al., 2013) of how sharks are covered in the media found that only 9% of all shark-related media coverage in the USA and Australia was related to shark conservation, but no more detailed breakdown of that shark conservation media coverage was performed. Additionally, to the best of our knowledge, no study has examined how shark conservation issues are presented in media coverage globally.

Here we present the results of a global media content analysis of shark conservation topics over the last decade, 2008–2017. We assessed the relative amount of coverage of various shark conservation threats and policy solutions (aggregate coverage bias) and determined if each was presented in a factually accurate manner with appropriate context provided. In addition to major threats (those identified by global-scale conservation analyses as threats facing many species) and the most common policy solutions, we also explored how a variety of minor and emerging threats (those facing some populations of some species, which may expand in the future) are covered and how information related to threats and solutions is covered. Overall, this study seeks to assess whether a concerned layperson (someone who is sympathetic to the goals of shark conservation but unaware of it, distinct from people who are actively involved in

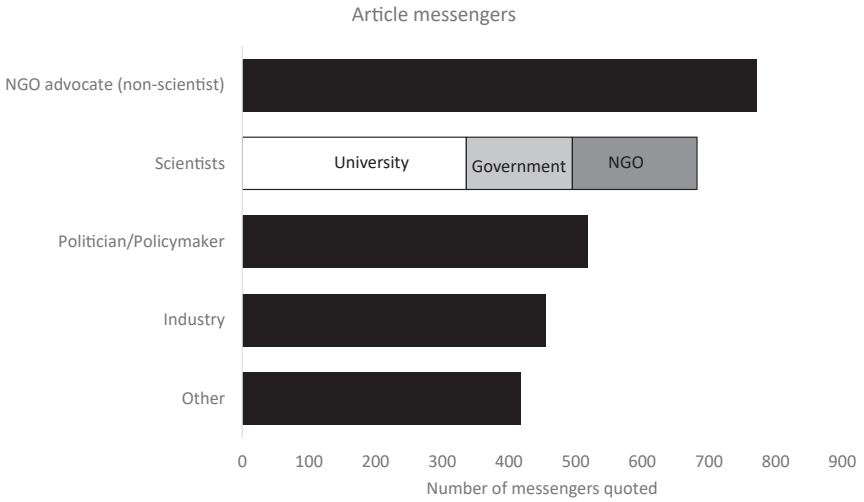

Figure 1. Numerical Frequency of Each Category of Messenger Quoted in This Analysis, with "Scientists" Broken Down by Employer Type

seeking out information about this issue) who learned about the state of shark conservation exclusively by reading mainstream media coverage would be learning accurate information about shark conservation issues.

RESULTS

We find that shark conservation threats and solutions are frequently presented in an oversimplified, biased, or factually inaccurate manner that would likely contribute to widespread public misunderstanding about these topics.

Shark conservation threats and solutions were the most common topic of sampled articles, with threats featured in a third of articles (N = 594, which is 32.8% of articles) and proposed or newly enacted policy solutions featured in nearly half of all articles (N = 816, 45.18% of articles). Articles that focused on new scientific research, new governmental or non-profit reports, or violations of existing conservation policies each received less than 10% of the topic focus of all articles and were not analyzed further.

Article Messengers

The most common messenger interviewed in articles analyzed here was a non-scientist conservation advocate working for non-governmental organizations (N = 772 interviews, Figure 1). Government decision makers, including elected officials and natural resource management policymakers, were interviewed 518 times, and industry representatives were interviewed 456 times (Figure 1). Of the 682 scientists featured as messengers, 59.1% were independent academic scientists working for educational institutions and the rest were a mix of scientists employed by government agencies or environmental non-governmental organizations (Figure 1). The most common employers of interviewed messengers were WWF, WildAid, the Pew Environment Group, and Oceana (each N > 50). Those categorized as "other" included attorneys, children, concerned members of the public unaffiliated with a non-profit group, and representatives of industries not directly related to shark fishing or shark conservation (e.g., beach tourism and surfing). There were no significant patterns in which type of messenger was correlated with which type of story, although many of the factual errors in describing conservation policy solutions (see below) came from non-scientist employees of environmental non-profit groups. We should note that not all non-profit group representatives had quotes attributed to them containing inaccurate information and inaccurate information was attributed to representatives of every type of messenger.

Shark Species Mentioned

In an era of highly publicized biodiversity loss, one might expect that more threatened species would get disproportionate media coverage, but this is not the case. The most threatened species are not the species

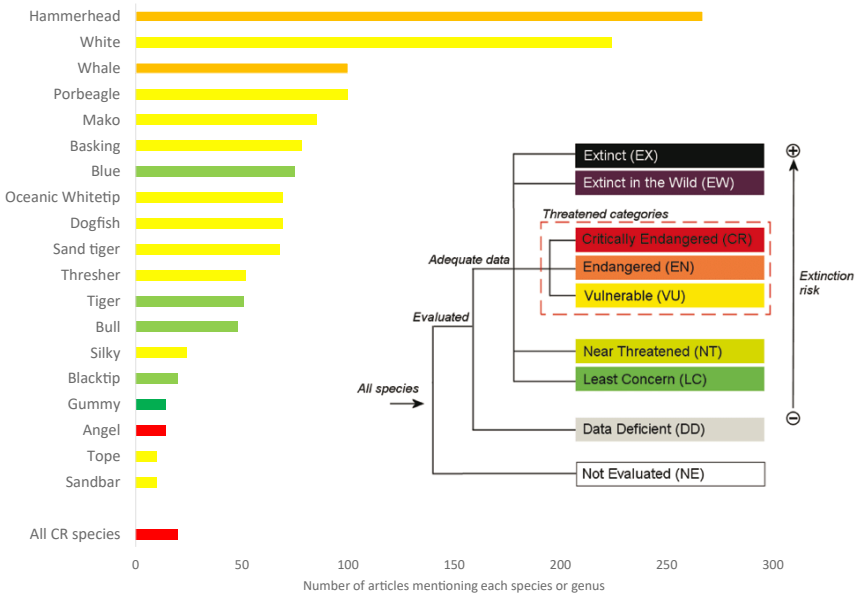

Figure 2. Species Mentions by Threat Status

The number of articles that mention specific shark species, genera, or families (e.g., hammerhead, mako, dogfish, angel), color-coded by IUCN Red List status. Red represents an assessment of "Critically Endangered," whereas Green colors are not threatened (either Near Threatened or Least Concern). Inset: Schematic diagram of the IUCN Red List Categories, with extinction risk increasing toward the top. Red List assessments are valid as of 2018 when the analysis was conducted.

that get the most media coverage (Figure 2). The most commonly mentioned species or genus groupings of sharks were hammerhead sharks (all *Sphyrna* spp.), white sharks, whale sharks, porbeagle sharks, and mako sharks both *Isurus* spp., Figure 2). There were a total of just 20 mentions (1.1% of articles) of the ten shark species assessed as Critically Endangered (CR) on the IUCN Red List as of this writing (a reassessment of all species is currently underway by the Red List, Figure 2), and 75% of those (15) were mentions of angel sharks (*Squatina spp.*).

Threats to Sharks

The most commonly mentioned threat, by far, was shark finning and the shark fin trade, mentioned in 1,222 articles (67.7% of articles, Figure 3) Although conflating shark finning and the shark fin trade is not a best practice (see definitions), this was done so often in these popular press articles that it was impossible to tease the two threats apart. In contrast, overfishing in general, which is a larger threat that includes but is not limited to shark finning, was mentioned in less than half of articles (742 articles, 41.1% of articles, Figure 3). The shark meat trade, which is a growing threat generally comparable with the shark fin trade, was mentioned in just 354 articles (19.6% of articles, Figure 3), often in the context of wrongly stating that there is *not* a significant shark meat trade but *only* a trade in shark fins. Recreational fishing, an emerging conservation threat, was mentioned in 179 articles (9.9% of articles, Figure 3), usually focusing on fishing tournaments rather than individual anglers. Other threats received less coverage, with climate change/ocean acidification mentioned in 76 articles (4.2% of articles, Figure 3) and ocean pollution mentioned in 90 articles (5.0% of articles, Figure 3).

Sharks' negative public image, and the associated idea that sharks are threatened at least partially because they frighten people, was mentioned in 288 articles (15.9% of articles) with the movie "Jaws" being specifically referenced in 136 articles (7.5% of articles, Figure 3, Table 2).

Shark population decreases were mentioned in 442 articles (24.5% of articles) with 474 articles (26.2% of articles) specifically mentioning the number of sharks killed by humans each year. The numbers provided were often misleading or exaggerated or involved quoting controversial and/or disputed figures from the scientific literature without context (Table 3). Within the literature, there are (disputed) reports showing approximately 90% declines in some subpopulations of some species (Baum et al., 2003, 2005). This is often

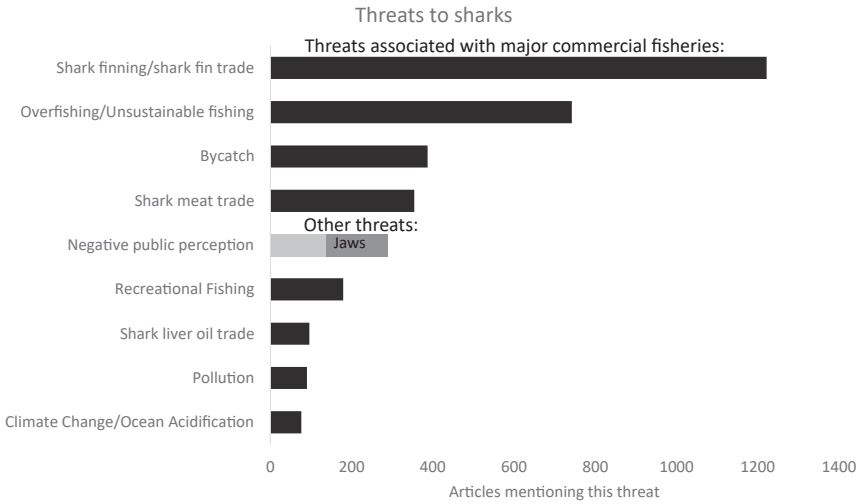

Figure 3. Mentions of Threats

The number of articles mentioning threats to sharks, categorized by threats associated with commercial fisheries and "other threats" (including comparatively minor threats as well as emerging threats). Mentions of the negative public perception of sharks are broken down into those specifically mentioning the film "Jaws" and those that do not. Recall that overfishing as a category includes bycatch, shark finning, and the shark meat trade and is the single most dominant threat to sharks globally

wrongly exaggerated to 90% declines in all shark species everywhere in media coverage (and media coverage almost never noted the existence of rebuttals to claims they were not accurately representing). Additionally, many media reports only noted shark fins and the shark fin trade as a reason for why sharks were being killed, which is not accurate and not what the sources they are referencing claim.

Four hundred and twenty-three articles (23.3%) noted the negative ecological consequences associated with shark population declines. Descriptions of these effects or of the ecological importance of sharks were often oversimplified, greatly exaggerated, or just plain factually incorrect (Table 4). Common factual errors and examples of incomplete context included claims that a loss of shark populations would result in widespread catastrophic ecological effects, when only limited impacts have been reported in the literature—and all of those have been disputed by other scientists via rebuttals.

Policy Solutions

The most commonly mentioned policy solutions were a shark fin trade ban (380 mentions, 21% of articles) and a shark finning ban (372 mentions, 20.6% of articles, which was most often in the context of why a shark fin trade ban is needed, e.g., "shark finning is already banned but the sale of shark fins is not," Figure 4). Such mentions were often misleading or factually incorrect, suggesting that allowing the sale of fins from sharks that have been landed whole (not finned) is an unintended loophole of US shark fisheries management policy, when in reality it was the stated goal of the policy at the time and the stated goal of nonprofit groups advocating for that policy (Atlantic shark fisheries management plan 1994). Shark finning bans were also mentioned in the context of a proposed shark finning ban in New Zealand, but much less frequently than mentions in the context of shark fin trade bans. Shark fin trade bans received more than twice as many mentions as all sustainable fisheries management tools combined. When categorized into policy families following Shiffman and Hammerschlag (2016a), this means that target-based policies were mentioned in 624 articles (34.6% of articles) and limit-based policies were mentioned in 643 (35.6% of articles, Figure 4); however, 59.1% of all articles that mentioned a target-based policy only mentioned a shark finning ban. Consumer boycotts were mentioned in 194 articles (10.7% of articles, Figure 4).

Wildlife tourism such as SCUBA diving or snorkeling with sharks was mentioned in 170 articles (9.4% of articles), with the idea that "sharks are worth more alive than dead" (and therefore that non-consumptive use is preferable to fishing) often mentioned in these articles. These mentions never included key context and limitations and often exaggerated the broad applicability of results (Table 5). It is true that, in some cases,

"In today's world, the shark is seen as an evil villain using the beauty of the ocean to stalk its prey. For most, the very thought of sharks has them fleeing water and running to safety from the predator. Yet, while many see the human as the shark's prey, the reverse is the case."
"When sharks eat children, or bite the legs off surfers, they really do make it difficult to care about their well-being."
"Why protect these sharks? They eat people right? Not really. Death by shark attack is more rare than a lightning strike, yet the perception remains that sharks are dangerous. In fact, many species of shark are becoming endangered."
"At the end of the day, sharks get a really bad rap, she said. Sharks are suffering declines all over the world and we need to raise awareness of sharks and their role in the ecosystem and that they're not trying to harm us."
"Every kid knows about sharks and knows to fear them… but they're not big bloodthirsty man-eaters."
"While sharks may have a reputation as Jaws-style savage killers, shark attacks are rare - there is a much higher chance of being killed by being struck by lightning than being killed by a shark."
"And despite sharks' reputation as fierce predators - enhanced by the Jaws films - none of the species found in Scottish water are known to attack humans."
"Sharks, it must be said, do not get a good press. You might blame Peter Benchley for that. The publication, and more importantly the filming, of his book Jaws scared a generation out of the water. Evidently the author felt remorseful for this, since he devoted the rest of his life to convincing the world that sharks were a threatened rather than a threatening species."
"They are the puppies of the ocean - they're not Jaws. They are very gentle creatures but we're down to the last 1500 or so."
"I think sharks are feared or loved. People fear them because they don't understand them or have watched Jaws one too many times."
"Of course people immediately think of Jaws and the teeth, but we're the predators really, not them. We kill millions and millions of them every year."

Table 2. Representative Examples of Mentions of Public Fear of Sharks/the Movie Jaws

wildlife tourism can be worth more money than extractive fisheries, but this is not always true and there are important caveats (wildlife tourism is not going to help Critically Endangered species, the revenue from wildlife tourism often goes to different people than the fishermen who lose revenue and/or food security when they stop fishing, etc.).

DISCUSSION

Through this analysis, we show that key issues surrounding shark conservation are not being communicated accurately to the public in the popular press. This could result in concerned members of the public who are learning about shark conservation primarily through reading articles in the popular press (henceforth "readers") being misinformed about the threats sharks face and the most effective solutions to those threats, with potentially problematic implications for eventual policy change via the media's agenda-setting, priming, and cultivation roles (Scheufele and Tewksbury, 2007). Although some people who are highly engaged in this issue would seek out information from a variety of sources, many people learn about wildlife conservation issues, including threats and solutions, primarily from the popular press (Mesemer et al., 2001).

Although exaggerated and oversimplified messages may be useful for getting concerned members of the public to engage with shark conservation, people who are misinformed about threats and solutions can undermine existing successful conservation initiatives through actively pursuing the wrong policies (i.e., policies that are not the best supported by available data and expertise, Shiffman and Hueter, 2017) or through voting for policymakers who support the wrong policies. Our data show that much of the wrong information presented is simply misquoting facts from the peer-reviewed literature or presenting them out of context, whereas some misinformation comes from unknown sources. Some may just be a simple typographical

"Shark's fin soup was popularized only in the last 30 or so years, and during this short span, shark populations have faced worldwide declines of approximately 80 per cent"
"90 per cent of the world's large-shark populations have been wiped out"
"Population collapses in the region of 80–99 per cent in the past 50 years"
"The world population of sharks has decreased by 80–90 per cent over the past few hundred years"
"Ninety percent of the world's sharks have disappeared over the past 100 years
"The demand for shark fin - seen as a delicacy in China - killed between 26 million and 75 billion sharks a year"
"About 89 million sharks are killed for their fins globally each year"
"73 million sharks are killed each year for their fins"
"We're killing 100 million sharks a year for shark fin soup"
"About 100 million sharks are killed worldwide [each year] and 70 per cent of them are targeted for their fins"

Table 3. Representative Examples of Misleading Exaggerated or Disputed References to Shark Population Decreases

These examples also demonstrate a wide range of quoted figures, sometimes even combining misquoted stats from multiple sources.

error (e.g., "billion" instead of "million"). Regardless, the way a problem is framed and described affects peoples' understanding of that problem and informs their support for various solutions.

Although there were no patterns in misinformation associated with our general analysis of messenger, much of the wrong information about threats and policy solutions came from non-scientist representatives of non-profit groups. There are a wide range of such non-profit groups in the very crowded public policy space of shark conservation (Shiffman and Hammerschlag, 2016a), with many who employ qualified experts and should be considered reputable sources for information, and many others who do not and perhaps should not.

We found strong evidence of aggregate coverage bias, with media outlets focusing overwhelmingly and disproportionately on just one threat sharks face (finning and the fin trade) and one type of policy solution to protect sharks (shark fin trade bans) at the expense of other important threats and policy solutions. This aggregate coverage bias was not aligned with the most serious threats to sharks or the most effective conservation policy solutions (based on scientific data, Dulvy et al., 2014, and the perceptions of experts, Shiffman and Hammerschlag, 2016b). Threats and policy solutions were also frequently covered in a misleading manner or with demonstrably false information. This is likely to impact policy change directly or indirectly

"Sharks are at the top of the food chain and they keep the populations of fish and other species in check. Should sharks become extinct, it will eventually cause fish stocks that are essential to our survival to be depleted. The fate of humans is closely tied to the survival of sharks. We certainly do not want our current or future generations to experience the day when we can no longer benefit from seafood as a source of protein as a result of shark extinction"
"No sharks means more skates and rays, and more skates and rays means less scallops and oysters and shellfish because the rays are eating them before the fishermen can catch them. Shellfish have filtration systems that improve water quality; with fewer shellfish, water becomes more susceptible to aberrations like brown tides"
"Removal of predators is likely to lead to an increase in ocean ecosystems' CO_2 production, and ultimately that fishing and shark finning are contributing to climate change"
"Sharks are essential to maintain the balance of the ocean's ecosystem"
"If no sharks are left, all the other fish will die"

Table 4. Representative Mentions of the Ecological Importance of Sharks/the Negative Ecological Consequences Associated with Shark Declines Highlighting some Examples of Misleading Phrasing

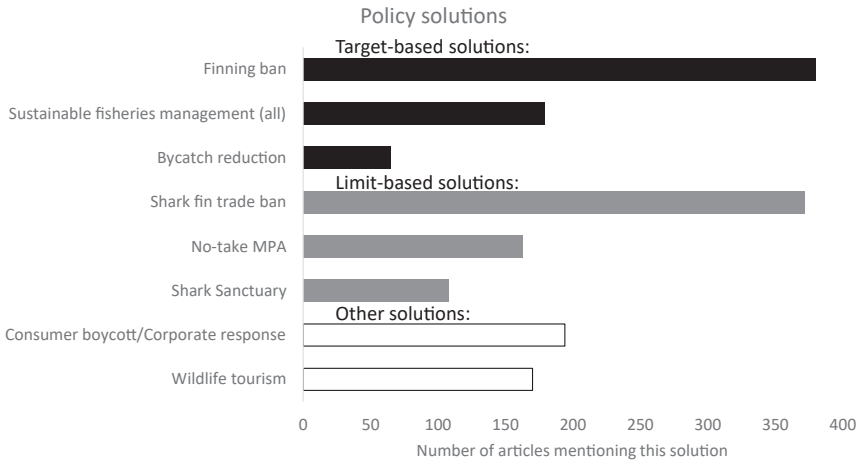

Figure 4. Relative Frequency of Policy Solutions Mentioned in Analyzed Articles, Sorted into Target-Based, Limit-Based, and Other

(policymakers learn about issues of concern from the popular press or from concerned constituents who have, Phillis et al., 2013).

Based on media coverage, readers may wrongly believe shark finning is the only major threat that sharks face and that the shark meat trade and overfishing in general are not significant threats. This is problematic because policy solutions focusing on only the shark fin trade allow other threats to proceed without the policy interventions that can come from public awareness and pressure (as argued in Shiffman and Hueter, 2017, although other policy tools are still actively discussed by decision makers, they often generate much less public pressure). Furthermore, readers would wrongly believe that shark declines are more severe and pervasive than they really are (see Burgess et al., 2005 for a discussion on why that is not the case and Peterson et al., 2017 for population increases) and would wrongly believe that the ecological consequences of shark population declines are worse than they really are (see Grubbs et al., 2016 for a detailed discussion about the lack of evidence of shark population declines causing trophic cascades). Sharks are a diverse taxon that experience diverse threats to varying degrees. Assumptions that homogenize beliefs about conservation challenges risk ignoring significant threats or building support for suboptimal policy solutions which are unsupported by scientific data and evidence. Total bans on shark fishing and trade in shark products can detrimentally affect employment, economic development, and food security, especially in the developing world (Simpfendorfer and Dulvy, 2017).

Readers would also have much more limited awareness of conservation issues affecting the most-threatened species of sharks, those assessed as Critically Endangered by the IUCN Red List, than awareness

"A live shark is worth over a million dollars in tourism revenue over its life span because sharks live for decades and thousands of people will travel and dive just to see them up close."
"Fishermen could be better supported through eco-tourism, where divers pay to swim with the sharks. In the Bahamas, such trips are worth US$78 million (S$99 million) to its economy each year. This would also be more sustainable in the long run."
"People from all around the world are dying to come to South Africa and witness them first-hand. We should be proud of that and should do everything in our power to make sure they're here for years to come."
"Sharks are charismatic animals that are beloved by divers and therefore can play an important role in attracting more tourists and tourist revenue for coastal communities"
"Diving destinations in Palau, the Maldives, Fiji, Mexico and other shark hot spots now realize they can make more money by protecting sharks than by butchering them for soup."

Table 5. Representative Examples of Mentions of Wildlife Tourism as a Conservation Solution

of the conservation issues facing better-known (but less threatened) species. These species are in the greatest need of conservation assistance and could perhaps receive the largest benefit from increased publicity toward their issues, which are often distinct threats from those facing more widely known species (e.g., habitat destruction for species with a narrow restricted range, Dulvy et al., 2014). It should be noted that this problem of disproportionate focus on a subset of better-known species is also a problem of the scientific literature, not just of the media (e.g., Bonnet et al., 2002 in general, Shiffman et al., 2020 for sharks).

The idea that the film "Jaws" and associated public fear of sharks can have a negative impact on public support for shark conservation has been discussed in the literature. However, proponents of these arguments do not claim that this is as significant or direct of a threat to sharks as the shark meat trade, and here the shark meat trade was mentioned only slightly more frequently than public fear of sharks.

Certain threats that received less attention in the popular press (pollution and climate change/ocean acidification) are indeed generally considered to be relatively minor threats facing sharks overall. Although plastic pollution has been proposed as a threat to filter-feeding shark species, there is no documented evidence of actual population-level harm caused yet (Germanov et al., 2018). Similarly, chemical pollutants have been shown to cause harm to a few subpopulations of a few species of sharks, but only in very high levels. Climate change and ocean acidification are generally not considered a major threat to sharks (Chin et al., 2010) because many sharks can just adjust their ranges to a more thermally suitable environment (e.g., Bangley et al., 2018). Recreational shark fisheries are also considered a relatively minor threat to sharks overall but are a problem for some subpopulations of sharks (Kilfoil et al., 2017; Kyne and Feutry, 2017; Shiffman et al., 2017.)

Readers of the articles analyzed here may wrongly believe that limit-based solutions (especially shark fin trade bans) are the best, most popular, most widely used policy solution, if not the only policy solution available—these tools receive by far the most media coverage of any policy tool analyzed here, but criticism of the effectiveness of these policies is almost never mentioned. Readers would learn much less about target-based tools and the large body of scientific evidence supporting their effectiveness. The authors would again like to stress that, although much of the media coverage surrounding shark fin trade bans contains factual inaccuracies or misleading statements, that does not mean that supporters of these policies, which include scientific and technical experts from universities and science-based non-profits, are in any way unscientific. Additionally, most of the mentions of shark fin trade bans included in this 2008–2017 analysis were at the US state level; discussions of a national US-level fin ban (which involve different stakeholder groups and supporters) occurred only at the end of this analysis.

Readers may wrongly believe that wildlife tourism and consumer boycotts of companies peripherally related to the shark fin trade are more effective solutions to protect sharks than they really are. Wildlife tourism is an effective solution in some circumstances, but the idea that "sharks are more valuable alive than dead" is not universally correct, and many of the most threatened species of sharks are not candidates for wildlife tourism because they are not reliably seen near any kind of tourism infrastructure, are small and uncharismatic, or are found offshore in cold or deep waters (Macdonald et al., 2017). Consumer boycotts of companies peripherally involved in the shark fin trade may generate flashy media-friendly protests, but even if they accomplish their stated goals, targeted companies typically do not have any influence over a significant amount of shark mortality.

The degree to which scientists and scientific expertise should be the key determinant of management decisions is debatable (see Backstrand, 2003). Some desire for total bans on shark fishing (or total bans on all fishing overall) may be based on personal or cultural values rather than scientific data (e.g., an animal rights perspective versus a goal of population-level sustainability). However, claiming to make a science-based argument while misrepresenting scientific data in support of a values-based argument is problematic. Additionally, current management norms call on scientific data to make determinations about environmental policy decisions, but such scientific data are often absent from mass media coverage of shark conservation issues that informs the public about this topic (e.g., Stone et al., 1998).

Although no individual media article can reasonably be expected to cover every dimension of a complex global conservation problem, the fact that so many media articles focused on the same subset of topics is

problematic in aggregate, and the presence of so many easily checkable factual inaccuracies goes against most journalistic norms. Additionally, it is important to note here that the media industry is changing rapidly and fewer science-specialty journalists are being employed by large media outlets. In our experience, the remaining reporters on the science beat, and those who work for science-focused specialty news outlets not included in this analysis, try very hard to get the story right and often succeed. Finally, scientists who are approached for interviews and want to make sure that journalists get the story right would benefit from media training and building relationships with reporters who cover their "beat"; in our experience this also leads to improved coverage, as does proactively reaching out to journalists who cover our beat and offering a background briefing.

Nevertheless, a concerned member of the public learning about sharks and their conservation from reading the popular press in aggregate would wrongly believe that shark finning and the demand for shark fins are the only major threat sharks face and that banning the sale of shark fins is the best available solution to protect sharks. Neither of these beliefs are aligned with the current state of scientific research on shark conservation or with scientific expert opinion.

Shark conservation is far more complicated than what the information in the popular press suggests. Targeting sharks for the meat trade may not be as flashy as the shark fin trade, but it is a significant source of mortality that should not be ignored, dismissed, or misrepresented. Conservation issues facing species such as the daggernose shark (*Isogomphodon oxyrhynchus*, largely threatened by fisheries bycatch in Brazil) may not drive as many clicks to a media organizations website as showing a video of a great white shark swimming near a popular resort community, but this Critically Endangered species could truly benefit from increased public attention and concern resulting from popular press coverage.

The real story of shark conservation is more complicated than the simplified, biased, and inaccurate version frequently presented in the popular press. However, the real story needs to be told if we are to effectively leverage public support to ensure the continued survival of these ecologically important, evolutionarily distinct animals. Although facts are not the only thing that influences public support for a policy, facts do matter, and currently the mainstream media is not contributing as fully as it could to accurate public understanding of these issues.

Limitations of the Study

The magnitude of observed trends and the frequency of documented factual errors gives us confidence that our central claims capture problems that genuinely exist in media reporting on shark conservation. However, we acknowledge several limitations of this study's approach. Although many people do get science and environment-related news exclusively from the popular press, such information can come from a variety of sources, which means inaccurate and biased information in the popular press could be partially counterbalanced by accurate information available through other sources (work analyzing the accuracy of several of those other sources is underway). Second, limitations of available databases and our own language skillsets meant that we focused exclusively on English-speaking media outlets, despite the presence of significant shark conservation issues in non-English speaking countries. A comparative study on how these issues are presented in Spanish (a great deal of shark meat consumption occurs in South and Central America) or in Mandarin Chinese (fin consumption mostly occurs in China) media outlets could potentially illuminate these issues further across cultural contexts, although we note that our corpus of articles does include English-language papers from these regions. Next, although we included most well-known, accurate, and reliable science to summarize facts about shark conservation threats and solutions in section 2.5 of Supplemental Information and facts provided were independently confirmed by numerous experts, this should not be treated as a comprehensive review of all the existing scientific literature on this topic. Additionally, the use of 10 coders introduces possible intercoder reliability issues not found with a smaller number of coders, although we minimized this risk through comprehensive training and categorization guides and choosing straightforward variables that leave little room for interpretation. Finally, in order to get a sense of the global scope of these issues, we did not focus exclusively on the most widely read media outlets, although it is probably fair to say that inaccurate information presented in a media outlet with a huge readership is a larger problem than wrong information presented in a smaller regional media outlet.

Resource Availability

Lead Contact

Lead author Dr. David Shiffman.

Materials Availability

All articles downloaded from LexisNexis are available upon request to lead author Dr. David Shiffman.

Data and Code Availability

All articles downloaded from LexisNexis re available upon request to Dr. David Shiffman.

METHODS

All methods can be found in the accompanying Transparent Methods supplemental file.

SUPPLEMENTAL INFORMATION

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AUTHOR CONTRIBUTIONS

D.S.S. conceived the study, trained readers, analyzed data, and produced the manuscript under the supervision of N.K.D. and with the assistance of C.C.M. C.C.M. also contributed significantly to the write-up and analysis. All other authors read, coded, and scored 1 year's worth of popular press articles and provided feedback on drafts.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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Supplemental Information

Inaccurate and Biased Global Media Coverage Underlies Public Misunderstanding of Shark Conservation Threats and Solutions

David S. Shiffman, Sarah Joy Bittick, Madeline S. Cashion, Sheila R. Colla, Laura E. Coristine, Danielle H. Derrick, Elizabeth A. Gow, Catherine C. Macdonald, Mikayla More O'Ferrall, Melissa Orobko, Riley A. Pollom, Jennifer Provencher, and Nicholas K. Dulvy

2.1 Search/Dataset

Using LexisNexis (See Appendix I for search terms), we identified popular press articles from 2008-2017 in English-speaking media around the world (N=1,806). Although a focus on English-language media leaves out an important audience (the leading consumers of shark fins are in Asia, the leading consumers of shark meat are in South America), it is a necessary limitation of our language skills and the databases we had access to. It should be noted that our analysis did capture many outlets from southeast Asia that were written primarily in English, including outlets from China and Singapore.

The internal LexisNexis similarity filter was applied to help ensure that each article was only counted once even if it was reprinted in multiple publications.

2.2 Coding and scoring

Ten readers were trained in media content analysis and the basics of shark conservation threats and solutions. Initially, every reader was assigned the same set of 25 articles, and intercoder reliability was measured at over 97%. A handful of initially-considered variables that were responsible for the greatest variation and confusion were discarded from subsequent analysis, placing intercoder reliability at 99.5%.

Each reader was then assigned one year of articles. For each article, readers answered 76 questions (mostly dichotomous yes/no questions asking if a given topic was mentioned in the article at all, e.g., "Is ocean acidification and/or climate change mentioned in this article: Yes/No," see Appendix II for questions and examples forming the codebook). Questions focused on the topic of the article, what threats to sharks were mentioned in the article, and what policy solutions were mentioned in the article, as well as miscellaneous related information described below.

When a coder was not 100% certain how to code and score a variable, they flagged it for author DSS to confirm; all but two of these flagged variables were coded correctly and those two were adjusted. Additionally, author DSS randomly selected 100 articles to code and score independently to further assess intercoder reliability; six out of 100 articles had one error in the original coding out of 76 questions, one out of 100 had two errors out of 76 questions, and the rest were correct. This is an extremely high rate of inter-coder reliability, likely due to the presence/absence nature of many questions that require little judgement or interpretation that could introduce personal bias.

We examined articles for information that was unequivocally false, information that was misleading due to incomplete context, and aggregate coverage bias. Representative quotes showing particular types of statements are included throughout in tables, with minor punctuation and spelling corrections made (errors were likely due to LexisNexis text import or export errors, not the original media article).

2.3 Messengers

An article messenger is an external expert interviewed and quoted by the journalist to provide their perspective. We categorized messengers into one of the following categories: NGO-employed advocate/non-scientist (someone who works for an environmental non-profit group in an advocacy based role not a science-based role), scientific researcher (someone whose role is performing scientific research rather than advocacy or management, further categorized into independent academic scientists, those who work for government natural resource management agencies, or those who work for environmental non-profits), representatives of industry (typically fishing or the seafood trade), and politicians and policymakers (those who make decisions, which may be elected officials or regulators associated with a natural resources management agency). Those who did not fit into one of these categories were listed as "other".

2.4 Definitions

We used the following definitions for the purpose of determining if a given threat or policy solution was mentioned in a media article for coding and scoring (Table 1).

2.5 Factual information for assessments of demonstrably false or misleadingly presented information

In addition to studying the relative coverage topics related to sharks and policy solutions to protect sharks, we assessed the factual accuracy of this coverage. To assess the factual accuracy of media coverage related to these topics, we first generated a list of verified accurate facts from the peer-reviewed scientific technical literature. Importantly, this was not used for initial coding and scoring of whether or not a topic was discussed in an article, but for a separate analysis of the factual accuracy of points that were discussed in articles searching for commonly shared misconceptions and inaccuracies.

To generate a list of verified accurate facts, we searched our extensive personal libraries for literature related to topics of interest (see codebook and questions in Appendix II); these libraries have been developed through many years of performing policy relevant research, conversations with experts in policy research and science based advocacy, and extensive experience in public engagement in shark conservation. For every statistic or figure or question, we refer to (and cite) the most commonly-available, widely-used sources of information on this subject. Section 2.5 was also independently checked by several independent expert colleagues.

Each question is categorized into either "threats to sharks" or "available policy solutions," and then answered in-depth highlighting key figures, key references, and common misunderstandings shared with us through conversations with relevant experts. Information presented in media articles that contradicts this without providing an alternative, reliable source was generally considered to be inaccurate, though much of the contradictory information was already known to us as "common misconceptions."

2.5.1 Threats to sharks: what are the biggest threats to sharks?

The biggest threat facing chondrichthyan fishes (sharks and their relatives) as a group is overfishing (Dulvy et al. 2014). Overfishing includes fishing that supplies the international shark fin trade as well as fishing that supplies that shark meat trade locally, internationally, and for subsistence. Overfishing further includes both targeted catch as well as unintentional bycatch that may or may not be landed. This report also noted that habitat destruction is a major threat facing some particularly threatened species (e.g., coastal mangroves being destroyed to create aquaculture operations, Dulvy et al. 2014). Claiming that shark finning and the shark fin trade is the only major threat that sharks face is not supported by the data (see "how extensive is the shark meat trade?" below).

2.5.2 Threats to sharks: how extensive is the shark fin trade?

The most commonly-used statistics on the scope of the shark fin trade come from Clarke et al. 2006, which noted that the fins of between 26 and 73 million sharks (with a median of 38 million) a year are traded in the shark fin trade. This figure has been misquoted so often that author Shelley Clarke wrote an opinion piece for the popular press about misunderstanding of her work in 2011, noting that "selective and slanted use of information devalues and marginalizes researchers who are working hard to impartially present the data." This opinion piece specifically criticized the misunderstanding that her figures show how many sharks are killed for their fins, when in reality it shows how many sharks have fins that pass through the fin trade—these are different problems that require different solutions, and understanding the difference is important. "Some sources quote these figures as "the number of sharks killed for their fins", or "the number of sharks finned" (carcasses discarded at sea), or the "number of sharks finned alive" every year. The truth is that no one knows how many sharks are *killed for their fins*, how many have their carcasses dumped at sea, or how many sharks are alive when finned," she wrote (emphasis ours). References to how "up to 73 million sharks each year have their fins pass through the fin trade" are defensible and fact-based, while references to how "up to 73 million sharks a year are killed for their fins" demonstrate a common misunderstanding (not all shark fins that are traded result from finning, see Definitions). Additionally, higher numbers than 73 million (for the fin trade specifically, not total shark mortality, see "how many sharks are killed every year" below) are unsubstantiated.

2.5.3 Threats to sharks: how extensive is the shark meat trade?

A recent global analysis of how all shark products are traded around the world, including trends over time, found that the shark meat trade is significant and increasing, and responsible for a great deal of shark mortality around the world (Dent and Clarke 2015). While it is commonly claimed that shark meat is never or rarely consumed, or that sharks are never or rarely killed for their meat, the truth is that the shark meat trade is a significant and rapidly growing source of shark mortality.

2.5.4 Threats to sharks: how many sharks are killed every year?

Worm et al. (2013) estimated that between 63 and 273 million sharks are killed per year, with median estimates of about 100 million sharks killed in 2000 and about 97 million sharks killed in 2010. This figure is the total number of sharks killed for all purposes from all sources of anthropogenic mortality. A common misuse of these data is wrongly claiming that this count refers exclusively to the number of sharks killed by shark finning or by the shark fin trade. Another common misuse of these data is combining them with the data from Clarke (2006,) i.e., "100 million sharks are killed each year, 73 million of which are killed for their fins". An earlier estimate, Manire and Gruber (1990), placed that number of sharks killed annually at "at least 25 million;" the higher estimate from Worm et al. 2013 may reflect changing trends in the fishery in the intervening 25 years or may reflect newly obtained access to global fisheries data. It should be noted that due to significant limitations in data availability beyond the control of the authors (largely due to decades of mismanagement around the world) Worm et al. 2013 is functionally an extensive "back of the envelope" calculation.

2.5.5 Threats to sharks: how many sharks are threatened or endangered?

Twenty-four percent of all known species of chondricthyan fishes (1,041 total species) were assessed or estimated to be threatened (Vulnerable, Endangered, or Critically Endangered) according to IUCN Red List criteria in 2014 (Dulvy et al. 2014, though reassessment is underway as of this writing). This figure is distinct from an earlier value that is widely misused;. Dulvy et al. (2008) calculated that 1/3 of all known species of pelagic sharks (21 total species) are IUCN Red List threatened. A common misuse of this narrower finding is attributing the 1/3 figure to all known species of chondrichthyans, generating 96 new threatened species out of thin air (1/3 of 1041 is 344, 24% of 1041 is 248). Additionally, reports that 55% of sharks and their relatives are threatened do not appear to be supported by any published papers or reports. Finally, combining the number of sharks in the threatened and Near Threatened categories is not a practice supported by IUCN Red List guidelines, as a Near Threatened designation means that a species *is not* threatened. It should also be noted that a global IUCN Red List status assessment of Endangered is a scientific assessment that intentionally comes with no inherent legal requirements, and that threatened and endangered mean something totally different in the context of laws such as the US Endangered Species Act. Reports that do not note this are misleading.

2.5.6 Threats to sharks: how severely have shark populations declined and over what time frame?

There are published reports of populations of some shark species declining in population by 90% or more since the 1970's (Baum et al. 2003, Baum et al. 2005), as well as a published report that the abundance of all large pelagic fishes (sharks, tuna, billfish, etc) have declined by approximately 90% over the last several decades (Myers and Worm 2005). However, these declines have been revised downwards by subsequent analyses by the original authors (Baum and Blanchard 2010) and are disputed by other scientists via published rebuttals and other independent re-analyses (Burgess et al. 2005, Braccini et al. 2015). Reporting 90% declines in some shark subpopulations without reporting that these figures are disputed by scientists does not accurately reflect the current state of scientific knowledge. Reporting that 90% of all sharks have been killed is misstating what the data in those disputed papers say (some populations of

sharks have declined by 90% and 90% of all predatory fishes including but not limited to sharks have declined).

2.5.7 Threats to sharks: what are the negative ecological consequences associated with shark population declines?

There are published reports that shark population declines cause ripple effects in the food chain called "trophic cascades," with examples off the coast of North Carolina (declines in sharks led to increases in cownose rays which fed on economically important scallop populations leading to a scallop fishery collapse, Myers et al. 2007) and in Pacific coral reefs (declines in sharks led to mesopredator increases that disrupted the reef food web, Ruppert et al. 2013). However, both of these papers have been disputed by other scientists via rebuttals (Grubbs et al. 2016 and Frisch et al. 2016 respectively), and reporting these results without noting these concerns from other experts presents only a partial picture. At least in the case of the North Carolina example, this purported trophic cascade played into a century old narrative circulating in the local scallop fishing industry, but the new evidence directly led to widespread persecution of cownose rays (a highly sensitive species whose numbers supposedly increased as a result of a trophic cascade) through the "save the bay, eat a ray" campaign. We note that for nine of the ten years of our analysis, the formal rebuttal to Myers et al. 2007 had not yet been published in the peer-reviewed scientific literature, though we can anecdotal reported that these concerns about Myers et al. 2007 were widely discussed in shark research circles. Additionally, references to Myers et al. 2007 appear well after the publication of the Grubbs et al. 2016 rebuttal, which received some, but not very much, coverage when it was published and is almost never mentioned outside of articles specifically about the publication of Grubbs et al. (2016).

2.5.8 Threats to sharks: What is known about comparatively minor/emerging threats to sharks, including climate change and ocean acidification, plastic pollution, recreational angling, and the "Jaws effect"?

There are several comparatively minor threats to sharks (some of which are considered emerging conservation issues) that we chose to analyze in this study. Here we define a minor or emerging issue as one that is not listed as a primary/major threat to sharks as a group worldwide in Dulvy et al. (2014,) but has been identified as a possible or emerging threat for some populations of some species in other literature. There are not enough articles about these minor threats to analyze inaccurate or misleading claims, but consideration of how they are portrayed in the popular press is important.

Climate change is currently considered a minor but emerging threat to sharks (Chin et al. 2010, Dulvy et al. 2014) because most species are capable of dispersing to a different more suitable habitat (e.g., Bangley et al. 2018). The key question that remains globally is whether these new habitats have a reduced carrying capacity, resulting in a decrease in abundance of sharks that move there, as indeed has been recently observed in South Africa (Currie et al. 2019). However, for a few species of sharks whose ranges are restricted, particularly to tropical estuaries, climate change can be a significant threat due to uncertain rainfall and changed water flow patterns (Chin et al. 2010).

Ocean acidification may cause direct disruptions to the sensory abilities (e.g., Dixson et al. 2015), hunting behavior (e.g., Pistevos et al. 2015), and swimming ability (e.g., Green and Jutfelt 2014) of individuals of some shark species but this is not yet expected to pose a significant population level risk to sharks. There may be indirect effects to sharks as a result of food web disruption to other organisms, but there is no currently no evidence that this represents a major threat.

While ocean plastic pollution (microplastics and larger pieces of litter) is a hot topic in ocean conservation at the moment, and ingestion of plastic may pose health hazards for some filter-feeding sharks (Germanov et al. 2018), there is currently no evidence that plastic pollution or other pollution poses any kind of significant risk for sharks at the population or species level. Inhalation of larger pieces of plastics and litter as recently observed in a whale shark in the Philippines may be a larger threat to filter-feeding sharks (Abreo et al. 2019), but again, there is no evidence to date that plastic pollution causes a significant population-level threat to sharks.

There is no doubt that artisanal and commercial fisheries pose the largest threat to sharks as a group, but recreational angling can pose a significant threat to some specific subpopulations of some at-risk species through fishing-related mortality including post-release mortality. Recreational angling is expected to be a threat to some populations in places like the USA and Australia where commercial fisheries are better regulated, and other threats are better recognized and minimized through policy (e.g., Shiffman et al. 2014, Kyne and Feutry 2017, Shiffman et al. 2017).

It has long been proposed that negative public perception of sharks can contribute to shark conservation issues (i.e., that people who are afraid of sharks are less likely to want to protect them, see Jacques 2010). This is often attributed directly to the film “Jaws” (Neff 2015) as well as inflammatory and false content on Shark Week (Myrick et al. 2014, O’Bryhim and Parsons 2015) and in popular press coverage (Neff and Hueter 2014). As noted in section 1.2, media coverage has the potential to shape public perception on environmental issues, and negative, inflammatory coverage may make the public less likely to support certain conservation measures (Houston et al. 2010).

2.5.9 Available policy solutions: What policy solutions are available to protect sharks?

There are at least 14 distinct conservation policies that can be applied to the conservation and management of sharks, and these can be broadly divided into target-based policies that aim to maximize sustainable fisheries exploitation and limit-based policies that aim to ban all fisheries and trade of shark products (for more detail on which policies are included in which category and why, please see Shiffman and Hammerschlag 2016). It should be noted while some limit-based policies can co-exist with some target-based policies (i.e., a marine protected area network that bans all fishing in some parts of a country’s territorial waters while allowing sustainable fishing in adjacent waters), many of these policies are mutually exclusive. A country cannot have a well-managed sustainable fishery while all fishing in that country is banned, a country cannot be a source of sustainably-exploited shark fins if the sale of shark fins is banned in that country.

Media coverage that focuses heavily on a subset of these policies and rarely or never mentions the other policies is misleading in aggregate.

2.5.10 Available policy solutions: are sustainable fisheries for sharks possible, and do sustainable shark fisheries exist?

While some environmental advocates claim that sustainable shark fisheries not only do not exist but cannot exist, this claim is easily refuted by scientific evidence. There is no doubt in the scientific literature that sustainable fisheries for sharks can exist in theory (Hoenig and Gruber 1990, Walker 1998) and do exist in reality (Simpfendorfer and Dulvy 2017, Shiffman and Hueter 2017), though it is important to note here that most current shark fisheries are unsustainable (over 90% according to Simpfendorfer and Dulvy 2017). There are some species whose life histories and population sizes are unlikely to support a sustainable fishery, and there are some nations which are unlikely to have a governance structure in place to support sustainable fisheries anytime soon. However, media reports that share a claim that sustainable shark fisheries cannot exist and/or do not exist are sharing demonstrably false information that directly undermines a popular (among surveyed experts) and effective (according to scientific data) management tool.

2.5.11 Available policy solutions: What is known about shark fin trade bans?

Shiffman and Hueter (2017) performed an analysis of a proposed shark fin trade ban in the United States and found that such a policy would likely do little to conserve sharks since the US is a comparatively minor player in the shark fin trade, but would also undermine existing efforts that have been successful at conserving sharks like international fisheries development aid (e.g. a 2016 NOAA fisheries workshop in West Africa that provided technical support and training for fisheries managers of nine nations, this aid would be unavailable when the US is no longer participating in a market for a given fishery). Many of the shark fin trade bans included in this analysis are state-level, occurring before the relatively recent discussion of a US national level ban. While fin trade ban policies undoubtedly have their supporters who include scientific and technical experts from academia and from science-based environmental non-profits, exclusively citing these supporters in media coverage implies that these policies are widely supported and have no potential downsides, which is misleading—especially when coverage of other proposed policies regularly quotes experts with concerns about those policies. While we looked for factual inaccuracy in coverage supporting fin bans, we do not mean to imply that support for fin trade bans is itself an example of scientific inaccuracy.

2.5.12 Available policy solutions: Which policy solutions are supported by scientific experts?

Shiffman and Hammerschlag (2016B) surveyed shark researchers about their conservation policy preferences, and found that researchers overwhelmingly believe that sustainable shark fishing exists (83% of respondents) and should be the goal of conservation policy rather a ban on all exploitation and trade whenever possible (90% of respondents). This survey also found that 63% of surveyed experts support the idea of a shark fin trade ban, which is a majority, but significantly less support than any other policy tool except Shark Sanctuaries- the only two

policy tools that multiple experts expressed specific concerns about. While this research came out after 9 of the 10 years of this media content analysis had elapsed, media reports that state or imply that bans are overwhelmingly supported by scientific experts, as well as media reports that do not mention that any experts oppose such bans, may be misleading readers into believing that no such disagreement is occurring.

2.5.13 Available policy solution: What is known about non-traditional policy solutions like wildlife tourism and consumer corporate boycotts with the goal of negatively impacting the shark fin trade?

In addition to these traditional policy solutions, there are two newer non-traditional conservation strategies that do not involve regulatory or legal changes that we wanted to investigate: wildlife tourism and consumer corporate boycotts. These have not been analyzed in the scientific literature sufficiently to assess misleading or inaccurate claims, but these emerging issues may have significant conservation implications in the near future.

Some conservation advocates and wildlife tourism operators claim that wildlife tourism is the solution to protect sharks, citing studies showing that sharks are "worth more alive (to wildlife tourism operations) than dead (to fisheries)" (e.g., Ahmed and Anderson 1994, Gallagher et al. 2011). This statement is true in some but not all cases, and therefore must be presented with appropriate caveats to avoid being misleading (Caitlin et al. 2013). While some species of sharks in some nations are excellent candidates for wildlife tourism-focused conservation initiatives, sharks are absolutely not "worth more alive than dead" overall—the total value of all shark fisheries far exceeds that of all shark wildlife tourism (Brunnschweiler and Ward-Paige 2014). Additionally, few of the most threatened species of sharks are suitable candidates for wildlife tourism because they live in the open ocean or the deep sea (MacDonald et al. 2017). Additionally, the people who profit from wildlife tourism are often not the fishermen who lost income when fishing was banned in favor of wildlife tourism, they are often wealthy westerners rather than locals (e.g. Akama and Kieti 2007).

Consumer corporate boycotts occur when consumers organize a protest of a company perceived as playing a role in the shark fin trade. Often these companies do not play a significant role in the shark fin trade and therefore cannot accomplish the stated goal of the protest organizers even if the company does exactly what protesters call for (e.g., a 2018 protest called on Starbucks coffee to end their involvement with the shark fin trade. The connection between Starbucks and the fin trade was tenuous, said involvement consisted of Starbucks selling coffee to a food distributor in Hong Kong that was owned by a separate food company which also owned restaurants that sold sharks fins).

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Appendix I: LexisNexis Search terms

shark and ((conservation) or (protection) or (threatened) or (endangered) or (endangered species act) or (species at risk act) or (sanctuary) or (population) or (fishing) or (commercial fishing) or (recreational fishing) or (bycatch) or (overfishing) or (fin) or (fin soup) or (finning) or (fin trade) or (finning ban) or (fin ban) or (fin trade ban) or (unsustainable) or (sustainable) or (convention on international trade in endangered species) or (convention on migratory species))

Appendix II: Codebook used in this analysis. Readers answered each of these questions for every article.

Question	**Possible answers**
Name of publication featuring this article	Open
Title of Article	Open
Year article was published	Open
What is the primary theme of this article?	Multiple choice: A new/proposed conservation policy, a violation of a policy, a conservation meeting, new scientific research, a new government/NGO report, a conservation threat (not a solution), other
What is a secondary theme of this article, if any?	Multiple choice, same options as above.
Who is the primary article messenger/ interviewed expert?	Multiple choice: scientist (university), scientist (government), scientist (NGO), NGO employee (not a scientist), policymaker, industry, other.
Who employs the primary messenger?	Open
Who is the secondary article messenger, if any?	Multiple choice, same options as for primary article messenger.
Who employs the secondary article messenger?	Open
Who is the tertiary article messenger, if any	Open
What shark species are listed by name in the article?	Open with options to list 5
THREATS AND BACKGROUND	
Is overfishing, overexploitation, and/or unsustainable fishing (i.e., killing too many sharks) mentioned at all in the article?	Yes/No, if yes copy/paste the entire mention
Is shark finning, the shark fin trade, and/or shark fin soup mentioned at all in the article?	Yes/No, if yes copy/paste the entire mention
Is shark fishing for meat and/or the shark meat trade mentioned at all in the article?	Yes/No, if yes copy/paste the entire mention
Is fishing for liver oil and/or the shark liver oil trade mentioned at all in the article?	Yes/No, if yes copy/paste the entire mention
Is fisheries bycatch mentioned at all in the article?	Yes/No, if yes copy/paste the entire mention
Is recreational shark fishing, fishing tournaments, and/or trophy fishing mentioned at all in the article?	Yes/No, if yes copy/paste the entire mention
Is shark wildlife tourism/SCUBA tourism mentioned at all in the article?	Yes/No, if yes copy/paste the entire mention
Is illegal fishing (explicitly noting “illegal” or “against the law”) mentioned in the article?	Yes/No, if yes copy/paste the entire mention

Is climate change, ocean acidification, and/or global warming mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Is ocean pollution mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Is negative public image (i.e., the idea that sharks are scary and people don't like them) mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Is the movie "Jaws" mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Are shark population decreases mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Are threatened or endangered shark species mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Does the article specifically mention the number of shark species that exist?	Yes/No, if yes copy/paste the entire mention
Does the article specifically mention the number of sharks killed by humans each year?	Yes/No, if yes copy/paste the entire mention
Does the article mention negative ecological consequences of shark declines and/or the ecosystem importance of healthy shark populations?	Yes/No, if yes copy/paste the entire mention
POLICY SOLUTIONS	
Are fishing quotas/total allowable catch mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Is bycatch reduction (i.e., gear requirements to reduce bycatch) mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Are finning bans (bans on the discarding of shark carcasses at sea, distinct from fin trade bans) mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Are consumer boycotts (e.g., of airline or shipping companies, hotels/restaurants, etc) and or corporate policy changes in response to these boycotts mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Are no-take marine protected areas/marine reserves mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Are Shark Sanctuaries (a ban on catching or landing sharks within a nation's entire EEZ) mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Are shark fin trade bans (making it illegal to buy or sell shark fins) mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Are public education campaigns (distinct from consumer boycotts) mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Are species-specific catch or trade bans (just for particularly threatened species not for all sharks) mentioned in the article?	Yes/No, if yes copy/paste the entire mention
Is a petition signed by concerned citizens mentioned in the article?	Yes/No, if yes copy/paste the entire mention