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Justice for Animals in Climate Change Integrated Assessment Models

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Integrated assessment models (IAMs) exclude individual non-human animal welfare, despite clear evidence that climate change will harm billions of animals through habitat loss, extreme weather, and ecosystem disruption. We argue that this is a significant moral oversight. Further, incorporating animal welfare into IAMs is technically feasible, using traditional economic methods or novel ones. Crucially, accounting for animal welfare in IAMs need not undermine considerations of justice for humans.

Integrated assessment models (IAMs) are used by policymakers to evaluate the causes and effects of climate change. They are *integrated* insofar as they combine knowledge from multiple disciplines, including economics, climate science, energy systems, and political science, to simulate the potential impacts of different climatic scenarios over time. By estimating costs and benefits of mitigation and adaptation strategies, IAMs inform major policy decisions, including those made by the Intergovernmental Panel on Climate Change (IPCC).

One significant limitation of IAMs is that economic models face difficulties accounting for values that are independent of human use. Among the non-use goods that are often omitted are those of biodiversity and of ecosystems. There is some consideration of ecosystemic values in IAMs, but it is most often framed in terms of ecosystem services, which covers the *use* value of ecosystems. However, there have been some recent efforts to model the intrinsic, non-use value of biodiversity[1–4].

Nonetheless, climate IAMs—even those updated to countenance the effects of climate on biodiversity—have failed to include another important non-use value: the welfare of *individual* non-human animals (hereafter, animals)[5]. Animals will be harmed by climate change in a number of ways[6]. They will be affected by habitat loss, natural disasters, increased conflict between humans and wildlife, phenological mismatches, invasive species, and forced migration. While these negative effects are typically understood at the level of species, they are also harmful to *individual* animals. For instance, while droughts may threaten biodiversity in an area, they do so by subjecting individual animals to desiccation and starvation. When gripping images of emaciated polar bears on what appears to be dwindling sea ice heightened public concern about climate change, the images' most salient feature is individual animals experiencing significant welfare harms[7]. Whether or not these images accurately depict trends in polar bear populations, the response to these images indicates that people are deeply concerned about the effects of climate change on individual animals.

In this paper, we will use "welfare" to refer to what is intrinsically good for an individual—what makes their life go well for them, independent of external aims or instrumental goods. Philosophers offer competing accounts of welfare, and we do not attempt to resolve those debates here. We do assume that the quality of an animal's valenced experience—its sentience — is at least a core component of its welfare, and we discuss in detail ways to measure it. Readers who endorse other conceptions of welfare are invited to adapt our methods accordingly.

Individual animal welfare has been all but entirely neglected in the literature on IAMs. For instance, the 29 IAMs listed on the United Nations Framework Convention on Climate Change website (UNFCCC 2025)[8] do not recognize impacts on individual animal welfare—nor do the IAMs discussed in Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES[9]) methodological report (IMAGE[10–12]; GLOBIO[13]; InVEST[14]; CLUE-S[15]), nor do the three main climate IAMs (DICE[16]; FUND[17]; and PAGE[18,19]). Animal welfare has been *mentioned* in the broader academic literature on climate IAMs, but, thus far, it has only received a passing reference[20]. While some IAMs are directed at regional and not global levels, and are used for various specific purposes (such as land use planning), we here are most concerned with global climate models such as DICE, FUND, and PAGE.

We are responsible for the harms we inflict on others, human or nonhuman, as a matter of basic justice[21–23]. In the context of climate change, there is a special injustice associated with neglecting harms that are imposed on others who bear no responsibility for these changes and have no voice in the decisions that worsen them. This is true of animals, who are entirely excluded from climate policy deliberations despite experiencing significant harms from climate change and not being at all responsible for such global shifts. It is true that concern for animal welfare is not identical to concern for justice for animals, as some welfare deficits are not due to injustice. However, given that the particular harms to animals associated with anthropogenic global climate change meet the conditions just specified, it is reasonable to describe them as concerns of justice (at least in the absence of some

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principled distinction between the human and nonhuman cases). Nonetheless, what matters for us here is to account for climate-based welfare harms caused to animals; so, we won't dwell on the specific ethical vocabulary used to describe these harms.

We also do not wish to downplay issues of justice arising from climate change that affect *humans* around the globe now and in the future; many of these problems are not accounted for, or even made worse, by current IAMs[24–26]. Nonetheless, the exclusion of one important set of issues does not justify the exclusion of others. Climate IAMs should attend to ways in which climate change affects individual animal welfare.

Individual animal welfare and climate policy

The basic case for incorporating animals into IAMs

There is an extensive literature arguing both that animals matter morally and that it is unjust to ignore the impacts of our actions for animals[27–31]. More strongly, many argue that the calculus of the social distribution of goods ought to include animals[32–38]. In fact, within the recent Anglo-American and European philosophical tradition, it is very rare for ethicists to claim that animals are not morally considerable, whereas granting intrinsic ecosystemic and biodiversity values is *highly* controversial.

We cannot make the full case for the moral considerability of animals in this brief space, though we believe that the reasons favoring it are overwhelming. Moreover, they are not parochial. Many traditions around the globe give moral considerability to animals[39]. In Buddhism, Hinduism, and Jainism, the central notion of *ahimsa* directs us to have compassion for all sentient beings. The Islamic and Jewish traditions consider animals as members of a moral community, and with strict rules of Halal and Kashrut, dictate that no unnecessary harm should be caused to them. Pope Francis, in his encyclicals Laudato Si and Laudatum Deum, expresses concern, albeit limited, for individual animals[40,41]. And the relational ethics of many Indigenous traditions emphasize human kinship with individual animals[42–44].

These traditions differ in their level of concern for individual animals and in their reasons for having concern. Our point here is not that high levels of concern for animals are widespread, but just that some level of concern is both widespread and justifiable from many perspectives. This matters because incorporating animal welfare into global climate policy will require uptake from cultures around the globe whose ethical framework differs from the philosophical animal ethics from which our own project springs. So, while we do not wish to overstate the level of concern that these traditions have for individual animals, we believe that the ethical concern for animals that is present in these traditions will make it feasible to achieve broad support for proposals like ours.

If animals matter morally, then we are responsible for the negative impacts our actions have on them. It would be unjust to ignore those consequences. IAMs are one of the key tools for identifying, quantifying, and trying to mitigate the negative impacts of a certain class of actions—namely, those actions that lead to climate change. Accordingly, it is important to incorporate individual animal welfare into IAMs so that negative impacts on animals can be identified, quantified, and, where possible, avoided.

Incorporating biodiversity is insufficient

One might think that, even given this objective, it is sufficient just to incorporate biodiversity into IAMs. This would be convenient because, as noted above, there are already proposals about how best to incorporate biodiversity. However, as a solution to the current issue, it is satisfactory only insofar as biodiversity is either (1) the same as individual animal welfare or (2) a good proxy for individual animal welfare. But neither is true.

First, as others have pointed out, biodiversity is a property of populations and systems, not a property of individuals[5,45–47]. Populations and systems exhibit biodiversity along some dimension when they include variation along that dimension—e.g., genetic, phenotypic, species membership, and ecological. By contrast, welfare is an attribute of individual animals[48].

Second, while there may sometimes be a relationship between biodiversity and animal welfare, the former is a poor proxy for the latter. For instance, biodiversity is set back by species extinctions, but these extinctions often occur because some other, more abundant animals are thriving. By contrast, biodiversity can be served by culling invasive nonnative species that hunt native ones (e.g., rats and feral cats, which are responsible for many reptile, bird, and mammal extinctions)[49]. But culling can involve causing prolonged and severe suffering to a larger number of animals than the number of animals benefited, as it is often accomplished via slow-acting poisons (e.g., anticoagulants like 1080).

We are not opposed to the consideration of biodiversity in climate models. However, if we want to capture individual animal welfare impacts, we ought to incorporate consideration for the welfare of non-human animals into climate policy directly, not via proxies. This raises several challenges, which we discuss in the remainder of the paper.

Incorporating individual animals in IAMs

Traditional economic methodologies

There are a few strategies that might be employed to incorporate animal welfare into IAMs. First, we could incorporate animal welfare in one of the same ways that scholars have tried to incorporate biodiversity: namely, via contingent valuation (CV) studies and benefit transfer[45]. Second, we could develop analogs of standard measures in health economics. For instance, IAMs such as DICE and FUND use the metric of the *value of a statistical life* (VSL)[50]. In addition to the VSL, we could have the VSAL (the value of a statistical *animal* life), or something more fine-grained (e.g., the value of a statistical *black bear* life), which could then be monetized[45,51,52]. Alternatively, we could use analogs of quality-adjusted life years (QALYs), which combine length of life with quality of life, assigning values from 0 (equivalent to death) to 1 (perfect health) to different health states and enabling cardinal comparisons across different health conditions. Just as QALYs can be monetized, the AQALY (the animal quality-adjusted life year), or something more fine-grained (e.g., the black bear quality-adjusted life year)[53] could be monetized[54].

There may be some incentive to pursue the first option involving a CV. After all, this has been the main strategy for incorporating non-use goods generally. However, William Nordhaus writes that contingent valuation approaches are "too unreliable at present to be used for assessing the costs of ecosystem effects triggered by rising CO_2 concentrations and climate change. We cannot today value ecosystems in a reliable way"[55]. Because of the lack of reliability, Nordhaus does not include such valuation in the DICE model.

Apart from worries about the validity of stated preferences, one of the standard complaints about CV is that individuals' judgments are often insensitive to scope; individuals have a difficult time understanding and making judgments about large quantities. This is especially problematic when it comes to animals, where two groups of affected animals can be enormously large and yet still differ by orders of magnitude. It would be a mistake to value benefits to those groups equally[56]. Nonetheless, CV is still used to determine the non-use value of biodiversity and incorporate it within a climate IAM, and similar methods could be used to do so for individual animal welfare.

Other economic methods are used to value non-marketed goods. For instance, choice experiments (CE) give respondents a more realistic set of hypothetical alternatives, described by multiple attributes, and give subjects choices of selecting their favored option[57,58]. CE has long been used to value farm animal welfare[59], and one study has implemented CE to quantify the value of wild animals in China[60].

Animal value can also be quantified using revealed preference methods. For instance, people's interest in non-human animal welfare can be demonstrated through donations to animal welfare societies, substitution of animal-based foods and consumer products with plant-based alternatives, purchasing animal products with "humane" labeling, zoo revenues for viewing wild animals in captivity, with preferences given to zoos and exhibits that emphasize animal welfare[61], ecotourism in places whose main attraction is viewing animals (even non-endangered ones), and so on. Many of these revealed preference strategies have not yet been explored, but there is no reason to think that they could not be made technically feasible.

However, there is a good reason to look beyond the most straightforward economic methods for valuing animal welfare. This is because, in some of their implementations, they are ultimately in tension with the concern that motivates the inclusion of animals in the first place: they do not assess the magnitude of the harms and benefits to animals, but rather the strengths of people's preferences regarding those harms and benefits (either as stated or as revealed by their behavior). Insofar as we are including animal welfare in IAMs because we think that animals matter in themselves, we have good reason to want different methodologies.

We will now outline one approach to measuring the impacts of climate change on individual animal welfare. However, the case for including animal welfare in IAMs does not depend on the viability of this particular proposal. We offer it just to illustrate that there are proposals worth exploring that are alternatives to the status quo, both in the sense that they would allow animal welfare to be incorporated and that they represent departures from more traditional monetization strategies of assessing non-use value.

Measuring the impacts of climate change on animals

One way to proceed is to develop a direct measure of the total welfare impacts on animals. This strategy requires the following:

- Estimates of how given animal population sizes are affected by climate change
- Estimates of the expected welfare impact on a given animal in a population from climate change
- An interspecies conversion metric

Estimates of climate change's impact on animal populations are required to assess the number of individuals affected. An estimate of climate change's expected impact on the welfare of a given animal in a population is equivalent to the average welfare impact in the population. This is required to assess whether climate change's impact is net positive, net negative, and its magnitude. (There will, of course, be significant variation across the population. But for the purposes of developing IAMs, a relatively coarse-grained approach suffices.) An interspecies conversion metric is required if and only if we have reason to believe that (or otherwise find it pragmatically useful to assume that) there are differences in the moral importance of animal welfare depending on the species of animal affected. For example, some might find it plausible that negative welfare impacts on elephants should count for more than negative welfare impacts on geckos. Given as much, an interspecies conversion metric makes it possible to express welfare impacts on a common scale (e.g., AQALYs). Jointly, this information allows us to specify the welfare impacts of climate change on animals.

Obviously, any such framework will be imperfect and contested. So, it is important to take a pragmatic, ecumenical approach, recognizing that the main purpose of an initial version of this framework is simply to show that animals can be included in a principled way, which, from the perspective of justice, is better than their not being included at all.

In what follows, we briefly outline possible methods for securing this information. We hope that these formal methods of quantifying harms to animals in IAMs, despite their limitations, demonstrate the feasibility of the project. If one finds flaws in the features of this proposal, it gives reason to pursue other methods of doing so rather than abandoning the project altogether.

Estimating animal populations and changes in those populations

The field of wild animal population estimation has undergone significant methodological advancement over the past decade, driven by the integration of sophisticated statistical frameworks, technological innovations, and the growing need for climate-relevant biodiversity data[62]. Spatially explicit capture–recapture (SECR) models and hierarchical distance sampling have emerged as gold standards for species-specific population estimation; N-mixture models and occupancy frameworks provide robust approaches for community-level assessments across multiple taxa[63]. Recent technological breakthroughs have revolutionized data collection capabilities, with deep learning-powered image analysis achieving 95% detection accuracy for large mammals and reducing standard errors by 31–67% compared to traditional aerial surveys[64]. Environmental DNA (eDNA) methods represent another major leap forward, with airborne eDNA monitoring enabling national-scale biodiversity assessment of over 1100 taxa simultaneously, providing the capacity for rapid, non-invasive population monitoring across terrestrial and aquatic ecosystems[65].

There are, of course, significant limitations to all these methods. For instance, some of them are essentially useless for taxa with very small individuals (e.g., image recognition on aerial photos). Still, these kinds of methods are slowly transforming what is possible to know about animal populations and the impacts of climate change, with high-level analyses beginning to emerge[66,67].

As Jeff Sebo points out, climate change will have significant consequences for the welfare of individual animals[47]. One complex theoretical question concerns how best to estimate these impacts such that they can be compared on a cardinal scale (in much the way that human health metrics can be so compared[68]. At present, perhaps the most sophisticated framework available is the animal quality-adjusted life years (AQALYs) framework, which is designed to mirror the standard QALY framework[53].

The first stage of the AQALY framework is a structured assessment of an animal's living conditions. Using a standard welfare assessment framework[69], evaluators (e.g., a veterinarian or animal welfare scientist) record all relevant welfare compromises and enhancement opportunities in four physical domains—nutrition, environment, health, and behavioral interactions—each supported by detailed checklists. In the second stage, evaluators can integrate these entries to give an overall welfare grade for each physical domain. Stage 3 involves a scoring function that converts any welfare grade into a cardinal AQALY value. The authors estimate this function through a hybrid discrete-choice/time-trade-off (DCE-TTO) experiment adapted from the human QALY literature: human respondents repeatedly choose which of two hypothetical lives for the same species is better for the animal. The result is a general method that can be applied to any set of animals in any context to provide cardinal welfare assessments that can readily be compared and aggregated across species.

Interspecies conversion metrics

The AQALY framework—like any other welfare assessment tool—is a species-relative framework. Its distinctive characteristic is that its scale is cardinal, allowing *intra*species aggregation. But just because the scale is cardinal, it does not follow that *inter*species aggregation is possible. To move from the intra- to the interspecies case, we need a conversion metric.

The simplest conversion metric is the one that assumes that all animal welfare is assessed on the same scale. That is, if AQALYs are scored on a −1 to 1 scale, we simply assume that this scale is the same for all animals, regardless of species. If we make this assumption and have a simple additive approach to welfare aggregation, then it may often work out that the welfare of particularly numerous animals dominates estimates of the net welfare impacts.

The alternative is to assume, plausibly enough, that the notable differences in the cognitive capacities of animals have some bearing on the scales we should use to compare their welfare. Perhaps, just to pick an illustrative example, the scale for an elephant should be −1 to 1, and the scale of a frog should be −0.001 to 0.001, given the differences between them.

To be clear: the suggestion is not that these scales are determined by something like intelligence. If welfare is determined by the intensities of valenced experiences (e.g., the intensity of suffering), as hedonism claims, then the relevant cognitive capacities are those related to the intensity of valenced experiences. If welfare is determined by the satisfaction and frustration of desires, as desire theories claim, then the relevant cognitive capacities are those related to the number and strength of animals' preferences. Here, we remain neutral between theories of welfare and, therefore,

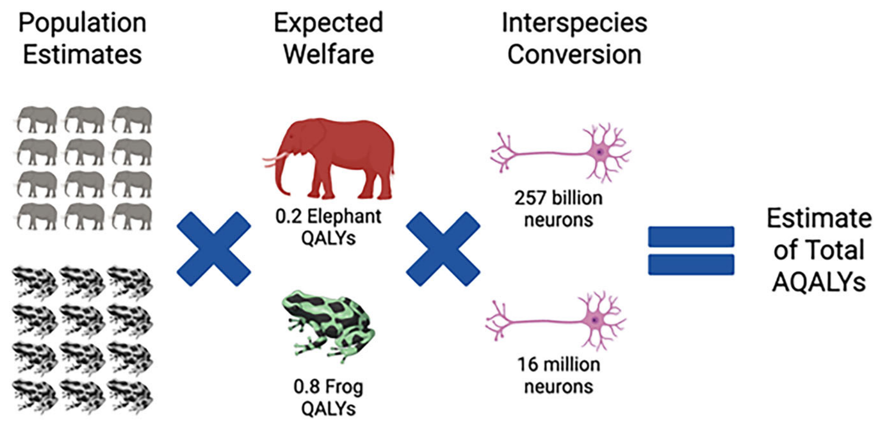

Fig. 1 | An estimation of total AQALYs in two animal populations. A relatively badly-off population of elephants is compared to a relatively well-off population of frogs using the number of neurons as an one type of interspecies conversion metric.

between proposals about how best to identify the relevant differences among animals.

Nevertheless, there is a growing literature on the challenge of estimating these differences, with two main approaches emerging. The first involves identifying a single proxy that may bear some relationship to the cognitive capacities of nonhuman animals, such as the number of neurons in the regions of the brain associated with integrative information processing[70]. This method has been subjected to scrutiny[71], and an alternative method involves a more complex set of cognitive and physiological proxies that, collectively, point toward the distinctive cognitive profiles of each species[72].

Either way, the result is a conversion metric that allows welfare assessments, expressed in AQALYs or comparable metrics, to be expressed on a single scale (see Fig. 1). To convert frog QALYs to elephant QALYs, multiply the number of frog QALYs by 16 million and divide by 257 billion.

Total expected AQALYs for n relevant populations of animals are thus $\sum_{i=1}^{n}(\text{Population estimate}_i \times \text{expected species-specific welfare measure}_i \times \text{interspecies conversion metric}_i)$.

Justice for animals and justice for people

Once we consider the negative effects on animals' sentient experience as an input to IAM damage functions, some may worry that it will swamp the value of human welfare—a consequence that some find unacceptable[36]. After all, there are a great many individual animals. So, it is possible that, even given human-friendly interspecies conversion metrics, impacts on animals will dominate estimates of the costs of climate change. This could entail that we should make extraordinary mitigation efforts that would severely limit human development and quality of life; moreover, it may imply that the specific mitigation and adaptation strategies should strongly prioritize animal welfare over human welfare. And as noted above, there are other challenges to be met for people to be treated justly in IAMs. We don't wish to neglect these issues, especially given that updated models will need buy-in from multiple (human) parties.

While this concern is understandable, we should note that we have yet to say anything about how to monetize AQALYs. If those are valued using more traditional economic methods (e.g., via contingent valuation), then it is highly unlikely that any such problem will emerge, as is highly unlikely that humans will value AQALYs at a rate high enough to generate the issue. However, suppose that AQALYs are monetized via a given interspecies conversion metric (say, neuron counts), where a frog QALY is assigned some fraction of the value of a human QALY based on the relative number of neurons in frogs and humans[54]. Then, the worry is more palpable, just given the sheer number of individual animals.

Still, the challenge can be addressed in several ways. We cannot review them all here, but here are four illustrative strategies.

The first strategy challenges the assumption that the most plausible interspecies conversion metrics will allow this eventuality. Nonhuman mammals outnumber humans by more than an order of magnitude, but it is not unreasonable to think that the cognitive differences between humans and most other mammals mean that human lives can be orders of magnitude better (and correspondingly worse) than (most) nonhuman mammalian lives. And if that is true for nonhuman mammals, then an analogous point is likely true given the yet-starker differences between humans and (most) nonhuman non-mammals. Since numerosity appears to be negatively correlated with cognitive sophistication, it is possible that the swamping problem is no problem at all.

A second strategy is to argue that, contrary to being in tension with human welfare, incorporating animal welfare into IAMs will often be a win for all parties. For instance, animal consumption by humans is one of the biggest drivers of climate change. Indeed, many proposals to combat climate change incorporate a reduction in animal consumption[73]. However, these proposals do not take into account the additional factor that doing so will lessen suffering for domesticated animals[47]. Taking animal welfare into account would thus give further reason to support mitigation efforts. To take a prominent current example, the One Health framework, whereby human and non-human health is seen as deeply intertwined, is well suited for this kind of approach[74].

A third strategy frames impacts on animal welfare as generating side constraints on permissible climate policies rather than as inputs to be maximized. On such a view, climate policies must not lower nonhuman animal welfare below some critical threshold, but within that constraint, human-centered considerations can dominate. This avoids any concerns about aggregating human and animal welfare but still takes animal welfare seriously.

A fourth strategy incorporates practical and political feasibility as explicit constraints. According to this strategy, we should acknowledge that policies requiring extreme economic sacrifice will not be implemented. So, we build in a political "discount rate" for animal welfare as a feasibility constraint on the solution space, in much the way that some IAMs already incorporate political and economic constraints. And while it is true that one weakness of this approach is that it risks letting political limitations override strong moral reasons, it is also true that some realized progress for animal welfare is better than hypothetical but unrealized progress.

Conclusion

Some have argued that IAMs are hopelessly flawed because of empirical and theoretical uncertainties regarding risk and discounting, as well as because of arbitrary choices made by modelers[75–77]. Others believe that these flaws are merely cause for refinement, and that IAMs can still be useful[16,78]. We cannot settle this deep issue about the overall viability of IAMs here. Assuming that IAMs will continue to be used in climate policymaking, they should be done as well as possible. Including considerations of animal welfare in IAMs would add complexity, but the problems associated with doing so are not different in kind than obstacles IAMs are already known to face.

Paul Kelleher writes of the “normative abridgment” of the calculation of the social cost of carbon (SCC), which is one output of some IAMs[79]. We already know that calculations of the SCC omit key normative considerations, and for Kelleher, this gives good reason not to determine SCC values just on the basis of economists’ calculations. Instead, we need alternative processes which incorporate the abridged ethical considerations. On the one hand, we support the creation of animal ethics frameworks analogous to the Kunming–Montreal Global Biodiversity Framework[77,78,80] and the IPBES[9], producing reports for the IPCC to consider on individual animal welfare. At the same time, IAMs that include a broader swath of morally-relevant concerns are bound to be improvements on other models, even if IAMs cannot *fully* be used to determine SCC and other climate-related policies.

While IAMs have flaws, it should also be noted that alternative, non-quantificational inputs to climate policy-making are themselves subject to biases, as well as to misunderstanding of risk and uncertainty. IAMs, by their transparent nature, make their own assumptions explicit. That can facilitate critique and refinement in a way that other methods cannot.

We have argued that considerations of animal welfare are morally important for reasons of justice and, accordingly, that IAMs should be structured to include animal welfare. We have also argued that, despite challenges, it is feasible to do so, although more empirical and theoretical work needs to be done for such a project to be brought to full fruition. Furthermore, the kind of argument we give here applies to many other domains. For instance, the UN’s Sustainable Development Goals (SDGs) do not include direct discussion of individual animal welfare, and some scholars are now working to find ways to incorporate animal welfare concerns into the SDG framework[74]. Insofar as animal welfare matters, its omission should be corrected across the board.

Data availability
No datasets were generated or analyzed during the current study.

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