What is an endangered species worth? Threshold costs for protecting imperilled fishes in Canada

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1. Introduction

Many fish species, and the fisheries they support, are in decline around the world [1]. In the marine realm, three-quarters of fish stocks are either fully exploited or overexploited [2]. Many targeted fisheries for large predatory species, as well as those targeting small fish at low trophic levels, have collapsed [3,4]. Furthermore, incidental bycatch has been implicated in the endangerment of many marine taxa [5,6]. Freshwater ecosystems are also under intense pressures [7,8], with inland fish biodiversity threatened by overfishing, habitat destruction and pollution [9]. Effective protection of fish species and their habitats is urgent.

Conservation legislation has been implemented in many countries to address the general biodiversity crisis. In Canada, the Species at Risk Act (SARA) was implemented in 2003. Under SARA, Canadian imperilled species can be legally protected from harm, capture and habitat destruction [10]. Although SARA has been lauded for clearly separating scientific assessment from policy [11], its implementation has been slow and uneven. In particular, there appears to be a clear bias against listing fishes [12–14]. In the first five years of SARA, approximately half of freshwater fishes and all marine fishes recommended for listing by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) – the independent scientific body which assigns a risk status to species based on scientific criteria – were rejected by the Canadian government, while most birds, reptiles, amphibians and plants were protected [12]. In those early years, there was a close association across all taxa between the likelihood of being rejected and being harvested as well as having Fisheries and Oceans Canada (DFO) as the authority responsible for recovery [12]. In 50% of cases where species were denied protection, socio-economic data used to inform listing decisions about threatened fishes over the past decade reveals that the likelihood of being listed declines non-linearly with increasing estimated costs of protection but does not vary with proposed threat status. The estimated threshold cost (i.e., the point at which the likelihood of not being listed = 0.5) was ~$5,000,000 (~$1,400,000 to ~$31,400,000, 95% CI) per decade for freshwater species but only ~$90,000 (~$50,000 to ~$140,000, 95% CI) per decade for marine fish taxa. In fact, no marine fish species with an anticipated cost of listing greater than zero was listed for protection. The presence of existing management legislation and qualitative statements about negative impacts of listing on exploitation generally led to denying protection to marine but not to freshwater species. These findings highlight both a large and inconsistent emphasis on costs of protection in SARA listing decisions, to the detriment of marine fish species.

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freshwater fishes, and to examine the relative importance of costs and threat status for the probability of being listed. By focusing on fishes, the influence of responsible authority – an important correlate of the likelihood of being listed – was removed since all fishes fall under the purview of Fisheries and Oceans Canada. As did [12], but now with a decade of listing decisions, the qualitative reasons invoked for listing and not listing fish species were examined, but with a focus on asking whether the same reasons consistently led to the same listing outcome for marine and freshwater fishes. In this way, transparency in the application of one of the most important legislative tools for species protection in Canada was assessed in terms of process and consistency across taxonomic groups.

2. Methodology

2.1. How SARA works

The process of listing species, subspecies, or distinct populations under SARA has been reviewed in detail elsewhere [11,12,15]. Briefly, COSEWIC undertakes status reviews of taxa found within Canadian borders. The choice of species for review does not depend on economic value or on the likelihood of federal consent to listing, but on perceived level of threat (J.D. Reynolds, COSEWIC Marine Fishes Species Specialist Committee, personal communication). COSEWIC scientific reports and listing recommendations are submitted annually to the federal Minister of the Environment (MoE) – a post held by an appointed politician – who reviews them in light of a socio-economic assessment and consultations with stakeholders and the public. Beyond having 90 days to declare how the Minister intends to respond to a COSEWIC recommendation, no timeline is specified for the consultation period, and species recommendations may undergo an extended consultation period if so designated by the Minister. Once the consultation is complete, the Minister forwards all information to the Governor in Council (i.e., Canada’s House of Commons), which must decide within nine months either to list a species as recommended by COSEWIC, not list the species, or refer the species back to COSEWIC for further evaluation. Species listed as Extirpated, Endangered or Threatened receive automatic legal protection (i.e., immediate prohibitions on direct take and destruction of residence, but ‘critical habitat’ is not protected until identified in a recovery strategy or action plan), while listing a species as Special Concern initiates a management plan but entails no prohibitions of deleterious activities. To maintain transparency, justification for each decision is published in the Canada Gazette, which publishes new laws, acts, regulations, official appointments and public notices on a weekly basis (www.canadagazette.gc.ca). The justifications include a Regulatory Impact Analysis Statement (RIAS), which is prepared by the sponsoring department (without external peer-review) and must include a cost–benefit analysis (for more details, see [11]). Once species are listed, their status may change with a new COSEWIC assessment, which occurs at least every 10 years, and subsequent listing process [16].

2.2. Species status information

Information was collected on the status of marine and freshwater fishes from the SARA Registry (www.sararegistry.gc.ca), including the COSEWIC recommended status and current SARA status. The realm occupied by each taxon was determined by the COSEWIC Species Specialist Committee (SSC) (i.e., Marine Fishes SSC or Freshwater Fishes SSC) that assessed the taxon. Thus all anadromous fishes were classified as marine, which is justified in this study since most of the anticipated costs of listing such species pertained to prohibitions of marine activities. Where the COSEWIC status and SARA status were the same, the taxon was considered ‘listed’. Otherwise, the taxon was scored as ‘not listed’ if a decision had been published and listing was denied. This study therefore did not include taxa for which recommendations were returned to COSEWIC for further evaluation or for which a listing outcome had yet to be published. Because COSEWIC often assesses distinct populations or subspecies separately [17], using units of assessment that are analogous to Distinct Populations Segments in the USA [18], the term ‘species’ is used to indicate any taxon for which COSEWIC conducted an assessment. This study was restricted to species with a COSEWIC recommended status of Extirpated, Endangered, Threatened or Special Concern, since species designated Extinct, Not at Risk or Data Deficient trigger no socio-economic assessment.

Initially, the intention was to compare the costs and benefits of listing marine species with that for terrestrial or freshwater species, focussing on mammals, molluscs and fishes. However, for species other than fishes, socio-economic data in the Canada Gazette either lacked dollar amounts (e.g., [19]), or multiple species were accounted for in general terms (e.g., [20]). Socio-economic impact reports on non-fish species from other sources were not publicly available.

The present study thus included marine and freshwater fish species that had undergone the SARA process outlined above and for which a listing decision had been made between 2003 and the end of 2010. The 30 species that were automatically listed when SARA came into force in 2003 (SARA 2003, Schedule 1) were not included, unless a species had been re-evaluated by COSEWIC, with a recommendation for change of status.

2.3. Analysis of quantitative costs and benefits

Listing notifications published in the Canada Gazette were examined to extract the anticipated costs and benefits of protecting freshwater and marine fishes. Costs were often assigned to specific economic activities that could be affected by species protection. These activities included: commercial and recreational fishing restrictions or closures, fish processing industry losses, impacts due to required reductions in bycatch in other fisheries, costs to other industries such as tourism and shipping, and indirect impacts on the economy. Also listed were some of the costs of implementing protection, such as the costs of habitat protection, monitoring fish populations in the absence of a fishery, research and public education. Listing a species also entails costs in terms of developing a management plan, recovery strategy or recovery action plan; however, since dollar values for these planning activities were not given, they could not be considered. In one case (the winter skate, Leucoraja ocellata), dollar amounts were not provided in the Canada Gazette, but were available in Department of Fisheries and Oceans (DFO) Socio-Economic Analysis Reports [21,22]. The information provided for this species was included because these reports are used in listing decisions [12], and the costs they provide are consistent with those published in the Canada Gazette when both are available (e.g., Atlantic cod, Gadus morhua [21,23]). The sum of all dollar amounts given for a particular species was recorded as the cost of listing, and scaled to a 10-year period because most amounts provided were per decade. For species for which no dollar amounts were given, the cost of listing was recorded as zero since impacts on economic activities were invariably described as negligible.

Economic benefits were seldom provided in dollar amounts (see Section 3 results). When they were provided as a range, the mid-range value was recorded and scaled to a 10-year period.
When benefits were either not mentioned, or described as ‘of no value but likely to accrue in the distant future’ or ‘likely limited’, the benefits of listing were recorded as zero.

An information-theoretic approach and logistic regression models were used to evaluate the relationships between the likelihood of being listed for protection and habitat (marine vs. freshwater), the anticipated cost of listing, and threat status, as reflected by the status recommended by COSEWIC (Special Concern, Threatened, or Endangered) [24]. For these analyses, striped bass Morone saxatilis was excluded, because it was the only species with a COSEWIC status of extirpated, hence there was no replication for this threat status. There was a strong association between the likelihood of being listed and cost (e.g., listed species often have low costs while non-listed species often have high costs), which introduced a separation or quasi-separation problem in logistic regression [12]. To address this issue, parameter estimates were calculated using Firth’s penalized log-likelihood [25,26] in the ‘logist’ package in R [27], which has been shown to be suitable for situations of separation in logistic regression [28]. A total of 11 logistic models were constructed to test various combinations of the three main effects (habitat, cost, threat status) and their two-way interactions. For each model, the Akaike information criterion corrected for small sample size (AICc) was calculated. Lower AICc values indicate better-supported models relative to others in the candidate set. The Akaike difference (ΔAICc) between the model with the lowest AICc and each of the other models was then calculated. As a rule of thumb, values of ΔAICc which are < 2 are considered to represent substantial support for a model [24]. Finally, the AICc weight (w) of each model, which indicates the probability that the model is the best among the candidate models, was obtained. The confidence set of candidate models included models with Akaike weights that were within 10% of the highest weight [24]. Model-averaged parameter estimates were calculated for each parameter in the confidence set.

To identify the habitat-specific threshold costs beyond which the likelihood of being listed became substantially reduced, logistic regressions were carried out of the effect of cost on the probability of being listed separately for marine and freshwater species. M. saxatilis was included in this analysis. Threshold cost was defined as the estimated cost at a 50% probability of being listed and 95% confidence intervals around each threshold cost were estimated from the standard error of the parameter estimate. Estimated costs or benefits were log_{10} + 1 transformed prior to analysis.

2.4. Qualitative factors invoked in listing decisions

The qualitative reasons and potential impacts (which we refer to as ‘factors’) associated with each listing decision were summarised, with a view to comparing the relative frequency with which each factor was invoked for listed and unlisted marine and freshwater taxa. There were 15 recurring factors, numbered and described below, grouped for convenience into six categories: cost/benefit statements, exploitation, development, legislation, biology and public opinion. Each factor mentioned in a species’ RIAS was scored as ‘invoked’ (score = 1) for that species, while all factors not specifically mentioned were scored as ‘not invoked’ (score = 0).

Under the ‘cost/benefit statement’ category, any phrase that was synonymous with either an ‘insignificant cost’ (factor 1) or a ‘significant cost’ (2) was counted if it described an overall expected financial outcome of listing. Similarly, benefits were scored as ‘benefit absent’ (3) when potential benefits were not mentioned or described as likely to be limited or to accrue only in the distant future, or as ‘benefit present’ (4), when anticipated benefits were listed. Anticipated benefits included: future commercial, non-use value, biodiversity and ecosystem benefits, aboriginal value and scientific value. ‘Exploitation’ impacts included mentions of costs of prohibitions to the commercial fishing industry (5), recreational fishing industry (6), or to another fishery due to bycatch regulation (7). SARA listing may ultimately entail habitat protection for many species (SARA Sect 58); therefore, restrictions on development were often cited as potential impacts. These included hydroelectric restrictions (8), such as limiting dams and water use, and coastal restrictions (9), which included limits on marina construction, dredging, urban development, road development and agriculture. These first nine factors related to potential economic consequences of listing.

Under ‘legislation’, mentions of existing management (10) or Aboriginal issues (11) were included. Existing management included species protection under another act (e.g., the Canada National Parks Act or Fisheries Act), sharing habitat with an already-listed species, or past protection under SARA when a species had a different status. Aboriginal issues were noted when it was stated that the food, social and cultural requirements of Aboriginal people, which are enshrined in the Canadian constitution, might conflict with SARA regulations. Within the ‘biology category, statements declaring that the species was unlikely to recover even if protected (12), and those stating that monitoring or research costs in the absence of a fishery were likely (13), were included. Finally, ‘public opinion’ statements were divided into those for (14) and against (15) listing.

The number of fish species whose RIAS mentioned each particular factor was tallied, and plotted as percentages of the number of marine or freshwater species with a listing decision, separately for listed and not-listed groups. More than one factor was usually given for each species. The total percentages therefore exceed 100.

3. Results

COSEWIC has recommended 110 fish species for listing since its inception in 2003. Of these, 54 had received a listing decision supported by economic data by the end of 2010 (Table 1). Decisions were pending for the remaining species.

3.1. Costs, benefits and likelihood of being listed

Overall, there was a significant difference in the likelihood of being listed between marine and freshwater species: 43% of marine fishes (9 of 21 species) and 87% of freshwater fishes (29 of 33 species) (χ^2 = 12.5, p < 0.001) recommended by COSEWIC had been listed under SARA by the end of 2010. The estimated cost of listing marine species was significantly higher (mean ± 1 SE; $75,289,000 ± $2,037,760 per 10 years) than that of freshwater species ($3,520,000 ± $2,401,750 per 10 years; t-test for unequal variances, t_{50.56} = 2.62, p = 0.016).

When cost, habitat and threat status were considered simultaneously, two models explaining likelihood of being listed obtained substantial support (ΔAICc < 2) compared to other models considered (Table 2). The anticipated costs of listing featured in both, while habitat was included in one of the top two models. Threat status did not predict the likelihood of being listed (Table 2). Increasing cost decreased the likelihood of imperilled fishes being listed (model-averaged parameter estimate ± SE: −3.15 ± 1.09), as did inhabiting marine habitats (−1.03 ± 0.98), although the effect of habitat was weaker than that of cost.
For marine species, no species with a cost greater than zero was listed for protection (Fig. 1a). Estimated threshold costs, at which the likelihood of being listed equals 0.5, varied from $90,309 ($46,165 to $137,365, 95% CI) over 10 years for marine taxa (Fig. 1a) to $4,998,400 ($1,398,833 to $31,359,366, 95% CI) per decade for freshwater species (Fig. 1b). Estimates in dollar amounts of the benefits of listing were given in the RIAS for only one-third of species (18 of 54; vs. 100% of species for cost estimates). Of these, 17 species were assessed as providing no benefit if listed (benefit value= $0); a non-zero value was given for a single species (chinook salmon Oncorhynchus tshawytscha, Okanagan population, modal value: $12.5 million per 10 years). It was therefore not possible to establish the nature of the relationship between benefits of listing and the likelihood of being listed.

3.2. Qualitative statements

The qualitative factors invoked to justify listing decisions sometimes differed in frequency of use and in listing outcome between marine and freshwater fishes (Fig. 2). Insignificant costs and the presence of benefits were the most common reason invoked to support the listing of fish species, regardless of biome. However, while significant costs contributed to not listing one-third of marine fishes, significant costs were never cited as a reason not to list freshwater fishes. Exploitation factors were the
most often mentioned issues for not listing marine species, with impacts on commercial exploitation, in particular, cited in nearly 60% of marine cases. Exploitation impacts were never cited for marine fishes that were listed. In contrast, commercial exploitation was mentioned for less than 5% of freshwater species, and bycatch issues for one-third of freshwater taxa, and in most cases, those species were listed. Potential impacts on development were only cited for freshwater fishes, most of which became listed. Legislation issues had contradictory effects for freshwater and marine species. More specifically, existing management was cited as a reason to list nearly half the species of freshwater fish, yet also cited as a reason to not list nearly half of marine fishes. Similarly, one-quarter of marine species were associated with aboriginal use and were not listed, while aboriginal use was mentioned for one-third of freshwater species, and these species were all listed. Biological monitoring and research costs were cited infrequently, but were most often mentioned for marine species that were not listed. Low probability of recovery was cited as a reason to not list ~30% of marine species but not mentioned for any freshwater fish. Note that it is not clear how recovery probability was assessed as it is usually not stated in COSEWIC reports. Finally, public opinion for protection supported decisions to list fishes in Canada while public opinion against listing was generally associated with not listing. Lack of public support for protection was invoked in one-quarter of marine species that were not listed.

4. Discussion

The results illustrate the considerable weight given to financial costs in conservation listing decisions of fishes in Canada. By contrast, the threat status of a fish species has little influence on its likelihood of becoming listed. The presence of an economic ‘glass ceiling’ – a threshold cost beyond which the likelihood of being listed becomes negligible – should be expected in analyses that measure costs and benefits to inform future action. However, the thresholds identified here did not appear to arise from obvious cost–benefit trade-offs. While anticipated benefits were qualitatively mentioned for many taxa that became listed, and their absence noted for unlisted taxa, quantitative economic benefits were provided for only one species (i.e., chinook salmon). Hence, while the possibility of future benefits may have played some role in listing decisions, cost considerations did so more evidently but also inconsistently. Marine and freshwater fish species had different threshold costs for not being listed (~$90,000 per decade for marine species vs. ~$5,000,000 per decade for freshwater species), with much greater certainty surrounding the marine than the freshwater estimate. The specific issues raised qualitatively in the socio-economic assessments to justify listing decisions for these two groups were also used inconsistently. These results highlight a lack of transparency in the way in which economic data and qualitative information are generated and used in the SARA listing process.

Economics clearly trump biology in listing decisions about fishes in Canada. In fact, any predicted cost was associated with the rejection of listing recommendations for marine fish species, while all marine species with no anticipated listing cost were protected. Specific examples demonstrate the extent of this pattern. Previous studies have highlighted the porbeagle shark, Lamna nasus, as an example of a species that was not listed despite a very low estimated economic impact of doing so [11,13,14,29,30]. In the present study, the cost of listing the porbeagle shark was $900 000–$1.75 million over a 10-year period. The winter skate (L. ocellata, Georges Bank-Western Scotian Shelf-Bay of Fundy population) was also not listed despite an even lower estimated cost of $180,000 over 10 years [22]. In contrast, two freshwater species, the lentic and lotic populations of the Misty Lake threespine stickleback (Gasterosteus aculeatus), each carried a potential protection cost of $160,000–$2 million over 10 years, and were nevertheless listed. A listing bias against fish species was suggested in the early years of SARA [12], which appeared to be associated with having the Department of Fisheries and Oceans (DFO) as the responsible authority. The current economic analysis suggests that this bias is ongoing, more pronounced against marine than against freshwater fishes, and not a DFO effect but an economic effect.

The qualitative factors cited in listing decisions also support the existence of a bias against marine fishes. The same factor was often cited in support of different listing outcomes for marine and
freswater species. This was particularly evident in relation to exploitation and existing management, which are discussed in turn below.

Economic impacts on various forms of fisheries were cited more often for marine than for freshwater fishes. This is not surprising at least for directed commercial exploitation and bycatch, given the relative values of marine ($447 million landed value) and freshwater ($60 million) fisheries in Canada [31]. However, while predicted impacts on recreational fishing always resulted in not listing species regardless of biome, mentions of impacts on commercial harvest and bycatch were associated with listing most freshwater species but not listing any marine species. Since commercial exploitation, bycatch and recreational fishing are important threats to North American fish populations [32,33], those species that are least likely to be listed may also be those in greatest need of protection. In this context, it seems ironic that fish species deemed unlikely to recover, as was the case for one-quarter of marine species (Fig. 2) threatened mainly by exploitation, were not afforded protection from their main cause of decline.

Existing management was cited in many of the RIAS examined. However, like exploitation, it led to different listing outcomes for marine and freshwater fishes. For almost half of marine species (but only two freshwater species), additional protection under SARA was deemed not necessary because other management legislation, such as fisheries restrictions, was already in place. Thus, those (mainly marine) species were not listed. In contrast, for almost half of freshwater species (but only two marine species), it was argued that there would be little additional cost of protection under SARA since protective measures already existed under other legislation. These (mainly freshwater) species were listed. Potential conflicts between protection and Aboriginal use led to similarly inconsistent listing; all marine species for which Aboriginal use was invoked were denied protection while the majority of freshwater species important to Aboriginal people were listed. It may be that prohibiting use of marine species entails greater cultural costs to Aboriginal people than prohibiting use of freshwater species. Nevertheless, this listing inconsistency means that Aboriginal rights are respected in potential conflicts with the protection of marine species, but not of freshwater species.

Why is there such a marked bias against the protection of marine fishes in Canada? A bias could arise if marine fishes cost more to protect. The anticipated costs of protection were indeed higher for marine fishes; hence, a greater proportion of marine fishes might be expected not to be protected given a fixed threshold cost of protection. However, this threshold is not fixed. It is lower for marine species, making it even less likely that these species will be listed. The root causes of bias may be a combination of politics and inadequate institutional capacity to implement marine protection. Fisheries and Oceans Canada (DFO) is the responsible authority for all fishes considered under SARA. However, while DFO has the sole responsibility for managing and protecting marine fishes, it shares this responsibility with the relevant provinces for freshwater fishes. Provincial governments can put pressure on their federal counterpart to list taxa within their boundaries. Perhaps more crucially, the provinces also share the costs of planning and implementing protection. The listing of freshwater species may therefore be a lesser financial and capacity burden on DFO than the listing of marine species.

A cursory look at the threatened species listing process used in other developed countries suggests that an emphasis on protection costs, to the near exclusion of information on threat status, is...
probably not common. For example, in Australia [34] and New Zealand [35], listing is based solely on threat status, which is determined on the basis of internationally recognized criteria (e.g., [36]), despite the opportunity given for public input, including lobbying based on economic concerns. The role of costs is clearest in the US protection legislation. The Endangered Species Act [37] specifically prohibits the consideration of economic impacts in making species listing determinations. In fact, it has been suggested that awareness of the costs of species protection in the US led Canadian businesses to strongly oppose SARA when it was proposed, three decades after the American legislation [38]. It was a much more cost-conscious and discretionary approach to wildlife protection in Canada.

In summary, there is a large emphasis on costs in Canadian listing decisions, and marine and freshwater fish species are currently assessed inconsistently in relation to the economic impacts of protection. The current cost-focused approach has three major flaws. First, it provides an incomplete accounting of the potential impacts of conservation on Canadian society because benefits are overlooked. These benefits can be considerable, as evidenced by studies of public willingness to pay to recover threatened marine species (e.g., [39,40]). Second, because cost estimates are provided early in the listing process, before formulating a management plan or recovery strategy, they have large but unacknowledged uncertainties [12]. Third, emphasis is currently placed exclusively on short-term, regional impacts [11], which magnifies immediate costs at the expense of longer-term benefits. These flaws are currently preventing the listing of imperilled marine fishes, whose continued declines make it evident that conservation management solely through fisheries legislation is insufficient. A cost-blind approach to conservation decisions is not being advocated here. Indeed, a single-minded focus on threat status rarely leads to cost-efficient actions (e.g., [41]). However, cost efficiency cannot be achieved with incomplete information. The changes required to the current process entail inclusion of benefits in cost-benefit analyses, full transparency in accounting — including acknowledging implicit discount rates, the use of thorough peer-review to match the intense scrutiny of scientific assessments of species status, and public availability — and clarity on how scientific and economic information are balanced. The result should be a more objective and transparent process, which will improve the protection of Canadian fish biodiversity, both for its intrinsic and economic value.

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