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Sociopolitical factors drive conservation planning timelines: A Canadian case study with global implications

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ABSTRACT

With global biodiversity declines, government regulations protecting wildlife serve a key role in species persistence. Despite its importance, planning for protection can be a slow process, taking up to several decades. Such delays have led to species declines and extinction. Here, we investigate the factors driving time between conservation listing and the creation of a plan to support species recovery. Using Canada's Species at Risk Act as a case study, we used Cox proportional-hazards models to test how quickly a species designatable unit (DU) would receive a recovery plan given the reasons for its designation, conservation status, taxon, sociopolitical climate, the extent of scientific research, and public awareness. AIC model selection revealed that sociopolitical factors best explained how quickly a DU would receive a plan. We found that the time for a DU to receive a plan decreased the more often a majority government was in power, the fewer environmental bills passed, and the lower average GDP growth rate during planning. Our results highlight the need for greater consistency in species recovery planning based on conservation needs and status, regardless of sociopolitical climate. We recommend further examination of the relationship between time for recovery planning and plan effectiveness to elucidate how planning delays impact species recovery.

1. Introduction

Globally, threats to biodiversity are driving declines and extinctions at alarming rates (IPBES, 2019). Over 30 countries have enacted species protection and conservation policies into law, including the USA, the UK, Australia, and Canada (Mooers et al., 2010). Despite the common goal of such regulations to reduce wildlife declines, the effectiveness of such legislation can be compromised by delays and poor implementation. Notably, the timeliness of conservation actions is impacted by taxonomic, economic, political, and social biases (Favaro et al., 2014; Ferraro et al., 2007). Delayed recovery planning is a pervasive problem in Canada (Ferreira et al., 2019), the US (Malcom and Li, 2018), and Australia (Scheele et al., 2018), and has led to continued declines of vulnerable species in Europe (Hermoso et al., 2017). The biological and societal drivers delaying the development of recovery plans need to be clearly identified, and their relative impacts quantified and accounted for, to ensure the effectiveness of conservation legislation.

In Canada, the Species at Risk Act (SARA), enacted in 2002, requires protection of species and their habitats via tailored conservation actions (SARA, 2002). Recommendations for which species should be covered under SARA are made by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an independent, arm's-length body of scientists established to impartially assess the status of Canadian species. COSEWIC integrates scientific research and community and aboriginal traditional knowledge to inform its recommendations to the government (SARA, 2002). In addition to different ways of knowing, planning under SARA considers the socioeconomic implications of species protection, and a cost-benefit analysis to gauge the economic impact of species

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recovery (SARA, 2002). The Canadian system also encourages public participation in conservation through a legislative obligation to publicize SARA listing decisions (SARA, 2002), and recovery planning must be completed in cooperation with all provincial and federal ministers with authority over the land on which species occur. SARA only has jurisdiction on federal lands, meaning that its regulations apply to a small proportion of species' ranges, making interjurisdictional cooperation critical for adequate protection (Bolliger et al., 2020). Other countries have also recognized a need for concerted conservation across jurisdictions (Hermoso et al., 2017), highlighting this cooperation as a strength of SARA; however, this could also be a detriment since there is no mandate for jurisdictions to list species the same way. Despite procedural differences, SARA is broadly similar to other conservation legislation globally in their shared objectives of species conservation and habitat protection, their approach of categorizing and prioritization by threat level, and the potential for external drivers to delay timely conservation planning (See Fig. 1 examples; Supplemental Material additional details).

The complexity of SARA's structure and availability of information inherently delay the implementation of conservation actions from listing, to recovery planning, to protection. 'Management plans', the recovery plan required for species listed as special concern, have a legislated completion date within three years of listing under SARA. However, there is no standardized time requirement by which 'action plans', the SARA recovery plan required for threatened and endangered species, must be completed (Fig. 2; VanderZwaag and Hutchings, 2005). The finalization of action plans is contingent on the completion of 'recovery strategies', of which only 21% are completed on time (Ferreira et al., 2019). Worldwide, well-studied species are more likely to be listed (Donaldson et al., 2016; dos Santos et al., 2020). The same pattern exists in both Canada and the US, as species are often listed based on the availability of information rather than their actual conservation status, leaving understudied taxonomic groups lagging behind in terms of evaluation and listing (Lukey et al., 2010; Malcom and Li, 2018). Taxonomic biases in both species listing and conservation implementation have also plagued conservation efforts since SARA's inception (Creighton and Bennett, 2019). For example, arthropods and amphibians are the least likely to receive protection or have approved recovery plans (Creighton and Bennett, 2019). Although SARA explicitly considers economic impact, subjective interpretations and prioritization of economic gain over conservation goals has also failed species protected under SARA. For example, after the recovery planning phase for woodland caribou (*Rangifer tarandus*) in the province of Alberta, the provincial government permitted continued oil and gas extraction within a core part of their range (Hebblewhite, 2017). This example also stresses that jurisdictional cooperation under SARA is not infallible.

When planning timelines for listing and protection are misaligned with conservation needs, consequences for species persistence can be severe. For example, the endemic Christmas Island forest skink (*Emoia nativitatis*) became extinct only four months after its listing under Australia's Environment Protection of Biodiversity Conservation Act, even though significant population declines were detected 15 years earlier (Woinarski et al., 2017). Similar declines, accompanied with delayed intervention, have been noted for Canadian species. Competing interests between conservation of woodland caribou and energy development in western Canada prolonged planning resulting in the extinction of three local populations (Hebblewhite, 2017). As time lags between listing and action increase, conservation actions become increasingly onerous, often requiring substantial financial investment to prevent extinctions (Henson et al., 2018). When species receive timely recovery plans and protection for critical habitat through the US's Endangered Species Act (ESA), populations can often successfully rebound (Valdivia et al., 2019). In Canada, however, listed species rarely recover as a result of conservation efforts, with only 5.4% of species assessed multiple times recovering to not-at-risk status (Favaro et al., 2014). Delayed conservation actions like designation of critical habitat have been linked to species continuing to decline in the interim (Favaro et al., 2014). To limit future extinction risk to Canadian species and species worldwide, it is imperative to identify factors that lead to delays in conservation efforts.

Here, using Canada and SARA as a case study, we investigated whether recovery planning timeliness is driven by the type and severity of threats to a species, or biases stemming from its taxonomy, the public awareness of the species, availability of research on the species, or the sociopolitical climate during planning. Specifically, we examined the time between a species being designated as 'special concern', 'threatened', or 'endangered' under COSEWIC and receiving a recovery plan as the final document required for SARA listed species. Depending on

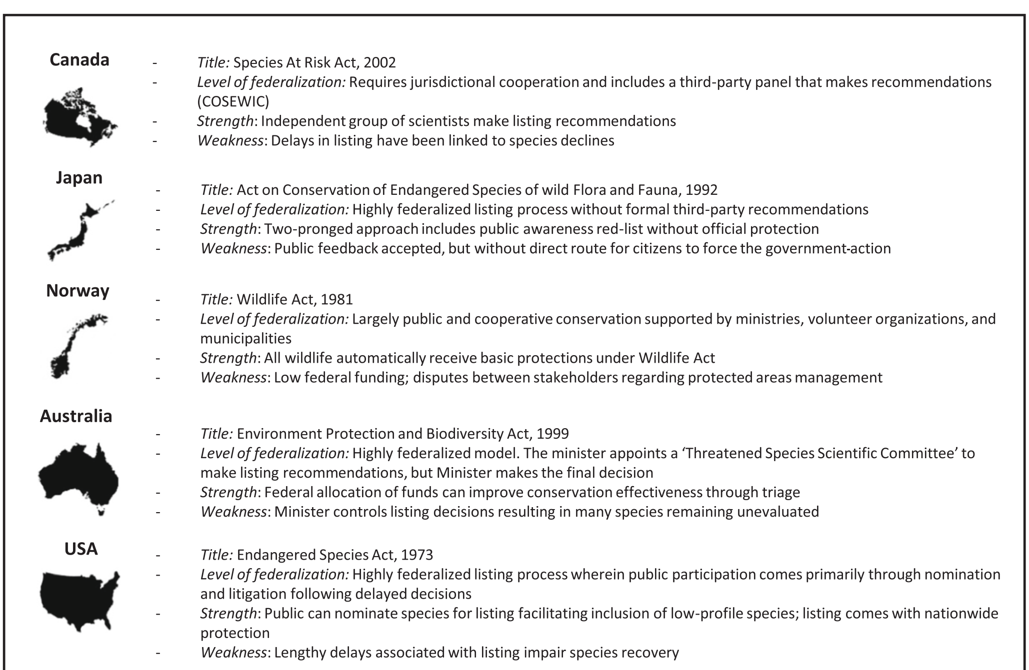

Fig. 1. Worldwide, biodiversity conservation calls for varying degrees of federal government and public involvement in species listing and recovery planning. National legislation falls along a continuum from strict federal oversight to collaboration between government and non-government bodies. These structural differences can have downstream consequences for species the procedures are designed to protect. Here we present five examples of species at risk legislation from different countries around the world (Canada, Japan, Norway, Australia, and USA) which represent diverse approaches along the continuum of centralized or decentralized control. See supplemental material for sources and additional details on species at risk legislation in these countries.

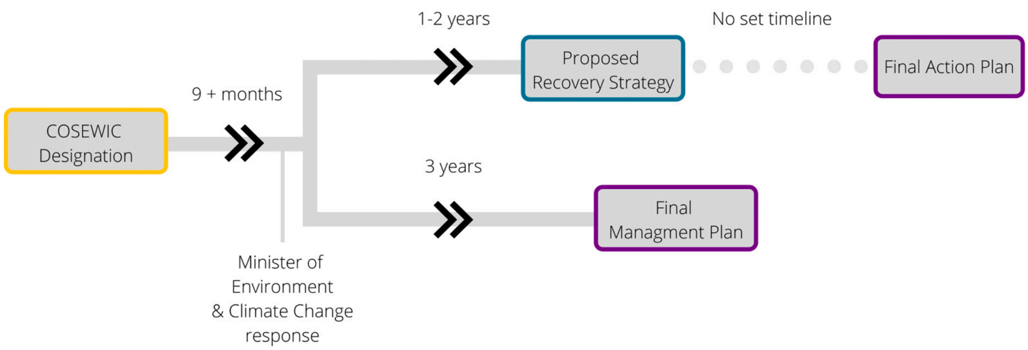

Fig. 2. Recovery planning process under the Canadian Species At Risk Act. In Canada, one of two planning documents is prepared depending on the status of the species designated by COSEWIC (yellow box). When a species is listed as either threatened or endangered following a decision by the Minister of Environment and Climate Change, the government must propose a 'recovery strategy' (teal box) that outlines threats to a species and its habitat, identifies critical habitat, and when possible, sets distribution and population size goals. Following the recovery strategy, a final 'action plan' (purple box, top branch) outlining the necessary steps to achieve the goals set out by the recovery strategy is required within one year of listing for endangered species, and within two years of listing for extirpated and threatened species. For species listed as special concern, the government must prepare a final 'management plan' (purple box, bottom branch) instead of a recovery strategy and an action plan. Management plans are similar but do not identify critical habitat. To simplify, we use the more general term 'recovery plan' to refer to both SARA management plans and action plans, and 'recovery planning' as a catch-all term to describe the process between listing by SARA and the finalization of either type of plan. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

designation status, i.e., special concern, threatened, or endangered, deadlines for recovery planning varies between 3 and 5 years (Fig. 2; SARA, 2002). However, these deadlines are rarely met within the legislated time period (Ferreira et al., 2019; McDevitt-Irwin et al., 2015). We predicted that if time for recovery planning follows actual conservation needs, then the reason for listing and its SARA conservation status would influence the time elapsed between COSEWIC designation and receipt of action or management plan under SARA. Alternatively, we predicted that if delays in recovery planning are biased, then taxonomy, public awareness, availability of research, or sociopolitical factors would influence the time for a species to receive its plan (Table 1).

2. Methods

2.1. Species data

We compiled all species listed as special concern, threatened, or endangered under SARA. We followed COSEWIC's assignments for

Table 1
Descriptions of model covariates and their predicted effects on time to recovery plan. Models are based either on the conservation needs of a species or biases known to influence listing or recovery planning. The '+' and '−' symbols denote covariates predicted to increase and decrease the time to recovery plan, respectively. Multiple symbols under prediction for designation status indicates faster or slower planning is predicted relative to the other covariates.

Hypothesis	Model	Covariate	Prediction	Reference
Recovery planning is determined by conservation needs	Designation status	Special Concern	+	Bird and Hodges, 2017
		Threatened	−	
		Endangered	− −	
	Reasons for designation	Habitat loss	+	Findlay et al., 2009
		Population decline	−	McCune et al., 2013
		Human effects	+	
		Indirect effects	−	
		Disease	−	
		Climate	+	
		Limited data	+	
		None	+	
Recovery planning is biased by…	Sociopolitical factors	Δ GDP	+	Ferreira et al., 2019
		Number of provinces present	+	Waldron et al., 2017
		Environmental productivity	−	
		Government efficiency	−	
	Taxonomy	Birds	− −	Bird and Hodges, 2017
		Arthropods	+	Dorey and Walker, 2018
		Molluscs	+	Creighton and Bennett, 2019
		Freshwater fishes	−	VanderZwaag and Hutchings, 2005
		Marine fishes	−	
		Mammals	− −	
		Reptiles	−	
		Amphibians	−	
		Lichens	+	
		Mosses	+	
		Vascular plants	−	
	Awareness	Wikipedia page views	−	Brambilla et al., 2013
		: Vertebrates	−	
		: Invertebrates	+	
		: Plant & lichens	+	
	Research	Number of publications	−	Donaldson et al., 2016
		: Vertebrates	−	Lukey et al., 2010
		: Invertebrates	+	
		: Plant & lichens	+	

designatable units (DUs), which separate species into populations representing distinct biological diversity or management needs. Our list comprised 846 unique DUs (661 unique species): 206 (202) vascular plants, 144 (90) mammals, 101 (74) freshwater and 90 (38) marine fishes, 87 (79) birds, 67 (63) arthropods, 43 (35) reptiles, 38 (37) molluscs, 27 (22) amphibians, 23 (21) lichens, and 20 (20) mosses. Of these, 591 DUs (539 unique species) were eventually listed under SARA before our final date of data collection on April 25, 2019. We included only these SARA-listed DUs in our final dataset because they would eventually undergo the planning process. For each DU, we identified its latest COSEWIC status, date of designation, the date it received a recovery plan (Fig. 2), and the number of provinces it occurred in. We calculated our response variable – time to plan completion – as the number of days between COSEWIC designation and the date of the earliest recovery plan. If the DU did not have a recovery plan, we used the final date of data collection, April 25, 2019. In cases where a DU was later reassigned to a higher or lower designation following acceptance of its initial plan, we used the date of the most recent recovery plan to reflect its most recent planning process.

2.2. Survival analysis

We used survival analysis to test whether conservation needs or bias influenced the time between COSEWIC designation of a DU and completion of its recovery plan. Traditionally, survival analysis follows the probability of individual survival over time in relation to factors suspected to influence time to death. For the purpose of our study, we substituted time to death for time to plan completion. The strength of this approach lies in its ability to censor cases without end dates, allowing us to include all DUs in the analysis regardless of whether or not they eventually received a plan.

We used Cox proportional-hazards (CPH) regression to quantify the likelihood of a DU receiving a recovery plan:

$$h(t) = h_0(t) \cdot exp\left(\sum \beta_i x_i\right) \tag{1}$$

where $h(t)$ is the anticipated 'hazard' of plan completion at time t, and β are the fixed effects coefficients describing the effect of covariates x on time to plan completion. We fit six total models, two representing conservation needs (designation status, reasons for designation) and four representing bias (sociopolitical, taxonomic, research, and awareness), using Eq. (1) with the *survival* package (Therneau, 2020). Within each model, we compared hazard ratios to determine the effects of each factor on time to plan completion. Finally, we compared the six models using Akaike Information Criterion (AIC) to determine whether conservation needs, or biases best accounted for time to plan completion. We conducted all analyses in R (R Core Team, 2020).

2.3. Designation status model

To determine whether recovery planning is influenced by conservation needs, we tested whether designation status influenced the time within which a DU received its plan. Endangered DUs are under the highest level of protection because without protection, they face imminent extinction. Threatened DUs are at risk of becoming endangered. In contrast, special concern DUs have the lowest level of protection because they are merely susceptible to negative effects from human disturbance (SARA, 2002). We expected DUs under consideration for higher levels of protection, i.e., threatened or endangered, to receive plans more quickly than those with a lower designation status, i.e., special concern.

2.4. Reasons for designation model

As part of the SARA listing process, the Minister of Environment and Climate Change Canada is required to issue a response statement indicating their reasons for accepting COSEWIC's recommendation (Fig. 2). If recovery planning for a DU is influenced by conservation needs, we expected these reasons (hereafter 'reasons for designation') to affect the time within which the DU received a recovery plan. We coded reasons for designation from response statements into eight categories (Supplementary Table S1). We expected species facing population declines to receive plans more quickly, as these species are more likely to be listed as endangered (Lukey et al., 2010). In contrast, we expected reasons related to harvest or economic use – such as human effects and habitat loss – to increase time to plan because these species are less likely to be listed in the first place (Findlay et al., 2009). Similarly, we expected a lack of information to increase time to plan (Lukey et al., 2010). Each reason was included as a separate Boolean variable in the model, coded 1 if it was provided as one of the reasons for designation, and otherwise 0. In several cases, no specific reason for designation was provided, which we included as a separate reason. We chose to consider each reason for designation as a Boolean variable because accurately quantifying the impact of each reason would be challenging, and likely species-specific.

2.5. Sociopolitical model

Economic growth is correlated with biodiversity declines worldwide (Waldron et al., 2017), including in Canada where Species at Risk protections directly conflict with economic development (Hebblewhite, 2017). Thus, we also expected economic growth to increase time to recovery plan. We quantified economic productivity by calculating the average annual per capita GDP growth rate (hereafter Δ GDP; World Bank, 2019) per year between the dates of the most recent COSEWIC designation and earliest recovery plan.

Canadian federal minority governments, where no party holds a legislative majority, are generally considered less effective than majority governments at passing legislation because they must work with other parties to do so (Conley, 2011). As such, we expected minority governments to delay recovery plans. We averaged the proportion of years the federal government was a majority between the most recent designation of a DU and its earliest recovery plan as a measure of government efficiency. We accessed bills passed into law through the Library of Parliament (Canada, 2020). As a measure of government productivity toward environmental activities, we also summed the number of environmental-themed federal bills passed into legislation per year between the most recent designation of a DU and its earliest recovery plan. Using the title and descriptions of each bill, or the entire bill if unclear, we defined environmental bills as the modification or creation of acts relating to the environment, wildlife management or protection, protected areas such as marine protected areas or national parks, fisheries or harvestable species, renewable and non-renewable resources, or impact assessments related to human activity. We did not make subjective judgements concerning their effect on the environment being positive or negative. We used the number of provinces and territories in which a DU occurred to account for the number of jurisdictions responsible for the DU during the planning process.

2.6. Taxonomic model

Ecological research is taxonomically biased, with effort directed toward more conspicuous vertebrates (Donaldson et al., 2016) and terrestrial mammals with larger body sizes (dos Santos et al., 2020). Thus, we tested whether the COSEWIC taxonomic category to which a DU belongs influenced its time to recovery plan. Specifically, we expected birds and mammals to receive recovery plans the quickest, and lichens, mosses, molluscs, and arthropods to receive plans more slowly.

2.7. Research model

Information on factors such as area of occupancy and population size is required to assign a DU to a designation status under COSEWIC (Lukey et al., 2010). In Australia, a lack of publicly accessible peer reviewed research has interfered with identification of threats and development of monitoring protocols for at-risk species (Woinarski et al., 2017). Thus, we expected availability of research to influence the time for a species to receive a plan. To quantify research availability, we systematically searched ISI Web of Science core databases for the number of publications (articles; all languages) with an exact match of the scientific name of the DU in the 'topic' field between its most recent designation and earliest recovery plan. Due to several changes in avian taxonomy between listing and recovery plan finalization, we searched for the common names of avian DUs instead of scientific names (e.g., Canada Warbler, *Cardellina canadensis*, formerly *Wilsonia canadensis*). Since we also anticipated an effect of taxonomy on research bias (Donaldson et al., 2016), we included an interaction between the mean number of monthly views and whether a DU fell into the broader taxonomic grouping of vertebrate, invertebrate, or plant and lichens.

2.8. Awareness model

Species perception by the general public plays a large role in their willingness to support conservation efforts (Kontoleon and Swanson, 2003), with downstream consequences for conservation status (Brambilla et al., 2013). Thus, we expected public 'awareness' to influence the time for a DU to receive its recovery plan. We evaluated awareness using the mean number of monthly English-language Wikipedia page views for each DU between its most recent designation and earliest recovery plan (Mittermeier et al., 2019). We extracted monthly views either with an exact match to the scientific name or common name of the DU using the pageviews package (Keyes and Lewis, 2020). Like taxonomic biases in research, there is more support for conservation of large, conspicuous vertebrates (Kontoleon and Swanson, 2003), so we also included an interaction between monthly views and broad taxonomic grouping.

2.9. Proportional hazards

Prior to model comparison and interpretation, we ensured all CPH models met the proportional hazards assumption via graphical inspection of the Schoenfeld residuals and confirmation of no pattern in the residuals over time ($p > 0.05$). While we initially included the proportion of time with a majority government (hereafter 'government efficiency') and average number of environmental bills per year (hereafter 'environmental productivity') as continuous variables in the sociopolitical model, there was a non-random pattern in the Schoenfeld residuals over time, meaning their inclusion violated the proportional hazards assumption. As a solution we binned both the government efficiency and environmental productivity covariates into three discrete levels: low, medium, and high. However, as we averaged the government efficiency, environmental productivity, and Δ GDP covariates over the time between designation and receiving a plan, residual variance was higher for DUs that received a plan faster than what is typical (see Fig. 2 for typical timelines), producing a non-random pattern in the Schoenfeld residuals. Thus, we further screened all DUs from the analysis that were both designated by COSEWIC and received a recovery plan within three years (see Supplementary Material regarding binning details and proportional hazards assumptions).

3. Results

The median time between the most recent designation and the earliest recovery plan was 6.5 ± 4.6 years. The fastest plan was developed in 29 days following designation (small whorled pogonia, *Isotria medeoloides*), with 32 DUs waiting less than one year for a plan. Most designated units (DUs) had wait times between 3 and 20 years. Three DUs had wait times of 20 years or longer, up to a maximum of 41 years for the Vancouver Island marmot (*Marmota vancouverensis*) which was designated pre-SARA. After screening out all DUs that were both designated and received a recovery plan within three years, our final data set included 461 DUs.

Model selection indicated that the sociopolitical model had the lowest AIC and thus the most support, followed by the taxonomic status, awareness, research, designation status, and reasons for designation models (Table 2). Other than high environmental productivity, all sociopolitical model hazard ratios were significant (i.e., 95% CI did not include 1, Table 3). Coefficient estimates and hazard ratios for taxonomic, designation status, awareness, research, and reasons for designation models are provided in Supplementary Tables S2-S6.

Government efficiency, Δ GDP, and environmental productivity were important predictors of the time between designation and recovery plan. DUs undergoing plan development with high government efficiency were approximately 20 times more likely to have a recovery plan than those undergoing plan development with medium government efficiency (Fig. 3 A, Table 3). For every 1% increase in Δ GDP between the time of designation and recovery plan, DUs were 60 times less likely to have a recovery plan (Fig. 4 A, Table 3). Increases in environmental productivity were associated with increased time between COSEWIC designation and plan acceptance for DUs. When the number of bills passed per year between the time of designation and recovery plan was low, DUs were almost twice as likely to receive a plan as those with a medium number of bills (Fig. 3 B, Table 3).

In contrast, the number of jurisdictions responsible for conservation of a DU decreased the time between designation and planning, particularly when DUs were present in more than 7 of 13 provinces or territories (Fig. 4 B). For every additional province in which the species was present, DUs were 11% more likely to receive a plan (Table 3).

Table 2
Comparison of ΔAIC scores from Cox proportional hazards models describing the effects of model covariates on the probability of a designated unit receiving a recovery plan.

Model	Covariates	ΔAIC
Sociopolitical	Δ GDP	0.00
	Number of provinces present	
	Environmental productivity	
	Government efficiency	
Taxonomic	Birds	158.04
	Arthropods	
	Molluscs	
	Freshwater fishes	
	Marine fishes	
	Mammals	
	Reptiles	
	Amphibians	
	Lichens	
	Mosses	
	Vascular plants	
Awareness	Wikipedia page views	169.24
	Taxonomic grouping	
	Interaction	
Research	Number of publications	175.00
	Taxonomic grouping	
	Interaction	
Designation status	Special Concern	190.03
	Threatened	
	Endangered	
Reasons for designation	Habitat loss	249.29
	Population decline	
	Human effects	
	Indirect effects	
	Disease	
	Climate	
	Limited data	
	None	

Table 3
Cox proportional hazard coefficients, standard errors, hazard ratios, and 95% confidence intervals of the effect of sociopolitical model covariates on the probability of completion of a recovery plan for COSEWIC designated units. Hazard ratios less than 1 indicate a negative effect of the covariate on the probability of the designated unit receiving a plan, and hazard ratios greater than one indicate a positive effect on its probability of receiving a plan. Asterisked covariates are significant at $\alpha = 0.01$.

Covariate	Coefficient ± SE	Hazard ratio (95% CI)
Average GDP*	−5.11 ± 0.61	0.006 (0.002, 0.020)
Government efficiency[a]		
High*	3.06 ± 0.33	21.38 (11.11, 41.14)
Low*	−0.84 ± 0.29	0.43 (0.25, 0.77)
Environmental productivity[a]		
Low*	0.64 ± 0.22	1.89 (1.23, 2.90)
High	−0.42 ± 0.33	0.66 (0.34, 1.25)
Number of provinces present*	0.11 ± 0.03	1.11 (1.04, 1.18)

[a] The medium category is the reference category.

4. Discussion

4.1. Factors influencing recovery plan completion

We tested whether recovery planning under SARA was influenced to a larger extent by conservation needs or sociopolitical, taxonomic, and awareness biases. We found that sociopolitical factors had the most influence on the duration of recovery planning. Specifically, recovery plans took longer to prepare when average per capita GDP growth rate was higher and when more environmental bills were passed per year during the planning process. When the DU was present in a larger number of provincial jurisdictions and a majority government was in power for a greater proportion of years during the planning process, recovery planning was faster. In contrast, we found that indicators of conservation need, such as the reasons for designation and designation status under COSEWIC, had comparatively little effect on the duration of recovery planning. Overall, our results suggest that recovery planning for Canadian species at risk is more heavily influenced by sociopolitical factors than conservation needs, which has important implications for biodiversity conservation.

The relationship between sociopolitical factors and recovery planning is especially striking given our current understanding of biases influencing conservation legislation. Taxonomic bias has been consistently identified as a factor influencing species protection in a number of countries (Clark et al., 2002; Walsh et al., 2013), including Canada (Bird and Hodges, 2017; Creighton and Bennett, 2019). Ferreira et al. (2019) found that biological factors (taxonomy, population size, ESA status) and sociopolitical factors (number of provinces involved in the recovery planning, number of land tenure types and road density within the species' current range) were the primary factors influencing time to the publication of an initial recovery strategy in species listed under SARA. Species with inadequate research are also less likely to be designated by COSEWIC (Lukey et al., 2010), thereby delaying their potential listing and recovery planning under SARA. However, we found that the economic and political climate had a greater effect on recovery planning than biases previously identified as influential.

Delays in planning despite economic growth is perhaps unsurprising given the lower financial priority federal governments afford to conservation activities when conservation conflicts with economic growth. We found that as average per capita GDP growth increased, a DU was less likely to receive a recovery plan. Indeed, Canada's reliance on extractive industries means there is often a direct conflict between economic growth and species conservation. For example, delayed recovery planning for woodland caribou in Alberta allowed time for oil and gas development (Hebblewhite, 2017), and commercially important Canadian species often face barriers to becoming listed to protect their economic value (McCune et al., 2013; McDevitt-Irwin et al., 2015; Mooers et al., 2007). Troublingly, Waldron et al. (2017) also detected a global pattern in which national GDP growth rate correlated with biodiversity declines. However, it should be noted that shrinking GDPs could also lead to biodiversity declines if conservation spending is among the first cutbacks. Regardless, species recovery is strongly linked to the funding available for conservation actions (Miller et al., 2002). In the US, the federal government has failed to measurably increase funding for the ESA in the decades since its passing despite more species being awarded status, reducing conservation funding per species (Henson et al., 2018). Declines often ensue for species whose recovery plans are underfunded as a result (Gerber, 2016). SARA is relatively young compared to the ESA; however, a similar unwillingness to scale conservation funding, such as when per capita GDP growth rate is highest, could also impede species recovery in Canada in the future.

Species recovery planning may also be influenced by government efficiency. We found that the more frequently a majority government was in power during plan development, the more likely that DU was to receive a recovery plan. Indeed, minority governments in Canada have historically been less productive than their majority counterparts when

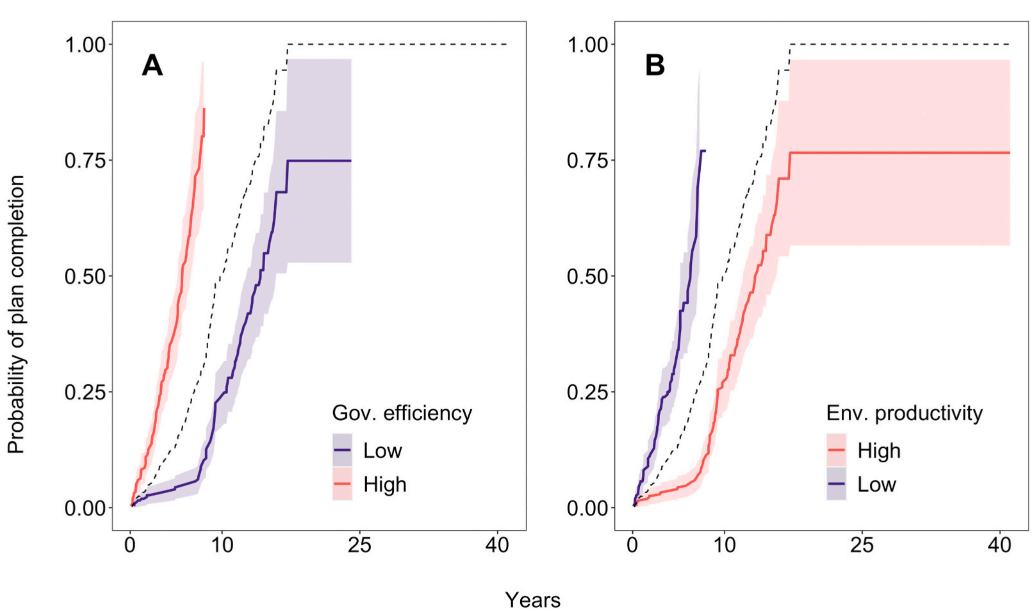

Fig. 3. Probability of plan completion for designated units based on government efficiency (A) and environmental productivity (B) during the time between designation of a COSEWIC designated unit (DU) and finalization of its recovery plan. The high (red) and low (purple) levels of each covariate are shown (the medium level is not shown for either covariate because it was included as the reference category; see text for details). The dashed black line represents the expected time to completion of a recovery plan for a DU without the influence of government efficiency or environmental productivity. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

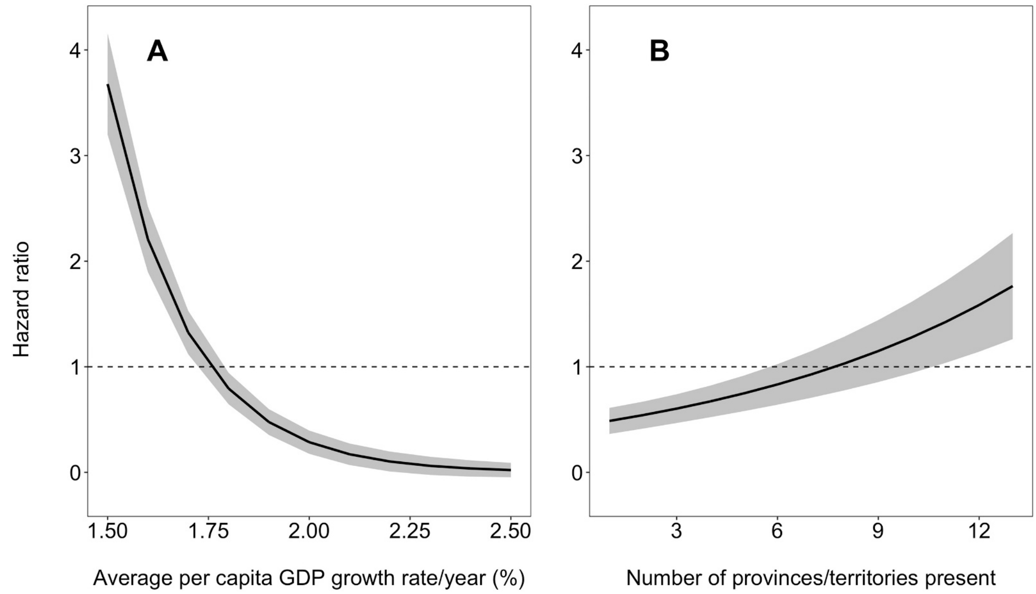

Fig. 4. Effect of average per capita GDP growth rate (A) and the number of provinces and territories in which a designated unit is present (B) on the probability that it receives a recovery plan. Hazard ratios less than 1 (dashed black line) indicate a negative effect of the covariate values on the probability of the designated unit receiving a plan, and hazard ratios greater than one indicate a positive effect on its probability of receiving a plan.

volume of legislation is used as a metric (Conley, 2011). In other nations, government efficiency has dramatic effects on biodiversity conservation. For example, a lack of urgency on the part of the Australian government to implement recovery actions led to the extinction of three species between 2009 and 2014 (Woinarski et al., 2017). In the US, frequent shifts between Presidential administrations has slowed the federal government's reaction to the impact of climate change on biodiversity (Delach et al., 2019). Even if federal governments are resolved to protect biodiversity, they may lack the capacity to do so, requiring partnerships with states, federal agencies, and private landowners (i.e., ESA; Wilkinson, 1999). It is possible that the correlation between faster timelines and majority governments reflects less thoughtful, and potentially less effective plans. Indeed, our observations suggest that when government efficiency is limited by the government in power, biodiversity may be an indirect casualty. However, in countries including Canada, political parties are not necessarily static in their environmental policies, and their effectiveness is difficult to gauge without also qualitatively assessing the value of bills passed by specific governments.

Our metric of environmental productivity – the number of environmental bills passed during the planning process – was also associated with slower recovery planning. However, we included any environmental legislation pertaining to environmental regulation, modification, and usage, without qualifying the magnitude or direction of their effect. Thus, the environmental bills we considered may not align with biodiversity conservation. Indeed, many North and South American and European Union (EU) countries take a "sustainable development" approach to environmental legislation that maximizes economic growth but does not always quantify ecological costs (Durac and Cărpușor, 2018; Kline et al., 2015). An alternate possibility is that federal governments that allocate more resources toward passing environmental legislation also oversee more robust conservation planning. While waiting for the best available knowledge risks further declines in species populations (Martin et al., 2012), effective conservation planning requires careful consultation with stakeholders and experts (Murray et al., 2015), a standard unlikely to be met if a DU is rushed through the listing and recovery planning processes to meet the legislative mandates. Thus, delayed recovery planning could also be a side effect of well-intentioned strategies to bolster conservation.

The effect of jurisdictional coordination on conservation success also has mixed influences on conservation worldwide. Hermoso et al. (2017) suggested conservation funding be planned at the level of the EU rather than nationally to increase conservation efficiency and eliminate taxonomically biased financial allocation. In agreement with this, we found that the number of Canadian provincial jurisdictions in which a DU occurred sped up the planning process. In contrast, Ferreira et al. (2019) found that for each additional province/territory involved in the recovery of species there was an 87% increase in the time to publish its 'recovery strategy'. They argued that a lack of synergy among jurisdictions makes the recovery planning process less efficient. Our results are not directly comparable to those of Ferreira et al. (2019) because not all provinces are involved in the recovery of federally listed DUs that occur there. However, Ferreira et al. (2019) considered recovery strategies and not recovery planning (Fig. 2), and it is still possible that following the development of recovery strategies, cooperation among provinces instead expedites finalization of critical habitat and facilitates the proposed planning for its protection. Indeed, Crouse et al. (2002) found that ESA recovery plans were more biologically sound and easily communicated to stakeholders when developed collaboratively with non-federal contributors. Thus, even if recovery planning is slower when jurisdictional involvement increases, the resulting action plans could lead to better recovery outcomes.

4.2. Recommendations for biologists

Our results present several new questions pertinent to species conservation in Canada, and indeed to government-administered conservation programs generally. First, how effective are recovery plans, and what effect does the timeliness of recovery planning have on plan success? Our study makes the assumption that less time between designation and the development of a recovery plan is beneficial for species recovery. However, rapidly developed recovery plans may sacrifice careful consideration for expediency. Evidence from the US also suggests that simply having a plan does not mean that it will be implemented (Gerber, 2016), especially without legal obligation to do so (Wintle et al., 2019). Furthermore, despite ongoing research and monitoring, the incorporation of data into policy decisions to support at-risk species is frequently delayed (Buxton et al., 2020). It is reasonable to build upon our results by investigating whether plans that take longer to develop may in fact have greater success rates. An especially important nuance is whether plan success is proportional to increased investment in planning time, or if there are diminishing returns past a certain point. Investigating the relationship between time to recovery plan completion and the implementation of conservation actions outlined in recovery plans could help distinguish between the two (Gerber, 2016).

Interdisciplinary collaboration with researchers from sociopolitical science backgrounds could also tease apart the impact of governing parties from the impact of minority governments on time to plan completion. The effect of minority governments we observed was understandable because minority governments must work in coalition with other parties, possibly compromising on biodiversity conservation to serve a more general populace. However, specific objectives of political parties vary through time, and salient predictions about political party influence on biodiversity conservation are beyond the scope of our investigation. An in-depth review of political platforms and policy positions, and their connection to recovery planning, could inform the effect of political parties on biodiversity conservation. Political scientists and social scientists are better equipped to ask precise questions about the impacts of specific political parties and environmental legislation than are biologists and ecologists, providing novel perspectives on historical and current relationships between humans and nature (Bennett et al., 2017).

Comparing alternative approaches to biodiversity conservation across different sociopolitical climates also merits consideration for its potential effect on recovery planning. One of the factors distinguishing these approaches is the extent to which federal governments oversee which species are considered for listing (Fig. 1). For example, in the United States and Australia, listing decisions are made within the federal government (Waples et al., 2013; Woinarski et al., 2017). In contrast, the Norwegian Red List is developed by the Norwegian Biodiversity Information Centre, an independent, science-based organization. The Canadian approach is similar in that COSEWIC, which is tasked with making recommendations for listing under SARA, is an independent entity from the federal government. Many countries also involve non-scientists in listing, planning, and recovery. For example, Norwegian municipalities are charged with protection of small, local protected areas (Fauchald and Gulbrandsen, 2012). In the US, private citizens can independently nominate species for listing that may not otherwise be considered (Brosi and Biber, 2012). Incorporating qualitative data from specific viewpoints (e.g., Indigenous knowledge, community stakeholders) provides a more holistic understanding of recovery effectiveness beyond population ecology metrics (Rust et al., 2017). However, in many countries the federal government is ultimately responsible for final listing decisions and recovery planning for species, potentially delaying conservation measures urgently needed to prevent their declines. A worldwide comparison of biodiversity conservation models across a continuum from highly federalized to grassroots could help identify the most effective models for expedient and effective recovery planning.

5. Conclusion

Biodiversity is declining at an unprecedented rate worldwide (IPBES, 2019), calling for new strategies to effectively plan conservation actions. To deal with this decline, some have recommended conservation strategies that are taxonomically unbiased (Creighton and Bennett, 2019) and cognizant of gaps in scientific knowledge (Lukey et al., 2010). However, our study suggests that even if we work to eliminate taxonomic biases and the influence of public and scientific interest on recovery planning, the economic and political climate still has a great deal of power over this process for Canadian species at risk. Thus, short of calling for increased conservation funding or changes to legislation through advocacy, there is likely little room for conservation biologists working within government-administered conservation programs to make recovery planning more effective. A more sensible approach – also advocated for by others (Bennett et al., 2017; Rust et al., 2017) – might be to normalize interdisciplinary collaboration between natural scientists and social scientists to better understand how sociopolitical factors impact recovery planning. Finally, by better coordinating conservation legislation with conservation needs, federal governments could exercise their influence over recovery plans to better support biodiversity conservation.

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CRediT authorship contribution statement

Levi Newediuk: Conceptualization, Investigation, Methodology, Formal analysis, Data curation, Writing – original draft. **Jeffrey P. Ethier:** Conceptualization, Investigation, Writing – original draft. **Sean P. Boyle:** Conceptualization, Investigation, Writing – original draft. **Jaclyn A. Aubin:** Conceptualization, Investigation, Writing – review & editing. **Juliana Balluffi-Fry:** Conceptualization, Investigation. **Emilie Dedeban:** Conceptualization, Investigation, Writing – review & editing. **Michel P. Laforge:** Conceptualization, Investigation, Writing – review & editing. **Christina M. Prokopenko:** Conceptualization, Investigation, Writing – review & editing. **Julie W. Turner:** Conceptualization, Investigation, Writing – review & editing. **Quinn M.R. Webber:** Conceptualization, Investigation, Writing – review & editing. **Eric Vander Wal:** Conceptualization, Investigation, Writing – review & editing, Supervision.

Declaration of competing interest

The authors have no conflicts of interest to report.

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Appendix A. Supplementary materials

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