CAPI
THE CANADIAN AGRI-FOOD POLICY INSTITUTE

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Science, Policy, and Governance for the Conservation of Biodiversity and Species at Risk on Canadian Agricultural Landscapes

A *Research* Report prepared for CAPI by Thomas D. Nudds

Research Report

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The Canadian Agri-Food Policy Institute's mission is to lead policy development, collaborate with partners and advance policy solutions within agriculture and food

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Note from CAPI

This report calls for a more inclusive approach to species-at-risk (SAR) conservation on Canada's agricultural landscapes. Current policies, scientific uncertainty, and limited engagement with producers often result in higher costs and delayed actions. To fix this, the report recommends participatory science—bringing producers, Indigenous communities, and other stakeholders into decision-making from the start. Key policy shifts required include providing legal assurances to encourage landowner participation, improving how we assess species status and threats, and investing in open, collaborative science. The result: faster, more effective, and locally supported conservation that works for both the conservation and the agri-food sectors.

This report is part of CAPI's Policies for Land Use, Agriculture & Nature (PLAN) program focused on advancing solutions that enable us to feed the world sustainably, protect farmland, preserve nature and biodiversity, and promote food security. The initiative is supported in part by the RBC Foundation through RBC Tech for Nature.

Key Takeaways

- **Uncertainty is costly and everybody's problem.** Scientific uncertainty about species at risk (SAR) status and threats leads to delayed decisions, missed conservation opportunities, and high costs for governments, producers, and conservationists alike.
- **Focus needs to be on cause.** Automatic listing is a silver bullet aimed at a wicked problem. Discerning the states of SAR and their causes is critical to avoid or reduce opportunity costs.
- **Producers are critical partners.** Unlocking landowner participation is critical, by addressing concerns about liability and privacy in return for land access will enable improved data collection critical to reliable and robust policy decisions.
- **Better science starts with better collaboration.** A successful conservation approach depends on inclusive, open science. A pan-Canadian, participatory approach—where farmers, Indigenous knowledge holders, and researchers co-design solutions—will improve species-at-risk assessment and recovery efforts.

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Antony John’s *The Last Bobolink*, 2014.
As with works by his muse, Alex Colville, perhaps rather than proclaiming, Antony is actually asking: what happens next? Does it have to be? Is that a gathering storm? Is evening settling in, or is a new day dawning? Like artists, scientists are obliged to ask probing, perhaps even uncomfortable, questions. But by embracing uncertainty and greater systems thinking, and with the help of farmers, they can better tackle the questions to inform the choices before society.

With permission of the artist. Antony farms, paints and counts birds in southwestern Ontario.

1. Summary

Canadian governments have regulatory, national, and international obligations to reconcile land use with social values additional to agricultural production. Among them is biodiversity conservation using best available evidence from science, traditional and local knowledge systems.

Biodiversity encompasses all species and their variants, from macrofauna such as plant and vertebrate species-at-risk (SAR) to the soil microfauna that contributes to sustaining the productive capacity of agricultural land.

Effects of uncertainty are manifest from "upstream" species' threat designations by the Committee on the Status of Wildlife Species in Canada (COSEWIC) to the "downstream" effects of legal listing and protection, key steps in the government's process of restoring and protecting SAR. In particular, reliable data about species' distributions and abundances are key inputs to threat assessments and designations. Among assessment criteria, this information contributes disproportionately to threat designations. But, under the best circumstances, species' detections can be notoriously tricky, potentially leading to under- or over-designation of threat status, compromised policy interventions, and inefficient or ineffective management actions. These require good data.

Researchers, however, face a Catch-22: even as they require better data, landowners are often reluctant to permit access to collect it, limiting the evidence for robust threat assessments. Two key opportunities would help to break the Catch-22.

The first, consistent with the federal government's pan-Canadian approach to transforming SAR conservation as described in Canada's Nature Strategy, is to facilitate even more fulsome collaboration between stakeholders in the agri-food and conservation sectors. The role of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), as defined in statutes, need not change. However, COSEWIC will need to reflect on the groundswell of evidence and opinion that, to improve their advice to policy makers, scientists need to go beyond input from multistakeholder advisory tables to participatory research and decision making in which the agri-food sector – from local farmers to industry associations – are involved from the outset in threat designations and mitigations such as beneficial management practices (BMPs). This will build trust.

The second, in return for land access to achieve the first, is to alleviate landowners' concerns about liability if SAR are present or appear. There is precedent: the Ontario Environmental Farm Plan (EFP) program was implemented only after farmers had legal assurances that they could not self-incriminate by disclosing environmental conditions on their farms. Packaging agreements to undertake surveys and/or create SAR habitat in EFP frameworks, now nationwide, would improve databases on which robust "upstream" threat designations depend; reduce "downstream" delays in

listing and implementation; and enable population monitoring in response to best management practices by landowners who do opt to maintain and/or create SAR habitat.

Together with improved databases and participatory research and decision-making with the agri-food sector, investment in collaborative, transparent and open science holds significant promise to advance an approach to SAR conservation that is truly pan-Canadian in every sense.

2. Background

Canada is a signatory to international conventions and agreements[i] to reconcile land use with biodiversity conservation[ii] using the best available evidence from science, Indigenous, and local knowledge systems to underpin policy and management interventions to that end. Paradoxically, well-intentioned legislation and policy to achieve these same goals may have perverse, unintended consequences, contributing to wicked problems[iii], particularly with regard to land use[iv]. One such problem concerns the conservation of rare and threatened species on private agricultural lands when policy and management interventions are perceived to threaten livelihoods.

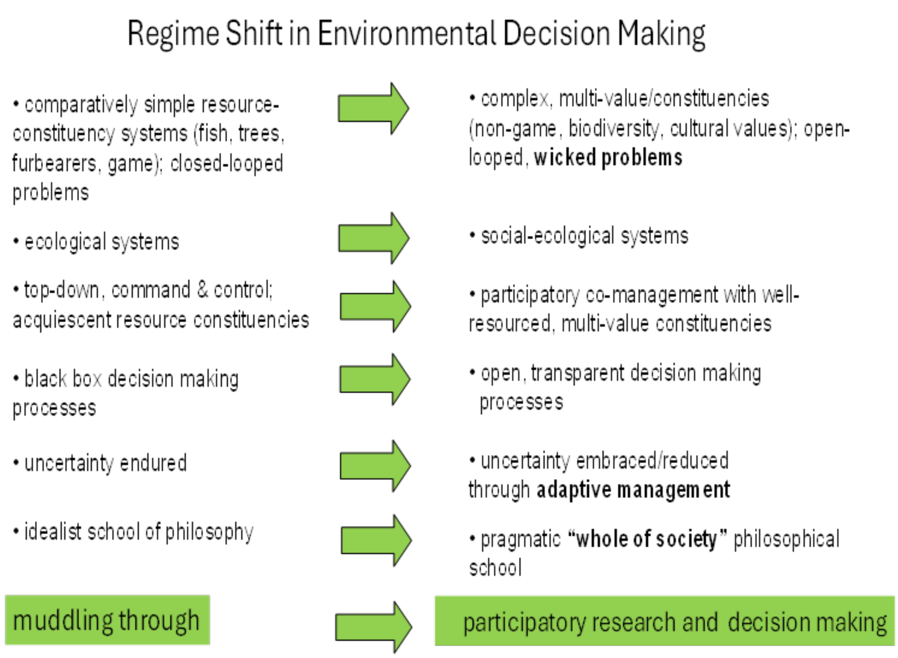

Figure 1: Evolving landscape of environmental decision making from comparatively simple, sector-based and closed-loop problems to complex, open-looped wicked ones as more diverse voices anticipate greater access to decison-making tables.

Perhaps more so than any other industrial human enterprise that operates in a social-ecological context[v], the agri-food sector has long held a social license[vi] to satisfy society's demands for various products from the land. Today, these values range also from biodiversity conservation, including species considered at-risk (SAR), to climate change mitigation – not only to address wider societal concerns, but to sustain the agri-food sector itself.[vii] The changing face of the agri-food industry, founded on continuing investments in new knowledge and technology, provides opportunities to embrace greater systems thinking[viii] with regard to SAR conservation while advancing prosperity[ix] in the agri-food sector. Together with the broader agri-food sector, producers are the largest players on an area basis on southern settled landscapes. They are well positioned – with the right supports – to help to investigate and adopt practices that can sustain economic viability while contributing to SAR conservation.

Conservation science has evolved too, from knowledge and practice rooted in natural sciences and focussed on ecological systems, to approaches rooted also in social sciences and focussed on social-ecological systems[x]. In a time of significant ecological change[xi], when society is facing ever greater prospects of encountering and managing emergent novel social-ecological systems[xii], so too are the voices desiring to advise policy makers more diverse. Across working land and seascapes, stakeholders increasingly expect to contribute actively to evidence-based decision-making tables intended to mitigate challenges and identify opportunities for biodiversity conservation, including SAR.

Diverse, sector-based knowledge, however, will give rise to different, often normative and sometimes competing perspectives, lending to uncertainty, ambiguity and complexity that characterize wicked problems. In such cases, navigating discussions about the effectiveness and efficiency of alternative policy and management interventions proves challenging, if successful at all. Decision-making tables can flounder under the weight of unclear objectives, predetermined conclusions, and conflicting evidence[xiii]; policy decisions may stall, and appropriate, feasible and supportable management interventions delayed.

There is acknowledged need for practical, analytical tools accessible to scientists and non-scientists – yet knowledge experts in their own rights – capable of expanding the evidentiary foundation of policy making while maintaining the scientific rigour of causality. Founded on decision networks grounded in causal analysisxiv not yet widespread in ecology and conservation science, these tools are familiar in other applications from economics to public health where weak causal inference can compromise policy decisions and the efficiency and effectiveness of management interventions. Druzdzel and Simon noted that “the effect of a structural change in a system cannot be induced from a model that does not contain causal information. Having the causality right is crucial for any policy making.”

This paper argues

1. the need to support the pan-Canadian approach to transforming the conservation of species at risk in Canada;[xv]

2. the need to identify and reduce high opportunity costs[xvi] imposed by scientific uncertainty about the states – *and* their causes – of species deemed at risk on agricultural landscapes; and

3. the need to remove barriers to the active participation of the agri-food sector generally in policy-relevant research and decision making; and why and how producers specifically can

help to improve the evidence base for assessing risk status – *and* its causes – to recover SAR as required.

3. Science, Uncertainty and Decision Making

In simplest terms, science[xvii] concerns ascribing *causes* to *states* of nature. Ecological science, specifically, concerns cause-effect relationships among organisms, including humans, with each other and with their physical environments. It is foundational to describing and explaining relationships between human society and the world around it, including wild and domestic agrobiodiversity.

The term 'science', however, is frequently confused with the term 'knowledge'. Science is actually a knowledge *system*, which includes the process by which its products – knowledge and technology – constantly evolve. Knowledge has a half-life[xviii], the length of which depends on the discipline; it becomes obsolete, irrelevant or wrong even as the urgency for the best available evidence to inform sound policy interventions and management practices becomes more pressing. What knowledge endures practice becomes as close to truth as science can get, until it isn't[xix]. To the extent that knowledge is constantly evolving and frequently highly specialized, conservation of agricultural, ecological and social/cultural values are always at risk of being addressed by policy interventions founded in obsolete and/or narrowly scoped knowledge.

Consequently, governance may become mired[xx], unable to keep pace with the rate of knowledge turnover. For policy makers and managers, uncertainty is exacerbated by rapidly changing environments and potential trade-offs among multiple values with competing policy objectives. Rather than lament the half-life of knowledge and omnipresent uncertainty, scientists are obliged to identify, characterize, incorporate and reduce it head on. Adaptive management has been advocated for biodiversity conservation, generally, and SAR conservation specifically.[xxi]

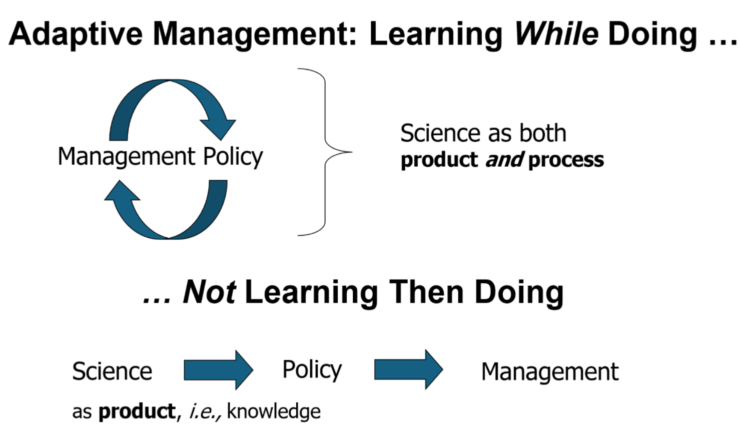

Figure 2: Science is more than knowledge. Adaptive management deliberately addresses scientific uncertainty by treating policies as hypotheses to be revised in light of management experience.

Nevertheless, embracing uncertainty faces significant headwinds, not least of which is that, to probe systems to test policy hypotheses may be at odds with legal prohibitions grounded in a precautionary approach[xxii].

Adaptive management emerged in natural resources management in the mid-1970s[xxiii], "as a stepwise iterative process in which management interventions are implemented, their effects monitored and evaluated, the next intervention is adapted according to knowledge gained"[xxiv]. Proponents intended it to improve science advice to policy makers in the face of uncertainty, reducing it through management experiments over time.

Lee[xxv] remarked that adaptive management is easy to understand, almost. Several types of management interventions have been described as adaptive, each affording different levels of assurance of cause-effect critical to sound policy and management decisions. Such assurance ranges from virtually none (*i.e.,* reactive management, as adaptive management is often described in popular, government and "grey" scientific literature) to policy/management experiments intended to approach the gold standard of scientific inference – random and controlled trials[xxvi]. Regardless of the design it may take, a constrained policy/management experiment is preferable to none for better assuring that the integrity of evidence intended to inform policy decisions is, in fact, the best available.

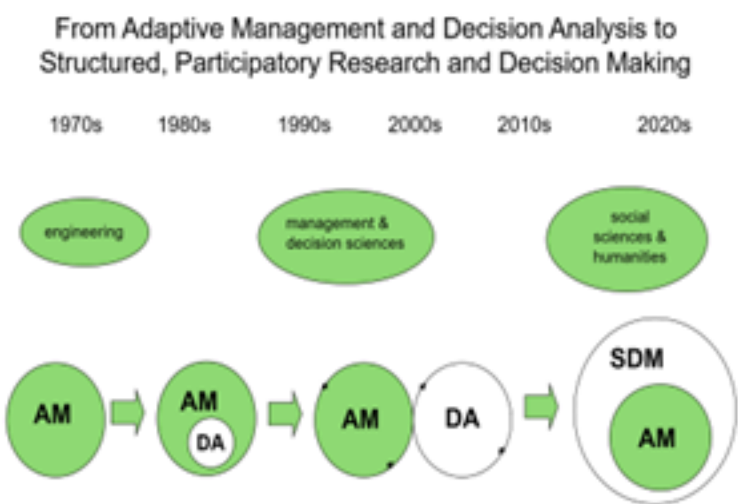

Figure 3: Adaptive management has become less an end in itself for experimentation by natural scientists interested un "applied" problems, and more means to an end for making robust and reliable decisions by eliciting and using also the expert knowledge of people to whom the results of policy/management experimentation matter most.

Adaptive management was largely the purview of natural scientists, and proved challenging to deploy because, by and large, those for whom the results of policy/management experiments mattered most were not in on the planning. Today, the scientific method from which it descended remains core to Canada's commitment to open science;[xxvii] virtually indistinguishable from "policy cycles";[xxviii] and foundational to more inclusive, structured and participatory research and decision-making. From a pragmatic perspective, adaptive management in its modern guise is better poised than ever to enable democratic discourses in which communities of inquiry test policy hypotheses to mitigate wicked problems.

4. The “SARA PROCESS” as Structured Decision Making

The process by which a species is assessed to be at risk, legally protected and its recovery planned, implemented and evaluated comprises a series of steps. The Species at Risk Act 2002 (SARA) sets apart the “upstream” scientific assessment of risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) from the “downstream” steps that consider the effects of protections and prohibitions on other social values, ostensibly to clearly distinguish scientific from political decisions. If COSEWIC designates a species as Endangered or Threatened, the Committee recommends to the responsible Minister that the species and its habitat be legally protected.

A similar process was laid out in Ontario’s Endangered Species Act 2007 (ESA), with important distinctions. Whereas SARA does not apply to non-federal lands except in emergencies, the ESA applied to provincial Crown and private land. To address delays in affording species and their habitats legal protections under SARA, the ESA introduced automatic protections. There was no opportunity for wider consultations following species’ risk designations by Ontario’s Committee on the Status of Species at Risk in Ontario (COSSARO).

Many species, in fact, are added reasonably smoothly to the list of protected species in the Act. Nevertheless, as a result of wider “downstream” consultations with other interests, a subset of species whose protection and recovery could plausibly, negatively affect economic or cultural activities may undergo extended consultations that delay recovery planning and implementation much longer than the timelines required under SARA.

To address bias and delays in implementing protections and recovery planning for species that are recommended to the Governor in Council, some conservationists called for automatic protections and/or prohibitions on activities considered to be harmful to SAR.[xxix] From the perspective of adaptive management, however, at that point, both would have to *assume* uncertain causal effects of the prohibited activities. Threats listed in status assessments are based on observations assembled for that purpose and not for causal inference; they properly constitute *hypothesized* causal factors. Therein lies the rub. Put simply, for example, it may be illegal to kill, harass or harm a listed species of grassland bird, but prohibiting hay cutting when hay is at peak quality is unlikely to arrest or reverse declines of grassland bird if nest destruction is not likely the causal factor at either that or farm scales[xxx].

Regardless of when legal protections for species and their habitats kick in, ‘science’ is restricted to narrow consideration of risk designation, *i.e.,* the *state* of the species. The process leaves *cause* to speculation, and policy makers to the tough task of deciding among policy interventions to address them without necessarily the benefit of formal means to incorporate relevant expert knowledge into causal analyses.

Next consider the SARA process as a cycle not unlike adaptive management and policy cycles, embodying status assessment that both identifies potential threats *and* assigns causal weights such that, if changed, could result in the desired policy outcome.

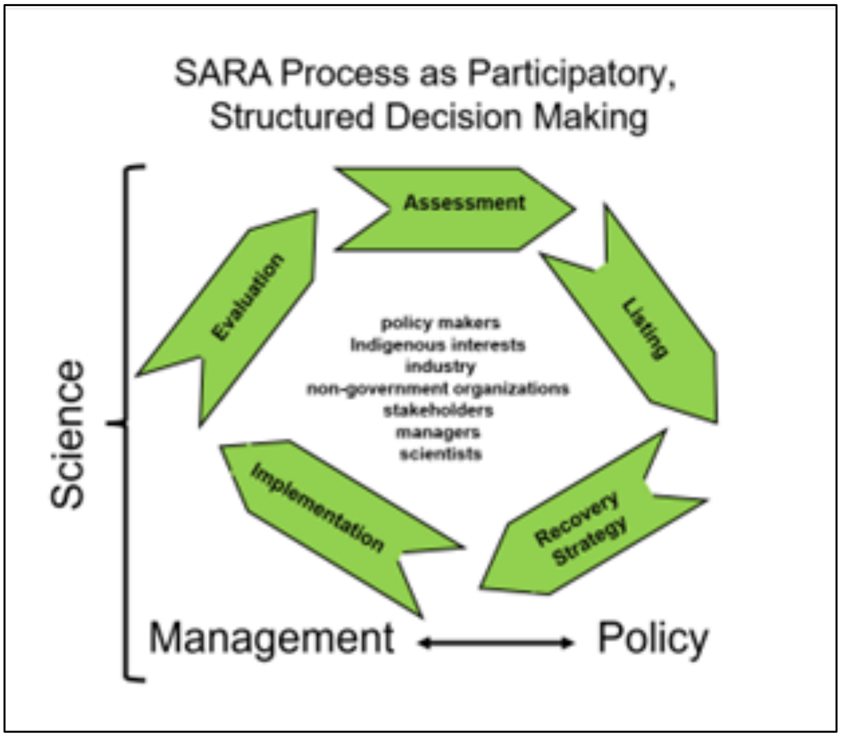

Figure 4: A participatory, structured decision - making approach to listing and recovery of at-risk species begins "upstream" with assessment of both the states of species and their causes. Consistent with scientific method, induction, deduction and inference are all implicated.

5. Uncertainty and the COSEWIC Process

COSEWIC works continuously to update its processes to be open and transparent with respect to how species are selected for assessment, assessed, and eventually designated 'Endangered', 'Threatened', 'Special Concern', 'Not at Risk' or 'Data Deficient'. Uncertainty is acknowledged, to be incorporated to the extent possible in virtually every aspect[xxxi].

Similar to other nationally and internationally recognized assessment frameworks, COSEWIC compares quantitative data for each of five criteria (A-E) to static thresholds for transitions between threat designations, *i.e.,* above which, say, for populations size, the species may be considered less at risk than below it. Consistent with a precautionary approach, COSEWIC scientists use their expert knowledge to weigh the effects of uncertainty with respect to the amount and quality of data on decisions about final designations. It is not always clear, however, how such expert opinion factors into deliberations,[xxxii] which has inspired research into methods to directly incorporate uncertainty into assessment and designation processes.[xxxiii]

COSEWIC's Criterion E enables COSEWIC to consider population viability analyses (PVAs), with which uncertainty can expressed as *probability*. But, for most species, there are not adequate data to perform 'gold standard' PVAs. COSEWIC reasonably relies on as much data as possible relevant to Criteria A-D about trends in population abundance and distribution of individuals.

COSEWIC's quantitative criteria B and D, in particular, concern changes in the spatial distribution of a species, *i.e.*, its Extent of Occurrence and Index of Area of Occupancy. Spatial location data are readily available across a wide range of species, relatively inexpensive to collect, and the basis for other criteria relating to changes in population size[xxxiv]. As such, information about spatial distribution has tended to contribute disproportionately to assessment and designation decisions. Similarly, if species are re-assessed and down designated (from Endangered to Threatened, or from Threatened to Special Concern or Not at Risk), it is sometimes because more of them are found in more places.

Distributions may, in the case of raw observations, be conservatively biased by false absences or, in the case of modelled distributions, liberally biased by false presences, leading to under- or over-designation of threat status[xxxv]. Advances in sampling and modelling species' occurrences can address these challenges,[xxxvi] but at the centre will always be a continuing need for raw occurrence data as reliable and robust as possible[xxxvii]. Even then, especially as it concerns distinguishing among *causes* of *states* of rarity, at least seven types of natural rarity are recognized.[xxxviii] To identify, characterize, incorporate and reduce uncertainty about the *causes* of variation in the distribution and abundance of species ultimately requires the help of farmers to provide private land access that will enable scientists to design and implement efficient inventory (sampling) surveys and monitoring protocols for species with varying detectability[xxxix].

6. Incentivizing Participatory Research and Decision-making with Producers and the Agri-Food Sector

Structural uncertainty arises from lack of a systems approach to understand the manners in which the conservation and agri-food sectors collectively understand how and why agroecosystems "work". To identify, characterize, incorporate and reduce structural uncertainty requires a community of inquiry to come together to test hypotheses about causal factors. Propelling COSEWIC decision-making forward in a fashion to address downstream opportunity costs of delays requires a broad range of input to participatory modelling in order to explore potential trade-offs in an expanded solution space. Decision networks grounded in causal analysis hold enormous promise to accommodate greater systems thinking about drivers of change in biodiversity and SAR.[xli]

Partial observability refers to data limitations to inform participatory modelling, such as location data for SAR, in turn, requiring land access. Addressing concern in the farming community about liability under endangered species legislation is paramount if governments, together with the help of the conservation and agri-food sectors, wish to reduce the high opportunity costs imposed by scientific uncertainty.

Partial controllability refers to uncertainty resulting from lack of implementing policy and management interventions as they are intended to work. For example, weak interventions resulting from limited uptake of programs intended to maintain and/or and restore SAR mean that both the provision of habitat and effectiveness monitoring[xlii] are compromised. Despite considerable effort to encourage private landowners to take up programs to maintain and/or restore the SAR habitat[xliii], many with financial incentives, it is clear that the response is at best tepid[xliv]. When landowners do opt to take up conservation initiatives, without appropriate measures in place, concerns about privacy may limit access to data available for participatory research and decision-making, including monitoring[xlv].

To address the hurdle at the centre of this 'Catch 22' situation will take policy innovation on a scale to match that which enabled Environmental Farm Plans in Ontario in 1995. So farmers could enrol in EFPs without self-incriminating by declaring environmental conditions on their farms, then Ontario Minister of Environment and Energy Brenda Chamberlain introduced "in good faith" a policy innovation that "balanced MOEE's regulatory responsibilities with the rights of individuals to evaluate their own environmental performance without fear of self-incrimination".[xlvi]

Ontario's initial success with environmental farm plans is today country wide.[xlvii] Uptake rates of EFPs had, by 2024, ranged across provinces from 23-76%; 5 of 9 exceeded 50%[xlviii]. In contrast, instruments to conserve SAR without legal assurances, such as safe-harbour agreements under Ontario's SAR, appear to be significantly undersubscribed.[xlix]

Pittman and coauthors observed that "… relative to other types of incentives, respondents [in their survey] ranked legal assurances low, but legal assurances could still be an important part of advancing conservation on working landscapes". Whether legal assurances against self-incrimination in return for land access would improve uptake of conservation initiatives on private land could be tested in a designed policy experiment in the spirit of collaborative, adaptive co-management.

7. Conclusion

Species at risk comprise a small part of agrobiodiversity; the greatest proportion of agrobiobiversity that most directly sustains agricultural production is underground[li]. The independent contributions of individual SAR to a range of agroecosystem services – such as seed transfer of native plants that, in turn, support crop pollinators, or as predators of crop pests – is either not well understood or widely appreciated. It is also unclear to what extent macrofauna like plants and vertebrates, SAR and otherwise[lii], may be bellwethers for those other components of agrobiodiversity that contribute more directly to agricultural production from which ecosystem services derive. Nevertheless, Aldo Leopold famously advised that the first rule of smart tinkering is to save all the parts[liii]. To contribute to the resilience of agroecosystems, it is wise to encourage conservation of SAR and biodiversity on agricultural landscapes.

Nevertheless, enthusiasm for automatic listing, protections and/or prohibitions of species deemed to be at risk – however frustrating may be due democratic process – is inconsistent with widespread calls and trends to "democratize science", so to speak[liv]. It is apparent that the experiment which assumed independent science advice should be vested in scientists alone and set apart in legislation, at least as currently interpreted, is failing. As an evidence-based way of knowing, Lewis Thomas pointed out that science is not less subject to subjectivism. It is first and foremost a human construct, and subject to human foibles.

Where implemented in Ontario, automatic listing served to illustrate pragmatism's fundamental contention: as a silver bullet aimed at a wicked problem, it proved only to exacerbate rather than resolve it. It matters more that, within existing statutes, discerning the *states* of SAR, *and their causes*, through participatory research and decision-making is upstream of wherever legal protections kick in, *e.g.,* into COSEWIC deliberations to avoid or reduce, to the extent possible, the very opportunity costs[lv] about which government and the conservation and agri-food sectors are all concerned, albeit for different reasons.

Not to re-imagine what is, *de facto*, the first step in the pan-Canadian approach to SAR conservation would be to miss an opportunity to do science *with* people to whom, arguably, the results matter more than to any other actors in the conservation space; for them, the consequences of getting the causality wrong are additive to those society more generally face.

Rather than double down on legislative and policy agendas that are less than satisfactory from the standpoint of reducing opportunity costs for government, agri-food and conservation sectors, advocates for sound upstream science should, instead, open science to the pent-up potential of local and traditional knowledge at the outset the assessment process. Certainly, participatory research and decision making is acknowledged to be resource demanding. The question is whether improved "upstream" stakeholder engagement might enable more nimble "downstream" decision making, reducing delays at almost every step that drive opportunity costs. Parallel virtual policy experiments using management strategy evaluation[lvi] would prove insightful and provide a logical first step to designing "on the ground" pilot assessments by COSEWIC when candidate species anticipated to be particularly contentious next come up, or around again at the required 10-year reassessment interval.

Antony John's *The Awakening*, 1986.

Similarly, among many agricultural producers, it is readily apparent that there is significant pent-up potential to "get on with it" too, waiting to be unleashed but for the fear of legal repercussions if it is. However important may be assurances from the conservation sector that it would welcome opportunities on marginally productive agricultural lands—as opposed to, say, broad scale "rewilding"—they appear to be largely insufficient. And farmers who do access funds to undertake restoration projects with potential benefits to SAR, *e.g.,* field management to reduce nutrient runoff, manage waste, and increase efficiencies that may also create wetlands attractive to wildlife – perhaps even SAR–are too often reluctant to disclose it outside of trusted circles lest SAR show up. Monitoring to evaluate the effectiveness of policy and management interventions that benefit SAR, even indirectly, goes wanting.

Democratizing science does not have to compromise the intent in SARA to invest science advice in COSEWIC (or Ontario's case, COSSARO). Instead, it would acknowledge simply that the nature of other knowledge systems, like science, is also to seek and respond to new information on a continual basis. Receiving advice from multistakeholder tables is important. But it is far cry from engagement by COSEWIC scientists with other knowledge holders intent also on probing for potentially greater conceptual space to address the age-old wicked problem posed by public wildlife on private land.

One version of French author Guy de Maupassant's famous quote goes: "In everything, there is an element of the unknown. We must find it." And then the next, and the next, and the next. An Indigenous person might advise that it's "turtles all the way down."[lvii]

8. Recommendations

1. Environment and Climate Change Canada, Agriculture and Agri-Food Canada with other federal, provincial and territorial Ministries and Indigenous leadership continue to implement the Pan-Canadian Approach to Conservation of Species at Risk in Canada.

2. Continue to support the role of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as defined in the Species at Risk Act 2002 as the lead body to assess and designate species considered to be at risk.

3. To efficiently assess, designate and implement conservation measures as appropriate across jurisdictions, and as befits constitutionally defined roles of provinces and territories to govern land use that may impact at-risk species, formally align and implement as necessary provincial and territorial committees including Indigenous leadership, such as the Committee on the Status of Species at Risk in Ontario (COSSARO).

4. Consistent with the pan-Canadian emphasis on priority species, further clarify COSEWIC's system of triage. Prioritize candidate species for assessment, designation and protections into those species anticipated to require additional investment in structured, adaptive and participatory research and decision making, with Indigenous, industry other local knowledge appropriate, and into those which expert opinion and/or formal "umbrella species" analyses indicate may be swept up coincident with a focused investment on priority species.

5. To improve the evidentiary foundation for decision-making by the responsible Minister and Governor in Council, charge COSEWIC to report, with the associated uncertainty, the *causes* as well as the *states* of priority species. For others, continue to identify potential causal factors implicated in the dynamics of species, accept lower assurance of cause-effect and, accordingly, clarify that such threats are hypothesized and predicted to be addressed through concerted conservation efforts on priority species.

6. For priority species as appropriate and necessary, charge COSEWIC to investigate and deploy new quantitative tools to elicit and incorporate Indigenous and other expert knowledge into participatory modelling for the purposes of recommending appropriate policy and management interventions to conserve species and the economic viability of farms.

7. Continue to provide conservation programs such as the Species at Risk Partnership on Agricultural Land and the Species at Risk Farm Incentive Plan, with financial and other support such as the Habitat and Biodiversity Assessment Tool, to incentivize and catalyze conservation of species at risk and associated biodiversity on private agricultural land.

8. Target uptake of conservation incentives and tools by producers to levels at least similar to those of Environmental Farm Plans (EFPs) by affording landowners legal assurances against self-incrimination by disclosing the condition of at-risk species on their land just as they do other environmental conditions.

9. Coordinate, collect and develop repositories for location data of species-at risk, and biodiversity more generally, across jurisdictions based on the models of the Alberta Biodiversity Biomonitoring Institute (ABMI) and the Natural Heritage Inventory Centre in Ontario.

10. Across jurisdictions, address residual landowner concerns with respect to privacy and confidentiality by implementing policy and procedures, such as those developed by ABMI to also permit access to data by researchers to improve assessments and designations of at-risk species, monitoring of at-risk species and biodiversity generally, ultimately to its conservation and restoration as appropriate on private agricultural land.

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Damme, Glenn Desy, and Laura Trout. Thanks, finally, to Antony John for his kind permission to use *The Last Bobolink* and *The Awakening*.

Endnotes

BACKGROUND

[i] *e.g.*, The Kunming-Montreal Global Biodiversity Framework (https://www.cbd.int/gbf) and its predecessor, the Convention on Biological Diversity (CBD; https://www.cbd.int/convention).

[ii] The Convention on Biological Diversity defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part [including] diversity within species, between species and of ecosystems". The UN Food and Agriculture Organization explicitly recognizes domesticated and wild biodiversity across the world's diverse agri-food systems, including non-harvested species that support them, as agrobiodiversity. (See https://www.fao.org/4/y5609e/y5609e01.htm).

[iii] A "wicked problem" is *a social or cultural problem that's difficult or impossible to solve* because of its complex potential causes and/or potential policy and management solutions with unknown consequences. It does not mean the issues at hand are in some sense evil. See: https://www.interaction-design.org/literature/topics/wicked-problems?srsltid=AfmBOoojgePTS_ymghtGISJAZiKhwRMqgSIY0J1Y0t_m-VhitUXdsrX2. James Kloppenburg pointed out that pragmatism embodies "discourse[s] of democratic deliberation in which communities of inquiry test hypotheses in order to solve problems". Pragmatists will point out that, no matter how well-intentioned , idealist, one-size-fits all "silver bullet" solutions tend often to exacerbate rather than resolve or mitigate wicked problems.

[iv] *e.g.*, van den Ende, M.A. et al. 2023. Wicked problems and creeping crises: A framework for analyzing governance challenges to addressing environmental land-use problems. *Environmental Policy and Management* https://doi.org/10.1016/j.envsci.2023.01.006.

[v] For a definition of social-ecological systems, see Petrosillo, I., et al. 2015. Socioecological systems. *In:* Reference Module in Earth Systems and Environmental Sciences. Amsterdam, NL: Elsevier. 10.1016/B978-0-12-409548-9.09518-X

[vi]More frequently encountered in the realms of wild, living and non-renewable resources management (fisheries, forestry, mining and energy), the concept of a social license refers to broad societal approval of industries' activities other than through regulation alone. See Gehman, J. et al. 2017. Social license to operate: legitimacy by another name? *Canadian Public Administration* doi.org/10.1111/capa.12218

[viii] *e.g.*, Bennett, E.M., et al. 2021. Ecosystem services and the resilience of agricultural systems. *Advances in Ecological Research* https://doi.org/10.1016/bs.aecr.2021.01.001; Jackson, L., et al. 2010. Biodiversity and agricultural sustainagility: from assessment to adaptive management. *Current Opinion in Environmental Sustainability* https://doi.org/10.1016/j.cosust.2010.02.007

[viii] Arnold, R.D. & Wade, J.P. 2015. A definition of systems thinking: a systems approach. *Procedia Computer Science* https://doi.org/10.1016/j.procs.2015.03.050.

[ix] Smart Prosperity Institute. 2018. Species in the Balance. Partnering on Tools and Incentives for Recovering Canadian Species at Risk. Report available at https://institute.smartprosperity.ca/library/publications/species-balance-partnering-tools-and-incentives-recover-species-risk; Smart Prosperity Institute. 2018. Economic instruments for protecting species at risk on private land. Policy Brief available at https://institute.smartprosperity.ca/library/publications/economic-instruments-protecting-species-risk-private-land.

[x] Nuno, A. et al. 2014. Managing social-ecological systems under uncertainty: implementation in the real world. *Ecology and Society* http://dx.doi.org/10.5751/ES-06490-190252; Bennett, N.J. et al. 2022. Social science for conservation in working landscapes and seascapes. *Frontiers in Conservation Science* https://www.frontiersin.org/journals/conservation-science/articles/10.3389/fcosc.2022.954930/full; Vari, Á. et al. 2025. Monitor social-ecological systems to achieve global goals for biodiversity and nature's contributions to people. *BioScience* https://doi.org/10.1093/biosci/biae133.

[xi] There remain few detractors that the weight of scientific, local and traditional evidence is consistent with this claim, and that the resource demands of human population growth are the root cause. Whether the term coined for the current period in Earth's history, the Anthropocene, measures up to the definition of an official epoch is a red herring. For a popular treatment, see Ellis, E.C. 2024. The Anthropocene is not an epoch – but the age of humans is most definitely underway. *UMBC Magazine* https://umbc.edu/stories/anthropocene-not-an-epoch/. The consequences for conservation on agricultural landscapes are expected only to be exacerbated under rapid environmental change (Yang Y., et al. 2024. Climate change exacerbates the environmental impacts of agriculture. https://www.science.org/doi/10.1126/science.adn3747). Closer to home, journalist Matt McIntosh opined to move past climate polarization to focus on the causal agents affecting variation in the properties of agroecosystems important to the agri-food and conservation sectors alike (https://farmtario.com/news/moving-past-climate-polarization/).

[xii] Ecologists speak of 'emerging novel ecosystems' in the context of predicting outcomes of policy interventions when it is uncertain which combinations of species might assemble, and where, in the face of rapid environmental change. See https://www.britishecologicalsociety.org/content/novel-ecosystems-the-new-normal/. Despite that novel ecosystems are characterized as difficult, if not impossible to restore to some previous condition, they are not so novel as to violate "laws of nature" with respect to the transfer of matter and energy amongst component species with different traits. To the extent that agroecosystems comprise, collectively, wild and domesticated biodiversity and are exposed to the same widespread driver(s) of environmental change generally, it is convenient to think also of agricultural landscapes as emerging novel agroecosystems.

[xiii] Holzer, J.M. et al. 2024. Managing environmental knowledge networks to navigate complexity. *Ecology and Society* https://doi.org/10.5751/ES-15493-290404; Norström, A.V. et al. 2020. Principles for knowledge co-production in sustainability research. *Nature Sustainability* https://doi.org/10.1038/s41893-019-0448-2; Cooke S.J. et al. 2020. On "success" in environmental research – what is it, how can it be achieved, and how does one know when it has been achieved? *Environmental Reviews* https://doi.org/10.1139/er-2020-0045.

[xiv] Druzdzel, M.J. & Simon, H.A. 1993. Causality in Bayesian belief networks. In: Uncertainty in Artificial Intelligence. San Francisco, CA, USA: Morgan Kauffman Publishers (https://doi.org/10.1016/B978-1-4832-1451-1.50005-6). As in other fields where causal inference is constrained by retrospective studies of observational data, causal analysis is critical for forecasting the effects policy and management interventions (Oliver, T.H. & Roy, D.B. 2015. The pitfalls of ecological forecasting. *Biological Journal of the Linnean Society* https://doi.org/10.1111/bij.12579 ; Law, E.A., et al. 2017. Projecting the performance of conservation interventions. *Biological Conservation* https://doi.org/10.1016/j.biocon.2017.08.029.) Though important for designing adaptive policy-management experiments, it is not as yet widespread for conservation decision-making (Arif, S. & MacNeil, M.A. 2022. Utilizing causal diagrams across quasi-experimental approaches. *Ecosphere* https://doi.org/10.1002/ecs2.4009). For an application to conservation of a threatened species, see Wilson, S.F. *et al*., A causal modelling approach to informing woodland caribou conservation policy from observational studies. *Biological Conservation* https://doi.org/10.1016/j.biocon.2021.109370 and Wilson, S.F. 2025. Causal attribution from retrospective data in Canada's woodland caribou system. *Ecological Applications* https://doi.org/10.1002/eap.70022.

Environment and Climate Change Canada. 2018. Pan-Canadian Approach to Transforming Conservation of Species at Risk in Canada. Available at CW66-582-2018-eng.pdf. Canadian Agri-Food Policy Institute. 2023. A Framework and Assessment of Conservation Strategies for Species at Risk and Biodiversity on Canadian Agricultural Landscapes. A

CAPI Research Report for the Canadian Roundtable for Sustainable Beef/Environment and Climate Change Canada Ag-SAR Core Project Team. Canadian Agri-Food Policy Institute, Ottawa ON.

[xv] Opportunity costs are commonly defined as the foregone benefits of an economic activity, like agriculture or residential development, if it was curtailed to use land instead as habitat for conservation. Appreciation of the economic value of natural and agricultural assets, in terms of avoided/reduced carbon emissions and/or biodiversity conservation for food security, is growing (*e.g.*, Natural Assets Initiative https://naturalassetsinitiative.ca/; Nature Investment Hub https://natureinvestmenthub.ca/). Conversely then, there are benefits forgone also by converting natural and agricultural land to other uses.

[xvi] More generally, opportunity costs extend to time, energy and resources spent in activities that return little on investment when potentially more effective and efficient activities are available. Conservation and agri-food sectors, together with government, bear high opportunity costs when time and energy need to be devoted to responding to unintended consequences of of ineffective legislation and/or policy. For example, government and the conservation sector similarly deplore "red tape" rooted in Ontario's Endangered Species Act 2007, albeit for different reasons. See also Buxton, R.T., et al. 2021. Avoiding wasted research resources in conservation science. *Conservation Science and Practice* https://doi.org/10.1111/csp2.329.

SCIENCE, UNCERTAINTY AND DECISION-MAKING

[xvii] For brevity, 'science' here and throughout refers simply to a knowledge *system*. Insofar as science values learning, it shares properties with local and Indigenous knowledge systems, these being the storage, transmission, revision and response to new knowledge gained in the course of experience, likening traditional ecological knowledge to adaptive management. See Varghese, J. & Crawford S.S. 2020. A cultural framework for Indigenous, Local and Science knowledge systems in ecology and natural resource management. *Ecological Applications* https://doi.org/10.1002/ecm.1431; Berkes, F. et al. 2000. Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications* http://dx.doi.org/10.2307/2641280.

[xviii] For a succinct introduction to the concept of the half-life of knowledge, see the review of Samuel Arbesman's book, The Half-Life of Facts. Why Everything We Know Has an Expiration Date. by R.M. Stein at https://www.tandfonline.com/doi/full/10.1080/14697688.2014.896123 .

[xix] Lewis Thomas (1983. *Late Night Thoughts on Listening to Maher's Ninth Symphony*, NY, NY. USA: Viking Press) explained what scientists are *really* up to in his essay Humanities and Science: throughout the history of scientific discovery "hard facts [have tended] to melt away to be replaced by new hard facts."

[xx] James Bailey introduced 'muddling through' to the field of wildlife management, some of whom were less than appreciative at the time. See Bailey, J.A. 1982. Implications of 'muddling through' for wildlife management. *Wildlife Society Bulletin* https://www.jstor.org/stable/3781207.

[xxi] Keith, D.A. et al. 2011. Uncertainty and adaptive management for biodiversity conservation. *Biological Conservation* https://doi.org/10.1016/j.biocon.2010.11.022; Runge, M.C. 2011. An introduction to adaptive management for threatened and endangered species. *Biological Conservation* https://doi.org/10.3996/082011-JFWM-045.

[xxii] Sunstein (2005. *Laws of Fear: Beyond the Precautionary Principle*. Cambridge, UK: Cambridge University Press) pointed out that, because advocates of potentially competing values each fear their loss, the precautionary principle is at best incoherent and at worst paralyzing. For example, some conservationists might consider experiments for the purpose of learning to conserve SAR to run afoul of legislation if, in the language of SARA, such a management experiment would kill, harass or harm a species or its habitat. Farmers, on the other hand, may fear loss of their

livelihoods altogether. Michael Runge (2011, *ibid*) assured that, in the US at least, it is simply a misconception that adaptive management is prohibited under the US Endangered Species Act.

[xxiii] Holling, C.S. 1978. *Adaptive Environmental Assessment and Management*. Chichester, UK: John Wiley and Sons. In 1986, Carl Walters' book, *Adaptive Management of Renewable Resources* (New York, NY, USA: Macmillan) contained a single chapter on decision analysis. By the 2010s, the adaptive management concept was embedded in textbooks about decision-making (Gregory, R. et al. 2012. *Structured decision making: A practical guide to environmental management choices.* Chichester, West Sussex, UK: Wiley-Blackwell; Conroy, M.J. & Peterson, J.T., 2013. *Decision Making in Natural Resource Management: A structured, adaptive approach.* Hoboken, NJ, USA: John Wiley; Bunnefeld, N. et al. 2017. *Decision Making in Conservation and Natural Resource Management*. Cambridge, UK: Cambridge University Press). The focus was by then clearly on adaptive management, less as a means to experimentation per se, and instead as means to better assure the best available evidence to inform quality decisions about policy and management interventions. The title of an edited volume hits the nail on the head: Fortman, L. (ed.) 2008. *Participatory Research in Conservation and Rural Livelihoods. Doing Science Together*. Hoboken, NJ, USA: Wiley-Blackwell. That more of the examples come from social sciences and experiences in the developing world make them no less applicable to engaging people in collaborative, participatory research and decision-making.

[xxiv] Månsson, J., et al. 2023. Understanding and overcoming obstacles to adaptive management. *Trends in Ecology and Evolution* https://doi.org/10.1016/j.tree.2022.08.009

[xxv] Lee, K.N. 1993. Compass and Gyroscope: Integrating Science and Politics for the Environment. Washington, DC, USA: Island Press.

[xxvi] Kingsford, R.T. et al. 2017 expressed it well: "… adaptive management has acquired different meanings, from rigorous experimentation to simple adaptability. Neither serves adaptive management well. The former is a straitjacket on the reality of managing large complex social-ecological systems with few opportunities for [traditional] experimentation while the latter allows managers to define mere changes in decisions as adaptive management." See Strategic adaptive management (SAM) of intermittent rivers and ephemeral streams. Pp. 535-562 in Datry, T. et al. *eds*. *Intermittent Rivers and Ephemeral Streams.* Amsterdam, NLD: Elsevier https://doi.org/10.1016/C2015-0-00459-2

[xxvii] Open Science – Helping to make science accessible for all Canadians. Available at https://science.gc.ca/site/science/en/open-science.

[xxviii] *e.g.*, Edelmann, N. & Albrecht, V. 2023. The Policy Cycle: A framework for knowledge management of practitioner's expertise and role in participatory processes. *Frontiers in Political Science* https://doi.org/10.3389/fpos.2023.1223013

THE "SARA PROCESS" AS STRUCTURED DECISION MAKING

[xxix] Turcotte *et al*. (2021. Fixing the Canadian *Species at Risk Act*: identifying major issues and recommendations for increasing accountability and efficiency. *FACETS* https://www.facetsjournal.com/doi/full/10.1139/facets-2020-0064) recommended to introduce automatic species and habitat protections, similar to Ontario's ESA, to SARA, in effect bypassing Ministerial review and recommendations to the Governor in Council. Though not technically removed from Ontario's ESA, Bergman *et al*. (2020. How to rescue Ontario's Endangered Species Act: a biologist's perspective. *FACETS* http://dx.doi.org/10.1139/facets-2019-0050) called for the return of automatic listing, or at least automatic prohibitions, to Ontario's *Endangered Species Act* which had been suspended by a series of exemptions beginning in 2010. Gordon et al. (2024. Assessing species at risk legislation across Canadian provinces and territories. *FACETS* https://www.facetsjournal.com/doi/full/10.1139/facets-2023-0229) recommended that every jurisdiction across Canada, but Manitoba and Nunavut, also adopt automatic protections of prohibitions. At the time of writing, the Ontario government had posted a proposal to repeal the ESA altogether to introduce a new Species Conservation Act. However, whether to introduce or restore automatic protections or prohibitions is, in one important sense, a red herring. Policy makers would have to be very sure those mesaures would produce the desired effects. What matters more than when

legal protections and prohibitions kick in is that COSEWIC and decision makers have the causality right. COSEWIC's role as defined in SARA does not exclude it: COSEWIC will "… assess the status of each wildlife species considered by COSEWIC to be at risk and, as part of the assessment, identify existing and potential threats …" (Species at Risk Act SC 2002, c. 29).

[xxx] Consider, for example, a series of papers chronicling the curious case of the declining bobolink in Ontario that, in the right circumstances, is an anthrophilic songbird which nests in surrogate grassland habitat including hay and pasture. It was designated as Threatened by COSEWIC, and consequently COSSARO, by reason, among others, of the risk posed by cutting hay during the breeding season. The research group first considered the *states* of bobolink populations at the scale of agricultural census districts, rather than at national- or provincial-level scales on which the threat assessments were based. Surprisingly, the recovery target for bobolinks agreed to by a Minister's Roundtable – to slow the rate of decline to less than 10% per year – was, on a reasonable probability, already met or exceeded in the majority of census districts (Ethier, D.M. & Nudds, T.D. 2015. Scalar considerations in population trend estimates: Implications for recovery strategy planning for species of conservation concern. *Ornithological Applications* https://doi.org/10.1650/CONDOR-15-89.1), raising doubts about the extent to which 1-size-fits-all policy/management interventions would effectively, efficiently or necessarily address concern about bobolink populations. Turning to *causes*, they elicited local knowledge from both the agri-food and conservation sectors to assemble a precursor to a Bayesian belief network. Together, knowledge holders identified potential causal factors not identified in primary scientific literature (Ethier, D.M. & Nudds, T.D. 2017. Complexity of factors affecting bobolink population dynamics communicated with directed acyclic graphs. *Wildlife Society Bulletin* https://doi.org/10.1002/wsb.739). On this foundation, they explored how those different causal factors might account for the wide variation in population trends across agricultural census districts (Ethier, D.M., et al. 2017. Spatiotemporal variation in mechanisms driving regional-scale population dynamics of a threatened grassland bird. *Ecology and Evolution* https://doi.org/10.1002/ece3.3004). Paradoxically, they detected a positive trend between growth of both human and bobolink populations and speculated that the 1.8M acres of greenbelt created around the Greater Toronto Area which retained smaller farms, more organic farms and lower loss of cattle farming might be responsible.

[xxxi] Committee on the Status of Endangered Wildlife in Canada. 2021. Instructions for preparing species status reports. Available at https://cosewic.ca/index.php/en/instructions-preparing-status-reports.html.

UNCERTAINTY AND THE COSEWIC PROCESS

[xxxii] For example, James Lukey and Stephen Crawford (2009. Consistency of COSEWIC species at risk designations: freshwater fishes as a case study. *Canadian Journal of Fisheries and Aquatic Sciences* https://doi.org/10.1139/F09-05) experimented with an algorithm to isolate the effect of informing designations for 49 freshwater fish species with quantitative evidence alone, compared to COSEWIC designations from status reports. Overall, there was 50% agreement between predicted and observed designations. Lukey et al. (2010. Effect of information availability on assessment and designation of species at risk. *Conservation Biology* https://doi.org/10.1111/j.1523-1739.2010.01555.x) subsequently demonstrated that information availability affected the risk designation assigned to a species and recommended "a conscious determination of whether such effects are desired, … [and] the development of methods to explicitly characterize and incorporate information availability and other sources of uncertainty in decision-making processes". Laura Trout (2013. *Uncertainty and decision-making for species-at-risk assessments in Canada*. https://atrium.lib.uoguelph.ca/server/api/core/bitstreams/c83c4934-b4d6-4278-a2c5-c27e02ba686d/content) updated Lukey's and Crawford's study with data from fish species re-assessed by COSEWIC in the interim, to which she added all other vertebrates with completed status assessments to that time. With a sample size of 374 species, she confirmed that the fewer the data, the greater the probability that a species was up- or down-designated compared to COSEWIC's designation. Importantly, the error in the pattern of expected (COSEWIC) against observed (algorithm-predicted) species' designations was random, *i.e.*, there was no evidence of systematic bias; chance provides the most parsimonious explanation.

[xxxiii] Scientists have addressed how to list species under uncertainty (*e.g.*, Akçakaya, H.R. et al. 2001. Making consistent IUCN classifications under uncertainty. *Conservation Biology* https://doi.org/10.1046/j.1523-1739.2000.99125.x; Newton, A.C. 2010. Use of a Bayesian network for Red Listing under uncertainty. *Environmental Monitoring and Software* https://doi.org/10.1016/j.envsoft.2009.07.016). As a proof-of-concept to improve transparency in how uncertainty is reported and considered in COSEWIC species' assessments, Lukey et al. (2011. Effect of ecological uncertainty on species-at-risk decision-making. COSEWIC expert opinion as a case study. Animal Conservation https://doi.org/10.1111/j.1469-1795.2010.00421.x) incorporated expert opinion directly into threat assessments. Nantel (2010. A Bayesian Belief Network for assessing species status under uncertainty. Internal COSEWIC Report. 21pp.) reported on the use of Bayesian belief networks to designate the threat status of marine fishes in Canada.

[xxxiv] Holt, A.R., et al. 2002. Occupancy-abundance relationships and spatial distribution: a review. *Basic and Applied Ecology* https://doi.org/10.1078/1439-1791-00083.

[xxxv] For assessment purposes, COSEWIC requires fairly straightforward calculations of Extent of Occurrence and Index of Area of Occupancy (https://cosewic.ca/index.php/en/assessment-process/cosewic-assessment-process-categories-and-guidelines.html). Beneath these quantitative criteria lie a number of general assumptions (Elith, J. & Leathwick, J.R. 2009. Species distribution models: ecological explanation and prediction over space and time. *Annual Review of Ecology, Evolution and Systematics* https://doi.org/10.1146/annurev.ecolsys.110308.120159) that have come under scrutiny (*e.g.*, Guisan, A. & Thuiller, W. 2005. Predicting species distribution: offering more than simple habitat models. *Ecology Letters* https://doi.org/10.1111/j.1461-0248.2005.00792.x; Fois, M et al. 2018. Using species distribution models at local scale to guide the search of poorly known species. *Ecological Modelling* https://doi.org/10.1016/j.ecolmodel.2018.07.018; Lee-Yaw, J.A., et al. 2022. Species distribution models rarely predict the biology of real populations. *Ecography* https://doi.org/10.1111/ecog.05877). See McCune (2016. Species distribution models predict rare species occurrences despite significant effects of landscape context. Journal of *Applied Ecology* https://doi.org/10.1111/1365-2664.12702) for an example of how species distribution models can increase search efficiencies for rare and patchily distributed species. Importantly, proximity to adjacent patches of the same rare plant species was a predictor of new occurrences. Nantel et al. (2018. Viability of multiple populations across the range of a species at risk: the case of Pitcher's thistle, *Cirsium pitcher*, in Canada. *Global Ecology and Conservation* https://doi.org/10.1016/j.gecco.2018.e00445) conducted a population viability analysis (COSEWIC's Criterion E) of a rare, patchily distributed thistle. Originally listed as endangered, it was down listed to special concern after more populations were found. Their multi-population stochastic projections based on these greater number of patches confirmed the lower risk category; the plant was likely to persist in Canada over the next 100 years. Had COSEWIC known in 2002 what it did by 2010, a recovery strategy would not necessarily have been triggered.

[xxxvi] Benoit, D., et al. 2018 Assessing the impacts of imperfect detection on estimates of diversity and community structure through multispecies occupancy modelling. Ecology and Evolution https://doi.org/10.1002/ece3.4023; Bennett, J.R., et al. 2024. How ignoring detection probability hurts biodiversity conservation. *Frontiers in Ecology and the Environment* https://doi.org/10.1002/fee.2782.

[xxxvii] To be sure, there comes a limit when there are sufficient data to rigorously test hypotheses, such as those about changes in the abundance and distribution of species considered at risk. Value of information (VOI) analyses help to make the business case about how much is enough. See Runge, M.C., et al. 2011. Which uncertainty? Using expert elicitation and value of information to design and adaptive program. *Biological Conservation* https://doi.org/10.1016/j.biocon.2010.12.020; Aikinlotan, M.D., et al. 2024. Beyond expected values: Making environmental decisions using value of information analysis when measurement outcomes matter. *Environmental Indicators* https://doi.org/10.1016/j.ecolind.2024.111828

[xxxviii] Ecologists have long recognized one of ecology's very few "laws" that species' abundances are log-normally distributed; that is to say, relatively few are naturally abundant, and the great majority are rare. Since it was first outlined by *Rabinowitz (1981.* Seven forms of rarity, in Synge, H. ed. The Biological Aspects of Rare Plant Conservation. NY, NY, USA: Wiley) it has been widely applied and adapted, very recently by Crisfield et al. (2024. How and why species are rare: towards an understanding of the ecological causes of rarity. *Ecography* https://doi.org/10.1111/ecog.07037). Some

species are widely abundant at low densities and, so rare locally. Others are locally abundant but patchily distributed at high densities, and rare over larger spatial extents. For many species, scientists may be reasonably assured to which type of natural pattern, or *state*, at a particular spatial resolution, a specie can be assigned. But teasing apart human *causes* of rarity from natural *causes* is not necessarily as straight forward as it may seem, and neither may be the policy/management interventions to address them.

[xxxix] *e.g.*, Steenweg, R., et al. 2017. Sampling scales define occupancy and underlying occupancy-abundance relationships in animals. *Ecology* https://doi.org/10.1002/ecy.2054; Steenweg, R., et al. 2019. Species-specific differences in detection and occupancy probabilities help drive ability to detect trends in occupancy. *Ecosphere* https://doi.org/10.1002/ecs2.2639.

INCENTIVIZING PARTICIPATORY RESEARCH AND DECISION-MAKING WITH PRODUCERS AND THE AGRI-FOOD SECTOR

[xl] *e.g.*, Williams, B. K. & Brown, E.D. 2012. Adaptive Management: The U.S. Department of the Interior Applications Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

[xli] Evans, M.C. 2021. Re-conceptualizing the role(s) of science in biodiversity conservation. *Environmental Conservation* https://doi.org/10.1017/S0376892921000114; Smetchska, B. & Gaube, V. 2020. Co-creating formalized models: Participatory modelling as a method and process in transdisciplinary research and it potential impacts. *Environmental Science and Policy* https://www.sciencedirect.com/science/article/abs/pii/S1462901119303909

[xlii] Too often considered 'nice to have' rather than 'need to have', monitoring the outcomes of policy and management interventions is critical evaluating the effectiveness and efficiency of policy/management interventions See Lyons, J.E., et al. 2010. Monitoring in the context of structured decision-making and adaptive management. *Journal of Wildlife Management* https://doi.org/10.2193/2008-141 and Campbell, S.P., et al. 2022. An assessment of monitoring plans in endangered species recovery plans. *Ecological Applications* https://doi.org/10.1890/1051-0761(2002)012[0674:AAOMEI]2.0.CO;2.

[xliii] Reiter, D., et al. 2022. Lessons learnt from multiple private land conservation programs in Canada to inform species at risk conservation. *Canadian Geographer* https://doi.org/10.1111/cag.12770; Ayambire, R.A., et al. 2021. Incentivizing stewardship in a biodiversity hot spot: land managers in the grasslands. *FACETS* https://doi.org/10.1139/facets-2020-0071

[xliv] Reiter, D., et al. 2019. Stakeholder engagement with environmental support systems: the perspective of end users. *Canadian Geographer* https://doi.org/10.1111/cag.12555.

[xlv] See Alberta Biodiversity Monitoring Institute policy with regard to land access, confidentiality and data usage. Available at https://abmi.ca/abmi-home/working-together/land-access/confidentiality-and-data-usage.html.

[xlvi] Cover letter and policy kindly made available from records of the Ontario Federation of Agriculture, Guelph ON and available on request.

[xlvii] Canadian Agri-Food Policy Institute. 2022. Achieving Balance: The Future of the Environmental Farm Plan Program in Canada. Canadian Agri-Food Policy Institute. Ottawa, ON. Report available at https://capi-icpa.ca/explore/resources/achieving-balance-the-future-of-the-environmental-farm-plan-program-in-canada/. Arguably, however, EFP programs require reinvigoration themselves, suggesting an opportunity to incorporate SAR-related modules involving surveys for species inventories and monitoring best management practices for the maintenance or creation of SAR habitat (*e.g.,* https://www.ontariosoilcrop.org/species-at-risk-farm-incentive-program/) in Ontario (https://farmtario.com/crops/new-online-decision-making-tool-for-species-at-risk/) and Alberta

(https://www.canadianfga.ca/en/projects/habitat-biodiversity-assessment-tool/) under the auspices of the Canadian Forage and Grass Association.

[xlviii] Sustainable Canadian Agricultural Partnership. 2024. Environmental Farm Plans Modernization Report. Available from the Ontario Soil and Crop Improvement Association (OSCIA) at https://www.ontariosoilcrop.org/wp-content/uploads/2024/07/EFP-Modernization-Report-2024-July-FINAL.pdf. Uptake rates of EFPs confirm OSCIA's earlier research indicating strong interest in environmental performance among landowners. See Garrah, L. 2014. Risk or Reward: An Investigation of Ontario Farmer Perceptions of Species at Risk. https://www.ontariosoilcrop.org/wp-content/uploads/2022/11/sar_survey_results.pdf.

[xlix] There are no provisions for safe harbour agreements (SHAs) under SARA. Since 2010, Ontario's ESA has provided for SHAs (https://www.ontario.ca/page/safe-harbour-habitat-under-endangered-species-act). As of spring 2025, "there has been limited uptake for safe harbour/stewardship agreements under the ESA (e.g., only two created since 2020). One created an artificial nesting structure for Bank Swallow with 120 burrow holes, and the other created approximately 87 ha of meadow habitat for Monarch butterfly. There has been a single registration for the safe harbour habitat conditional exemption, which was for a safe harbour instrument from prior to 2020" (G. Desy, Ontario Ministry of Environment, Conservation and Parks, *personal communication*). It is difficult to assess uptake of other conservation incentives, for example, under the Species at Risk Partnerships on Agricultural Lands (SARPAL,) or the Species at Risk Farm Incentive Program (SARFIP), perhaps due to landowners' privacy concerns (J. Pittman, U Waterloo, *personal communication*).

[l] Pittman, J., et al. 2025. The social fit of conservation policy on working landscapes. *Rangeland Ecology and Management* https://doi.org/10.1016/j.rama.2025.01.009.

CONCLUSION

[li] Whether expanding regulatory frameworks to soil biodiversity is necessary or feasible in a North American agricultural context (Köninger, J., et al. 2022. In defence of soil biodiversity: towards an inclusive protection in the European Union. *Biological Conservation* https://doi.org/10.1016/j.biocon.2022.109475), huge attention is being paid to it (*e.g.*, Geisen, S., et al. 2019. Challenges and opportunities for soil biodiversity in the Anthropocene. Current Biology https://doi.org/10.1016/j.cub.2019.08.007; Filho, W.L., et al. 2023. Handling the impacts of climate change on soil biodiversity. *Science of the Total Environment* https://doi.org/10.1016/j.scitotenv.2023.161671; Saleem, M., et al. 2019. More than the sum of its parts: Microbiome biodiversity as a driver of plant growth and soil health. *Annual Reviews of Ecology, Evolution and Systematics* https://doi.org/10.1146/annurev-ecolsys-110617-062605).

[lii] Rainsford, F.W., et al. Biodiversity accounting on farms: relating diversity of bird assemblages to ecosystem condition. *Science of the Total Environment* https://doi.org/10.1016/j.scitotenv.2024.177974.

[liii] As with so many famous quotes, different versions of this one are available. "To keep every cog and wheel is the first precaution of intelligent tinkering" is from Leopold, A. 1949. Sand County Almanac. Oxford, UK: Oxford University Press.

[liv] Swerdfager and Olive (2023. Laws matter: a foundational approach to the conservation of biodiversity in Canada. FACETS https://doi.org/10.1139/facets-2022-0095) provide a compelling review of the adequacy of Canadian law for the conservation of biodiversity, that sidesteps automatic listing, protections and prohibitions.

[lv] It is hard to imagine just how long the list of opportunity costs might be. It extends at least to time, energy and resources to administer permits under Ontario's ESA that, according to the Auditor General of Ontario (https://www.auditor.on.ca/en/content/annualreports/arreports/en21/ENV_ProtectingSpecies_en21.pdf) have never been denied. Perhaps, from a systems perspective, they extend also to human health and welfare (See *Burnout a problem*

in the conservation sector by Farmtario's Matt McIntosh https://farmtario.com/news/burnout-a-problem-in-conservation-sector/.

[lvi] The term 'management strategy evaluation' is more frequently encountered in the realm of adaptive management of fisheries (*e.g.,* Punt, A.E., *et al*. 2014. Management strategy evaluation: best practices. *Fish and Fisheries* https://doi.org/10.1111/faf.12104). However, it has the "potential to transform terrestrial conservation" by including stakeholders and others in participatory scenario analyse of alternative policy/management interventions in a virtual setting before real world applications (*e.g.,* Bunnefeld, N., et al. 2011. Management strategy evaluation: a powerful tool for conservation? *Trends in Ecology and Evolution* https://www.cell.com/trends/ecology-evolution/abstract/S0169-5347(11)00133-9?large_figure=true). See also Decision Support at Nature Analytics (https://natureanalytics.ca/mse/).

[lvii] 'Turtles all the way down' refers to the creation story that the world was made on the back of a giant turtle that stands on the back of an even larger turtle, and so on (Turtles all the way down - Wikipedia). It is appealing to link the problem of infinite regress with which pragmatists grapple to Indigenous wisdom, and both to the important idea that scientists are compelled, or ought to be, to keep asking why until they understand (Copeland, C.L. 1994. *Really Important Stuff My Kids Have Taught Me*. NY, NY USA: Workman Publishing. https://www.goodreads.com/book/show/24693029-really-important-stuff-my-kids-have-taught-me). Infinite regress is not a problem if it is accepted that wicked ones resist silver bullet solutions because they are open- rather than closed-looped by their nature.