Science Advances

Supplementary Materials for

Hallmarks of science missing from North American wildlife management

Kyle A. Artelle, John D. Reynolds, Adrian Treves, Jessica C. Walsh, Paul C. Paquet, Chris T. Darimont

The PDF file includes:

- Supplementary Text
- fig. S1. Number of criteria (out of possible 11) present in wildlife management plans across Canadian provinces/territories and U.S. states ($N = 667$).
- fig. S2. Effect of management characteristics on number of criteria present.
- fig. S3. Effect of management characteristics on number of criteria present.
- table S1. Inter-observer agreement.
- References (*29–44*)

Other Supplementary Material for this manuscript includes the following:
(available at advances.sciencemag.org/cgi/content/full/4/3/eaao0167/DC1)

- database S1 (Microsoft Excel format). Assessment data (assessments of all available management documents, for example, online resources, wildlife management plans, or other available documents).
- metadata S1 (Microsoft Excel format). Metadata about all management documents scored in this analysis (that is, those referenced in database S1; including URLs, where possible).

Supplementary Text

Hallmarks of science-based management: Expanded descriptions

Measurable objectives
Setting measurable objectives guides management, ensuring approaches are consistent with reaching pre-determined outcomes for wildlife populations being managed (*5, 6, 29*). Clear objectives provide concrete baselines against which to assess efficacy (*30, 31*); ecological data are particularly useful if they inform an underlying objective (*11*) or, in research, a hypothesis (*1*). We focused on objectives for the wildlife populations being managed, not social objectives such as increasing hunter participation or maintaining public support for wildlife management.

Criterion evaluated
Provide measurable objectives: Are measurable objectives provided in the plan (*e.g.* limiting probability of extinction below a threshold, maintaining desired population sizes and sex ratios)?

Evidence
Considering and applying scientific evidence can help to support well-informed decision-making (*8, 32–34*). The importance of incorporating scientific information and other forms of evidence into conservation practice is now broadly recognized (*35, 36*). Moreover, effective wildlife management requires baselines to evaluate success in meeting objectives; knowledge on how many individuals comprise populations, population status and trends, and the impacts of human-caused mortality are fundamental to managing hunted populations effectively (*7, 8*). Seeking external evidence, whether from publications, or through collaboration with scientists (*e.g.* academic researchers), can also improve the use of scientific evidence in management decisions (*36, 37*). Finally, careful consideration and communication of the uncertainty inherent to most scientific evidence is necessary to safeguard against errors arising from the precision, quality, or limitations of the data (*5, 7, 9, 14, 19, 38, 39*).

Criteria evaluated
Report quantitative information about populations: Is quantitative information provided for the managed populations (*e.g.* densities, trends)?
Report uncertainty in population parameter estimates: Are estimated population parameters reported with confidence intervals or as ranges?
Estimate realized hunting rates: Is the total hunting mortality in the population measured and reported?

Transparency
Describing all evidence, methods, assumptions, and prior knowledge in a replicable and cogent fashion allows external verification of the reliability, credibility, and relevance of approaches used (*40*). Ensuring this information (and access to agencies) is available and interpretable to the public might similarly be expected for resource management that is publicly funded (*41*). Similarly, transparency of decision-making might shed light

on the necessary involvement of factors other than science (*5, 19, 42*). Beyond good governance, such transparency might also lead to better management outcomes (*10*).

Criteria evaluated

Explain technique for setting hunting quotas: Is there a description of the approach used to set quotas?
Explain how population parameters are estimated: Is the technique used to estimate population parameters (*e.g.* abundance, density, trend) specified (*e.g.* aerial surveys/genetic tagging/ expert opinion/camera trapping)?
Explain how realized hunting rates are estimated: Is there an explanation of how hunting rates are measured (*e.g.* hunter survey/mandatory reporting/check-in stations/hunting tags)?
Provide publicly-available management information: Is the species management plan (or similar wildlife management documents) publicly available?
Respond to public inquiry: Did the management agency respond to our emails asking for verification of scorings and/or further information?

Independent review
Reviews allow approaches to be assessed for potential shortcomings, errors, and general rigor, as well as to ensure that approaches are defensible, transparent, appropriate for achieving goals, informed by relevant evidence, and that evidence presented supports conclusions reached (*5, 8, 29, 43*). Independent (external) review might better ensure impartiality in the assessment (*7*).

Criteria evaluated
**Subject management plans to any review**: Does the plan mention being subjected to any form of review?
Subject management plans to external review: If the plan was reviewed, were reviewers external (*e.g.* from the public, an outside organization, or a university)?

Non-exhaustive indicators
The criteria we examined were not exhaustive, but might instead be considered indicators of identified hallmarks. For example, although beyond our scope, assessing whether management objectives are being met, with appropriate responses planned for when they are not, might be an important component for achieving *measurable objectives* (*29*). Moreover, a clear accounting of how decisions flow logically from evidence to management prescriptions would be an important component of *transparency*, and assessments of the *quality* of *evidence* being used might be important for conveying the level of risk involved with a given management prescription (*44*).
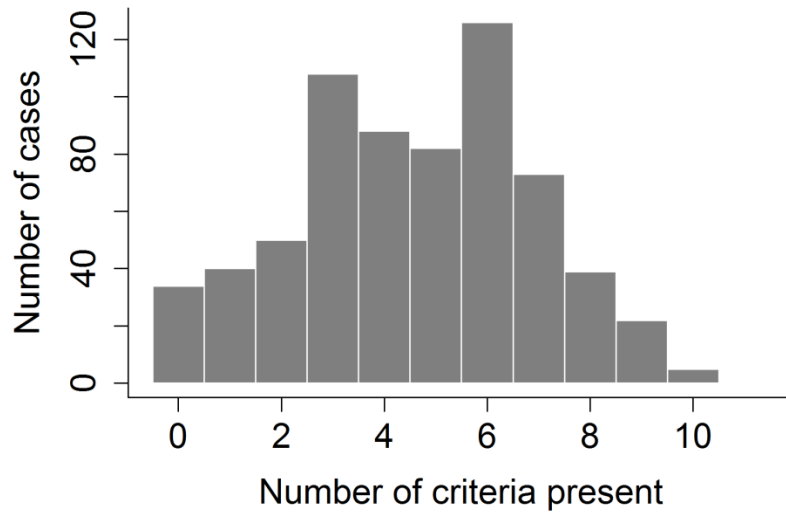
fig. S1. Number of criteria (out of possible 11) present in wildlife management plans across Canadian provinces/territories and U.S. states (*N* = 667).
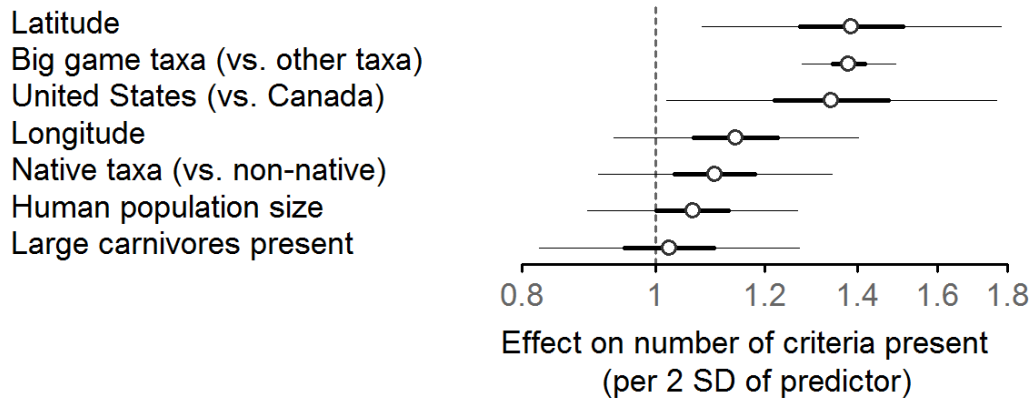
fig. S2. Effect of management characteristics on number of criteria present. Number of criteria out of 11, including both independent review hallmark criteria as responses (c.f. Fig 2) across plans. Coefficients shown are odds ratios from a multi-level model, with thick and thin bars representing 50% and 95% confidence intervals, respectively, and plotted on a log scale.
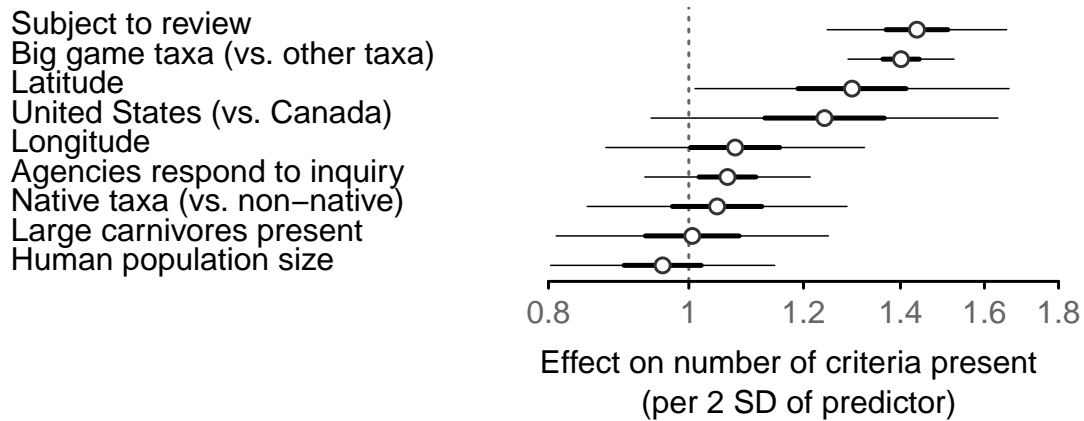
fig. S3. Effect of management characteristics on number of criteria present. Number of criteria out of 8, excluding both independent review hallmark criteria and the response of agencies criterion as responses across plans. Coefficients shown are odds ratios from a multi-level model, with thick and thin bars representing 50% and 95% confidence intervals, respectively, and plotted on a log scale

table S1. Inter-observer agreement. Calculated as the percentage of initial scorings (by Marlie van Roy) that matched rescores (by Kyle A. Artelle and Kate Field).

Hallmark	Criterion	Inter-Observer Agreement (%)
Measurable objectives	Provide measurable objectives	86
Evidence	Estimate realized hunting rates	93
	Report quantitative information about populations	88
	Measure uncertainty in population parameter estimates	86
Transparency	Provide publicly-available management information	96
	Explain how realized hunting rates are estimated	80
	Explain how population parameters are estimated	75
	Explain technique for setting quotas	88
Independent review	Subject management plans to any review	89
	Subject management plans to external review	96
		Mean: 88%