The costs and benefits of publicising species discoveries.

Gerard Edward Ryan[1,2,*], Emily Nicholson[3], Christopher M. Baker[4,5,6] Michael A. McCarthy[3]

[1] Telethon Kids Institute, Nedlands, 6009, WA, Australia

[2] Melbourne School of Population and Global Health, University of Melbourne, 3010, VIC, Australia

[3] School Agriculture, Food and Ecosystem Services, University of Melbourne, 3010, VIC, Australia

[4] School of Mathematics and Statistics, University of Melbourne, 3010, VIC, Australia

[5] Melbourne Centre for Data Science, University of Melbourne, 3010, VIC, Australia

[6] The Centre of Excellence for Biosecurity Risk Analysis, School of BioSciences, University of Melbourne, 3010, VIC, Australia

*Corresponding author: gerard.ryan@telethonkids.org.au

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Abstract

Public information about where species are found can influence what happens to them – from building support to protect their habitat, to telling poachers where to find a target. Recent heated scientific debate about whether to release information about species' locations when new species or populations are found have highlighted the trade-off between the risk of damage or loss versus the benefits of funding and public support. But no research so far has considered how such decisions are actually made, and no decision tools easily compare a range of decision-making scenarios. Here we present a simple decision tool to compare the costs and benefits of decisions about the disclosure of information about newly-discovered species and populations. We implement our method for seven ongoing conservation projects, where information about a species is currently completely or partially secret. We ask decision-makers to estimate the costs and benefits associated these case studies, and apply our method to them. The method is a structured but flexible approach to making decisions about whether to publicised the discovery of species, and one that can allow the process of decision-making to be transparent and easily communicated if needs be.

Introduction

Species continue to be discovered and rediscovered (Keith & Burgman 2004; Scheffers et al. 2011; Meijaard & Nijman 2014). Discoveries strike public interest, are rare environmental good news (Smith et al. 2010; Watson & Davis 2017), and provide data for managing biodiversity (Tulloch et al. 2018). Environmental news is dominated by sensational negativity (Lowe & Morrison 1984), and conservation science traditionally focussed on crises (Soulé 1985). Yet positive messaging and hope is necessary to solve environmental problems (Chawla & Cushing 2007; Garnett & Lindenmayer 2011). Discoveries and publicity can bring funding or protection for species (Scheffers et al. 2011; Veríssimo et al. 2017). The drive to rediscover species can also bring resourcing for poorly known species (Butchart et al. 2005; Watson & Davis 2017). Separately, impetus exists to make data open and accessible, for better inference, reproducibility, and use of existing information (Reichman et al. 2011; Costello et al. 2013; Hampton et al. 2013). Clearly publicising discoveries of species and populations can be beneficial.

However, publicising discoveries can be detrimental too (Meijaard & Nijman 2014; Ryan & Baker 2016; Lindenmayer & Scheele 2017). Species can be harmed by disturbance (Kelly et al. 2003), exposed to disease (NSW Department of Environment and Conservation 2006), and risk poaching if their location is known (Webb et al. 2002) — even a vague location (Meijaard & Nijman 2014). Species are often more valuable when rare (Angulo et al. 2009), and so newly discovered species may be at particular risk of exploitation if their existence is public (Stuart 2006). As data become more accessible, rapid growth in internet use increases the spread of information about biodiversity, and it is increasingly necessary for databases to obscure or hide sensitive occurrence records (Chapman 2020). Understanding the nature of this trade-off in costs and benefits is increasingly important.

Releasing locations when new species or populations are found is hotly debated (Meijaard & Nijman 2014; Lindenmayer & Scheele 2017). In several discoveries, researchers and managers have chosen to withhold locations from the public: the Night Parrot in Australia (Worthington 2013), or the silver-backed chevrotain in Vietnam (Nguyen et al. 2019). Such decisions rely on knowledge and intuition; whereas decision support tools could explore the trade-offs in the range of decisions available, account for uncertainty, and consider risk attitude.

Some methods exists to assist such decisions, but none of these fulfil all desirable criteria (Ryan & Baker 2016, 2019; Tulloch et al. 2018). Meijaard and Nijman (2014) present a graphical model of relative costs and benefits, and suggest that publicity should only occur if the benefits will increase relative to the costs. This is a simple heuristic, but it provides a discrete solution to a continuum of options. Alternatively, Tulloch and colleagues (Tulloch et al. 2018) provide a decision-tree approach to publishing biodiversity data in general, dependent on relevant threats. This approach is a useful guide, but relies on discrete alternatives and doesn't explicitly allow managers to explore trade-offs, apply their own risk attitude, or consider the probabilities of different outcomes. Ryan and Baker (2016, 2019) constructed a general theoretical framework to balance the costs and benefits when deciding to publicise the discovery of species, which can incorporate uncertainty and considers the probability of adverse outcomes whether the information is made public or not. Although Ryan and Baker's method can compare a suite of options, it is designed to be calculated as a binary choice between disclosing information not, rather than as a comparison of options. No studies that attempt thoroughly explore how such decisions are made, and none are tested in a real-world context.

Here we examine the costs and benefits in such decisions and use decision theory to assess them. First we generalise Ryan and Baker's (2016, 2019) method to trade-off costs and benefits, and examine the decision space. We then examine real-world examples by asking decision-makers to estimate the costs and benefits of disclosing information about real species discoveries and rediscoveries. We apply our method to these case studies whilst accounting for uncertainty and consider the suite of types of potential benefits and costs that decision-makers identify. This is the first such study to analyse this emergent problem in species conservation, and the methods provided can be used directly to inform future decisions about publicising species discoveries.

Methods

An updated decision analysis

Options confront decision makers, gradations from publishing all information, to publishing none, while considering the potential costs and benefits against some objective. A typical objective might be minimising the species' probability of extinction in some time-frame (Ryan & Baker 2016; Tulloch et al. 2018). If the decision affects resourcing for conservation, such as increased funding or increased costs, then the species' probability of extinction, PE, may change from some baseline PE_0, may to some PE_d (figure 1). Here we propose a method to make the decision to publicise a species discovery whilst minimising the probability of extinction based on the methods of Ryan and Baker (2016, 2019).

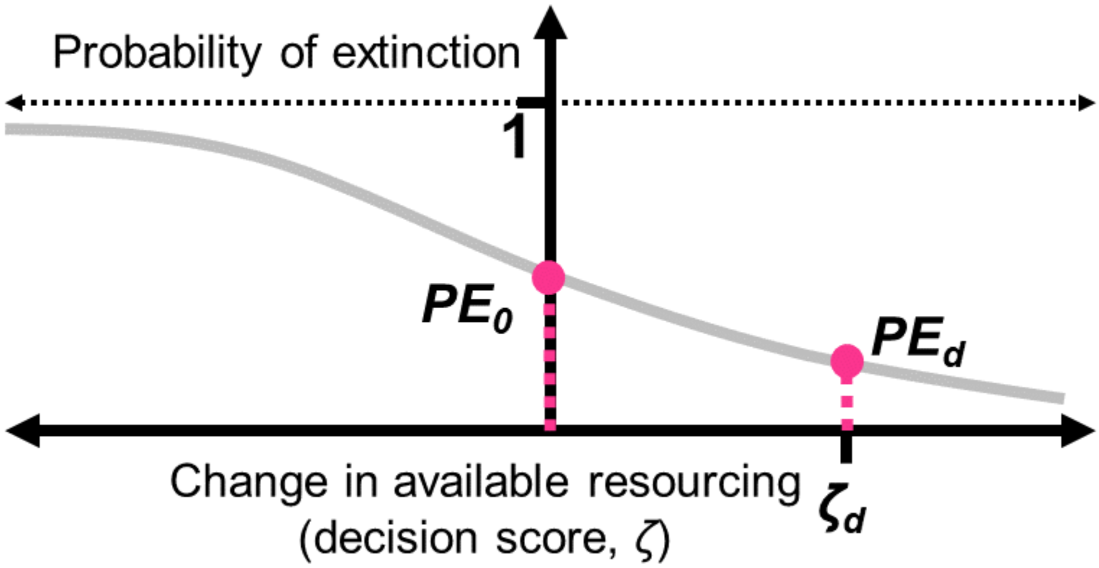

Figure 1. Grey line shows one possible relationship between probability of extinction (y-axis) and change in available resources or decision score (x-axis), with pink points showing baseline probability of extinction, and an example probability of extinction resulting from some decision *d*.

For decision *d*, there is some expected benefit B_d, and some expected cost C_d. If information were entirely public, the expected cost is C_p. Regardless of the decision, there is some probability p_d, that the information may become public anyway (such as a leak or accidental discovery) and the public scenario realized. If the decision is to publicise all information, then p_d equals one. Using these values we can calculate a decision score ζ_d, that represents the change in expected available resources (i.e., net benefit) towards conserving the species such that:

$$\zeta_d = B_d - C_d - p_d(C_p - C_d) \quad \text{Eq 1.}$$

This calculates the expected net benefits while accounting for the probability that information may become inadvertently public. If the relationship between the probability of extinction and the change in available resourcing resulting from the decision is monotonically decreasing with a range between 0 and 1 (e.g. figure 1), then the decision that maximises decision score ζ_d is the one that minimises the species probability of extinction, so meets the objective. The derivation of equation 1 is detailed in supporting information.

Simulation and Case studies

As an initial test of the utility of the method, we explore decision scores for four simulated species, over five levels of possible decisions. This is detailed further in supplement 1.

To obtain information on the costs and benefits of real decisions about whether to publicise information about species locations, we identified recent cases studies. Each case study species had either been newly discovered, rediscovered after considered extinct, or a new population was discovered in an area where it was not known to occur, and some or all information about this discovery was withheld from the public. For each species, we identified a key informant with knowledge of the decision. Informants were asked to complete a structured, written questionnaire about the decision.

Regardless of the actual decision made, informants were asked to provide estimates for three decision scenarios — if the discovery was made:

- Public (releasing the species identity and a location that could reasonably expect the species to be found)
- Partially public (releasing the species identity, but vague or no information about its location), or
- Not public / secret (they may inform other management agencies, scientists, or donors, in such a way that the information is not intentionally publicly released)

We asked informants for estimates of the costs and benefits associated with the case study using a four-point elicitation method: informants were asked the lowest and highest possible expected values, a most likely value, and the percentage degree of confidence that the true value lay between within their specified range (Speirs-Bridge et al. 2010; McBride et al. 2012). Informants were also asked the single best estimate of the probability of information becoming unintentionally public. Informants were instructed to consider all kinds of benefits and costs, and make an estimate of their equivalent monetary value, in the currency of their choice.

We asked informants to name the types of benefits and costs they expected to accrue for this case study, what kinds of entities were expected to accrue these benefits, and the source of such benefits. We then asked informants to name the types of benefits and costs associated with species discoveries in general, and to specifically consider if there were any additional costs or benefits to the species, the individuals, and the organisations involved in the discovery. Lastly informants were given the opportunity for free comment.

To protect the privacy of informants and information that is public, we only name species and the continent on which they occur if such information was already public and we received the express written consent of informants. The questionnaire was administered with approval of the University of Melbourne Faculty of Science Human Ethics Advisory Group, project ID 1750658.1.

Data analysis

All quantitative analyses were conducted using R 3.6.2 (R Core Team 2019). We use Monte Carlo simulation to explore our results and represent uncertainty (Burgman 2005). We encoded estimates of costs and benefits into probability distributions using numerical approximation. For each parameter, the fitted mode was equal to informants' estimates of the most likely value, and the fitted density between their upper and lower estimates was equal to their confidence that the true value occurred there. We fitted lognormal distributions to most responses; but exponential distributions when the lower and most likely estimates were equal to zero; and triangular distributions when either confidence was equal to one or where the lower and most likely value were equal and greater than zero, and the confidence interval was large such that a lognormal distribution could not be fit (table S3). Fitting is illustrative rather than definitive because we did not ask informants the distributions they expected and other distributions may also be reasonable (McBride et al. 2012).

From fitted distributions we drew 1000 replicate random samples of costs and benefits for each scenario (public, part, and secret) and calculated decision scores. For a given replicate, the decision scores for each scenario used their scenario-specific sample of costs, C_d, and benefits, B_d, and shared the replicate estimate of costs when public, C_p, (equation 1). To discriminate among scenarios we determined for each replicate which decision was best or worst, i.e., had the highest or lowest the decision score, and whether a given decision resulted in an expected net benefit, i.e., the decision score was greater than zero, and calculated the cumulative density of decision scores and first-order stochastic dominance (Canessa et al. 2016). Stochastic dominance is a decision-analytic tool that compares the probability distributions of alternative actions to determine whether some actions are preferential to others over the range of uncertainty.

Lastly, we consider the types of costs and benefits by coding responses into generic sub-classes (Supporting information 2), and calculated the frequencies of response types.

Results

Decision scores for simulated species' scenarios are in figure S1 and table S3, and are largely in line with expectation — that secrecy was better for species that may be poached or affected by tourism, and involving fewer groups, while openness and inclusion better for species with purely intrinsic values.

Eight informants returned the questionnaire. Two of the case studies are not public; we refer to these as "Species1" and "Species2". Six species have some information about the species' identity and location made public (i.e. made partly public). For Species2 the informant was unable to provide quantitative estimates, however completed the text responses to the questionnaire.

Estimated decision scores show generally high overlap and long distribution tails (figure 2 and figure S2). Smooth newts are the only species with a first-order dominant scenario — public. For alpine tree-frog, Giant Ibis, and red handfish, part-public dominates secret; while for tiger, public dominates secret. (Dominant means always better than over the distribution). Often decisions that may dominate for much of the range of values (figure 2) do not necessarily dominate at the tails (figure S2), and in this context tails may be of concern, especially lower bounds. Partial publicity is most frequently the best decision, while secret was the most frequent worst decision (figure 3, table S4). Often the decision that was most frequently the best decision was also beneficial, i.e., the decision score was usually greater than one (figure S3, table S5). Many decisions likely result in a net cost, and all decisions for Species1 (fig 1, and figure S3).

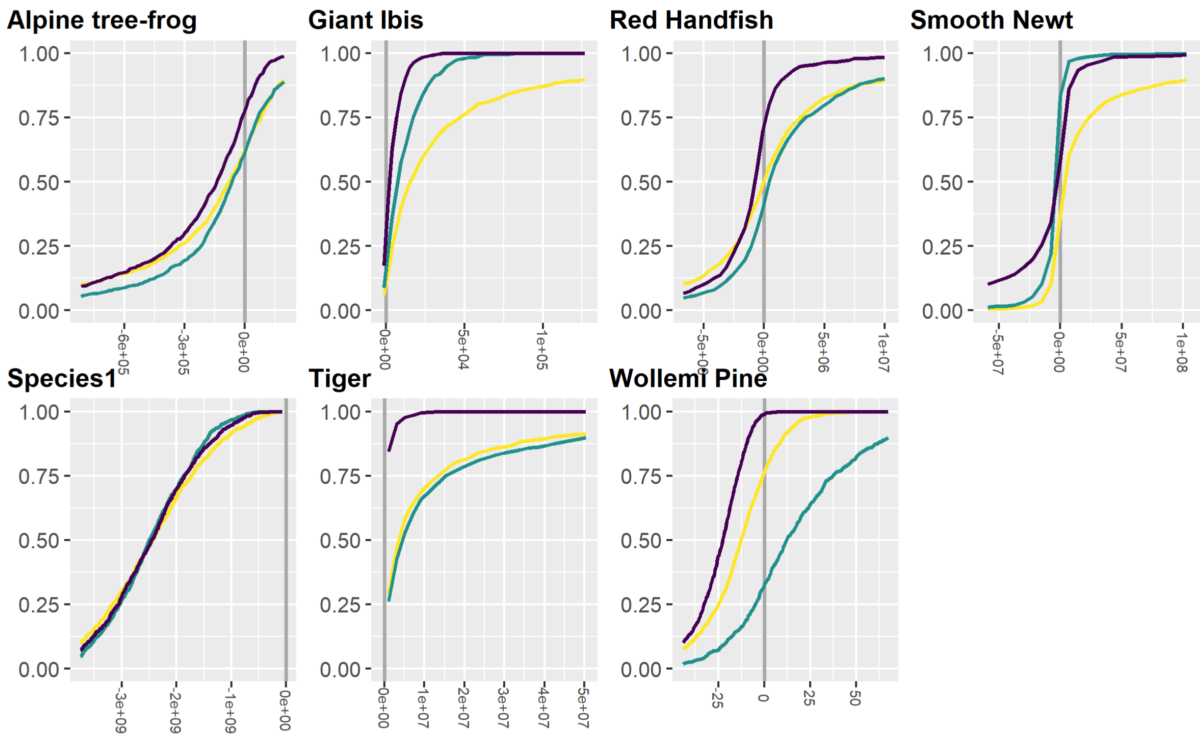

Figure 2. Cumulative densities (y-axis) of estimated decision scores, ζ, (x-axis), for case study species, for each of decision — public (yellow), part public (green) and secret (purple). For each species, panels show the middle 80th percentile ranges of all scenarios for that species (full range in figure S2). Grey line equals zero, and x-axis is relative to the range of scores for each species.

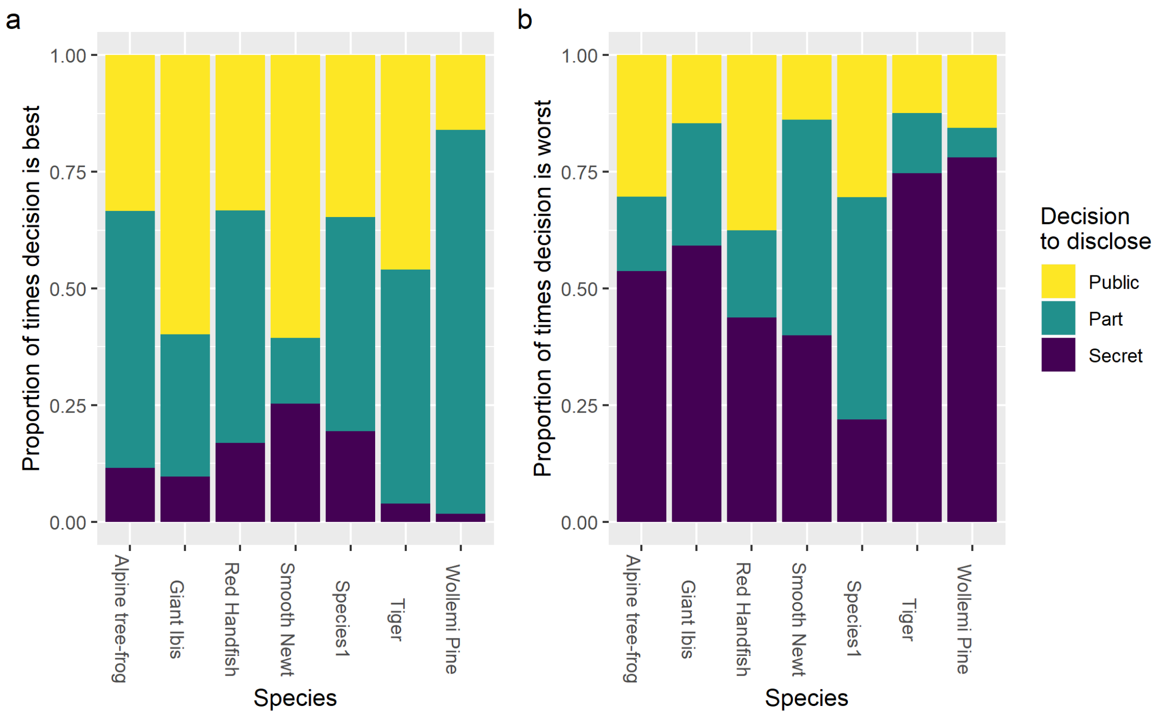

Figure 3. Proportion of simulation replicates that a given decision is (a) the best decision, i.e. highest decision score, or (b) the worst decision, i.e., lowest decision score.

All informants identified funding as a key benefit, most also identified awareness and public support, and efforts to protect and recover species (figure 4). Benefits were most often perceived as flowing to government agencies and NGOs, rather than necessarily to species themselves, though government agencies and NGOs were also perceived to be the sources of benefits too (figure. 5). Poaching was the most frequently identified cost, and government agencies and the species themselves were the most frequently identified bearers of costs (figure 4).

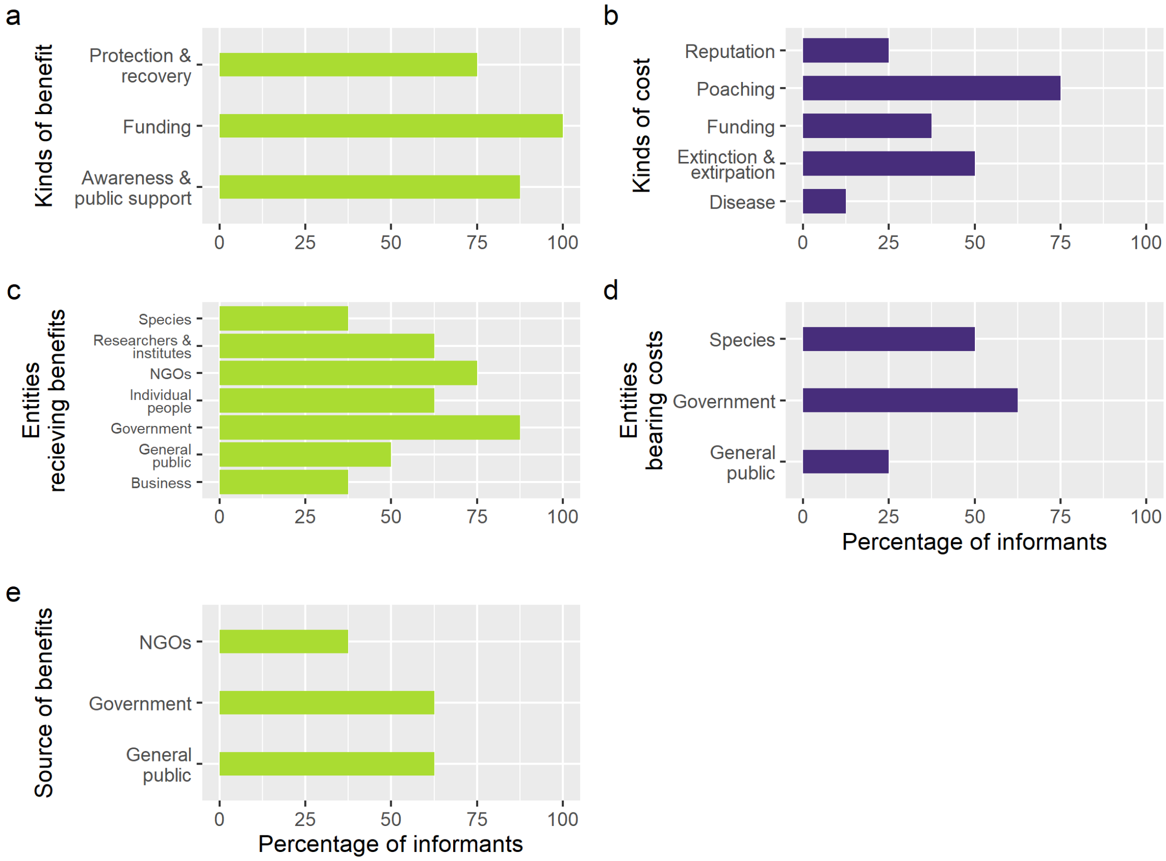

Figure 4. Percentage of informants providing types of responses to questionnaire about kind, recipient, and sources of benefits and costs.

Several informants made it clear that they had considered a range of benefits and costs and risks in making their decisions, though none claimed to have used a structured method to do this. Several identified difficulty estimating the magnitude of possible costs and benefits. Informants mentioned a range of motivations for not disclosing information, including to avoid taxonomic vandalism (Kaiser et al. 2013), and respect the wishes of local Indigenous peoples.

Discussion

We aimed to make decisions about publicising species discoveries transparent, to understand decision-makers' perceptions of the costs and benefits involved in real decisions, and to apply our method to real case studies. Our method appears to be appropriate, as results from the simulated species match intuitive expectations (figure S1). For instance, the largest relative benefits of publicity are expected for the species with mainly intrinsic values, as there is little cost to publicity. Species with high illegal value are best kept secret to avoid large costs. The better options for species with tourism value are either secret, where costs are not incurred, or public, where benefits are realised; rather than part-public, where greater costs are incurred than secret, but without realising the benefits of full publicity. The method can be applied usefully to case studies. For the smooth newt, publicity is the best decision over the range of possible outcomes, regardless of risk attitude, and is most often the best and least often the worst decision. Other species give less clear but still helpful outcomes. For the Wollemi Pine, partial publicity is clearly dominant over much (though not all) of the range of possible values (fig. 2), and is mostly best, and least often worst. For Species1 all outcomes resulted in net costs, while for tiger and Giant Ibis, almost all outcomes resulted in benefits. Such results can provide decision-makers with confidence.

In many decisions, the "best" outcome may depend on the decision maker's attitude to risk (Tulloch et al. 2015; Canessa et al. 2016), and may change depending on uncertainty in the state of the system (Regan et al. 2005; Nicholson & Possingham 2007); this is true in many of our case studies, and our method can help elucidate the process identifying attitude and uncertainty. In many cases the uncertainty about the state of the system, i.e., the range of possible costs or benefits, is larger than the differences in expected utility from a given decision (e.g. long-tailed, overlapping distributions in fig. 3). Where the system does not show clear first-order dominance, decision-makers may still defer to other tools such as assessing second-order dominance given their own risk preference (Canessa et al. 2016), choosing from the most-likely best or least-likely worst option (fig. 4), the most likely to return a positive outcome (which is also least-likely to return a negative one, figure S3), or explore the range of uncertainty necessary to change the optimal decision. We did not assess risk attitudes of our informants, however decision-makers applying the method can make such judgements for themselves. Our method is a mechanism for reassessment of decisions with additional information and changing circumstances. For instance it may be desirable to ensure protections are in place prior to publishing information (Stuart 2006), and increasing amounts of information released as suitable protections are enacted, such as happened with the night parrot (Murphy et al. 2017). This method allows for assessment of the utility of all such scenarios together.

A common objective in conservation is to minimise the probability of extinctions (Tulloch et al. 2018). Here we assume this is the main objective of decision makers too, and this is corroborated by informants' comments. Informants identified a wide range of costs and benefits to the species concerned, and those involved in their discovery, but reported some were not considered as part of the decision-making – such as benefits to reputations. There may be internal tensions between agencies that may expect to receive benefits from releasing information, such as through donations and esteem, against the risks of harm borne by species, and costs borne by agencies tasked with protection. Although this method compares costs and benefits among decisions, it does not compare differing objectives. Where decision-makers identify a range of objectives, broader approaches such as structured decision-making (Gregory et al. 2012) can incorporate our method. Costs and benefits may covary, and though here we assume they are independent, our framework could account for this. Costs are important to maximise conservation outcomes (Naidoo et al. 2006; Joseph et al. 2009), and the direct incorporation of costs and benefits into this method is an important differential from alternative approaches (e.g., Meijaard & Nijman 2014; Tulloch et al. 2018).

Although there is a public interest in discoveries of species (Watson & Davis 2017) and wider benefits to the systematic cataloguing of biodiversity data (Tulloch et al. 2018), there is also a tension with the potential for harm (Meijaard & Nijman 2014; Lindenmayer & Scheele 2017). Our method can interrogate this tension, and systematically and transparently justify choices. Using such a framework may reduce perverse outcomes like suppression of information for arbitrary purposes (Hannam 2017), or overeager sharing against the best interests of a species (Meijaard & Nijman 2014).

Data availability

All data for this study, including simulated and questionnaire data, and the questionnaire template is available at http://doi.org/10.26188/11357126.

R-language code to reproduce the analyses and figures is available at https://doi.org/10.5281/zenodo.10622197.

Supporting information

Supporting information 1: Supplementary text, figures, and tables.

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Supporting Information 1 to “The costs and benefits of publicising species discoveries”

GE Ryan, E Nicholson, CM Baker, and MA McCarthy

Supporting methods: Derivation of equation 1.

The methods we present in this paper simplify and generalise the solution to the problem of deciding which decision to publicise a species’ discovery is optimal as described Ryan and Baker (2016, 2019; hereon RB). Their equation 1 (p. 186 Ryan & Baker 2016, corrected p. 47, 2019) allows for the benefits of some decision for some amount of publicity to be compared with a decision for no publicity, and these benefits to be offset by the likelihood and possible costs associated with information leaking out in the event of no publicity (and no benefits). The RB formulation does not need different data to what we propose here, however it has several drawbacks which we have sought to ameliorate. The RB formulation considers only a logistic type relationship between available resourcing and probability of extinction, while this may not necessarily be the case. A greater difficulty is that the RB approach sets up a binary problem: publicity or not, and ‘benefits’ are turned on or off with publicity. Although as RB note, it is possible to compare several different publicity scenarios with a no publicity scenario, this is not a straightforward or intuitive means to compare a range of scenarios. This mechanism means that if there are a range of scenarios from no-publicity to full publicity and gradations in-between (e.g., releasing some information such as the discovery of the Night Parrot, but not the location), costs must be accounted for in one of several unintuitive ways. One way is that for in-between scenarios, the costs (“damages” in RB) incurred if information unintentionally becomes public despite a decision not to publicise will only be the costs for that in-between scenario, not for information becoming fully public which may be more likely. The alternative is that costs for each decision are directly accounted into the benefit term, making it actually a net-benefit term, and that the costs term represents the costs of associated with a fully public scenario. Another implication of this RB binary approach is that there are no benefits associated with a no-publicity scenario. This therefore means that if there may be benefits with such a scenario, the benefits for other scenarios must be adjusted to be relative to the no-publicity scenario. Lastly, the RB formulation assumes that costs and benefits are already scaled as relative to their functional relationship with probability of extinction, and the nature of this scale may not be known, though it is not required to be known to produce an answer (RB).

We can therefore propose an formulation similar to RB such that:

$$PE_d = f\left(g(PE_0) + z\left(C_d + p_d\left(C_p - C_d\right) - B_d\right)\right) \qquad \text{Eq. S1.,}$$

Were for some decision *d*:

PE_d is the probability of extinction of a species' given that decision,

f is some function of the relationship between probability of extinction and resources available for conservation, and monotonically decreases from 1 to 0 with range -∞ to ∞,

g is the inverse function of *f*,

PE_0 is the species' baseline probability of extinction,

z is a scaling coefficient,

C_d are the costs associated with that decision,

C_p are the costs associated with that a decision to fully publicise the discovery,

p_d is the probability that information will become fully public despite the decision, and

B_d are the benefits associated with this decision.

Using equation S1, the best decision is the one that minimises PE_d. This approach solves several of the issues raised above with RB, namely it allows the inclusion of any functional form of *f*, rather than just logistic, it separately accounts for the costs and benefits of a decision, meaning that any given scenario can be calculated rather than some binary comparison, and removing the problems associated with this. While we may not know *f*, *g*, PE_0, or *z*, these terms to not change with the decision, so we can simplify the solution further by extracting the multiplicand of *z*, and multiplying it by negative one to get equation 1 in the main text:

$$\zeta_d = B_d - C_d - p_d\left(C_p - C_d\right)$$

Because the terms are now negated, the decision that maximises ζ_d is the one that minimises PE_d and so is optimal for the species.

Supporting methods: Simulated species

To explore the behaviour of this method and check that results are useful, we simulate four decision scenarios:

1. a species with high value on illegal markets and high risk of poaching,
2. a species with high potential tourism value, and therefore potential for disturbance due to visitation,
3. a species where its major value is intrinsic, rather than direct monetary values, and
4. an exotic and possibly invasive species at risk of spread by the general public.

For each species we consider a set of five decision choices where both the amount of information publicly disclosed, and the group of people who are informed of the species exact location varies (table S1, Supporting information 1). These choices were:

- Public disclosure of the exact location of the species,
- Partial public disclosure of the location, e.g. the species' name and protected area, and inform government and local community groups of the exact location,
- Partial public disclosure of the location, e.g. the species' name and protected area, and inform government of the exact location,
- Secret, don't publicly disclose any information, but inform government and local community groups of the exact location, or,
- Secret, don't publicly disclose any information, but inform government of the exact location.

These possible decisions represent a gradient of levels of control, formality, and number of people with knowledge. The expected cost of management associated with the decision was varied with the level of public disclosure, the expected benefits were varied with the groups informed, and probability of the exact location becoming public was varied with both level of disclosure and group involved. (Values table S1 in Supporting Information 1). We applied equation 3 to these scenarios to estimate decision scores.

We broadly expect that: the best decision for the species at risk of poaching and the invasive species would tend toward secrecy because of the high costs of publicity; partial publicity would not be beneficial for the tourism species because of the high management costs, greater risk of publicity than secrecy, and high benefits of publicity; and publicity would be the best result for the species with primarily intrinsic values.

Table S1. Potential costs, benefits, and probabilities, for decision scenarios of four simulated species. Costs are listed on right, and dependent on information disclosed to the public. Benefits are listed below, and are dependent on stakeholder groups involved. Probabilities that information will become public anyway are in the central matrix, dependent on both stakeholders and level of publicity.

S1a: Species 1 – High value on illegal markets

	Publicly Disclose				**Cost (C_d)**
Inform and involve	**Probabilities of Publicity (p_d)**	*Government*	*+ Local Community Groups*	*Public*	
	Secret	0.01	0.1		10,000
	Part	0.4	0.8		1,500,000
	Public			1	5,000,000 (C_p)
Benefit (B_d)		1,000,000	1,500,000	3,000,000	

S1b: Species 2 – High tourism value

	Publicly Disclose				**Cost (C_d)**
Inform and involve	**Probabilities of Publicity (p_d)**	*Government*	*+ Local Community Groups*	*Public*	
	Secret	0.01	0.05		20,000
	Part	0.6	0.8		4,000,000

	Public			1	4,500,000 (C_p)
Benefit (B_d)		200,000	2,500,000	5,000,000	

S1c: Species 3 – Intrinsic value

	Publicly Disclose				**Cost (C_d)**
Inform and involve	**Probabilities of Publicity (p_d)**	*Government*	*+ Local Community Groups*	*Public*	
	Secret	0.01	0.02		20,000
	Part	0.05	0.1		20,000
	Public			1	20,000 (C_p)
Benefit (B_d)		10,000	15,000	20,000	

S1d: Species 4 – Invasive species

	Publicly Disclose				**Cost (C_d)**
Inform and involve	**Probabilities of Publicity (p_d)**	*Government*	*+ Local Community Groups*	*Public*	
	Secret	0.01	0.02		500,000
	Part	0.5	0.7		1,500,000
	Public			1	5,000,000 (C_p)
Benefit (B_d)		500,000	1,500,000	2,000,000	

Table S2. Decision scores for each simulated species in each decision scenario.

species	**involve**	**Secret**	**Part**	**Public**
Sp.1 illegal value	Government	940100	-1900000	
	Local community group	691000	-2750000	
	Public			-2000000
Sp.2 tourism value	Government	135200	-2800000	
	Local community group	2256000	-1900000	
	Public			500000
Sp.3 intrinsic value	Government	-10000	-10000	

	Local community group	-5000	-5000	
	Public			0
Sp.4 invasive species	Government	-45000	-2750000	
	Local community group	910000	-2450000	
	Public			-3000000

Table S3. Numeric estimates of cost and benefit from questionnaires for each case study species and decision scenario, statistical distribution fit to those estimates, and estimates of parameters corresponding to the relevant distribution.

species	decision	type	Lower estimate	Most likely estimate	Upper estimate	confidence	distribution	sigma	mu	lambda	a	b	c
Alpine tree-frog	Public	Benefit	25000	150000	4.00E+05	0.9	lognormal	0.538738	12.20863				
Alpine tree-frog	Public	Cost	0	1.00E+05	1.00E+06	0.9	lognormal	1.006397	12.52576				
Alpine tree-frog	Part	Benefit	25000	1.00E+05	4.00E+05	0.9	lognormal	0.694365	11.99507				
Alpine tree-frog	Part	Cost	0	50000	2.00E+05	0.9	lognormal	0.699705	11.30936				
Alpine tree-frog	Secret	Benefit	25000	25000	3.00E+05	0.9	triangular				0	361111.1	25000
Alpine tree-frog	Secret	Cost	0	0	2.00E+05	0.9	exponential			1.15E-05			
Giant Ibis	Public	Benefit	1000	2000	20000	0.5	lognormal	1.485846	9.808641				
Giant Ibis	Public	Cost	0	0	2000	0.5	exponential			0.000347			
Giant Ibis	Part	Benefit	0	0	10000	0.5	exponential			6.93E-05			

Giant Ibis	Part	Cost	0	0	2000	0.8	exponential			0.000805
Giant Ibis	Secret	Benefit	0	0	10000	0.8	exponential			0.000161
Giant Ibis	Secret	Cost	0	0	2000	0.8	exponential			0.000805
Red Handfish	Public	Benefit	0	250000	2.00E+06	0.5	lognormal	1.442027	14.50866	
Red Handfish	Public	Cost	20000	5.00E+05	2.00E+06	0.5	lognormal	1.177353	14.50852	
Red Handfish	Part	Benefit	0	250000	2.00E+06	0.5	lognormal	1.442027	14.50866	
Red Handfish	Part	Cost	0	20000	5.00E+05	0.5	lognormal	1.794123	13.12236	
Red Handfish	Secret	Benefit	0	75000	5.00E+05	0.5	lognormal	1.37736	13.12236	
Red Handfish	Secret	Cost	0	20000	5.00E+05	0.5	lognormal	1.794123	13.12236	
Smooth Newt	Public	Benefit	0	50000	1.00E+06	0.2	lognormal	2.20205	15.6688	
Smooth Newt	Public	Cost	0	8.00E+05	2.00E+06	0.35	lognormal	1.169087	14.95913	
Smooth Newt	Part	Benefit	0	20000	1.00E+05	0.2	lognormal	1.757418	12.99201	
Smooth Newt	Part	Cost	0	7.00E+05	2.00E+06	0.35	lognormal	1.235224	14.98461	
Smooth Newt	Secret	Benefit	0	8.00E+05	2.00E+06	0.3	lognormal	1.254692	15.16662	
Smooth Newt	Secret	Cost	0	1.00E+05	1.00E+06	0.2	lognormal	1.995506	15.49497	

Species1	Public	Benefit	50000	750000	1.50E+07	0.66	lognormal	1.536246	15.88788				
Species1	Public	Cost	0	2.50E+09	5.00E+09	1	triangular				0	5.00E+09	2.50E+09
Species1	Part	Benefit	50000	750000	1.50E+07	0.66	lognormal	1.536246	15.88788				
Species1	Part	Cost	0	2.50E+09	5.00E+09	1	triangular					5.00E+09	2.50E+09
Species1	Secret	Benefit	50000	1.00E+06	1500000	0.5	lognormal	0.636761	14.22098				
Species1	Secret	Cost	0	2.50E+09	5.00E+09	1	triangular				0	5.00E+09	2.50E+09
Tiger	Public	Benefit	50000	2.00E+05	2.00E+07	0.8	lognormal	1.758138	15.29712				
Tiger	Public	Cost	0	0	180000	0.3	exponential			1.98E-06			
Tiger	Part	Benefit	50000	2.00E+05	2.00E+06	0.3	lognormal	1.793519	15.42278				
Tiger	Part	Cost	0	0	180000	0.3	exponential			1.98E-06			
Tiger	Secret	Benefit	0	70000	2.00E+05	0.3	lognormal	1.319825	12.89819				
Tiger	Secret	Cost	0	0	180000	0.3	exponential			1.98E-06			
Wollemi Pine	Public	Benefit	0	25	50	0.95	lognormal	0.347844	3.339871				
Wollemi Pine	Public	Cost	5	35	75	0.95	lognormal	0.376959	3.697446				
Wollemi Pine	Part	Benefit	0	40	70	0.7	lognormal	0.530494	3.970304				
Wollemi Pine	Part	Cost	5	8	50	0.7	lognormal	1.036047	3.152835				
Wollemi Pine	Secret	Benefit	0	10	20	0.95	lognormal	0.347844	2.42358				
Wollemi Pine	Secret	Cost	5	7.5	20	0.95	lognormal	0.298059	2.103742				

Table S4. Data corresponding to figure 2 – proportion of times a decision is the best (left) or worst option (right), given in simulations. Highest proportions in bold.

Species	**Proportion of times best option**			**Proportion of times worst option**		
Decision	*Public*	*Part*	*Secret*	*Public*	*Part*	*Secret*
Alpine tree-frog	0.334	**0.55**	0.116	0.303	0.16	**0.537**
Giant Ibis	**0.598**	0.305	0.097	0.146	0.262	**0.592**
Red Handfish	0.333	**0.498**	0.169	0.375	0.187	**0.438**
Smooth Newt	**0.606**	0.141	0.253	0.138	**0.462**	0.4
Species1	0.347	**0.459**	0.194	0.304	**0.477**	0.219
Tiger	0.46	**0.501**	0.039	0.124	0.129	**0.747**
Wollemi Pine	0.16	**0.823**	0.017	0.156	0.063	**0.781**

Table S5. Data corresponding to figure S3 — proportion of times a given decision resulted in a net benefit, i.e., a decision score greater than zero. "Best" is whichever decision had the maximum score in a given simulation replicate.

Species	**Best**	**Public**	**Part**	**Secret**
Alpine tree-frog	0.527	0.377	0.386	0.221
Giant Ibis	0.984	0.903	0.836	0.7
Red Handfish	0.778	0.492	0.584	0.268
Smooth Newt	0.782	0.622	0.136	0.405
Species1	0	0	0	0
Tiger	0.995	0.893	0.909	0.539
Wollemi Pine	0.708	0.22	0.66	0.006

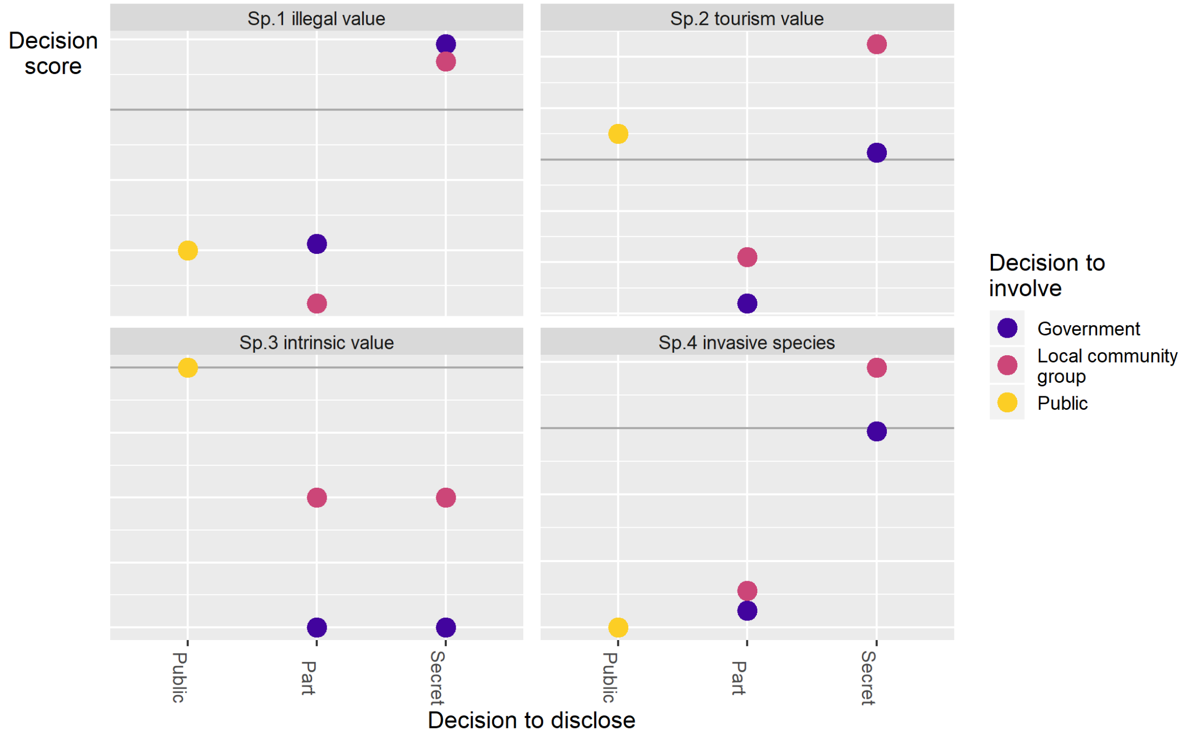

Figure S1. Decision scores, ζ, for simulated species, for each combination of disclosure of location (x–axis) and involvement of group of people (colour). Grey line indicates a score of zero, and the y-axis is relative to the range of scores for each decision scenario.

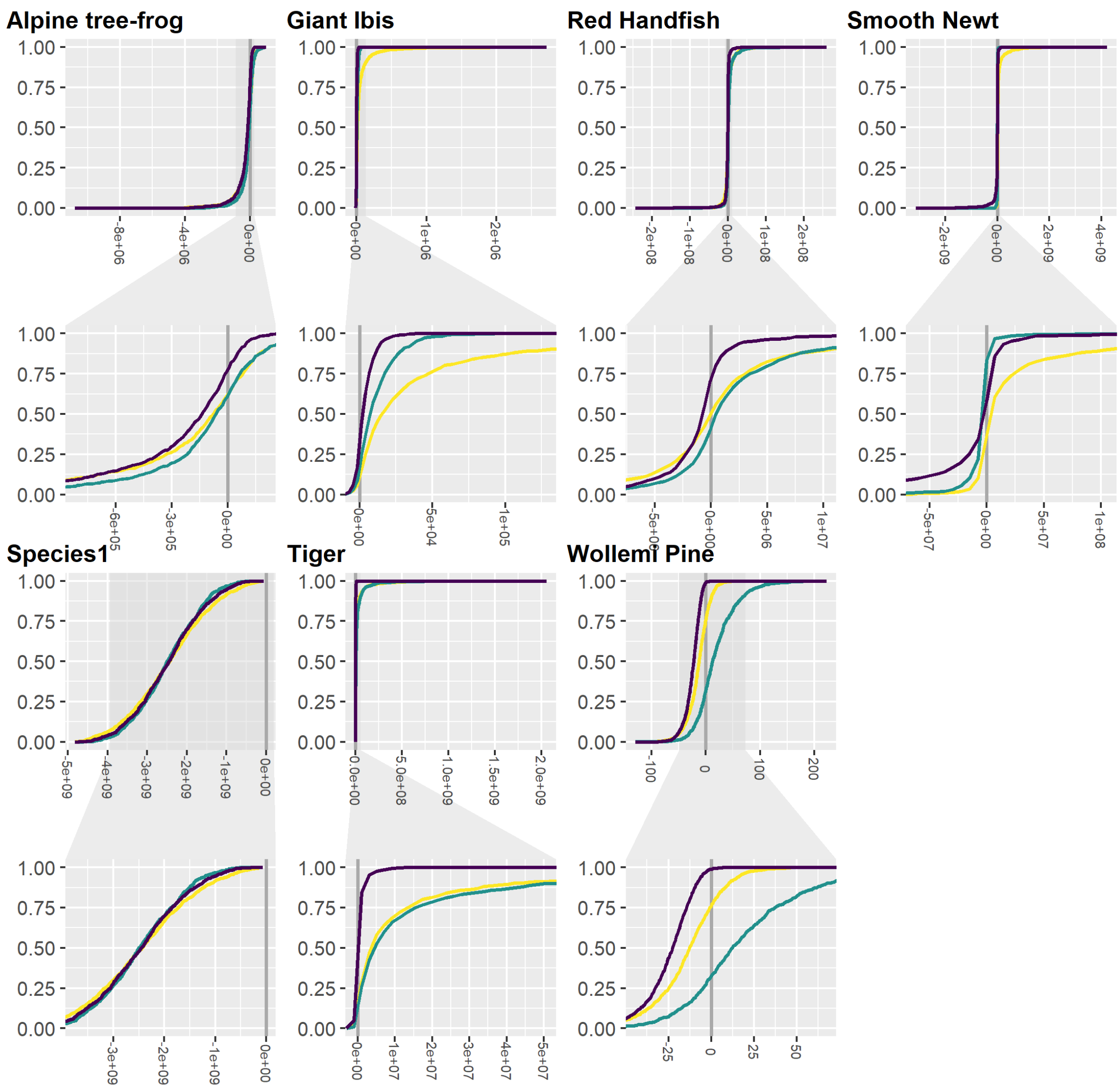

Figure S2. Cumulative densities of estimated decision scores, ζ, for case study species, for each of disclosure decision — public (yellow), part public (green) and secret (purple). For each species panels above show the full range of values, while panels below zoom to encompass the middle 80th percentile ranges of all scenarios for that species. Grey line equals zero, and x-axis is relative to the range of scores for each species.

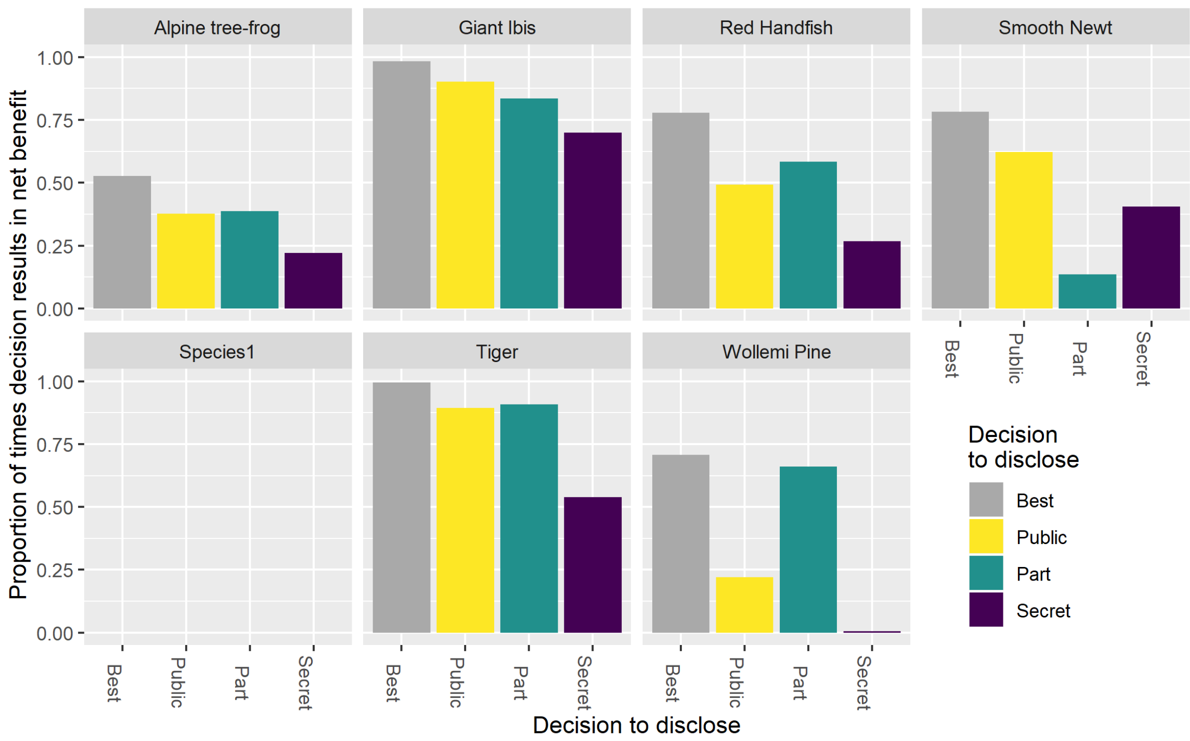

Figure S3. Proportion of simulation replicates that a given decision resulted in a net benefit, i.e., the decision score was greater than one. "Best" decision is the one with the highest decision score in each replicate.