Biodiversity is rapidly deteriorating at a global level as human actions like development, overexploitation, and pollution have led to a dramatic increase in the rate of extinction (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) 2019). The U.S. Endangered Species Act (‘ESA’ or ‘the Act’) is widely considered one of the strongest laws in the world for protecting imperiled species. Part of the law’s strength comes from the central role of science: from listing to recovery planning to consultation (Schwartz 2008, Malcom and Li 2015, Evansen et al 2020), Congress directed that the ‘best available scientific and commercial data available’ be used to make decisions that ultimately determine the fate of species (see critiques of the standard, Doremus 1997). The use of best available science helps ensure short-term non-biological considerations do not take precedence over a species’ long-term conservation.

The best available science mandate allows the two services that implement the Act, the US Fish and Wildlife Service and the National Marine Fisheries Service (FWS and NMFS; ‘Services’ collectively), to improve conservation outcomes through adaptive management. In brief, adaptive management uses and generates the best available science. The adaptive management process lays out a cycle of optimization that improves management by learning from outcomes. In the ecological management domain, this translates to planning actions; carrying out the actions; monitoring the effects of the action; and then repeating and adjusting plans and actions based on monitoring results (Walters and Hilborn 1978). The integral role that monitoring plays in the adaptive management cycle means that monitoring is essential for the production of the best available scientific data required by the Act.

Although monitoring is intrinsic to adaptive management, the unfortunate reality is that monitoring the implementation of the ESA is inconsistent at best and, more typically, absent. For example, a 2009 Government Accountability Office report found that the FWS lacked a systematic way to track monitoring reports required in biological opinions under section 7 of the Act and had little knowledge of compliance with monitoring requirements; Malcom and Li (2015) found huge interoffice variation in section 7 consultation data recorded; Evansen et al (2020) found monitoring of authorized harm that varied from the use of Excel to whiteboards; Owley (2015) found a disturbing lack of basic record-keeping; the authors are finding little and inadequate monitoring in an evaluation of the habitat conservation plan (‘HCP’) program; and the Service suspended a broadscale status monitoring program in 2010 (US Fish and Wildlife Service (USFWS) 2011) attributed to inadequate reporting standards. This lack of consistent monitoring means the Services cannot accurately evaluate the effects of authorized harm to species or habitats; weigh the effectiveness of recovery actions; make effective listing, delisting, and downlisting decisions; or learn about effective mitigation measures across regions or species. In other words, science-based adaptive management is not possible.

Without the optimization of management decisions from adaptive management, there is the likelihood of the misallocation of scarce conservation funding (Evans et al 2016). Misallocation of conservation funding means a small number of listed species have received many more times the funding called for in their recovery plan, while other listed species have received far less (Gerber 2016). Unsurprisingly, what monitoring data that does exist suggests that while some ESA-listed species may be improving or at least remaining stable, the majority are declining (Evans et al 2016, Malcom et al 2016).

Funding for conservation is consistently insufficient,
Table 1. Monitoring stipulations found throughout the implementation of the Act.

| Where found | Monitoring focus | Legally binding on services? |
|-------------|------------------|------------------------------|
| Section 4(c) of the Act | 5 year reviews on the biological status and threats of the species | Yes—Mandated in text of Act (A review is required, but there is no requirement for a document to be produced.) |
| Section 4(g) of the Act | Monitoring the status of delisted species for up to 5 years post-delisting | Yes—Mandated in text of the Act |
| 50 CFR 402.14(i)(3) | Effects of the action of a section 7(a)(2) consultation | Yes—In implementing regulations |
| Section 7 Consultation Handbook | Monitor for compliance with consultation requirements (e.g. impacts on species, conservation measures, project area limitations) | No—Handbook guidance only |
| Recovery Planning Handbook | Monitor for recovery action effectiveness | No—Handbook guidance only |
| Habitat Conservation Planning Handbook | Monitor to evaluate need for adjustment and adaptive management | No—Handbook guidance only (HCPs may require monitoring) |
| Safe Harbor Agreements (SHAs) | Dependent on individual agreement | No (SHAs may require monitoring) |
| Candidate Conservation Agreements with Assurances (CCAAAs) Handbook | Dependent on individual agreement | No—Handbook guidance only (CCAAAs may require monitoring) |

with the FWS receiving less than half of what is required to implement the Act as Congress intended (Malcom et al 2019). With inadequate resources, it is imperative that the Services implement conservation actions that have a marked effect on moving a species toward recovery. We are missing key information on how actions and plans are affecting conservation outcomes.

We posit that the widely observed lack of consistent monitoring of ESA implementation—and the consequences for species and habitats—is driven by missing or inadequate policy direction. Congress did not explicitly require monitoring for threatened or endangered species or critical habitat beyond 5 year status reviews in section 4(c) and post-delisting monitoring, stipulated in section 4(g) (U.S. Congress 1973). The Services, however, do recognize the general need for monitoring in regulation and in internal documents that guide the implementation of the Act, though this guidance is usually not legally binding (table 1). In contrast, consider the extensive policy direction on other aspects of the ESA (table 2). Detail on listing species, recovery planning and designating critical habitat encompass most of section 4. It is subject to multiple regulations and policies; guided by a handbook for recovery planning that has been revised repeatedly over the years; and has garnered significant scientific attention. Interagency cooperation under section 7 receives similar treatment, with a full section of the Code of Federal Regulations (50 CFR Part 402), a handbook, and a considerable amount of scientific research focused on its implementation. Permitting under section 10 also receives extensive attention under the ESA, with amendments, guidance by multiple regulations and policies, and handbooks3. While monitoring appears in some of these, it is a minor element, which speaks to the fact that monitoring is a low priority for the Services despite its essential nature. Were it given priority based on its importance, we should expect the availability of one or more policies, perhaps a monitoring handbook, an emphasis on funding for monitoring, and a larger body of literature on monitoring in ESA implementation. But those things do not exist.

When monitoring does occur, it is frequently done through myriad stakeholders or agencies, each with their own method of gathering essential data. Monitoring data on the same species might be simultaneously collected through different contractors for HCPs and reported to local Service offices, through National Wildlife Refuge System biologist surveys, and/or through data collected by other agencies and provided to the Service through section 7 consultation. Incorporating such data into range-wide analyses such as those needed during five year reviews of listed species is hampered by lack of coordinated monitoring. For example, when scientists attempted to aggregate data from surveys of non-breeding waterfowl in certain national wildlife

3 For a comprehensive list of government sources referenced, see the U.S. Fish and Wildlife Service’s Regulations and Policies page at www.fws.gov/endangered/laws-policies/regulations-and-policies.html.
refuges, they found inconsistency in how and when refuges collected their data which impeded analysis of aggregated data. Here, the main cause of inconsistency was the fact that survey method design was largely left to individual refuges (Andersson et al. 2015). While not about the ESA—we are not aware of any published, citable examples for the ESA, only that we have been told it is a problem—this example highlights how lack of coordination of monitoring can preclude essential inferences. The lack of monitoring of programs under the Act means that we cannot know whether there are similar systemic problems that should be addressed. If such problems exist, in addition to being wasteful of government and private sector resources, the species meant to be protected bear the brunt of these errors.

Without such a framework, it is far more difficult for the Services to use knowledge gained through monitoring to assess implementation, oftentimes leaving the best available science off the table. Despite the ‘best available scientific and commercial information’ mandate in the listing and consultation provisions of the Act, existing monitoring data useful to one agency biologist may be languishing on the shelf of another (Government Accountability Office (GAO) 2009, Owley 2015). A concrete monitoring policy framework is thus needed to improve effective conservation of imperiled species under the ESA. We introduce ideas for a monitoring policy framework as a starting point for detailed monitoring policy and guidance that can help ensure efficient and effective implementation of the Act and lead to better conservation outcomes for imperiled species. A comprehensive monitoring policy will not by itself ensure effective system-wide monitoring; implementation and compliance will also be critical. The framework we offer can serve as a starting point, and certain provisions we offer (for example, the public dissemination of monitoring data) can strengthen compliance.

### 1. A monitoring policy framework

Here we present a proposal of a monitoring policy framework for the ESA (SI appendix A (available online at stacks.iop.org/ERL/16/031001/mmedia)).

The monitoring policy framework covers five key areas for reporting: (a) biological status monitoring; (b) threats status monitoring; (c) compliance monitoring; (d) effectiveness monitoring; and (e) investment analysis. The framework further incorporates cross-cutting themes, including the need for increased transparency within and outside the Services; accommodating emerging technologies for monitoring; and addressing the need for qualitative and quantitative data (figure 1).

The framework addresses the following core needs, which stem from implementation gaps and lack of transparency within current monitoring practices, and areas where increased monitoring may improve ESA-based conservation outcomes for listed species:

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### Table 2. Direction and guidance provided for the implementation of aspects of the ESA.

| ESA element | Regulations | Selected policies and handbook guidance | Handbook guidance |
|-------------|-------------|----------------------------------------|-------------------|
| Section 4 (including listing, critical habitat, recovery planning and 5 year reviews) | 50 CFR Part 17 (USFWS), 50 CFR Subpart A (NMFS), 50 CFR Part 424 (joint) | Distinct Population Segment Policy, 61 FR 4722 (Feb. 7, 1996); Significant Portion of its Range Policy, 79 FR 37577 (July 1, 2014); Policy for Evaluation of Conservation Efforts When Making Listing Decisions, 68 FR 15100 (March 28, 2003); Director’s Memo: Streamlining 90 d and 12 month Petition Findings | Yes (NMFS/FWS Recovery Planning Guidance) |
| Section 7 (including interagency cooperation) | 50 CFR Part 402 | U.S. Fish and Wildlife Service Mitigation Policy; Procedures for Implementing Programmatic Consultation Strategies | Yes (Consultations Handbook) |
| Section 10 (Permitting including habitat conservation plans (HCPs), safe harbor agreements (SHAs), candidate conservation agreements (CCAs) and scientific collection Monitoring (other than post-delisting)) | 50 CFR Part 13 | Candidate Conservation Agreements with Assurances Policy; Guidance for the Establishment, Use, and Operation of Conservation Banks (68 FR 24753, May 8 2003) | Yes (Habitat Conservation Planning Handbook) |
| Monitoring (other than post-delisting) | None | None | None |

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4 Unless the in-text citation states otherwise, all listed policies and handbook guidance can be found at https://www.fws.gov/endangered/esa-library/index.html.
Figure 1. The structure of the monitoring policy framework.

(a) Incorporation of Adaptive Management. The adaptive management process produces the best available science to be used in the implementation of the Act (Green and Garmestani 2012).

(b) Increased Recovery Implementation and Effectiveness. Prescribing and implementing effective recovery actions is essential for restoring populations. The framework addresses the need to monitor the implementation and effectiveness of recovery actions outlined for listed species.

(c) Increased Compliance with the Act. Compliance with permits and agreements is essential for ensuring proper implementation and for assessing where improvements might be made (Malcom et al 2017).

(d) Consistent Data Collection and Resolution. Improved coordination, collection and resolution of data gathered is incorporated as part of the monitoring process. This includes timely and accurate reporting and the use of standardized measures for qualitative and quantitative data.

(e) Scientific Capacity Building. The timeliness and accuracy of data recorded enables the use of the best available science by decision-makers. The adaptive management process can assess the efficacy of conservation actions prescribed for species’ recovery.

(f) Implementation of Cost Effectiveness Analysis. The framework includes a cost-effectiveness analysis of monitoring efforts when the benefits or impacts of a conservation measure are not ones that can be monetized, but rather quantified in the increase in population of a species (Shwiff et al 2012). This will help avoid inefficient use of resources, and may have the additional benefit of reducing monetary costs of monitoring.

(g) Adoption of Modern Technology. Modern technology can improve monitoring methods. For example, the use of an electronic database that can be updated by staff from any FWS region to enable consistent data recording and facilitate effective conservation reporting.

(h) Increased Transparency. Data transparency to enable agencies, academic researchers, nongovernment organizations and other stakeholders to access the most up-to-date information on imperiled biodiversity facilitates better conservation and decision-making.

(i) Increased Coordination Among All Partners. Coordination with federal, state, local, Tribal, non-governmental and academic partners who share in the responsibility for monitoring species and/or who can assist in the monitoring process will increase the efficiency of monitoring data collection efforts.

2. Next steps

Developing and adopting a monitoring policy for the Act will require the Services to take the next steps, including internal development, extensive collaboration with other government agencies, and engagement outside of government (e.g. academics and practitioners). We hope this contribution offers a strong starting point for the process. As the process develops, a number of step-down actions could
both improve current monitoring while setting the stage for the Services’ development of an overarching monitoring policy. The following changes to current practices would improve adaptive management processes in the short term and help with adoption of a monitoring policy in the long term:

(a) Improved use of modern technology. Enabling Service biologists to share and access monitoring data through the use of electronic databases would improve coordination and transparency among biologists, offices and regions. Currently, no such centralized database for monitoring data exists or is in use. Incorporating the use of remote sensing technologies will allow for more efficient monitoring. Increasing the availability of these data will generally improve the science used for decision-making.

(b) Increase funding for monitoring-specific actions. Increasing the funding for monitoring through avenues such as funding requests to Congress, adjustment (where permitted) of existing appropriations, grants, and through permit conditions that specify monitoring investment requirements, will allow more resources to be dedicated solely to monitoring efforts and establish monitoring a priority. Monitoring the funding increases can inform adaptive management to optimize funding allocations and identify additional funding needs to bring to the attention of decision makers.

(c) Dedicated personnel for compliance monitoring. With the addition of a minimum of one additional staff person in each USFWS Regional office dedicated solely to compliance monitoring, the Services can increase the capacity for monitoring internally and more effectively coordinate across federal agencies and with other stakeholders. The duties of compliance monitoring personnel can be outlined and prioritized in the policy.

(d) Enhanced interagency coordination. The Services can enhance an emerging monitoring program with early, dedicated engagement with federal agencies that share the need to monitor imperiled species. Such coordination is required by sections 7(a)(1) and 7(a)(2) of the Act and can improve access to key monitoring information, increase data collection efficiencies, and highlight knowledge gaps.

(e) Coordination with other stakeholders. The Services can maximize capacity and reduce the burden of monitoring by establishing partnerships with those stakeholders for which monitoring efforts are part of their duties. These stakeholders may include but are not limited to: state agencies, Tribes, nongovernmental organizations, regulated entities, and academic partners.

We encourage the Services to move toward the implementation of a comprehensive monitoring policy, starting with initial steps outlined above, to improve the conservation of threatened and endangered species.

3. Conclusion

Conserving biodiversity is imperative for the sake of natural systems and people, all of whom depend on functioning ecosystems that biodiversity helps to maintain (IPBES 2019). The ESA is the best route to protect imperiled species within the United States, but it can only do so if it works as designed. Currently, the lack of a cross-cutting and comprehensive monitoring policy means that despite the strengths of the Act, we cannot determine if it is reaching its full potential. The monitoring policy framework outlined here would fill a major gap in implementing the Act, establish monitoring as a priority and give rise to using the best available science to improve conservation outcomes for the species that need it most: threatened and endangered plants and animals protected by the ESA.

Data availability statement

No new data were created or analysed in this study.

ORCID iDs

Megan Evansen  https://orcid.org/0000-0002-5734-5259
Andrew Carter  https://orcid.org/0000-0001-9002-6463

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