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Hopeful insights from wildlife recoveries in Canada

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Abstract

Facing the global biodiversity crisis, conservation practitioners and decision-makers seek to catalyze wildlife recoveries in their region. Here we examined social-ecological attributes related to threatened species recovery in Canada. First, we used a retrospective approach to compare the trajectories of the original species assessed by Canada's species-at-risk committee and found that only eight of 36 species now have decreased extinction risk relative to the past. There were no significant differences in human or financial capacity provided for recovery across species doing better, the same, or worse; the only significant difference was whether the primary cause of decline was alleviated or not. Second, when looking at species assessed at least twice between 2000 and 2019 we found that only eight of 422 (1.9%) experienced *both* increasing abundance and decreasing extinction risk. The defining characteristic of successful recoveries was first alleviating the original cause of decline, which was most often accomplished through strong regulatory intervention. Once declines were halted, practical interventions were highly species-specific. It is instructive to learn from conservation successes to scale resources appropriately and our results emphasize the importance of threat-specific intervention as a fundamental precursor to the successful restoration of biodiversity in Canada.

Key words: Canada, endangered species conservation, Kunming–Montréal Global Biodiversity Framework, Species at Risk Act, wildlife recovery

1. Introduction

Humans are acutely aware of our myriad impacts on the biosphere and have more information on how our actions—or lack thereof—contribute to biodiversity loss than ever before. This knowledge combined with our species' singular responsibility to halt the overexploitation of wildlife and restore ecosystems has led to urgent calls for reform, especially from youth (Stockholm + 50 Youth Task Force 2022; YOUNG 2022) and historically marginalized groups (Schlosberg and Collins 2014; Temper et al. 2020), many of whom are disproportionately impacted by a changing planet. Still, progress in ameliorating our climate and biodiversity crises has been incremental at best, despite five decades of international environment-focused dialogues.

The most recent high-level commitments related to the conservation of Earth's biodiversity are outlined in the Kunming–Montréal Global Biodiversity Framework (GBF), the new strategic agreement for 2030 under the United Nations Convention on Biological Diversity (CBD 2022). Adopted in 2022, the GBF replaces the Aichi Targets, which countries worked to implement during the United Nations (UN) Decade on Biodiversity (2011–2020). Although domestic approaches and results varied among countries, all 20 Aichi Targets were unmet at a global scale (CBD 2020) and the most recent Global Biodiversity Outlook explicitly highlighted a need for countries to learn from—and scale-up—successful efforts wherever feasible (CBD 2020). This perspective is in keeping with calls from the scientific community highlighting the scale and urgency of action needed to address today's interconnected environmental crises (Bradshaw et al. 2021) and calling for timely, inclusive, solutions-focused research to help address pervasive conservation challenges (Lubchenco 2016; Cooke et al. 2022). Equally, research documenting "bright spots" of species and ecosystem health (Cinner et al. 2016; Rossbach et al. 2023; Schiller et al. 2024) highlights the importance of looking at how aspects of human stewardship can contribute to better-than-expected outcomes for seemingly intractable conservation challenges. This turn toward identifying and learning from successful conservation approaches is of immediate relevance, especially given the latest commitments made by countries to restore and protect wild species and spaces through the GBF agreement and its 23 Targets (Langhammer et al. 2024).

The Canadian federal government has repeatedly asserted that Canada is a nation committed to addressing biodiversity loss. In 1992, Canada was the first high-income country to ratify the CBD and, in 1995, the federal government published a National Biodiversity Strategy outlining how the objectives of this agreement would be met at a national scale (Ray et al. 2021). Recently, the federal government has committed to managing all fish and other marine resources sustainably by 2025 (DFO 2020), and achieving net-zero carbon emissions by 2050 (ECCC 2022*a*). As part of its pledge at COP-15 in 2022, the Canadian government also committed $800 million to help support Indigenous-led conservation initiatives, including the implementation of Indigenous Protected and Conserved Areas. These efforts are in keeping with the broader international aspiration to conserve 30% of the planet's land and ocean area by 2030 (Office of the Prime Minister of Canada 2022) and Canada's vision of achieving "a full recovery for nature by 2050" (ECCC 2022*b*).

Here, we respond to the call to action of Buxton et al. (2021) who ask practitioners, knowledge holders, and scientists to improve our understanding of effective Canadian conservation policies and actions. We focus on species-level conservation in Canada since this was one of three areas where Aichi Target commitments were not met (ECCC 2019), and because the overarching objective of Canada's new Nature Strategy is to halt and reverse biodiversity loss by 2030 (ECCC 2024). Using both a historical perspective and a case study approach, we investigate attributes of successful wildlife recoveries and present an overview of known conservation successes. We provide insight into how these recoveries were achieved and review what sets them apart from threatened species that have not shown similar signs of recovery.

2. Materials and methods

2.1. Overview of study region

Canada is the world's second largest country by land area (9.98 million km^2) and has the world's longest coastline (>243 000 km). Canada is also one of five countries that collectively contain over 70% of Earth's remaining intact ecosystems (ECCC 2024) and it has been labelled a "conservation superpower" for its high relative contribution to global ecosystem values (Coristine et al. 2019). Roughly one-quarter of the world's boreal forest, temperate forest, and wetland area, respectively, are found in Canada (Government of Canada 2022). Prior to colonization by European settlers, Indigenous communities relied on a diversity of wildlife to meet nutritional and medicinal needs and maintained strong spiritual and cultural connections with ecosystems for millenia (Kuhnlein and Turner 1991; Turner et al. 2000; Hummel and Ray 2008; Cannon and Yang 2017). Such connections to place still exist for many communities, and 96% of Canadians believe that nature is important to their well-being (ECCC 2024). Many Canadians also rely heavily on natural resource sectors for sustenance, livelihoods, or broader national economic security.

In general, balancing economic dependence on natural resources with wildlife conservation has been a long-standing challenge in Canada (Van Wilgenburg et al. 2013; Hutchings et al. 2019; Kapoor et al. 2021; Sergeant et al. 2022). At the same time, inconsistent efforts to recognize the rights of Indigenous Peoples to self-determination has perpetuated social injustices in Canada (Hill et al. 2019; Muir 2022) while exacerbating conflict over valuable and vulnerable habitats and wildlife (e.g., Hebblewhite 2017; Moore 2022). Over 80% of remote northern Canadian wilderness remains unmodified by direct human activities; however, more southern regions are subject to high human pressure (>56%–70%), due to cumulative impacts associated with urban development and industry (Hirsch-Pearson et al. 2022). For example, the Canadian boreal plains are home to the world's fourth largest extractable fossil fuel reserve, and crude oil is the country's leading international export (Government of Alberta 2022). Canada is also the world's primary exporter of sawn timber (OEC 2022) and ranks among the top producers of metallic and non-metallic minerals, with mining operations in all 13 provinces and territories (NRC 2022). In general, species richness is also highest along the country's southern border and, thus, coincides with the highest human population density (Coristine and Kerr 2011).

At least 80 000 species of wild flora and fauna (Fig. 1) are found in Canada, over 300 of which are endemic (Kraus et al. 2023). In 2020, 20% of wildlife in Canada was determined to be at some level of extinction risk, although this included many species not yet assessed (CESCC 2022). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is the scientific body charged with assessing the status of species in Canada and providing recommendations for inclusion on the regulated federal list of at-risk species (COSEWIC 2021). From this process, COSEWIC publishes status reports, which systematically incorporate information on threats affecting a specific species, population, or subspecies and assigns a risk status of: (i) Extinct, (ii) Extirpated, (iii) Endangered, (iv) Threatened, (v) Special Concern, (vi) Not At Risk, or (vii) Data Deficient; designations that are revised (e.g., split into multiple units) become (viii) De-Activated. Currently, one-third of 1173 assessed wildlife species are categorized as "Endangered" (COSEWIC 2023).

The 2002 Species At Risk Act (SARA) is the federal government's primary legislative tool to protect wild species that have been classified as threatened with extinction by COSEWIC. However, in the two decades since SARA was implemented, little has changed in terms of the threats facing Canadian wildlife. In 2013, the primary threat facing SARA-listed species (which were mostly plants), was habitat destruction because of human disturbance, especially recreational activities (McCune et al. 2013). While species in Canada are subject to an average of five different threats (Currie and Marconi 2020), habitat loss remains the main threat to threatened Canadian wildlife, although 38% of species are now also

Fig. 1. Examples of Canadian biodiversity and key natural resources. Fifteen unique ecozones across Canada provide habitat for over 80 000 species of wildlife (e.g., *a–c*). At the same time, many of Canada's ecozones also provide some of the world's largest forestry and mineral exports (e.g., *d–f*). This dichotomy continuously presents challenges for Canada's federal and provincial governments when it comes to balancing resource extraction and conservation. (Photos: Laurenne Schiller (*a* and *b*); Mark/Adobe Stock (*c*); IanChrisGraham/iStock (*d*); BGSmith/Shutterstock (*e*); and Cavan Images/Alamy Stock Photo (*f*).)

likely impacted by threats related to climate change (Woo-Durand et al. 2020).

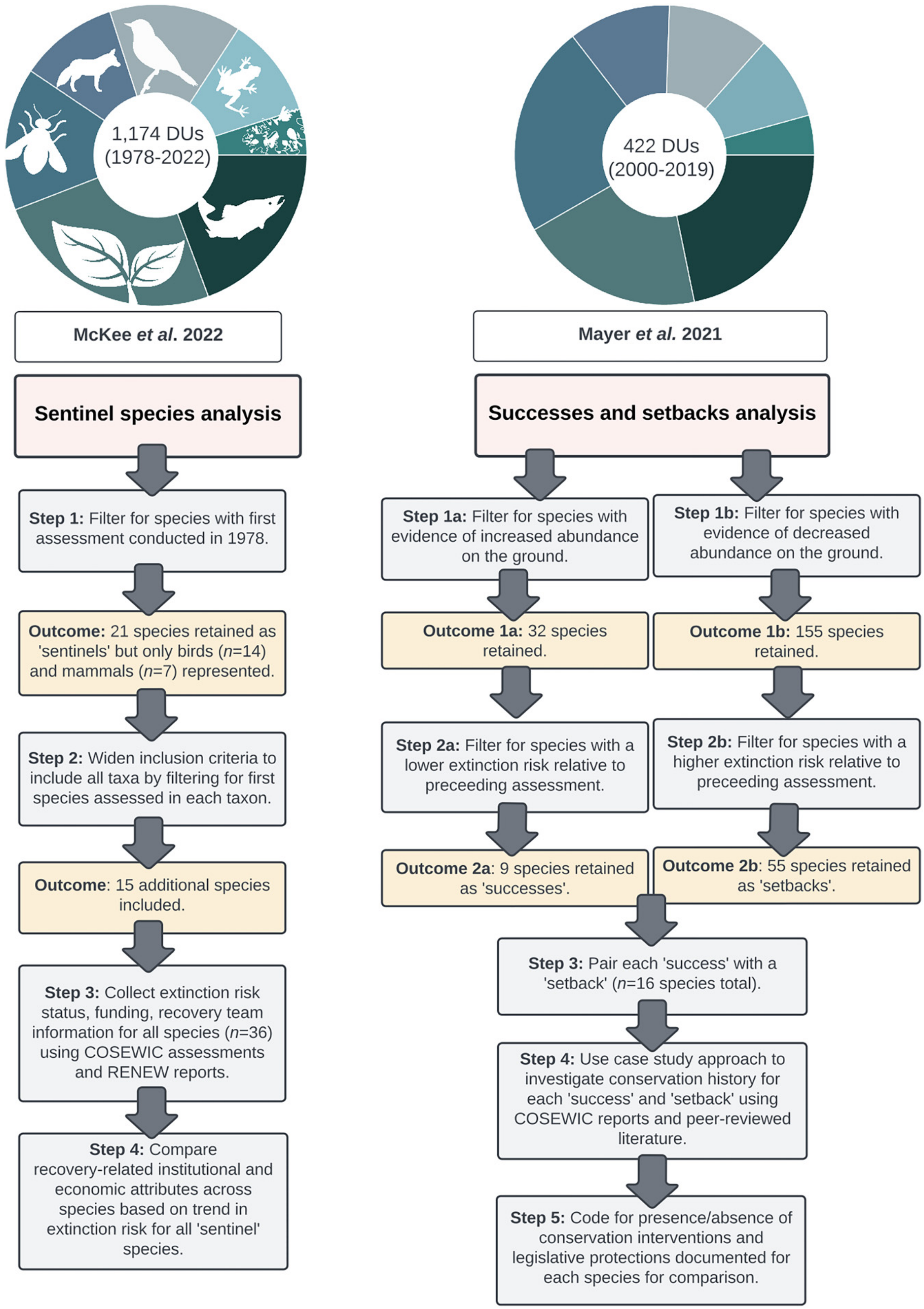
2.2. Data sets and analyses

For the purpose of our paper, we use the SARA definition (ECCC 2014) and refer to all COSEWIC assessed units as "wildlife species" (hereafter: "species"). We used two previously unpublished databases of COSEWIC-assessed species with information covering different timeframes to investigate species recovery in Canada (Fig. 2). First, we used the database of McKee et al. (2022; Supplementary Data File 1) as part of a retrospective analysis to investigate trends in extinction risk for the first species in each taxonomic group ever assessed by COSEWIC. We termed this group, the *sentinel* species given their symbolism as indicators of long-term species' fates in Canada. Based on changes in their COSEWIC extinction risk over time, we classified them into four trajectory groups: "doing better", "the same", "doing worse", and "unknown". We gathered funding and recovery team data for each species from existing RENEW Reports (1989–2006) as well as information on each species' recovery history (Table S2). Using this information, we tested whether recovery team size and composition, total allocated funding, number of COSEWIC assessments published, and the time taken to publish the first recovery document, were significantly different across the "better", "same", and "worse" groups (see Supplementary Methods for details). We also compared these groups based on whether the cause of decline for each species had been mitigated. While we gathered information for all sentinel species, we did not include those with "unknown" trajectories in these analyses. Information in the McKee et al. (2022) database was current up to 1 May 2022 and included 1174 species (with assessments spanning 1978–2022).

Next, we took a more detailed and contemporary look at successful species recovery in Canada using data from Mayer et al. (2021; Supplementary Data File 2). This was an unpublished content analysis database that scored criteria information from COSEWIC assessments using a standardized approach (see Supplementary File 4). It included 422 species that had at least two assessments conducted between 2000 and 2019 and were not classified as "Data Deficient", "Extirpated", or "Extinct". Unlike both ECCC (2022*c*) and McKee et al. (2022), the information in this dataset was able to provide context related to the drivers of COSEWIC status change since it translates specific COSEWIC assessment content into numeric scores. This information enables analyses related to how different aspects of species-specific threats and trajectories have changed over time. Using this dataset, we first filtered for species that met a two-fold definition of recovery *success*: (i) increased population abundance and (ii) decreased extinction risk (see Supplementary Methods Section 2.2.1 for definition rationale and details). To obtain a comparison group, we then filtered for *setback* species with (i) decreased population abundance and (ii) increasing extinction risk. We paired each *success* with a *setback* species based on similar life history and geographic traits (Table S4) and conducted a case study review for all paired species to identify aspects related to their conservation.

First, we identified whether the setbacks and successes were listed on international agreements/treaties and domes-

Fig. 2. Methodological overview. Shown is the process for identifying "sentinel" species and recovery "success" and "setback" case studies. Please see Section 2 as well as Supplementary Methods for detailed information related to selection criteria, exclusions, and data collection. McKee et al. (2022) data are provided as Supplementary Data File 1 and Mayer et al. (2021) data are provided as Supplementary Data File 2.



tic species-specific protective legislation. To do this, legislative protections were divided into five broad jurisdictions: multi-national, American federal, Canadian federal, Canadian provincial, and Indigenous land claim within Canada (Table S5). Second, we identified what types of practical (i.e., on-the-ground) interventions had been used to promote their recovery. Such interventions were divided into similarly large categories: reintroduction to the wild, captive breeding program to maintain genetic diversity, habitat protection, habitat restoration, and disease/invasive species monitoring. For both the legislative protections and on-the-ground interventions, all were considered in terms of their relevance to individuals in the Canadian population and only those that had been implemented up to the most recent assessment year were included (see "Assessment window" in Table 2).

For each species, all legislative and on-the-ground interventions were coded for presence ("1") and absence ("0") (Tables S6 and S7) and cumulative results were compared between setbacks and successes. In addition to comparing the number of interventions, our case studies focused on reviewing the unique circumstances associated with all *success* and *setback* species, the main findings of which are presented as a qualitative summary of key observed commonalities and differences. Full details on methodology for all analyses are available in the Supplementary Materials.

3. Results

3.1. Attributes of sentinel species and their trajectories over time

Overall, eight of 36 sentinel species (22%) are now in a lower risk category relative to their first COSEWIC assessment (i.e., "doing better"), 14 are the same (39%), 11 are in a higher risk category (31%; i.e., "doing worse"), and three are unknown due to having only one assessment (8%; Table 1). Among the sentinel species, six were assessed as having no evidence for decline. The primary cause of decline for 14 of the remaining 30 sentinel species was related to the loss or degradation of habitat, followed by overexploitation and persecution by humans (nine species).

For the 28 sentinel species with known extinction risk trajectories and where the original cause of decline could be ascertained, we find the cause of decline has been mostly or entirely alleviated for nine species (Table 1); seven of these are now in a lower risk category and two are in the same risk category (whooping crane and peregrine *pealei*). Six of nine alleviated declines were originally due to overexploitation (or direct persecution by humans) while declines of three peregrine falcon subspecies (*anatum, tundrius*, and *pealei*) were linked to impacts of the agricultural insecticide, dichlorodiphenyltrichloroethane (DDT). The cause of decline was not sufficiently addressed for any species now in a higher risk category (i.e., "doing worse"), and we found a statistically significant difference between the three groups when comparing the proportion of species that had their original cause of decline alleviated or not ($p < 0.001$; Fig. 3A).

There was no statistically significant difference between species doing better, the same, or worse based on total number of COSEWIC assessments conducted ($F_{[2,30]} = 0.898$, $p = 0.42$). When considering different institutional, social, and economic aspects of recovery interventions, we further found no statistically significant differences among the three groups in terms of the time taken to publish their first recovery document ($F_{[2,25]} = 1.290$, $p = 0.29$; Fig. 3B), total allocated funding ($F_{[2,27]} = 0.117$, $p = 0.89$; Fig. 3C), recovery team size ($F_{[2,19]} = 0.707$, $p = 0.51$; Fig. 3D) or recovery team composition ($F_{[2,19]} = 0.929$, $p = 0.41$; Fig. 3E). Notably, a key objective stated in the inaugural 1989 RENEW report was to have all recovery documents for (existing) threatened species completed within 3 years. We found that the median time taken to produce the first recovery document exceeded 18 years across all three groups (Fig. 3B).

Overall, we found substantial variation in financial support allocated to different species over time (Fig. 3C) as well as notable concentration of resources: the top four most heavily funded species (wood bison, piping plover *circumcinctus*, Vancouver Island marmot, and whooping crane) received more financial aid (CAD 25 million) than all other species combined (CAD 20 million), and one mollusc—the northern abalone—received 79% of CAD 5.2 million allocated to all eight non-vertebrate species (Table S3). The recovery team for the monarch butterfly (doing worse) was the largest across all species ($n = 41$ people). Among species doing better, the peregrine falcon *tundrius* had the smallest recovery team (six people) while the sea otter had the largest (39 people).

3.2. Comparing Canada's "successes" and "setbacks".

We found eight of 422 species (1.9%) met our two-fold definition of recovery success: increasing population abundance and decreased extinction risk between 2000 and 2019. At the same time, 55 species (13%) met our antithetical criteria for setbacks. The group of successes included three marine mammals, three terrestrial mammals, one vascular plant, and one bird (Table 2). The eight setbacks we chose to pair with these species also included three marine mammals, as well as two terrestrial mammals, one vascular plant, and two birds (Table S4). Interestingly, three successes and one setback identified in this part of our analysis were also among the 36 sentinel species (Table 1). Below, we report quantitative differences in the number of interventions for successes and setbacks and provide key findings from our qualitative synthesis (Table S9) across all species studied here.

While many species were—and continue to be—subject to multiple human-induced threats, historic overexploitation and persecution by humans was the most common cause of decline across successes and setbacks (six of 16 species), followed by habitat loss (three species; Table 2, Table S9: *Causes of population decline*). On average, successes had a total of 5.4 ± 1.5 recovery interventions compared to 4.0 ± 0.53 for setbacks (Fig. 4), which revealed a significant difference between the two groups ($t_7 = 2.43$, $p = 0.029$). All species have been afforded some legislative protection in Canada and/or through international agreements, but we find that no species was protected across all five jurisdictions reviewed, and only three of 16 species (two successes

Table 1. COSEWIC status history for sentinel species.

Trajectory	Taxon	Species	COSEWIC status assessment history	Cause of population decline	Was cause of decline alleviated?	Primary current threat(s)?
Better (n = 8)	Birds	American white pelican	1978 1987	Historic overexploitation, habitat loss and disturbance	Mostly	Breeding site disturbance
		Trumpeter swan	1978 1996	Historic overexploitation, habitat loss	Mostly	Lead poisoning, habitat alteration
		Caspian tern	1978 1999	No evidence for decline	N/A	Contaminants, breeding site disturbance
		Peregrine falcon (*anatum*)	1978 1999 2000 2007 2017	Agricultural pesticides (especially DDT)	Yes	Unknown
		Peregrine falcon (*tundrius*)	1978 1992 2007 2017	Agricultural pesticides (especially DDT)	Yes	Unknown
	Mammals (marine)	Sea otter	1978 1986 1996 2000 2007 2022	Historic overexploitation	Yes	Contamination from oil spills
	Mammals (terrestrial)	Swift fox	1978 1988 2000 2009 2021	Persecution by humans (incidental mortality caused by predator control programs)	Mostly	Pollution (poisoning from legal or illegal rodenticides/ predacides)
		Wood bison	1978 1988 2000 2013	Historic overexploitation	Mostly	Hunting and population control (controlled and unregulated)[a]
Same (n = 14)	Arthropods	Karner blue	1997 2000 2010 2019	Habitat loss (land conversion for residential development and agriculture)	No	N/A
		Maritime ringlet	1997 2000 2009	No decline documented (no baseline information available)	N/A	Habitat impacts (flooding and sea-level rise)
	Birds	Whooping crane	1978 2000 2010	Habitat loss; human disturbance	Mostly	Habitat loss and degradation (coastal development in wintering grounds)
		Prairie falcon	1978 1982 1996	No evidence for decline	N/A	Habitat loss and nest disturbance (conversion of grazing land to cropland)
		Gyrfalcon	1978 1987	No evidence for decline	N/A	Climate change (impacts on Arctic habitat and prey)
		Eskimo curlew	1978 2000 2009	Historic overexploitation	No	None listed
		Peregrine falcon (*pealei*)	1978 1999 2001 2007 2017	Agricultural pesticides (especially DDT)	Yes	Pollution (oil spills, contaminants in seabird prey)
	Fishes (freshwater)	Giant threespine stickleback	1980 2013	No evidence for decline	N/A	Introduction of invasive species (predatory fishes)
		Shortnose sturgeon	1980 2005 2015	Habitat modification (dam construction)[b]	No	None specified

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Table 1. (*continued*).

Trajectory	Taxon	Species	COSEWIC status assessment history	Cause of population decline	Was cause of decline alleviated?	Primary current threat(s)?
	Mammals (terrestrial)	Vancouver Island marmot	1978 1997 2000 2008 2019	Habitat alteration (leading to increased predation)	No	Habitat alteration (leading to predation), climate change (habitat contraction)
		Black-footed ferret	1978 2000 2009 2021	Disease, persecution of primary prey (black-tailed prairie dog)	Partly	N/A
	Reptiles (marine)	Leatherback sea turtle	1981 2001 2012	Overexploitation (fishery bycatch and poaching), marine pollution	No	Fishery bycatch and marine pollution (in Canada), poaching (nesting beaches outside of Canada)
	Reptiles (terrestrial)	Prairie skink	1989 2004 2017	Habitat loss and degradation (agriculture)	No	Invasive plants, habitat degradation
	Vascular plants	Furbish's lousewort	1980 1998 2000 2011	Habitat degradation (dam construction)	No	Habitat alteration (loss of shade due to road construction and agriculture), recreational activities
Worse (n = 11)	Amphibians	Fowler's toad	1986 1999 2000 2010	Habitat loss and human disturbance	No	Habitat loss and degradation by invasive species
	Arthropods	Monarch butterfly	1997 2001 2010 2016	Habitat loss and degradation (wintering sites), declining food availability, climate change	No	Habitat loss (logging and wood harvesting), Pollution (use of agricultural herbicides on milkweed)
	Birds	Greater prairie chicken	1978 1990 2000 2009 2021	Habitat loss (agriculture)	No	N/A
		Piping plover (*melodus*)	1978 1985 2001 2013	Habitat loss and human disturbance (recreational beach use)	Partly	Predation (of eggs and chicks), human disturbance, habitat loss and degradation
		Piping plover (*circumcinctus*)	1978 1985 2001 2013	Habitat loss and human disturbance (recreational beach use)	Partly	Predation (of eggs and chicks), human disturbance, habitat loss and degradation
	Fishes (freshwater)	Speckled dace	1980 2002 2006 2016	Habitat loss and degradation (forestry)	No	Habitat modifications (water withdrawal exacerbated by climate change)
	Lichens	Cryptic paw	1995 2006 2019	Habitat loss (forestry)	No	Habitat loss (logging and wood harvesting)
	Mammals (terrestrial)	Black-tailed prairie dog	1978 1988 1999 2000 2011	Unknown (in Canada)[c]	No	Sylvatic plague, drought
	Molluscs (marine)	Northern abalone	1999 2000 2009	Overexploitation (legal fishing and poaching)	Partly	Harvest (illegal), predation (sea otters)
	Molluscs (terrestrial)	Banff Springs snail	1997 2000 2008 2018	Unknown (extreme fluctuations in number of individuals)	No	Climate change (decline in habitat quality due to thermal drying)
	Mosses	Rigid apple moss	1997 2000 2009	No evidence for decline	N/A	Habitat destruction (urban development and recreational use), changes in grazing intensity (deer)

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Table 1. (*concluded*).

Trajectory	Taxon	Species	COSEWIC status assessment history		Cause of population decline	Was cause of decline alleviated?	Primary current threat(s)?
Unknown (*n* = 3)	Birds	Double-crested cormorant	1978		Persecution by humans, contamination by DDT	Yes	Conflict with humans (namely sport and commercial fishers)[d]
	Fishes (marine)	Blueback herring	1980		No evidence for decline	N/A	Overexploitation[e]
	Mammals (terrestrial)	Cougar (Eastern pop.)	1978	1998	Habitat fragmentation and loss	Unknown	N/A

Note: Taxonomic categories based on Committee on the Status of Endangered Wildlife in Canada (COSEWIC) classifications. Species list derived from McKee et al. dataset (Supplementary Data File 1; current to 1 May 2022). Note: the three species with "Unknown" trajectories were not included in the sentinel species analysis since we relied on a species having at least two COSEWIC assessments to determine a trajectory. All causes of decline and primary threats were obtained from the species' most recent COSEWIC assessment (i.e., last year listed in "COSEWIC status assessment history"; see Table S2 for sources). Colour codes: Dark red = Extirpated, Red = Endangered, Dark pink = Threatened, Light pink = Special Concern, Teal = Not At Risk, White = Data Deficient.

[a]An imminent threat assessment determined that the recovery of two herds of wood bison (~200 individuals total) could be negatively affected by the localized prevalence of bovine tuberculosis and brucellosis but no immediate conservation concerns were identified for disease-free herds (ECCC 2020).

[b]This species is believed to spawn within a 10 km stretch below the Mactaquac Dam, which was fragmented the Saint John River when it was built in 1967. No quantitative abundance data for this population are available prior to 1973 so this information is based on local ecological knowledge. COSEWIC (2005)states: "Based on the personal observation of elders of the Oromocto First Nations, representatives from the Oromocto First Nation's fisheries technician team (Levi Sabattis, Harold Paul and Brian Paul) indicated that there is a general sense among the elders that there has been a decrease in numbers of shortnose sturgeon over the past thirty years. They linked the decrease to the presence of the Mactaquac Dam".

[c]There has been no COSEWIC assessment for this species since 2011, but the 2021 recovery plan highlights that the species was subject to substantial range contraction (i.e., 98% reduction in historic distribution by the late 1990s) because of land conversion of prairie habitat, eradication programs, and sylvatic plague (Parks Canada Agency 2021).

[d]The potential impact of this threat on cormorant abundance is not discussed, only that such conflicts are likely to continue (Government of Canada 2015).

[e]Although there is no updated COSEWIC assessment for this species, the most recent government stock assessment states that the population is showing clear signs of depletion from overfishing (DFO 2022).

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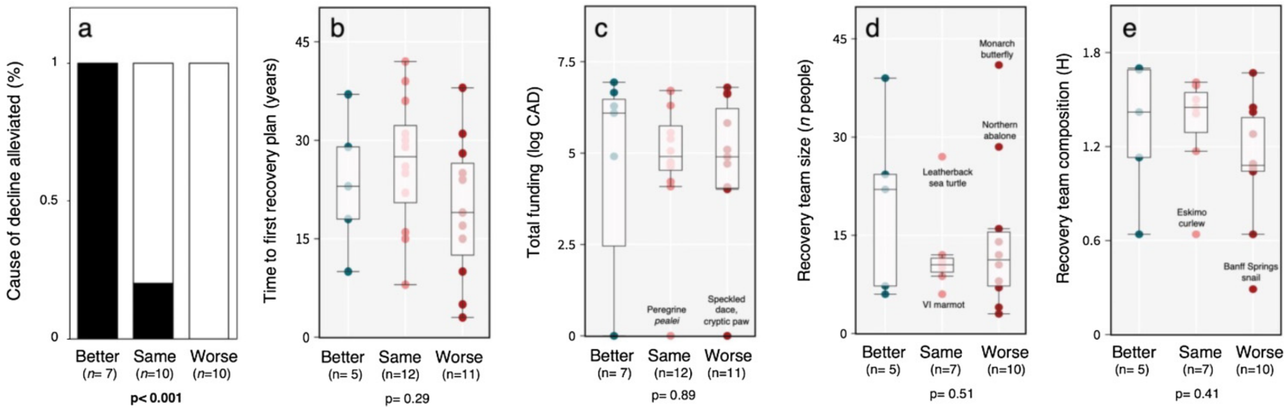
Fig. 3. Comparing recovery attributes for sentinel species. Dating back to 1978, we find a significant difference in the number of sentinel species in a lower extinction risk category ("better") relative to those in the same category or with higher extinction risk ("worse") based on whether their initial cause of decline was alleviated (*a*). We find no significant differences between the three groups in terms of time taken to publish their first recovery document (*b*), allocated funding (*c*), recovery team size (*d*), or recovery team composition (*e*). Note: median ± 1.5 IQR depicted for figures *b*–*e*; see Table S2 for details.



and one setback) were protected in at least four jurisdictions (Table S7).

Results from our Fisher's Exact Test showed a significant difference between successes and setbacks based on the proportion of species in each group that had their cause of decline alleviated as part of recovery interventions over time ($p = 0.009$). For successes originally threatened by overexploitation, the most common catalyst for alleviating declines was strong multilateral agreements and/or American legislation—much of which began over a century ago (Table S9: *[Removal of] the silver bullet*). Complementing species-specific laws and regulations, most species have also been aided by a combination of practical (on-the-ground) interventions (e.g., Fig. 5). The average number of practical efforts relative to total interventions was nearly identical for successes (0.36 ± 0.19) as for setbacks (i.e., 0.36 ± 0.17) and only one species (Fernald's braya) had a recovery portfolio composed of proportionately more practical efforts than legislative protections (Fig. 4).

After laws that led to the cessation of overexploitation, we found that increases in population abundance for three of eight successes were initiated by targeted reintroduction programs. However, as seen in the case of certain setbacks, this practical intervention was not systematically successful, especially when the original threat was not alleviated prior to reintroduction, if environmental conditions (e.g., suitable habitat and/or prey availability) were compromised (Table S9: *First stop the decline, then focus on recovery*). Critically, while 15 of 16 species had some form of designated habitat protection, habitat restoration efforts were documented for only one species, the Pitcher's thistle (Table S8). Indeed, while targeted habitat protection can provide valuable benefits, our case study results suggest that effectiveness is amplified when the most proximate cause of population decline is also being addressed and additional effort is made to improve habitat quality (Table S9: *First stop the decline, then focus on recovery*). Similarly, for sessile species, such as plants, potential conservation benefits provided by provincial-level protection appear to be contingent on whether designated parks or species-at-risk listings also lead to reduced local disturbance. Six of 16 species—four terrestrial mammals and two plants—were also subject to disease monitoring efforts and/or the control of competitive invasive species as part of their recovery effort portfolio (Table S8).

Lastly, across the case studies in our review, we observed that individual people and communities can play an important (but difficult to quantify) part of recovery efforts. Equally, when focusing first and foremost on ecological outcomes, rightsholders living where conservation interventions occur may be disproportionately affected by the intervention itself, or by its outcome (Table S9: *Don't underestimate the importance of people*).

4. Discussion

We set out to investigate the attributes of successful species recoveries in Canada. Our finding that 22% of the 36 sentinel species are now in a lower extinction risk category is consistent with what ECCC (2023*a*) reports for all 530 species that have been reassessed (i.e., 20%). Surprisingly, however, we also found that only eight of 422 species (1.9%) with multiple COSEWIC assessments met our initial criteria for "success": increasing abundance and decreasing extinction risk over time. This finding corroborates the limitations noted by ECCC (2023*a*) and demonstrates that measuring change in extinction status only is an imprecise way to deduce whether population-level change in the wild is also happening concurrently.

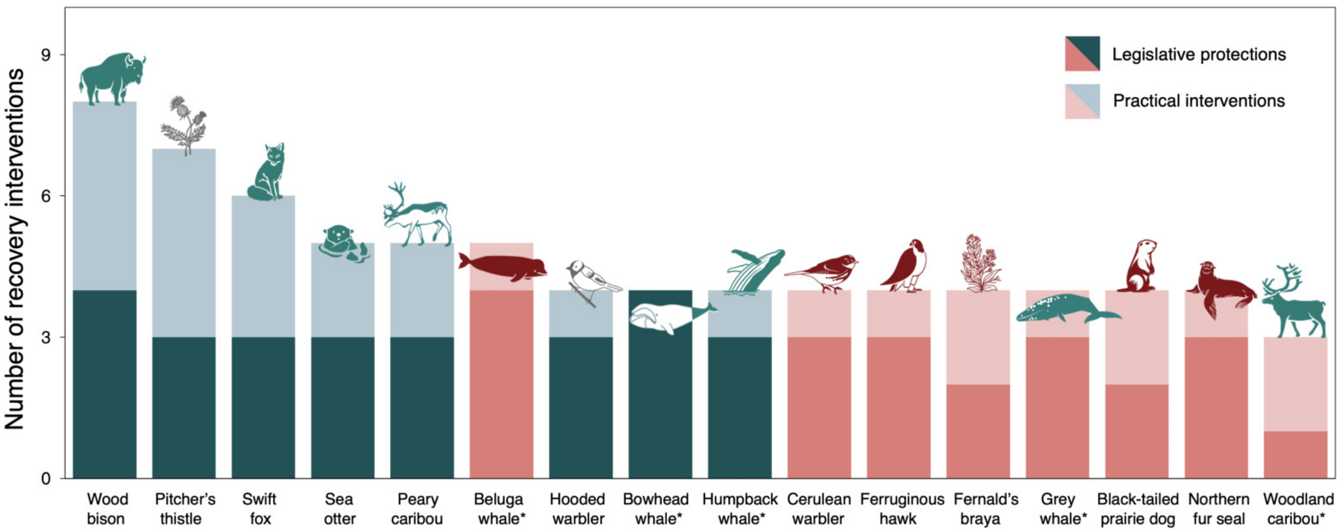
We found that the targeted alleviation of their initial causes of decline was the common thread that tied recovering species together, even when considering the personnel and financial resources invested. While it is perhaps unsurprising that alleviating the source of decline supports recovery, the relative rarity of this outcome was apparent across our

Table 2. Successes and setbacks identified for case studies.

Group	Taxonomic group	Species	Assessment window (years)	Change in abundance (%)	Cause of decline	Was cause of decline alleviated?	Area of occupancy (km^2)	Endemic?
Successes	Birds	Hooded warbler	1994–2012	200	None documented (population thought to be expanding its range northward)	N/A	15 000	No
	Mammals (marine)	Bowhead whale (Bering-Chukchi-Beaufort)	1985–2005	3.4	Historic overexploitation	Yes	90 000	No
		Humpback whale (N. Pacific)	1985–2011	4.1	Historic overexploitation	Yes	476 284	No
		Sea otter	2000–2007	2900	Historic overexploitation	Yes	10 000	No
	Mammals (terrestrial)	Swift fox	1998–2009	130	Incidental mortality from predator control programs	Mostly	4411	No
		Wood bison	1988–2013	150	Historic overexploitation	Yes	121 480	No
		Peary caribou	2004–2015	142	Extreme weather events leading to limited forage	Yes	366 384	Yes
	Vascular Plants	Pitcher's thistle	1999–2010	200	None documented (populations susceptible to human disturbance and threatened by competition with invasive species)	N/A	136	No
Setbacks	Birds	Cerulean warbler	2003–2010	−16	Habitat loss, degradation, and fragmentation	No	1250	No
		Ferruginous hawk	1995–2008	−30	Habitat loss and degradation, human disturbance	No	2000	No
	Mammals (marine)	Beluga whale (St. Lawrence estuary)	2004–2014	−1	Poorly understood but likely a combination of habitat degradation, pollution and human disturbance following historic overexploitation	Partly	36 000	Yes
		Northern fur seal	1996–2006	−39	Unknown (population declining following recovery from historic overexploitation)	No	2000	No
		Grey whale (NE. Pacific)	1987–2004	−10	Extreme weather events leading to suboptimal feeding seasons (two mass mortality events)	Yes	150 000	No
	Mammals (terrestrial)	Black-tailed prairie dog	1978–2011	−28	Unknown	No	12	No
		Woodland caribou (Newfoundland)	1984–2014	−47	Limited forage and predation when the population was at high density, high harvest	Mostly	44 781	Yes
	Vascular Plants	Fernald's braya	1997–2012	−64	Habitat loss, human disturbance	No	120	Yes

Note: All species categorized as "successes" showed increasing abundance and decreasing extinction risk over time and those categorized as "setbacks" showed the opposite (decreasing abundance and increased extinction risk). Information obtained from relevant COSEWIC assessment reports (see Table S6). Note: all species met our two-fold inclusion criteria based on a status change sometime between 2000 and 2019; "Assessment window" refers to the specific timeframe reviewed since this was different for each species and, in some cases, the first assessment pre-dated 2000 and/or multiple assessments determined the same at-risk status before a change occurred. Since noticeable changes in abundance can take time to observe, information related to the species' recovery trajectory was reviewed up to the end of their assessment window for case studies.

Fig. 4. Comparing recovery interventions for successes and setbacks (2000–2019). When comparing successes (teal) to setbacks (pink), we find a significant difference in the number of interventions between the two groups ($t_7 = 2.43$, $p = 0.029$), with successes having an average of 5.4 ± 1.5 total interventions compared to 4.0 ± 0.53 for setbacks. We find additional significance ($p = 0.009$) in the proportion of species in each group that had their cause of decline alleviated (green/darker animal icon) or not (red/lighter animal icon); the Pitcher's thistle and hooded warbler (grey icon) had no documented declines and were not included in that part of the analysis. See Tables S7 and S8 for specifics of legislative and practical efforts and Table S9 for qualitative review of recovery interventions. (Note: specific populations reviewed for species marked with an asterisk [*]: Beluga whale = St. Lawrence estuary; Bowhead whale = Bering-Chukchi-Beaufort; Humpback whale = North Pacific; Grey whale = North East Pacific; Woodland caribou = Newfoundland.)



historical analysis of sentinel species (Table 1) and more recent case studies (Table 2). It is important to acknowledge that for many successes, the original cause of decline was tangible, and could often be addressed through a singular targeted measure. As a result, during the first half of the 20th century, the primary approach to species recovery and conservation was through regulatory intervention, often to reduce overexploitation. For certain species with distributions extending into the United States (e.g., grey and humpback whales, Peregrine falcon), the prevailing American socio-political climate of the 1960–70s enabled widespread support for many environmental laws (including the ESA), which were seen as both effective and desirable (Waples et al. 2013). Today, as wildlife populations are subject to cumulative anthropogenic pressures, action taken to address declines must also be considerate of this complexity, making both design and implementation exceedingly challenging relative to the past.

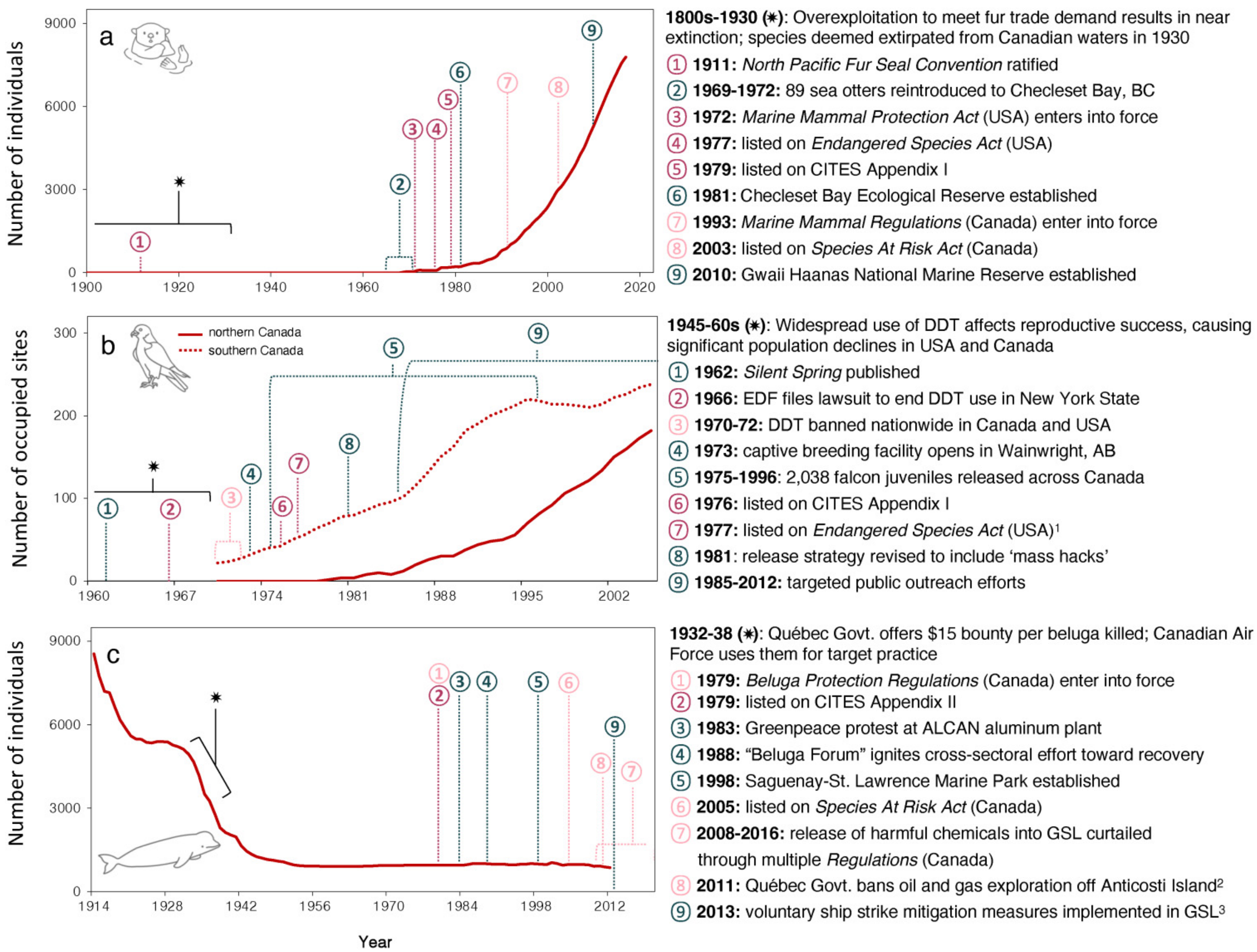
4.1. Identifying successful recovery pathways

The onset of recovery efforts for some successes dates back over a century. And, in all cases, the most important first step was to *stop* doing something harmful before *starting* recovery interventions. We found that when laws and regulations were focused on alleviating direct, identifiable human threats and pressures, their implementation helped ensure the conditions necessary for successful recovery were met. Our findings are consistent with the results of Ingeman et al. (2022), who show that the recovery of apex predators around the world is most significantly linked to the implementation of national legislation and international agreements that directly limit mortality. We also find that regulatory intervention was only the first step in rebuilding abundance and strategic applied approaches were also needed, especially for severely depleted or extirpated species such as the sea otter and swift fox. This finding is in keeping with work documenting the recovery of large carnivores in Europe, which showed that coordinated legislation to alleviate mortality from human–wildlife conflict across species' ranges paved the way for these species to benefit from subsequent habitat restoration efforts (Chapron et al. 2014).

Further, while reintroductions are not an option for all wildlife, we find they have helped increase abundance and decrease extinction risk for a diversity of birds and mammals in Canada following legislative protection and alleviation of their main cause of decline (e.g., Figs. 5*a* and 5*b*). Similarly, Bolam et al. (2021) found that legislation, reintroductions, and ex situ conservation (e.g., captive breeding) are the interventions most likely to have prevented extinction for mammal populations around the world (with invasive species control, ex situ conservation, and habitat protection being the top preventative actions for birds). In Canada, reintroduction and other translocations are considered relevant for 38% of SARA-listed species (mostly plants), including Fernald's braya (Swan et al. 2018). Our results suggest that ensuring translocated wildlife enter an environment dissimilar to their current one (i.e., places with significantly reduced human disturbance) is likely critical for long-term success.

To this end, although we found significant differences in the number of interventions between successes and setbacks, our case study review shows that it is also the *quality* as well

Fig. 5. Contrasting recovery trajectories and interventions. Shown are abundance trends for (*a*) the sea otter (success), (*b*) peregrine falcon *anatum* subspecies (sentinel) in northern and southern regions, and (*c*) Gulf of St. Lawrence beluga whale (setback). Species abundance trajectories over time paired with key international agreements/treaties (red), Canadian legislation (pink) and practical efforts (teal). Abundance data originally published in Nichol et al. (2020; sea otter), Holroyd and Bird, (2012; peregrine falcon), and DFO (2014; beluga). Note: recovery interventions listed are not comprehensive but represent notable actions taken over time; (1) De-listed in 1999 due to strong recovery; (2) Government of Quebec extended this ban to the entire province in 2022 (first jurisdiction in the world to ban oil and gas exploration); and (3) Transport Canada made measures mandatory in 2020.



as the *quantity* of interventions that matters. This appears especially true for habitat protection. While most species had some degree of habitat protection, our case studies showed substantial variation in how much of a given species' range or habitat type this included, whether sensitive life history areas were covered (e.g., breeding sites), and if the spatial protection also effectively mitigated human disturbance. Further, we found evidence of dedicated habitat restoration for only one species, the Pitcher's thistle. Unlike protection, restoration requires perpetual maintenance and long-term monitoring of site characteristics to achieve outcomes related to habitat quality and the maintenance of associated ecological processes (Ruiz-Jaen and Aide 2005). Focusing on restoration efforts to bolster existing spatial protections appears especially important for sedentary species, such the Fernald's braya, which suffers from degraded habitat quality from recreational disturbances within (and adjacent to) areas designated to provide protection.

These observations are in keeping with past research showing that the primary threat for most species in Canada—habitat loss and degradation—has been insufficiently addressed for a large majority of threatened species (Coristine and Kerr 2011; Favaro et al. 2014; Ray et al. 2021). Indeed, the benefit and efficacy of area-based conservation can also only be realized at-scale if protection in one place is not negated by development or habitat degradation in another. For migratory species, habitat protection in breeding or over-wintering locations appears especially important but often these areas fall outside of Canadian jurisdiction. One of the setbacks, the Cerulean warbler, exemplifies both challenges. This bird has been significantly impacted by the loss of old growth forests in southern Ontario and by logging, agriculture, and land development in the Andes—where it overwinters—with 60% of its habitat already lost by 2006 (COSEWIC 2010).

4.2. Where to from here, Canada?

Although many threats related to overexploitation were historically addressed by targeted legislation, more diffuse threats—and their cumulative impacts—are harder to remedy. In June 2024, the Canadian federal government released its 2030 Nature Strategy which aims to ensure ecosystem-level action to halt and reverse biodiversity loss through an integrated, inclusive, adaptable, holistic evidenced-biased approach whereby all levels of government and social sectors are involved (ECCC 2024). Based on our research we offer three main considerations as federal, provincial and territorial governments, businesses, and conservation leaders move toward achieving this vision.

First, to manage, restore, and conserve areas for enhancing species diversity and ecological processes (Targets 1, 2, and 3)—including the recovery of threatened species (Target 4)—we need an integrated approach that views the objectives of these Targets as synergistic and complementary rather than independent (WCS 2024). We agree with the message highlighted repeatedly in the 2030 Nature Strategy (ECCC 2024) that no single jurisdiction can protect threatened wildlife, and that restoration and conservation planning will need to embrace broader ecosystem restoration goals across all levels of government. In general, collaborations between municipal, provincial, and Indigenous governments continue to be well positioned—and have substantial power—when it comes to ensuring habitat restoration and protection since the Canadian federal government cannot achieve 30% protected area (Target 3) without assistance from other jurisdictions (ECCC 2024).

Inconsistencies in provincial species-at-risk legislation and how it gets implemented need to be alleviated across jurisdictions (Gordon et al. 2024). We also suggest that stronger bilateral action will be necessary to effectively protect transboundary species (i.e., species distributed across the Canada–US border), as well as other migratory species, and their associated ecosystems. This is especially important as many of these species are already endangered and suffer from the added impacts of climate change influencing their distribution (O'Brien et al. 2022). Results from our case studies showed that consistency in US and Canadian legislation (e.g., concurrently prohibiting DDT), as well as joint efforts from American and Canadian recovery teams benefited multiple successes. To-date, however, transboundary collaboration has been limited for at-risk species and should be strengthened to ensure maximum efficacy of habitat protection and recovery interventions (Olive 2014). At the other end of the spatial scale, thoughtful municipal spatial planning will also play a vital role in the coming years, especially since achieving both positive conservation and socio-economic outcomes from protected area establishment depends heavily on meaningful inclusion of local stakeholders (Oldekop et al. 2016). As municipal governments work to meet the needs of growing human populations, so too must they strive to freeze their spatial footprint to prevent further loss of natural habitat while simultaneously restoring natural spaces adjacent to areas of high human density.

Second, for species that are endemic to Canada or lack the potential of a rescue effect, having strong domestic legislation combined with comprehensive on-the-ground interventions appears especially important. The original RENEW species recovery program was established to be "pan-Canadian" and cross-sectoral, to "establish a national programme for recovering wildlife at risk [that is] shared by all and not confined by territorial or provincial boundaries" (RENEW 1989). While RENEW no longer exists, the Pan-Canadian approach was reinvigorated in 2018 to provide a cross-jurisdictional framework for the planning and operationalizing of multi-species and ecosystem-based conservation (ECCC 2018). Notably, two successes in our study (Peary caribou and wood bison) were included in the first subset of six "priority species" identified for coordinated recovery through this initiative. The chosen priority species (four caribou, wood bison, and sage grouse) were selected largely for their cultural significance and most are distributed across higher latitudes in regions with low direct human impact (ECCC 2023*b*). Yet, the Arctic (>66.5°N) is also warming faster than anywhere on Earth (Rantanen et al. 2022) and industrial resource extraction is anticipated to increase throughout the region (Hanaček et al. 2022). Since our findings show the importance of addressing both the underlying threat and ensuring environmental conditions are conducive to recovery, we emphasize that for the Pan-Canadian initiative to be successful long-term, reductions in greenhouse gas emissions combined with spatial efforts to ensure population connectivity and survival are required (Mallory and Boyce 2019). Such measures could include, for example, prohibitions on all extractive activities in calving grounds and ice crossing corridors (Kitikmeot Regional Wildlife Board 2016).

In addition to planning for climate-related threats, we note that ongoing extractive activities, development, and human disturbance (including in protected and conserved areas) continue to limit wildlife recovery, including for certain provincially listed at-risk species in our study (i.e., piping plover *melodus* and Fernald's braya). Three decades ago, Canadian species recovery documents emphasized that, "although development projects produce short-term economic benefits, a truly sustainable economy requires a healthy environment" (RENEW 1994) and the private sector was viewed as an important stakeholder in helping achieve recovery targets (RENEW 1990). Today, GBF Target 15 specifically asks businesses for better assessment and disclosure of dependencies and risks to biodiversity and private sector actors are explicitly called on to combine their "net zero" approach in the face of climate change with a "nature positive" approach to reduce biodiversity loss (UNEP 2022). As such, there is a genuine opportunity for the private sector to invest in conservation and sustainable practices, especially for industries that rely on natural resources and are thus affected directly by biodiversity loss (ECCC 2024).

Lastly, in keeping with GBF Target 21, we encourage further review of successful pathways leading to species recovery within Canada and stronger accountability when it comes to the outcomes associated with aspirational federal goals. Intention is the first step for establishing recovery documents and designating interventions but, as we found, intent alone does not guarantee the quality of an intervention or that recovery will occur. Thus, we suggest that not only measuring progress toward the implementation of the 2030 Nature Strategy objectives but also explicitly defining metrics to assess the outcomes of these objectives is a critical aspect of accountability missing from Canada's recently proposed *Nature Accountability Act* (Bill C-73, first reading 13 June 2024). Basic indicators such as changes in absolute population abundance, which we used here, could be useful in this regard (Callaghan et al. 2024), but many other options to measure the effectiveness of conservation approaches have also been identified (Westwood et al. 2014; Geldmann et al. 2021).

Equally, while our study focused primarily on the outliers (i.e., best and worst cases), future work could attempt a more comprehensive analysis of ecological and socio-political attributes associated with all COSEWIC species. Such information could perhaps contribute to the new IUCN Green List (Akçakaya et al. 2018) or equivalent national framework that more comprehensively defines and collates successful recovery interventions. Although species recovery teams no longer exist in the same way as in the past (i.e., the years of our sentinel species analysis) we also encourage a continued focus on understanding who is represented in species conservation in Canada, how relationships between different stakeholders and rightsholders evolve, and where meaningful ecosystem-focused conservation efforts can be applied in keeping with the many commitments made under the GBF. For example, we found that zoos and environmental NGOs have been prominent in ex-situ conservation (reintroduction and maintenance of genetic diversity) and the involvement of these institutions is likely to increase in light of the GBF, with calls for multi-scale coordination to foster the implementation of the GBF Targets (Moss et al. 2023). Equally, many First Nations, Métis, and Inuit are already leading by example when it comes to species recovery in Canada (Menzies et al. 2021; Lamb et al. 2022; Rachini 2023). Indeed, the recovery of culturally important wildlife is of critical importance to Indigenous communities who have legal and cultural ties to these species (Lamb et al. 2023). Yet, as with many species and habitat protection efforts in North America over time (Kantor 2007), the social, cultural, and economic impacts of successful sea otter and wood bison reintroductions discussed in our case studies demonstrate the complexity inherent in balancing the benefits to wildlife with the rights of people (Targets 9 and 22). As such, meaningful co-facilitation with affected rightsholders must remain a fundamental aspect of ethical conservation initiatives going forward. Conservation of species and spaces in Canada must support Reconciliation with Indigenous communities and not infringe on their aspirations to self-govern (Zurba et al. 2019).

4.3. Recovery is a moving target: research limitations

While this work reviews some of the interventions and legal frameworks that have contributed to reversing species declines, we stress that our results highlight patterns and commonalities rather than direct causalities. As such, our findings are not meant to suggest that the interventions we discussed are the only pathways whereby recovery efforts could or should occur, nor that efforts lacking these elements will ultimately fail. Rather, we hope this work provides food for thought as part of a much larger conservation conversation, and the importance of reviewing and learning from successes—which are often outliers—as a critical part of planning to achieve biodiversity protection goals.

We intentionally chose to investigate all Canadian wildlife. However, the taxonomic diversity in our analysis made comparing interventions and outcomes challenging given inherent differences in life histories, scale and location of threats, and applicability of different conservation interventions. The primary analytical challenges we faced were the availability consistency of information for the species we reviewed. While our approach to analysing the two COSEWIC datasets was systematic, we did have to decide which setback species to retain for detailed analysis, which introduced some subjectivity and meant that certain taxonomic groups (e.g., fishes) were not included.

Unfortunately, not all wildlife in Canada have been assessed by COSEWIC, much less received multiple assessments. As we observed for multiple caribou species (see Supplementary Methods), a species' risk status can change with new information, which can make comparisons between assessments challenging. Further, the classification of species into only three at-risk categories may also mask progress (or a lack thereof). For long-lived species with low fecundity and/or high age at maturity, noticeable population-level changes could take decades even under optimal environmental conditions and recovery efforts, while the high vulnerability of some species to catastrophic natural events may always preclude them from being listed as anything other than "Endangered" despite population increases (e.g., whooping crane, Banff Springs snail). The irregular release of COSEWIC assessments and recovery documents meant certain species were not included in the analysis and/or the trajectory of a species may have changed since its most recent assessment. For example, over half of sentinel species' last COSEWIC assessments were conducted before 2014, which means information we obtained related to their "causes of decline" or "key threats" (Table 1) is likely outdated in some cases. Equally, the RENEW funding data we used were available for only a subset of years and the substantial allocation of funds to some high-profile birds and mammals may be linked to the fact they were assessed decades before the first mosses and arthropods.

For the successes and setbacks, the asynchrony of COSEWIC assessments resulted in a relatively low sample size of species for investigation and, potentially, a mismatch between the information we used and what is currently happening in the wild for those we did investigate. We acknowledge that any attempt to quantify recovery will only ever capture a single snapshot in time and space and while COSEWIC assessments can provide important information on long-term trends, a de-listing should not be considered an endpoint for conservation interventions and monitoring. Rather, it is a single grade on a continuous report card.

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5. Conclusion: looking back with the hope of moving forward

Conducting retrospective analyses such as these offers researchers a unique opportunity to travel back in time. For most of the authors, the first RENEW report we reviewed for the sentinel species analysis was published around the year we were born (1989), and the last around the time we graduated high school (2006). Twenty years on, as we reviewed these documents, we were repeatedly struck by the sincere optimism in text highlighting recovery goals as well as the mission of RENEW that "no new species be allowed to become threatened or move from threatened to endangered status" (RENEW 1989). It was equally humbling to read the efforts undertaken over 30 years ago for so many species that remain threatened today, especially when the underlying drivers of their declines have not changed and remain insufficiently addressed.

Despite these prevailing trends, our findings also show that species recovery in Canada is possible with targeted and sustained efforts. Most notably, our case studies demonstrated that the implementation and enforcement of effective action (be it regulatory or voluntary) is needed to first halt the underlying cause of population decline, otherwise auxiliary on-the-ground efforts to increase abundance will likely be unsuccessful long-term. Big challenges demand equally big responses from those in power and meaningful accountability of progress toward meeting aspirational targets. If we are to remain hopeful that the GBF Targets and outcomes envisioned in Canada's 2030 Nature Strategy are realized, we need an integrated approach for implementing and assessing objectives that is facilitated by urgency, increased coordination, and ambitious actions by all levels of Canadian government and our country's conservation leaders.

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Data availability

All data used for the case studies and the sources used to gather this information are included in the Supplementary Materials. The two previously unpublished COSEWIC datasets, as well data obtained from the RENEW reports (recovery team funding and team personnel) are provided as Supplementary Data Files.

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The authors declare no conflicts of interest.

Supplementary material

Supplementary data are available with the article at https://doi.org/10.1139/facets-2024-0084.

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