Contributed Paper

Evaluating institutional fit for the conservation of threatened species

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Abstract: Recovery and conservation of threatened species require adequate institutional responses. We tested an approach to systematically identify and measure how an institutional framework acknowledges threats and required responses for the recovery of endangered species. We measured institutional functional fit with a drivers-pressure-state-impacts-response (DPSIR) model integrated with a quantitative text mining method and qualitative analysis of statutory instruments to examine regulatory responses that support the recovery of 2 endangered species native to Australia, the bridled nailtail wallaby (Onychogalea fraenata) and the Eastern Bristlebird (Dasyornis brachypterus). The key components of the DPSIR model were present in the institutional framework at statutory and operational levels, but some institutional gaps remained in the protection and recovery of the Eastern Bristlebird, including feral predator control, weed control, and grazing management in some locations. However, regulatory frameworks varied in their geographic scope and the application and implementation of many instruments remained optional. Quantitative text mining can be used to quickly navigate a large volume of regulatory documents, but challenges remain in selection of terms, queries of co-occurrence, and interpretation of word frequency counts. To inform policy, we recommend that quantitative assessments of institutional fit be complemented with qualitative analysis and interpreted in light of the sociopolitical and institutional context.

Keywords: DPSIR, environmental governance, functional fit, institutional analysis, mixed methods, recovery plans, social-ecological systems, text mining

Resumen: La recuperación y la conservación de las especies amenazadas requieren de respuestas institucionales adecuadas. Evaluamos una estrategia para identificar y medir sistemáticamente cómo un marco de trabajo reconoce las amenazas y las respuestas requeridas para la recuperación de las especies en peligro. Medimos la aptitud funcional institucional mediante un modelo de fuerzas motrices-presión-estado-impacto-respuesta (DPSIR) integrado con un método cuantitativo de extracción de textos y un análisis cualitativo de los instrumentos legales para examinar las respuestas regulatorias que apoyan a la recuperación de dos especies en peligro nativas de Australia: Onychogalea fraenata y Dasyornis brachypterus. Los componentes clave del modelo DPSIR estuvieron presentes en el marco de trabajo institucional a niveles legales y operativos, pero algunos vacíos institucionales permanecieron en la protección y recuperación de D. brachypterus, incluyendo el control de depredadores ferales, el control de malezas y el manejo del pastoreo en algunas localidades. Sin embargo, los marcos de trabajo regulatorios variaron en cuanto a su enfoque geográfico y la aplicación e implementación de muchos de los instrumentos siguieron siendo opcionales. La extracción cuantitativa de textos puede usarse para navegar rápidamente un gran volumen de documentación regulatoria, pero todavía existen obstáculos en la selección de términos, consultas sobre la coocurrencia e interpretación de los conteos de frecuencia de palabras. Para orientar...

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Conservation Biology, Volume 00, No. 0, 1–14
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a las políticas recomendamos que las evaluaciones cuantitativas de la aptitud institucional estén complementadas con análisis cuantitativos e interpretadas a la luz del contexto institucional y sociopolítico.

Palabras Clave: análisis institucional, aptitud funcional, DPSIR, extracción de textos, gestión ambiental, métodos mixtos, planes de recuperación, sistemas socioecológicos

Introduction

Environmental institutions are the rules, procedures, and norms that govern the way humans interact with natural systems (Young et al., 2008). Achieving conservation outcomes not only depends on science-based solutions, but also on effective institutional frameworks that mediate interactions between human and natural systems (Ostrom, 2007). Institutional frameworks define the spatial boundaries and elements of interest in an ecological system, structure the management interventions, specify the rights and responsibilities of the users and management authorities, and provide incentives and disincentives for particular courses of action (Ostrom, 2009a; Young, 2002). Thus, understanding the institutional framework of conservation problems is key for the development of effective solutions (Armitage et al., 2012; Bennett & Satterfield, 2018).

An evolving trend in the environmental sciences literature is to approach the design and operation of institutions as a problem of fit (Young, 2002). It centers on the idea that effective institutions align with the different characteristics of the biophysical and social domains in which they operate (Folke et al., 2007). The concept of institutional fit provides an umbrella for several analytical foci covering ecological, social, and political dimensions of institutional performance (Brown, 2003; Cumming et al., 2006; Epstein et al., 2015). But what constitutes a good fit under which contextual factors remains unresolved in the literature (Epstein et al., 2015). This is in part because multiple aspects of the broader governance system influence environmental outcomes, including so-called institutional interplay—the idea that the functioning of an institution can affect another institution within and between sectors (Young et al., 2008). Much of the research applying institutional fit in studies of environmental problems revolves around the concept of scale, in particular its spatial, temporal, and functional dimensions of alignment between institutions and ecosystems (Cumming et al., 2006; Guerrero et al., 2013). Functional fit has received less attention and is concerned with how well institutions address the relevant biophysical and social-ecological functions and processes in the system being managed (Ekstrom & Young, 2009). Analysis of functional fit is particularly relevant to conservation problems because it supports a systems perspective in which the relationships between multiple social and ecological components are the focus of analysis (Anederies et al., 2004; Guerrero et al., 2013). A focus on functional fit permits systematic assessment of how well institutions reflect the multiple relationships between social and ecological components of a conservation problem.

Despite rapid conceptual development, methodological approaches to institutional analysis of social-ecological systems in general, and dimensions of fit in particular, are still in an early stage of development (Cumming et al., 2020). Researchers employ a broad range of approaches, ranging from qualitative analysis of interview data (e.g., Berdej & Armitage, 2016) and semiquantitative measures (e.g., Lebel et al., 2013) to quantitative approaches that draw from network science to model the interacting social and ecological components (e.g., Guerrero et al., 2014; Sayles & Baggio, 2017). A quantitative text-mining method has been proposed to assist with the analysis of the large volumes of documents comprising institutional systems (Ekstrom & Young, 2009; Ekstrom et al., 2010). This has triggered the application of quantitative metrics to various dimensions of institutional fit (e.g., Cook et al., 2017; Ekstrom & Crona, 2017). Although these methods have the potential to tackle the complexity of institutional frameworks, debates on validity, methodological strengths and weaknesses, and recommendations for future improvements are in their infancy (e.g., Ekstrom et al., 2018). With increasing pressures affecting environmental quality, the recognition, management, and recovery of threatened species is becoming an important regulatory problem. Yet, institutional analyses for threatened species are rare and tend to focus on a particular type of institutional response, such as protected areas, recovery programs, or market mechanisms (Alvarado-Quesada et al., 2014; Bottrill et al., 2011), or on the role of communities and other actors in wider governance structures (Guerrero et al., 2015b; Morgans et al., 2017). Few researchers have applied the concept of institutional fit to examine the performance of institutional frameworks in conservation settings (Clement et al., 2017; Guerrero et al., 2015a; Petursson et al., 2013).

We applied a social-ecological perspective to the analysis of institutional fit for the recovery of threatened species. We pursued 2 aims. First, through the analysis of 2 case studies, we investigated the institutional factors influencing threatened species recovery efforts in Australia. Second, we examined the usefulness and applicability of new quantitative approaches to analyzing the functional fit of an institutional framework. We considered our results in relation to other dimensions of institutional fit and aspects of broader governance systems that influence conservation outcomes.
Methods

Case Study

The bridled nailtail wallaby (Onychogalea fraenata) (BNTW) and the Eastern Bristlebird (Dasyornis brachypterus) (EBB) are Australian native species listed as endangered under the EPBC Act and in the legislation of the 3 states in their range (BNTW in Queensland; EBB in New South Wales [NSW], Queensland, and Victoria). The EBB is a small, brown, ground-dwelling bird that inhabits low, dense vegetation (Higgins & Peter, 2002). Since European settlement, its distribution and abundance has declined, and it now exists in 4 genetically isolated populations distributed across 3 states (Roberts et al., 2011; Appendix S1). The northern population lives in southeastern Queensland and northeastern New South Wales, 2 central populations live in the Illawarra region and the Jervis Bay region of eastern NSW, and the southern population lives in the NSW/Victorian border coastal region. We focused on the northern and central populations in Queensland and NSW, which are threatened by the loss, fragmentation, and degradation of habitat driven by inappropriate fire regimes (northern population) and historical clearing for urban or agricultural development (central population). Other threats include feral predators, habitat degradation caused by disturbance from feral animals, weed invasion, grazing, inbreeding, and human disturbance (OEH, 2012; Stewart 2006).

The BNTW is a medium-sized macropod that inhabits semi-arid areas with dense acacia shrub land and grassy woodlands. From 1937 to 1973, the BNTW was believed to be extinct before rediscovered in central Queensland. From 1979 to 1984, the habitat area of the last population was acquired by the Queensland Government and designated as a national park (Taunton National Park). A small population was translocated to Idalia National Park and Avocet Nature Refuge (Appendix S1). A population of over 2000 BNTWs is kept inside an 8000-ha fenced area at Scotia, managed by the Australian Wildlife Conservancy. We focused on the remnant wild populations in Queensland in Taunton and Idalia National Parks and Avocet Nature Refuge, which are threatened by competition with domestic herbivores, habitat alteration, and predation by feral predators. Other threatening processes include drought, disease, parasites, non-native weed invasion, and fire (Lundie-Jenkins & Lowry, 2005).

The EBB and BNTW have been subject to conservation management for more than 20 years, with each having periods and locations of recovery and decline (Appendix S1). The institutional framework for threatened species conservation in Australia is complex and involves a range of agencies. At the national level, the Environmental Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) covers management of “matters of national environmental significance,” which include nationally threatened species and ecological communities. At the state level, numerous statutes, regulations, and other statutory instruments address various environmental matters. These are complemented by numerous strategic frameworks and operational management plans.

Analytical Approach

We followed Ekstrom and Young’s (2009) analytical method developed to assess the functional fit between any given ecological system and the set of governing institutions. The crux of the approach lies in identifying the key social-ecological linkages (known causal relationships between human and biophysical components) in a given system and using a text-mining tool to quantitatively measure the extent to which they are captured by the relevant set of institutions. The elements and interactions depicted in the system’s model form the basis for scoping and analyzing the documents comprising the institutional system. A key assumption of the quantitative analysis of functional fit is that the co-occurrence of terms, representing different components of the model, indicates that the social-ecological linkage has been potentially acknowledged by the institutional system (Ekstrom & Young, 2009; Ekstrom et al., 2018). A lack of co-occurrence is interpreted as an institutional gap, defined as a situation in which the institutional framework does not address a key linkage between 2 subcomponents of the system—an indication that the institutional alignment with the social-ecological processes affecting the ecological system is suboptimal (Ekstrom & Young, 2009).

A key advantage of the text mining method is that it can be used to quickly navigate a large volume of regulatory documents to identify potential gaps in regulatory responses to a broad range of environmental issues (Ekstrom et al., 2010). The method does not measure the effectiveness of institutional arrangements, which depends on many other determinants, including the capacity and willingness of institutional actors to implement the rules (Fidelman & Ekstrom, 2012; Treml et al., 2015), and on the interplay between formal and informal institutions (e.g., the norms that shape how formal rules are interpreted and applied). Although the latter is outside the scope of our study, our methodological approach addresses limitations in current applications of the text-mining method. Specifically, current applications of the method have been limited to laws and regulations and formal international agreements, but scoping and analysis of operational documents have remained outside the scope of the studies (e.g., Cookey et al., 2017; Ekstrom & Young, 2009; Treml et al., 2015). In addition, while several studies have concluded that the method is efficient in identifying agency involvement and possible institutional gaps (Cookey et al., 2017; Ekstrom et al., 2018;
Treml et al., 2015), it is also recognized that quantitative text mining alone cannot replace qualitative examination and interpretation of statutory frameworks (Ekstrom & Crona, 2017). We, therefore, extended the scope of documents comprising institutional framework and complemented the quantitative assessment with a qualitative analysis of the statutory instruments to verify and interpret the results and provide more detailed insights into the regulatory issues at play. Qualitative analysis also forms the basis for the discussion of the applicability of the quantitative method. Specifically, we constructed a social-ecological system model, scoped the institutional framework, conducted a text-mining analysis, and triangulated and qualitatively analyzed statutory instruments.

We applied the drivers-pressures-state-impact-response (DPSIR) framework to develop a social-ecological system model for each species (Ekstrom & Crona, 2017; OECD, 1993) (Figures 1 & 2). The DPSIR framework permits a description of the causal effects between the different social and ecological components of a system. The drivers are the social, cultural, and economic activities (e.g., agricultural development) that increase or mitigate pressures on the environmental system (e.g., vegetation clearing). The state or state change is the change in condition of the environment (e.g., degradation of habitat) and impacts are the effects of environmental degradation (e.g., species’ population decline). Responses are the current responses to the environmental problem (e.g., regulation and management actions).

National recovery plans for both the EBB and the BNTW (Lundie-Jenkins & Lowry, 2005; OEH, 2012), developed by the Australian Government in partnership with the state governments, formed the key source
of data. The models were validated through discussions with key experts in EBB and BNTW ecology (personal communications). Early appraisal of the impact component revealed that some of the key linkages would be site specific. Sites assessed for the northern EBB population in Queensland were Conondale, Border Ranges, Mount Barney, and Lamington National Park \((n = 4)\). Sites assessed for the central EBB population in NSW were Jervis Bay, Budderoo, Booderee, and Morton National Parks, Barren Grounds and Red Rocks Nature Reserves, Woronora Plateau, and Bherwerre and Beecroft Peninsulas \((n = 9)\). Sites assessed for the BNTW populations in Queensland were Taunton and Idalia National Parks and Avocet Nature Refuge \((n = 3)\).

We define species’ institutional framework as all legislation, regulations, policies, plans, and other regulatory and management instruments aiming to regulate activities directly related to the species’ conservation. This definition does not encompass so-called broader governance regimes or sets of institutions that influence attainment of these goals (Paavola et al., 2009). Two broad groups of regulatory instruments were used as sources of data: statutory instruments, which included statutes and regulations in force in November 2015, and management or operational documents, which included strategies, management action plans, and management guidelines. Statutes and regulations were sourced from Australian, NSW, and Queensland government databases by examining long titles and objective clauses to establish whether they aim to provide regulatory responses to threats identified in the species model. Strategies, policies, and management plans published in the last 20 years were retrieved from the websites of governmental

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**Figure 2. Conceptual model of the social-ecological system affecting the viability of the bridled nailtail wallaby (D, drivers; P, threats; S, changed state; I, impact; R, required responses; †, site-specific threats and site-specific social-ecological linkages). Feedbacks between (R) and other components of the drivers-pressures-state-impact-response framework are not within the scope of our analysis and therefore are not included here. Illustration of the bridled nailtail wallaby by Emilia Guerrero Hayllar.**
agencies. This time frame was selected based on available information about when a decline in the populations was first observed and when conservation efforts were initiated. We used the corresponding recovery plans as a starting point. We then used a snowball sampling approach to search for relevant management documents in document appendices (which referenced existing plans, strategies, and programs pertaining to each of the species and their habitats). This was repeated until we could not find any new documents. In addition, we searched online databases and websites of relevant government agencies and organizations at national, state, and regional levels. Our search returned 259 documents. Detailed information on the document-scoping process and a list of documents included is in Appendix S2.

The quantitative analysis was conducted using the text mining software MINOE, developed for the analysis of functional fit (Ekstrom & Young, 2009; Ekstrom et al., 2010). MINOE scans digitized documents for the co-occurrence of user-defined keywords or phrases representing linked elements of the social-ecological system’s model and presents results in a matrix format (Ekstrom et al., 2010). We identified linkage terms that represented the pressure, state, impact, and response components of the system models for the species (Figures 1 & 2). We selected the combinations of terms most commonly used in the management documents (Appendix S2). In co-occurrence matching, the results display how often a term or a combination of terms appears within 100 words of another term. We also manually checked a number of co-occurrence thresholds.

We cross-checked the results of the text mining analysis with a manual examination of the matches to establish whether co-occurrence (or lack thereof) of terms in the text represented the linkages being assessed and was not due to limitations of the approach (e.g., corruption of text during the conversion, poor selection of terms, and matches with unrelated terms). We documented alternative explanations where lack of co-occurrence was genuine (Appendix S3).

As a final step, we conducted a qualitative analysis of 56 statutes and regulations from 3 jurisdictions. We identified parts of the statutes and regulations relevant to the social-ecological linkages depicted in both system models and interpreted provisions according to their plain meaning with regard to the objects of the statute. Regulatory provisions were classified based on how they addressed the social-ecological components in the DPSIR models (e.g., 0, does not contain provisions to address the social-ecological link; 3, mandates exclusion of activities or requires management of impact) (Table 1 & Appendix S4).

### Results

#### Quantitative Analysis of Term Co-Occurrence

Most of the key social-ecological linkages in the DPSIR model for both species across all locations were acknowledged in the corresponding institutional documents, with a few exceptions. The quantitative analysis showed 10 institutional gaps for the northern population of EBB, 16 for the central population of EBB, and 2 for BNTW. However, some of these gaps were removed after cross-checking results (details in Appendix S3). The quantitative analysis resulted in 2, 7, and 0 gaps, respectively (Table 2).

Habitat protection and fire management were the most frequently referenced responses in the institutional framework for the EBB; captive breeding received less attention (Table 2). For the northern population of the EBB, grazing management constituted an institutional gap for the Conondale and Mt Barney National Park (Appendix S3). For the EBB central population, a potential institutional gap was found for grazing management at Woronora and for weed, feral cat, and feral fox control on private land on the Bherwerre Peninsula and Woronora Plateau (Appendix S3). For the BNTW, habitat protection and predator control dominated the institutional framework, and no institutional gaps were identified (Table 2).

The quantitative analysis revealed that co-occurrence of terms representing the DPSIR models were found predominately in management documents. Co-occurrence

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| Classification | Description of regulatory response |
|---------------|------------------------------------|
| 1             | does not prescribe specific measures but incorporates general management principles, guidelines, or other provisions that either acknowledge threatening processes or the status of species or enable or recommend actions that may address the problem |
| 2             | incorporates measures that mitigate threatening processes but do not fully exclude human activities or manage the impact (e.g., assessable development and exemptions from vegetation clearing provisions) |
| 3             | mandates the exclusion of the human activities that threaten the Eastern Bristlebird and bridled nailtail wallaby or their habitat or requires a management response (e.g., monitoring, translocation, and feral predator trapping) |

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Table 1. Classification of regulatory responses for qualitative institutional analysis of statutes and regulations associated with the social-ecological links in drivers-pressures-state-impact-response (DPSIR) models.
Table 2. Institutional gap analysis for the northern population of the Eastern Bristlebird (EBB) in Queensland, central population of EBB in New South Wales, and Queensland population of the bridled nailtail wallaby (BNTW).

|                     | No. of documents that acknowledge threat response | No. of times threat response was acknowledged in the institutional framework | No. of key linkages described in the conceptual model | No. of key linkages that are represented institutional framework (P1) | No. of institutional gaps (P2) | Extent value | No. of institutional gaps (after manual check) | Extent value\(^c\) (corrected) |
|---------------------|-------------------------------------------------|-----------------------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------------------------|-------------------------------|-------------|------------------------------------------------|----------------------------------|
| **Northern population of EBB** |                                                 |                                                                             |                                                      |                                                                        |                               |             |                                                |                                   |
| fire management     | 19                                              | 223                                                                         | 5                                                    | 5                                                                     | 0                             | 1.00         | 0                                              | 1.00                             |
| grazing management  | 3                                               | 5                                                                            | 5                                                    | 3                                                                     | 2                             | 0.60         | 2                                              | 0.60                             |
| habitat protection and management | 47                                              | 867                                                                         | 5                                                    | 5                                                                     | 0                             | 1.00         | 0                                              | 1.00                             |
| weed control        | 12                                              | 83                                                                          | 5                                                    | 5                                                                     | 0                             | 1.00         | 0                                              | 1.00                             |
| dieback control     | 3                                               | 8                                                                            | 5                                                    | 3                                                                     | 2                             | 0.60         | 0                                              | 1.00                             |
| feral cat control   | 4                                               | 6                                                                            | 5                                                    | 1                                                                     | 4                             | 0.20         | 0                                              | 1.00                             |
| feral fox control   | 6                                               | 17                                                                          | 5                                                    | 3                                                                     | 2                             | 0.60         | 0                                              | 1.00                             |
| captive breeding    | 1                                               | 58                                                                          | 1                                                    | 1                                                                     | 0                             | 1.00         | 0                                              | 1.00                             |
| translocation       | 1                                               | 86                                                                          | 1                                                    | 1                                                                     | 0                             | 1.00         | 0                                              | 1.00                             |
| education           | 2                                               | 6                                                                            | 1                                                    | 1                                                                     | 0                             | 1.00         | 0                                              | 1.00                             |
| total               |                                                 |                                                                              |                                                      |                                                                        |                               |             |                                                |                                   |
| **Central population of EBB** |                                               |                                                                              |                                                      |                                                                        |                               |             |                                                |                                   |
| fire management     | 38                                              | 1224                                                                        | 10                                                   | 10                                                                    | 0                             | 1.00         | 0                                              | 1.00                             |
| grazing management  | 5                                               | 8                                                                            | 10                                                   | 5                                                                     | 5                             | 0.50         | 1                                              | 0.90                             |
| habitat protection and management | 79                                              | 2770                                                                        | 10                                                   | 10                                                                    | 0                             | 1.00         | 0                                              | 1.00                             |
| weed control        | 29                                              | 173                                                                         | 10                                                   | 7                                                                     | 3                             | 0.70         | 2                                              | 0.80                             |
| feral cat control   | 9                                               | 15                                                                          | 10                                                   | 6                                                                     | 4                             | 0.60         | 2                                              | 0.80                             |
| feral fox control   | 23                                              | 70                                                                          | 10                                                   | 6                                                                     | 4                             | 0.60         | 2                                              | 0.80                             |
| captive breeding    | 1                                               | 58                                                                          | 1                                                    | 1                                                                     | 0                             | 1.00         | 0                                              | 1.00                             |
| translocation       | 3                                               | 93                                                                          | 1                                                    | 1                                                                     | 0                             | 1.00         | 0                                              | 1.00                             |
| education           | 2                                               | 7                                                                            | 1                                                    | 1                                                                     | 0                             | 1.00         | 0                                              | 1.00                             |
| total               |                                                 | 56                                                                           | 16                                                   | 0.78                                                                  | 7                             | 0.89         | 1                                              |                                  |

Continued
Table 2. (Continued).

| Threat Response                          | No. of Documents that Acknowledge Threat Response | No. of Times Threat Response was Acknowledged in the Institutional Framework | No. of Key Linkages Described in the Conceptual Model | No. of Key Linkages that are Represented in Institutional Framework (P1) | No. of Institutional Gaps (P2) | Extent Value | No. of Institutional Gaps (after Manual Check) | Extent Value (Corrected) |
|-----------------------------------------|--------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------------|--------------------------------|--------------|-----------------------------------------------|--------------------------|
| BNTW                                    |                                                  |                                                                                |                                                         |                                                                         |                                |              |                                               |                          |
| fire management                         | 13                                               | 103                                                                            | 3                                                       | 3                                                                      | 0                              | 1.00         | 0                                             | 1.00                     |
| grazing management                      | 1                                                | 5                                                                              | 3                                                       | 1                                                                      | 2                              | 0.33         | 0                                             | 1.00                     |
| habitat protection and management       | 34                                               | 1366                                                                          | 3                                                       | 3                                                                      | 0                              | 1.00         | 0                                             | 1.00                     |
| weed control                            | 11                                               | 76                                                                             | 3                                                       | 3                                                                      | 0                              | 1.00         | 0                                             | 1.00                     |
| rabbit control                          | 5                                                | 56                                                                             | 3                                                       | 3                                                                      | 0                              | 1.00         | 0                                             | 1.00                     |
| feral cat control                       | 4                                                | 104                                                                            | 3                                                       | 3                                                                      | 0                              | 1.00         | 0                                             | 1.00                     |
| feral fox control                       | 11                                               | 79                                                                             | 3                                                       | 3                                                                      | 0                              | 1.00         | 0                                             | 1.00                     |
| drought control                         | 6                                                | 35                                                                             | 3                                                       | 3                                                                      | 0                              | 1.00         | 0                                             | 1.00                     |
| captive breeding                        | 7                                                | 128                                                                            | 1                                                       | 1                                                                      | 0                              | 1.00         | 0                                             | 1.00                     |
| translocation                           | 8                                                | 267                                                                            | 1                                                       | 1                                                                      | 0                              | 1.00         | 0                                             | 1.00                     |
| education                               | 3                                                | 21                                                                             | 1                                                       | 1                                                                      | 0                              | 1.00         | 0                                             | 1.00                     |
| total                                   | 25                                               | 25                                                                             | 2                                                       | 2                                                                      | 0                              | 0.93         | 0                                             | 1.00                     |

*a Social-ecological linkages modeled in Figures 1 and 2. Linkages related to captive breeding, translocation, and education are not site specific. Social-ecological linkages are associated with response components (%).

b The measure of fit is calculated as the ratio of the sum of co-occurrences and the total number of linkages (Ekstrom & Young, 2009): extent = P1/P1+P2, where P1 is the total number of social-ecological linkages described in the system model represented in the institutional framework and P2 is the total number of social-ecological linkages described in the system model not represented in the institutional framework. The full results are in Appendix S3, which includes site-specific results.
matching in the statutes and regulations returned only a few linkages, mainly in regulatory documents providing for threatened species protection and management (Appendix S3).

Qualitative Analysis of Statutory Framework

Out of 26 statutory frameworks (statutes and regulations) from all 3 jurisdictions, 20 contained provisions that to some degree addressed one or several social-ecological linkages identified in the system models (Table 3 & Appendix S4). In particular, protected areas provisions for habitat conservation, vegetation clearing, wildfire management, and species protection either mandated exclusion of human activities or required a management response (category 3, Table 1). However, responses outside protected areas and most of the remaining social-ecological linkages tended not to prescribe specific measures but incorporated general management principles, guidelines, or other enabling provisions (category 1, Table 1).

For both the EBB and the BNTW, the EPBC Act, at the federal level, and conservation statutes at the state level are the key pieces of legislation. National parks in NSW and Queensland offered the highest level of protection from unlawful interference with natural values. Outside protected areas, all native fauna is protected wildlife and cannot be killed or harmed unless specific conditions are met. This protection, however, does not extend to threats, such as habitat loss, inappropriate fire regimes, weed invasion, feral predators, or competitors. Outside protected areas, grazing pressures remained largely unregulated. Fire management frameworks were designed to protect people and properties, and the management of environmental fire regimes, in particular on private land, was a regulatory gap. Most feral predators and competitors that threaten EBB and BNTW were declared as pests. However, regulatory provisions only enabled (category 2, Table 1) and did not mandate response actions. Furthermore, domestic cat management remained an unresolved issue. Finally, management responses, such as research and monitoring, translocation, and captive breeding, did not have strong statutory backing. See Appendix S4 for a more detailed statutory analysis.

Discussion

The key idea behind the concept of institutional fit is that ensuring a good fit between institutions and the problems they are meant to address should lead to better outcomes (Epstein et al., 2015; Folke et al., 2007). Our results showed that key social-ecological linkages for the recovery of 2 threatened species in Australia have been acknowledged at both statutory and operational levels, but some institutional gaps remained.

Our results showed that institutional gaps for the EBB remained in grazing management in some national parks for the northern population and feral animal predator and weed control on private land for the central population. Although the EBB has benefited from effective and ongoing management of feral animal predators in reserve areas (Garnett et al., 2018), off-reserve areas containing key habitats for threatened species, such as the EBB, did not receive strong protection from grazing, weed invasion, inappropriate fire regimes, and effects of neighboring developments (Table 3 & Appendix S4).

Despite our results showing that all the key threats to the BNTW are addressed in the institutional framework, remnant wild populations have declined in recent years (Garnett et al., 2018; Woinarski et al., 2017). The high occurrence of terms found in management documents indicated that operational responses have been planned to ensure survival and recovery of both species. But a recovery plan does not necessarily translate into actions or outcomes (Bottrill et al., 2011). Threatening processes, such as feral predators or competitors, weed invasion, and inappropriate fire management, require ongoing responses that depend on the financial and resource capacities of the management authorities. Similarly, captive breeding, translocation, research and monitoring, and specific management programs can be affected by gaps in budget allocation processes (e.g., Garnett et al., 2018).

Challenges in the Application of the Concept of Institutional Fit for Threatened Species Conservation

Our findings for the BNTW suggest that a good functional fit may be necessary for the recovery of threatened species, but it does not necessarily ensure it. Ideally, assessments of institutional fit should include the informal rules and norms that shape how formal rules are interpreted and applied (Ostrom, 2009a). Such assessments can reveal instances of institutional interplay between formal and informal institutions that can be detrimental to the outcomes sought (Young, 2002). For example, recovery outcomes are influenced by the stakeholder processes through which specific recovery actions are formulated and implemented (Evans et al., 2016). In these processes, preferences for prevailing management practices and conflicting views that hamper cooperation can reduce the effectiveness of recovery programs and lead to the implementation of actions that do not reflect the needs of the species as a whole (Guerrero et al., 2017). This suggests that formal and informal processes need to be addressed—as part of institutional fit—to ensure the recovery of threatened species.

Even when well designed on paper, the interpretation and use of institutions—and therefore their effect—can be different from the intended effect and can vary over time. Our qualitative analysis of regulatory documents revealed that statutes contain a number of regulatory tools...
Table 3. Results of the qualitative analysis of statutes and subordinate legislation related to the conservation of the Eastern Bristlebird and the bridled nailtail wallaby.

| Regulatory scope | Conservation of nature (NPWA, NCA) | Conservation of threatened species (TSCA, NCA, EPBCA) | Mgmt of state forests (PA, NSW and Qld) | Native vegetation clearing (NVA, VMA) | Land mgmt. (LA) | Land mgmt. (LGA) | Weed mgmt. (NWA, LPA) | Mgmt. of pest or feral species (GFACA, LLSA, LPA) | Fire mgmt. (RFA, FESA) | Pollution mgmt. (PEOA, EPA) | Development planning and applications (EPAA, SPA) |
|------------------|------------------------------------|--------------------------------------------------------|----------------------------------------|--------------------------------------|----------------|------------------|------------------------|-----------------------------------------------|-----------------------|-------------------------------|-----------------------------------------------|
| Administrative boundaries | PA incl. private PAs NSW, QLD | listed species on all tenures NSW, QLD | state forest (SF) tenure NSW, QLD | all, except PA and SF tenures NSW, QLD | leasehold land QLD | local govt. land NSW | all tenure NSW, QLD | all listed species, all tenures NSW, QLD | all tenures NSW, QLD | all tenures NSW, QLD | all tenures, except for PA, SF |
| Habitat protection and conservation | 3 | 2 | 2 (QLD) | 1 (QLD) | 2 (NSW) | | | | | | |
| Prevention and mitigation of habitat loss | 3 | 2 | 1 (NSW) | 2 | 1 (QLD) | | | | | 1 (NSW)/2 (QLD) | 2 |
| Prevention and mitigation of human disturbance | 3 | 3 | 1 (NSW)/2 (QLD) | 2 (NSW) | | | | | | 1 (NSW) | 1 |
| Prevention and management of wildfires | 1 | 1 | 1 (NSW)/2 (QLD) | 1 | | | | 3 | | | 1 |
| Management of environmental fire regimes | 1 | 1 | 1 (QLD) | | | | | | | | |
| Prevention and management of weed distribution | 1 | 1 | 1 | 2 (QLD) | 2 | | | 1 (QLD) | | | |
| Dieback control | 1 | 1 | | | | | | | | | |
| Control of feral predators | 1 | 1 | | 1 (QLD) | | | 1 (NSW)/2 (QLD) | | | |
| Control of feral competitors | 1 | 1 | | 1 (QLD) | | | 1 (NSW)/2 (QLD) | | | |
| Exclusion or management of grazing | 2 (QLD) | 2 (QLD) | | 1 (QLD) | | | | | | | |
| Captive breeding | 2 | | | | | | | | | | |
| Translocation | 1 | | | | | | | | | | |

Continued
Table 3. (Continued).

| Regulatory scope | Conservation of nature (NPWA, NCA) | Conservation of threatened species (TSCA, NCA, EPBCA) | Mgmt of state forests (FA NSW and Qld) | Native vegetation clearing (NVA, VMA) | Land mgmt. (LA) | Land mgmt. (LGA) | Weed mgmt. (NWA, LPA) | Mgmt. of pest or feral species (GFACA, LISA, LPA) | Fire mgmt. (RFA, FESA) | Pollution mgmt. (PEOA, EPA) | Development planning and applications (EPAA, SPA) |
|------------------|-----------------------------------|-----------------------------------------------|-----------------------------------|-------------------------------------|----------------|----------------|-------------------|-----------------------------------------------|-------------------|--------------------------|-----------------------------------------------|
| Administrative boundaries | PAs, incl. private PAs NSW, Qld | listed species on all tenures NSW, Qld | state forest (SF) tenure NSW, Qld | leasehold land QLD | local government land NSW | all tenures NSW, QLD | listed species, all tenures NSW, QLD | all tenures NSW, QLD | all tenures NSW, QLD | all tenures, except for PA, SF |
| Education of landowners and broader public | | | | | | | | | | 1 |
| Research and monitoring | | | | | | | | | | 1 |
| | | | | | | | | | | 1 |

Abbreviations: EPA, Environmental Protection Act 1994 (Qld); EPAA, Environmental Planning and Assessment Act 1979 (NSW); EPBCA, Environmental Protection and Biodiversity Conservation Act 1999 (Commonwealth); FA (NSW), Forestry Act 2012 (NSW); FA (Qld) Forestry Act 1959 (Qld); FESA, Fire and Emergency Services Act 1990 (QLD); GFACA, Game and Feral Animal Control Act 2002 (NSW); LA, Land Act 1994 (Qld); LGA, Local Government Act 1993 (NSW); LISA, Local Land Services Act 2013 (NSW); LPA, Land Protection (Pest and Stock Route Management) Act 2002 (Qld); NCA, Nature Conservation Act 1992 (Qld); NPWA, National Parks and Wildlife Act 1974 (NSW); NSW, New South Wales; NVA, Native Vegetation Act 2003 (NSW); NWA, Noxious Weeds Act 1993 (NSW); PA, protected areas; PEOA, Protection of the Environment Operations Act 1997 (NSW); QLD, Queensland; RFA, Rural Fires Act 1997 (NSW); SPA, Sustainable Planning Act 2009 (Qld). NSW regulation applies to the central population of EBB and Queensland regulation applies to the northern population of EBB and the BNTW. Results include analysis of regulations adopted under the statute (see Appendix S2 for the full list of regulatory documents). Values go from 0 (does not contain provisions to address the social-ecological link) to 3 (mandates exclusion of activities or requires management of impact) as defined in Table 1. TSCA, Threatened Species Conservation Act 1995 (NSW); VMA, Vegetation Management Act 1999 (Qld).

Grazing is not considered a threat for EBB NSW population, and regulatory responses in NSW framework are not included in the analysis.
that can be used to improve protection of threatened species and their habitats. However, their application and implementation tends to be optional (i.e., the regulator may develop or approve an instrument). As a result, important tools remain largely tools on paper. For example, although the EPBC Act allows the federal government to prevent developments that are likely to threaten “matters of national environmental significance,” many developments affecting threatened species have been approved (Woinarski et al., 2017). In turn, these approvals set a precedent and are therefore likely to affect the way regulatory tools for the protection of species are interpreted and used in the future. Furthermore, as highlighted in the recent Interim Report of the EBPC Act review, recovery plans are not mandated for all threatened species and only 719 of 1890 threatened species listed under the Act have a recovery plan. There is no regulatory requirement to implement the plans or report on progress or outcomes (Samuel, 2020). Development of enforceable national environmental standards, including granular and measurable standard for threatened species to support recovery, has been recommended as a foundation to closing the gap (Samuel, 2020). Expansion of potential habitats is also affected by gaps in vegetation clearing laws operating at the state level. In particular, in Queensland, the introduction of vegetation protection widened the gaps, enabling further clearing of remnant vegetation (Rhodes et al., 2017), including in Brigalow Belt (Simmons et al., 2018), habitat of the BNTW. Restoration support remains another important regulatory matter requiring revision (Samuel, 2020). These examples highlight that the interplay of institutions is an important consideration alongside assessments of functional fit.

### Applicability of the Quantitative Method to the Measurement of Institutional Fit

We found that using the quantitative text-mining method to analyze the functional fit of institutional frameworks was useful for identifying potential gaps in regulatory responses to social and ecological pressures that threaten species. This confirms the findings of other researchers applying the method (e.g., Ekstrom & Crona, 2017). However, our application revealed several challenges that warrant attention.

The quantitative analysis of functional fit identifies the presence or absence of institutional responses related to the linkages in the system’s model. Focus on the functional dimension alone, however, is not sufficient. Our results showed that regulatory instruments vary in their application boundaries, which can be based on various criteria, such as administrative area, tenure, or even the presence of groups of species or types of vegetation. The failure to consider the spatial and other boundaries of instruments may affect the results of functional fit. For example, an instrument may address several links of the model, demonstrating perfect or near perfect fit, while being applicable to a small administrative area (e.g., a national park). Therefore, we recommend identifying and adding boundaries of an instrument to the metadata, thereby allowing analyses of scale fit alongside functional fit (Cumming et al., 2006; Guerrero et al., 2013). In addition, while applying a social-ecological systems framework to conservation problems permits a systems approach in which key interactions between social and ecological factors can be identified (Ban et al., 2013; Guerrero & Wilson, 2017). DPSIR-based models do not account for interactions between pressures (Patricio et al., 2016). In threatened species management, the costs, benefits, and feasibility of one action can influence other actions and change where and when another actions should be taken (Auerbach et al., 2015). For example, successful recolonization of a subpopulation of EBB after fire was attributed to appropriate fire regime (leaving unburnt refuges) and predator (fox) control actions (Lindenmayer et al., 2009). Incorporating interactions among the pressures would improve the models and assist with identifying the regulatory responses requiring integration.

We also identified several problems related to the queries of term co-occurrence. First, our quantitative analysis returned far fewer matches in statutory instruments than the qualitative approach (Appendix S3). Low co-occurrence could be partially attributed to the selection of concepts. Statutes are rarely designed to address a single environmental problem, and in the language of the law, ordinary words may have different meanings. Furthermore, terms can differ across jurisdictions or even regulatory domains of the same jurisdiction. Therefore, selection of concepts should start with analysis of statutory definitions. Second, the selected distance (100 words) returned many false positives as well as irrelevant records. At the same time, in provisions containing long lists or many subsections, this distance was insufficient to detect a match. The precision of the text-mining results in legal documents is an acknowledged problem, largely attributed to the complexity of the language, the structure of legal documents, and the limitations of the algorithms ( Francesconi et al., 2010; Son et al., 2016). Consequently, even in close proximity, 2 or several terms can be used in different contexts. In contrast, no matches will be returned if the legal text incorporates references to other sections or regulatory instruments for definitions or regulatory provisions. This problem was not limited to statutes: false-negatives were also detected in management documents, highlighting an inconsistency in the execution of the search and matching function. Future applications should consider these limitations and include qualitative checks as part of the method. Finally, interpretation of the co-occurrence of terms and their frequency is not straightforward. Frequency of co-occurrence may not be a good indicator
that the problem is more or less acknowledged. For example, different drafting techniques might influence the number of times a particular term is included in a document (e.g., some documents may be more wordy). Furthermore, co-occurrence does not reveal how a problem is addressed. To assess this, inclusion of other terms may be needed. For example, behaviors or activities associated with a particular threat can be enabled, included, excluded, prohibited, or postponed. Statutory instruments also perform a range of other functions that are not captured by the method (and the metrics), such as allocating management authority; prescribing monitoring, reporting, penalties, and funding allocations; and applying or designing other instruments. Consequently, quantitative degree of fit alone may not provide a reliable foundation for policy recommendations.

Data mining can assist with navigation of large volumes of documents and can act as an indicator of the potential problems with institutional responses. However, limiting the analysis to statutory documents, as previous researchers have done (e.g., Ekstrom & Young, 2009), can be problematic. Inclusion of operational-level documents is required to analyze species- or ecosystem-specific responses. More research is needed on the use and interpretation of quantitative results that would allow use of the degree of fit as a reliable measure. To be useful for policy recommendations or reforms, quantitative results of institutional fit should be interpreted in light of the sociopolitical and institutional context and supported by the findings from a qualitative investigation.

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Supporting Information

(Appendix S1) Case study species historical timelines of their state and conservation efforts. (Appendix S2) Methodology. (Appendix S3) Text mining results and cross-checking. (Appendix S4) Detailed results of the qualitative analysis. Additional information is available online in the Supporting Information section at the end of the online article. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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