CONTRIBUTED PAPER

The contributions of nature to people within the Yawuru Indigenous Protected Area

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Managers of Indigenous Protected Areas (IPAs) may need to communicate the value provided by their protected area to indigenous and nonindigenous stakeholders, especially if a political focus on maximizing economic opportunities conflicts with traditional priorities. To facilitate this process, we used the latest Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services conceptual framework and the IPA plan of management to identify the diverse ways that nature contributes to people in the Yawuru IPA (Western Australia). 68 out of 144 of the IPA management objectives related directly to ecosystem goods and services of which 65 are nonmaterial, 35 material, and 24 regulating (some services overlap). As a guide for management to assess relevant contributions, we identified valuation methods applicable to the IPA’s wetlands and found that a wide range of options are available to assess ecosystem value. We also performed a detailed assessment of fresh water flow over the IPA.

KEYWORDS
Australian water balance model, context-specific perspectives, ecosystem services, hydrology, management objectives, material contributions, nature’s contributions to people, nonmaterial contributions, regulating contributions, Roebuck Plains

1 | INTRODUCTION

An important part of Australia's National Reserve System, Indigenous Protected Areas (IPAs) are areas of traditional indigenous lands which may exist over multiple terrestrial and marine tenures (Farr, Stoeckl, Esparon, Grainger, & Larson, 2016). IPAs are dedicated (with federal government approval and funding) by indigenous groups for biodiversity, cultural heritage, and natural resource conservation and are managed in line with International Union for the Conservation of Nature protected area categories (Farr et al., 2016). Balancing ecological and cultural goals with traditional owner land-use preferences and economic needs is a common management challenge (Farr et al., 2016; Jackson & Palmer, 2015; Zander, Parks, Stratton, & Garnet, 2013). Like other indigenous societies, Australian aboriginal cultural practices and beliefs incorporate land management techniques, such as fire management, which are entwined with protecting “country” and natural resources (Farr et al., 2016; Finn & Jackson, 2011; Jackson & Palmer, 2015; Sangha et al., 2018). In this context, western land management techniques that consider ecological or economic goals independent of cultural values are inadequate for balancing all the objectives of IPA management.

One strategy for identifying and balancing the competing aspects of IPA management is to engage an ecosystem services approach. The term “ecosystem services” describes the benefits provided to humans from environmental assets and...
reserves such as land, water, vegetation, and the atmosphere (Brauman, Daily, Ka‘eo Duarte, & Mooney, 2007; Costanza et al., 1997). The 2005 Millennium Ecosystem Assessment first formally categorized these services, before being revised by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in 2013 and 2018 when ecosystem services were recategorized as nature’s contributions to people (NCPs) (Diaz et al., 2018; Peterson et al., 2018). NCPs can be considered as four categories across two perspectives: Context-specific perspectives, useful when accounting for local or indigenous perspectives of ecosystems and which do not require external validation; and generalizing perspectives (Diaz et al., 2018). Generalizing perspectives fall under three categories: Regulating contributions are analogous to the Millennium Ecosystem Assessment’s regulating and supporting services, as they modulate the environment and maintain conditions for ecosystem functions (e.g., flood mitigation); nonmaterial contributions (e.g., sacred sites) are similar to cultural services as categorized by the Millennium Ecosystem Assessment;; and supporting material contributions (e.g., food) are similar to provisioning services (Diaz et al., 2018; MEA, 2005).

IPA managers need to communicate the value provided by their protected area to their own indigenous community and to external stakeholders. Friction has always existed in terms of what, how and by whom NCPs are valued (D’Amato, Rekola, Wan, Cai, & Toppinen, 2017; Pascual et al., 2017; Van Riper et al., 2017). The key is that NCPs and context-specific perspectives exist, have value and are reliant on natural features or processes to persist. In the case of the Yawuru IPA, Broome is a significant hub for resource developments. Though not all such developments have eventuated, it is important for IPA managers to at least understand how potential developments could impact the natural processes that underpin their IPA’s NCPs. Identifying NCPs through the management plan and then quantifying the processes that support them is the first step to achieving that, although debate rages as to the feasibility and desirability of applying monetary metrics to some natural processes (Costanza et al., 2014; Diaz et al., 2015; Polasky, Tallis, & Reyers, 2015).

The process of identifying, measuring, and assigning values to NCPs can be challenging, as indigenous and non-indigenous perspectives may differ. Nonetheless, valuation tools have been developed to measure NCP provision in both financial and nonfinancial terms (Pascual et al., 2012). Material contributions (provisioning services) and certain regulating contributions, such as water use and water quality are comparatively straightforward to quantify as they produce goods and services valued by humans. Nonmaterial contributions (cultural services) are more difficult to measure directly due to their interlinkage with the other contributions (Diaz et al., 2018; Pascual et al., 2012; Small, Munday, & Durance, 2017). Indigenous perspectives of nature may value similar NCPs to scientific methods but are arrived at through different historical experiences and thought processes (Diaz et al., 2018; Sangha et al., 2018). Where indigenous and nonindigenous perspectives coalesce, that is ideal, from a management point of view. However, when indigenous perspectives diverge, rather than trying to inadequately fit them into a western framework, (e.g., by using the concept of cultural services as a “miscellaneous” category) context-specific perspectives allow for their preservation (Diaz et al., 2018; James, 2015). Context-specific perspectives are not subject to economic valuation—they are better described as having relational or moral values (Chan et al., 2016; Diaz et al., 2018). Identifying, recording, and preserving them is important for communicating indigenous perspectives externally and for maintaining indigenous traditions that have environmental benefits (Chan et al., 2016; Diaz et al., 2018; Sangha et al., 2018).

We explored the potential for an NCP approach to be used by an IPA to describe their ecological, economic and cultural objectives. To do so, we pursued three aims. First, we considered how each of the eight management targets specified in the Yawuru IPA plan of management could be described in terms of NCP categories. Second, we identified valuation approaches for NCPs related to the specific management target of Bilarra (the Yawuru language term for wetlands). Third, we demonstrated how to calculate the contribution of a single NCP by estimating the surface flow available to sustain the wetlands on Roebuck Plains Station.

2 | METHODS

The 2,005 sq km Yawuru IPA covers both terrestrial and marine environments and is located around Broome, Western Australia (Yawuru RNTBC, 2014). Dedicated in 2017, 1,084 sq km IPA is within a viable pastoral lease—Roebuck Plains station—with significant ecological and cultural sites (Yawuru RNTBC, 2014). The implementation of the IPA plan of management occurs through a formal, partnership process, involving Yawuru community and external stakeholders (Yawuru RNTBC, 2014). Nyamba Buru Yawuru Ltd. is the operational arm of the Yawuru corporate group and conducts day-to-day management of the IPA through its Yawuru Environmental Services Team (from here on described as “managers”).

Ecologically, the IPA encompasses Ramsar Convention on Wetlands of International Importance (Ramsar) designated wetlands, is home to migrating shorebirds, and harbors threatened species (e.g., bilbies and dugongs) and fish nurseries (Yawuru RNTBC, 2014). Culturally, the IPA also covers important indigenous heritage sites. Across the IPA, managers must balance ecological and cultural considerations with economic considerations due to pressures that are internal (e.g., cattle grazing may affect cultural sites) and
external to the IPA (e.g., surrounding agricultural development may affect groundwater).

This project was initiated after a discussion between the Yawuru IPA coauthors and the University of Queensland coauthors about the possibility of performing an exploratory assessment of using ecosystem services thinking to describe IPA conservation objectives. The Yawuru IPA coauthors were curious about the possibility of using such thinking to more broadly describe IPA objectives to policymakers. The University of Queensland-based coauthors had the capacity to perform this initial exploration and received feedback on project design, plan of management interpretation, and paper framing and style from the IPA manager coauthors.

### 2.1 Possible NCPs provided by the Yawuru IPA

To classify the potential NCPs provided by the IPA, we reviewed the IPA 10-year plan of management (Yawuru RNTBC, 2014) to consider how the stated goals corresponded with ecosystem service categories and identify potential valuation methods for each service.

The management plan identified eight targets relating to the IPA’s cultural, ecological, and economic values. Each target included stated management objectives:

- **Target 1**: Yawuru cultural knowledge and practice
- **Target 2**: Yawuru significant areas
- **Target 3**: Yawuru rights and responsibilities
- **Target 4**: Niyamarri — sand dunes
- **Target 5**: Bilarra — wetlands
- **Target 6**: Birra — bush and pindan country
- **Target 7**: Nagulagun — saltwater country (deep water and intertidal)
- **Target 8**: Seasonal resources and biodiversity

Using the IPA management plan as a starting point, we first identified the individual management objectives for each target that related directly to NCPs. Management objectives that did not relate directly to NCPs were eliminated (these were mostly highly specific management objectives related to good governance such as: “Hold regular sub-committee meetings”). We then matched each management objective to appropriate NCPs using four categories based on the definitions provided by the IPBES (Table 1) (Diaz et al., 2018)—context-specific perspectives, or one of three generalizing perspectives—regulating, material, or nonmaterial (Table 2).

### 2.2 Strategies to measure NCPs for Bilarra (wetlands)

To communicate the value of protected areas such as IPAs, managers need to identify and value NCPs. We outline existing options for valuation methods and approaches that could conceivably be used by any protected area manager or management team using the Yawuru IPA context as an example (Table 3). For simplicity, we chose to use one management target as a case study. Target 5, Bilarra (wetlands), was selected because wetlands link terrestrial and marine ecosystems across northern Australia, thereby providing a wide range of NCPs (Zander & Stratton, 2010). In the case of the Yawuru IPA, the nutrient outflow from the wetlands to the estuarine environment helps to sustain recreational and customary fisheries (Yawuru RNTBC, 2011, 2014). Roebuck Plains’ extensive wetlands and waterholes or “jila” are also important spiritual and cultural sites associated with mythological beings, for example, the rainbow serpent (Semeniuk & Semeniuk, 2000; Yawuru RNTBC, 2011, 2014). We matched the NCPs listed for target five (wetlands) to valuation approaches and methods from the literature using Table 3; Table S1, Supporting Information. Human beneficiaries for each NCP were added based on industry activities in the Kimberley as listed by the Department of Regional Development (2014) with the addition of First Nations, Broome, and Ramsar.

### 2.3 Calculating the provision of one NCP by the IPA

To demonstrate how to calculate the contribution of a single NCP, in this case regulation of freshwater quantity, location, and timing, we calculated the runoff available for the recharge of the IPA’s wetlands over the period 2009–2016. The IPA ecosystems rely on both surface water inflow and groundwater recharge (Semeniuk & Semeniuk, 2000). Runoff is important because monsoonal flooding is crucial for the survival of the wetlands and associated NCPs.

To calculate available surface water, we simulated runoff over the entire watershed (5,250 sq km) from the area of the IPA (2,102 sq km) from 2009 to 2016. Calculating the runoff over the watershed provided an upper bound estimate of the total amount of water that could flow through the IPA, while calculating the runoff expected within the boundaries of the IPA gave a lower bound estimate. Runoff was simulated with the Australian Water Balance Model in the eWater Rainfall Runoff Library program (eWater, 2017). The Australian Water Balance Model predicts runoff based on analysis of previously observed runoff, evapotranspiration, and rainfall using data collected across Australia and is appropriate for estimating runoff in ungauged catchments (Boughton & Chiew, 2003).

To make accurate predictions, the Australian Water Balance Model required data on rainfall, evapotranspiration, and streamflow. We used data for evapotranspiration (mm/day) and rainfall (mm/day) from the Broome weather station because Roebuck Plains weather station records terminate in 2011. Daily streamflow data were obtained from the Bureau of Meteorology website (BOM, 2017a) for the Isdell River, covering the years 2009–2016. The Isdell River was a suitable proxy for the watershed as its location was the closest of the three BOM hydraulic stations in north-west Western Australia. Daily and monthly runoff calculations for the period 2009–2016 were generated, from which annual
TABLE 1  Nature’s contributions to people (NCPs) definitions and categories (Diaz et al., 2018) relating to targets in the IPA plan of management

| IPBES no. | NCP                          | Definition                                                                 | CSP | R  | NM | M  | IPA targets |
|-----------|------------------------------|---------------------------------------------------------------------------|-----|----|----|----|-------------|
| 1         | Habitat creation and         | Formation of habitat for animals and plants useful to humans              | ●   | ●  |    |    | 3, 4, 5, 7, 8 |
|           | maintenance                  |                                                                           |     |    |    |    |             |
| 2         | Pollinations and dispersal   | Movement of pollen or seeds by animals of plants useful or detrimental to  | ●   | ●  |    |    | 5           |
|           | of seeds and propagules      | humans                                                                     |     |    |    |    |             |
| 3         | Regulation of air quality    | Filtration, fixation, degradation, or storage of pollutants                | ●   | ●  |    |    | 7           |
| 4         | Regulation of climate        | Regulation of greenhouse gases, organic compounds and climate feedback    | ●   | ●  |    |    | 7           |
|           | processes                    |                                                                           |     |    |    |    |             |
| 5         | Regulation of ocean          | Regulation, by photosynthetic organisms, of atmospheric CO2 and            | ●   |    |    |    | None identified |
|           | acidification                | therefore seawater pH                                                     |     |    |    |    |             |
| 6         | Regulation of freshwater     | Regulation, by ecosystems, of the quantity, location, and timing of the    | ●   | ●  |    |    | 2, 5        |
|           | quantity, location, and      | flow of surface and groundwater                                           |     |    |    |    |             |
|           | timing                       |                                                                           |     |    |    |    |             |
| 7         | Regulation of freshwater     | Regulation—Through filtration of particles, pathogens, excess             | ●   | ●  |    |    | 2, 5        |
|           | and coastal water quality    | nutrients, and other chemicals—By wetland and marine ecosystems           |     |    |    |    |             |
| 8         | Formation, protection, and   | Formation and long-term maintenance of soil structure and processes by    | ●   | ●  |    |    | 5, 7        |
|           | decontamination of soils     | plants and soil organisms                                                  |     |    |    |    |             |
|           | and sediments                |                                                                           |     |    |    |    |             |
| 9         | Regulation of hazards and    | Amelioration, by ecosystems, of the impacts on humans/infrastructure      | ●   |    |    |    | 4, 5, 7     |
|           | extreme events               | caused by extreme events                                                   |     |    |    |    |             |
| 10        | Regulation of detrimental    | Regulation, by organisms, of pests, pathogens, predators or competitors   | ●   |    |    |    | 3, 4, 5, 6, 7, 8 |
|           | organisms/biological         | directly/indirectly affecting humans                                       |     |    |    |    |             |
|           | processes                    |                                                                           |     |    |    |    |             |
| 11        | Energy                       | Production of biomass-based fuels                                         | ●   | ●  | ●  |    | 3           |
| 12        | Food and feed                | Production of food/feed from/f or wild, managed, or domesticated           | ●   | ●  | ●  |    | 1, 2, 3, 4, 5, 6, 7, 8 |
|           | organisms                    |                                                                           |     |    |    |    |             |
| 13        | Materials, companionship,    | Materials derived/animals sourced from cultivated or wild ecosystems, for | ●   | ●  | ●  |    | 3, 5, 6, 7, 8 |
|           | and labor                    | construction, clothing, and ornamental purposes                           |     |    |    |    |             |
| 14        | Medicinal, biochemical,      | Production of medicinal, veterinary, and pharmacological purposes.         | ●   | ●  |    |    | 3, 5        |
|           | and genetic resources        | Production of genes for plant and animal breeding                         |     |    |    |    |             |
| 15        | Learning and inspiration     | Nature facilitates education, acquisition of knowledge, and development of | ●   | ●  | ●  |    | 1, 3, 4, 5, 7 |
|           |                              | skills                                                                     |     |    |    |    |             |
| 16        | Physical and psychological   | Nature as basis for physically and psychologically beneficial activities,  | ●   | ●  | ●  |    | 1, 3, 4, 5  |
|           | experiences                  | example, healing, relaxation, and recreation                              |     |    |    |    |             |
| 17        | Supporting identities        | Landscapes, seascapes, habitats/organisms being basis for religious/spiritual | ●   |    |    |    | 1, 2, 3, 4, 5, 6, 7, 8 |
|           |                              | experiences                                                                |     |    |    |    |             |
| 18        | Maintenance of options       | Capacity of ecosystems, habitats, species/genotypes to keep options open   | ●   | ●  | ●  |    | 3, 5, 6, 7, 8 |
|           |                              | to support good quality of life                                           |     |    |    |    |             |

Note. NCPs include context specific perspectives (CSPs) and three types of Generalizing perspectives—regulating (R), non-material (NM) and material (M) services—Which may overlap. See Table 2 for detailed allocation of NCPs to IPA management objectives within Targets.

averages were calculated as was average runoff over the period 2009–2016. We verified the predictions of the Australian Water Balance Model against the average monthly and yearly runoff simulations from the Australian Bureau of Meteorology for the watershed and IPA. This was done by calculating average runoff of pixels within the IPA and the watershed using data from the NETCDF4 data files located on the Bureau’s website (BOM, 2017b).

Formal ethics clearance for this project was deemed unnecessary by The University of Queensland as the project scope was to review the management plan, sort the management objectives into ecosystem services/NCP categories and analyse the contribution of a selected service using geographical information systems. Thus, our work was interpreted as not directly interacting with the Yawuru people, but only their plan of management. However, our Yawuru IPA coauthors were instrumental in initiating the project and providing the materials and direction necessary to complete the study.

3 | RESULTS

3.1 | Possible NCPs provided by the Yawuru IPA

Here, 68 out of 144 total management objectives of the Yawuru IPA plan of management were related directly to NCPs. Nonmaterial contributions could be provided by almost all management objectives, as they were associated with 65 out of 68 objectives, followed by material contributions (35 out of 68) and regulating contributions (24 out of 68) (Figure 1—see Table 2 for the assigned relationships). We found that Nagulagan (saltwater country) management objectives had the highest numbers of NCPs and all categories were represented. Niyamarri (sand dunes) management
### TABLE 2  
Assessment of regulating (R); non material (NM) and material (M) NCPs and CSPs provided by the Yawuru IPA based on relevant management objectives outlined in the IPA plan of management

| Management objectives | NCP | CSP | R  | NM | M  | IPBES no. |
|-----------------------|-----|-----|----|----|----|-----------|
| **Target 1**          |     |     |    |    |    |           |
| **Yawuru Cultural Knowledge and practice** | Yawuru cultural knowledge and practice is recorded, active and being passed on to younger generations. | [ ] | [ ] | [ ] | 15 | 
| Yawuru people, especially the youth, are accessing country for cultural, educational, and recreational purposes. | [ ] | [ ] | [ ] | 15, 16 | 
| Successful interpretive and educational projects across the Yawuru estate are providing opportunities for Yawuru and others to learn and practice Yawuru culture. | [ ] | [ ] | [ ] | 15 | 
| Develop programs for Yawuru people to access Yawuru country for cultural purposes, hunting, and recreation. | [ ] | [ ] | [ ] | 12, 15, 16 | 
| Using the Yawuru language | [ ] | [ ] | [ ] | 15, 17 | 
| Maintaining culture through art | [ ] | [ ] | [ ] | 16 | 
| Fostering good liyan between people and country | [ ] | [ ] | [ ] | 17 | 
| **Total** | 7 | 0 | 7 | 1 | 12, 15–17 | 
| **Target 2**          |     |     |    |    |    |           |
| **Yawuru significant areas** | Protect and manage Bugarrigarra areas | [ ] | [ ] | [ ] | 17 | 
| Protect and manage named sites | [ ] | [ ] | [ ] | 17 | 
| Protect and manage camping sites | [ ] | [ ] | [ ] | 16 | 
| Protect and manage hunting and harvesting areas | [ ] | [ ] | [ ] | 12, 17 | 
| Protect and manage water sites—Wetlands, jilji, and springs | [ ] | [ ] | [ ] | 6, 7, 17 | 
| Protect and manage historical sites | [ ] | [ ] | [ ] | 17 | 
| Protect and manage burial sites and rayi places | [ ] | [ ] | [ ] | 17 | 
| Protect and manage old sites: Archaeological and other heritage sites such as at Kunin. | [ ] | [ ] | [ ] | 17 | 
| **Total** | 8 | 1 | 8 | 2 | 6, 7, 12, 16, 17 | 
| **Target 3**          |     |     |    |    |    |           |
| **Yawuru Rights and Responsibilities** | Yawuru people are working as land and sea managers, with a functioning and well-resourced Yawuru country manager group. | [ ] | [ ] | [ ] | 17 | 
| Yawuru run a well-funded and continuing IPA project based on culture-based business models. | [ ] | [ ] | [ ] | 17 | 
| Employ and train a team of Yawuru country managers (fulltime/part time/flexible work arrangements) using all on-ground activities as opportunities for employment, training, and education. | [ ] | [ ] | [ ] | 15 | 
| Economic independence: To develop a cultural conservation economy that supports the Yawuru. | [ ] | [ ] | [ ] | 12, 15, 17 | 
| Yawuru access to country. | [ ] | [ ] | [ ] | 1, 10–18 | 
| Youth programs such as Yawuru youth rangers. | [ ] | [ ] | [ ] | 15 | 
| **Total** | 3 | 1 | 6 | 2 | 1, 10–18 | 
| **Target 4**          |     |     |    |    |    |           |
| **Niyamarri—Sand dunes** | Maintain and protect coastal sand dunes and maintain ecosystem health. | [ ] | [ ] | [ ] | 1, 9, 12, 17 | 
| Coastal and inland middens are mapped and being protected. | [ ] | [ ] | [ ] | 17 | 
| Coastal monsoonal vine thickets are mapped, assessed, and being protected from threats. | [ ] | [ ] | [ ] | 9, 12, 17 | 
| Biodiversity and habitats of inland, linear sand dunes are being protected. | [ ] | [ ] | [ ] | 1, 12, 17 | 
| Rehabilitate damaged dune systems by track closure, revegetation, and removal of weeds from monsoonal vine thickets. | [ ] | [ ] | [ ] | 1, 10, 17 | 
| Investigate archaeological sites. | [ ] | [ ] | [ ] | 15, 17 | 
| Engage Yawuru people and supporters in dune rehabilitation, maintenance, and protection, starting with Kennedy Hill. | [ ] | [ ] | [ ] | 1, 9, 16, 17 | 
| Bugarrigarra stories | [ ] | [ ] | [ ] | 17 | 
| Middens | [ ] | [ ] | [ ] | 17 | 
| Burial and rayi (conception/spirit) sites | [ ] | [ ] | [ ] | 17 | 
| Mayingan Manja bulu—monsoonal vine thickets | [ ] | [ ] | [ ] | 12, 17 | 
| Camping and cooking areas | [ ] | [ ] | [ ] | 16 | 
| Kennedy Hill | [ ] | [ ] | [ ] | 17 |
### TABLE 2  (Continued)

| Management objectives                          | NCP | CSP | R | NM | M | IPBES no. |
|-----------------------------------------------|-----|-----|---|----|---|----------|
| Management objectives                         |     |     |   |    |   |          |
| Old living areas such as *Jilbanumg*          |     |     |   |    |   | 17       |
| **Total**                                     | 7   | 5   | 14| 4  |   | 1, 9, 10, 12, 15–17 |
| **Target 5**                                  |     |     |   |    |   |          |
| Wetland vegetation intact to support the biodiversity of habitats, including those for migratory birds. |     |     |   |    |   | 6, 7, 17 |
| Yawuru rights in groundwater management are promoted and secured. |     |     |   |    |   | 1, 2, 6–9, 12, 16, 17 |
| Regenerate native vegetation (trees, shrubs, and grasses) in selected lakes and springs, using resources from Yawuru native nursery. |     |     |   |    |   | 18 |
| Ramsar wetland of intertidal mudflats, samphire/saline grasslands of high value, bird habitats supporting globally significant biomass of marine invertebrates. |     |     |   |    |   | 1, 2, 6, 10, 12, 13, 15–18 |
| Protect and manage springs                   |     |     |   |    |   | 1, 6–9, 12, 15, 18 |
| Protect and manage lakes                     |     |     |   |    |   | 6, 7, 17 |
| Protect and manage groundwater (flows and recharge) |     |     |   |    |   | 15–17 |
| Protect and manage cultural sites            |     |     |   |    |   |          |
| **Total**                                     | 4   | 8   | 7 | 7  |   | 1–2, 6–10, 12–18 |
| **Target 6**                                  |     |     |   |    |   |          |
| The biodiversity of Yawuru pindan country is mapped, assessed and being protected from known threats |     |     |   |    |   | 10, 12, 17, 18 |
| Protect traditional hunting and harvesting areas on Roebuck Plains station and within the Yawuru Conservation Park. |     |     |   |    |   | 12, 17, 18 |
| **Total**                                     | 2   | 1   | 3 | 3  |   | 10, 12, 17, 18 |
| **Target 7**                                  |     |     |   |    |   |          |
| Sustainable fishing is being practised in Roebuck Bay by all users. |     |     |   |    |   | 12, 18 |
| Nutrient and stormwater run-off into Roebuck Bay is reduced significantly. |     |     |   |    |   | 7 |
| Work with partners to develop a model of marine conservation and management that builds on Yawuru cultural traditions to ensure a healthy marine environment, for example, adapt fishing regulations to match Yawuru seasonal harvest of marine resources. |     |     |   |    |   | 12, 18 |
| Develop an education program for Broome’s fishing community to generate respect for the Yawuru saltwater seasons and customary fishing practices. |     |     |   |    |   | 15 |
| Maintain and develop monitoring of drainage and nutrient run-off into Roebuck Bay, and improve drainage management by adopting environmentally sustainable principles with partners and stakeholders. |     |     |   |    |   | 7, 10, 18 |
| Build a scientific knowledge base of marine species and health of country alongside Yawuru traditional knowledge, by developing relevant marine research projects with partners. |     |     |   |    |   | 15, 18 |
| Protect saltwater *jurru* (metaphysical serpent-like beings) |     |     |   |    |   | 17 |
| Protect fish-traps                            |     |     |   |    |   | 12, 17 |
| Protect dolphins and whales                  |     |     |   |    |   | 12, 17 |
| Protect dugong and turtle                    |     |     |   |    |   | 12, 17 |
| Protect fish                                 |     |     |   |    |   | 12, 17 |
| Protect stingray                             |     |     |   |    |   | 12, 17 |
| Protect shellfish                            |     |     |   |    |   | 12, 17 |
| Protect reef & coral                         |     |     |   |    |   | 1, 12, 17 |
| Protect mudflats (calcium carbonate and intertidal area) |     |     |   |    |   | 1, 8, 12, 17, 18 |
| Protect mangroves                            |     |     |   |    |   | 1, 3, 4, 8, 9, 17, 18 |
| **Total**                                     | 13  | 6   | 16| 12 |   | 1, 3, 4, 7–10, 12, 15, 17, 18 |
TABLE 2 (Continued)

| Management objectives                                    | NCP | IPBES no. |
|-----------------------------------------------------------|-----|-----------|
| **Target 8**                                              |     |           |
| Cultural and ecological corridors are in place across Yawuru country. | CSP R NM M | 1, 10, 12, 17 |
| **Seasonal resources and biodiversity**                   |     |           |
| Ecologically-sustainable harvesting of species practised by Yawuru and other users. | CSP R NM M | 12, 17, 18 |
| Assess and monitor harvesting of seasonal resources by Yawuru and other indigenous people living in Yawuru country. | CSP R NM M | 12, 18 |
| Assess impacts of cane toad invasion on popular harvest animals, such as goanna, and develop appropriate seasonal harvest practices to adjust to these changes. | CSP R NM M | 10, 12, 18 |
| **Total**                                                 | 46  | 24  | 65  | 35  | 1, 10, 12, 17, 18 |

*Note.* Management objectives were allocated NCPs based on the IPBES definitions (the final column corresponds to the numbered IPBES definitions in Table S1).

objectives also contributed all NCPs but were particularly useful for nonmaterial contributions. Conversely, the targets related to the IPA’s wetland ecosystems—*Nagulagan* and *Bilarra* (wetlands) had management objectives that were more likely to provide material contributions. All targets had management objectives that were classified as context-specific perspectives. The targets Yawuru cultural knowledge and practice and Yawuru significant areas had high proportions of their management objectives classified in this way. Table 2 shows that context-specific perspectives always overlapped with nonmaterial contributions, but not the other way around. Regulating contributions were primarily found in management objectives associated with wetlands, saltwater country, and sand dunes targets.

### 3.2 Strategies to value NCPs for Bilarra (wetlands)

IPA managers who need to communicate the value of the ecosystems within their protected area (in this case, *Bilarra*) have several potential NCP valuation methods available. Stated preference methods (appropriate for 11 NCPs) were the most common potential valuation methods that could be appropriate for measuring NCPs associated with *Bilarra* (Wetlands, Table 3, see Gren, 1993 and Loomis & Richardson, 2000 for overview of methods). Cost-based methods (nine NCPs) and production-based methods (seven NCPs) are also good candidates for valuing many NCPs (for information on method, see Pascual et al., 2012). Revealed preference methods (four NCPs) and benefits transfer (two NCPs) were less commonly appropriate (see Costanza et al., 1997; Zander & Straton, 2010; Pascual et al., 2012; Varcoe et al., 2015 for information on methods). These valuation strategies were based on *Bilarra* providing 14 of 18 potential NCPs. Seven are regulating NCPs; three are material NCPs; four are nonmaterial NCPs; and one can be considered as all three categories of NCPs (Tables 1 and 3). Regulation of air quality, regulation of climate, regulation of ocean acidification, and energy (Table S1) were not considered relevant to the wetlands for this assessment.

#### 3.3 Calculating the provision of one NCP by the IPA

We aimed to use available data sources to determine the amount of rainfall runoff available to wetlands of the IPA. Our analysis suggested 180GL–549GL available from runoff across the actual area of the IPA and 449GL–1297GL available across the wider watershed (Figure S1). Most runoff occurred during and immediately after the monsoon, between December and March.

#### 4 DISCUSSION

There seems to be great scope for an NCP approach to be used by our case study IPA to describe the cultural, ecological and economic benefits of its existence and management. If managers want to quantify relevant NCP provision to interact more effectively with external stakeholders and gain support for management decisions, they must first identify possible NCPs and determine how to measure them. This study has performed the first step in this process by examining how to classify management objectives as NCPs. We found that NCPs were prevalent across all targets in the IPA plan of management and context-specific perspectives, nonmaterial NCPs and regulating NCPs were particularly common. To use identified NCPs for policy and management decision-making, managers would need to know if and how different NCPs could be measured. To assist this process, we identified possible valuation approaches and methods for the subset of management objectives relating to the *Bilarra* (wetland) target and provide suggested references for management. We also demonstrated a process for measuring a single NCP and show how available data can be used to estimate the volume of runoff (relevant for sustaining inflow dependent ecosystems) within the IPA.

We found that most of the IPA management plan objectives could be classified as NCPs and all the IPA management plan targets had associated NCPs. Nonmaterial NCPs are the most prevalent generalizing perspectives in the IPA management plan, closely followed by material NCPs. This is unsurprising as many traditional owner groups assess the
effectiveness of regulating NCPs through the condition of material NCPs (e.g., the amount of fat on kangaroo tails) and nonmaterial NCPs (e.g., the amount of time spent on country) (Moorcroft et al., 2012). The variability of these perspectives compared to nonmaterial NCPs across all targets demonstrates the utility of separating context-specific perspectives rather than combining them as nonmaterial NCPs. Allocation of context-specific perspectives in Table 2 was based on a thorough reading of the plan of management and consideration of whether the management objectives

| NCP                              | Valuation approach | Valuation methods                                                                 | Beneficiary                                      |
|----------------------------------|--------------------|----------------------------------------------------------------------------------|-------------------------------------------------|
| Habitat creation and maintenance | ✓                  | Choice modeling\(^a\); replacement costs\(^b\)                                   | First Nations, Broome, Tourism, RAMSAR          |
| Pollinations and dispersal of    |                    | Factor income\(^c\)                                                             | First Nations, RAMSAR                            |
| seeds and propagules             |                    |                                                                                  |                                                 |
| Regulation of freshwater quantity| ✓                  | Choice modelling\(^d\); participatory valuation\(^e\); public investments\(^f\);  | First Nations, Broome, Tourism, RAMSAR, Agriculture, Construction |
| location and timing              | ✓                  | avoided costs\(^g\); replacement costs\(^h\); and restoration costs\(^i\)      |                                                 |
| Regulation of freshwater and     | ✓                  | Factor income\(^j\); contingent valuation methods (CVM\(^k\)); avoided costs\(^l\);  | First Nations, Broome, Tourism, RAMSAR, Agriculture, Fisheries |
| coastal water quality            |                    | mitigation costs\(^m\); replacement costs\(^n\); and restoration costs\(^o\)   |                                                 |
| Formation, protection and        | ✓                  | Choice modelling\(^p\); CVM\(^q\); restoration costs\(^r\)                      | First Nations, RAMSAR, Agriculture               |
| decontamination of soils and      |                    |                                                                                  |                                                 |
| sediments                        |                    |                                                                                  |                                                 |
| Regulation of hazards and        | ✓                  | CVM\(^s\); participatory valuation\(^t\); avoided costs\(^u\); and replacement   | First Nations, RAMSAR                            |
| extreme events                   |                    | costs\(^v\)                                                                      |                                                 |
| Food and feed                    | ✓                  | Choice modelling\(^w\); contingent ranking\(^x\); CVM\(^y\); participatory       | First Nations, Broome, RAMSAR, Agriculture,     |
|                                  |                    | valuation\(^z\); stakeholder analysis\(^\|\); factor income; production function; | Fisheries                                       |
|                                  |                    | opportunity costs\(^\|\); replacement costs\(^\|\); and restoration costs\(^\|\); |                                                 |
|                                  |                    | public investments\(^\|\); benefits transfer\(^\|\)                             |                                                 |
| Materials, companionship and     | ✓                  | Contingent ranking\(^\|\); CVM\(^\|\); participatory valuation\(^\|\); opportunity | First Nations                                   |
| labor                            |                    | costs\(^\|\); restoration costs\(^\|\); and replacement costs\(^\|\); public   |                                                 |
|                                  |                    | investments\(^\|\); benefits transfer\(^\|\)                                   |                                                 |
| Medicinal, biochemical and       | ✓                  | Bio-economic modelling\(^a\); participatory valuation\(^b\); opportunity costs\(^c\); | First Nations, RAMSAR, Fisheries                |
| genetic resources                |                    | replacement costs\(^d\); and restoration costs\(^d\)                          |                                                 |
| Learning and inspiration         | ✓                  | CVM\(^e\)                                                                       | First Nations, Broome, Tourism                  |
| Physical and psychological       | ✓                  | Choice modelling\(^f\); CVM\(^g\); hedonic pricing\(^h\); consumer surplus; TCM; | First Nations, Broome, Tourism, Retail          |
| experiences                      |                    | participatory valuation\(^i\); opportunity costs\(^j\); protection costs\(^k\); |                                                 |
|                                  |                    | replacement costs\(^l\); and conversion costs\(^m\); benefits transfer\(^n\)  |                                                 |
| Supporting identities            | ✓                  | Choice modelling\(^o\); CVM\(^p\)                                               | First Nations, Broome                           |
| Maintenance of options           | ✓                  | Choice modelling\(^q\); CVM\(^q\); restoration costs\(^r\); replacement costs\(^r\) | First Nations, Broome, RAMSAR, Fisheries        |

Note. Acronyms are stated preference (SP), revealed preference (RP), production based (PB), cost based (CB), and benefits transfer (BT).

\(^a\) Zander et al. (2013).
\(^b\) Jackson, Finn, and Scheepers (2014).
\(^c\) Seidl and Moraes (2000).
\(^d\) Emerton (2005).
\(^e\) Varcoe, O’Shea, and Contreras (2015).
\(^f\) Gren (1993).
\(^g\) Verma (2003).
\(^h\) Barbier (2007).
\(^i\) Colombo, Calatrava-Requena, and Hanley (2006).
\(^j\) Loomis and Richardson (2000).
\(^k\) Bateman and Turner (1993).
\(^l\) Costanza et al. (1997).
\(^m\) Emerton (1996).
\(^n\) Baral, Basnayat, Khanal, and Gault (2016).
\(^o\) Hanley and Craig (1991).
\(^p\) Costanzo van Kooten, Withey, and Wong (2011).
\(^q\) Zander and Stratton (2010).
\(^r\) Bergstrom, Stoll, Tire, and Wright (1990).
\(^s\) Pak and Turker (2006).
\(^t\) Pascual et al. (2012).
\(^u\) Rosenberger and Loomis (2000).
selected made specific reference to culture or were directly related to culturally important sites. However, as the plan of management is informed by the Yawuru's indigenous perspectives, it is arguable that a broader interpretation would see potentially all management objectives categorized as context-specific perspectives.

Comprehensive valuation of NCP provided by the Yawuru IPA would require the implementation of detailed local research, including regular data collection for key NCP. We have provided valuation approaches and methods (Table 3) to give management suggested starting points for designing local studies. Accurate valuation for all NCPs on a protected area would likely be prohibitively expensive if the costs of environmental impact statements of AUD$130,000–$2,230,000 identified by Macintosh (2011) can be considered indicative (we could not identify NCP valuation costs for northern Australia). For this reason, management should carefully consider their desired goals for undertaking an NCP evaluation of a protected area and identify key NCP to proceed with. Key NCPs could be identified based on features such as the utility of knowing the value of the NCP, feasibility of measurement, and existing data sources. In some cases, cheaper solutions that require less technical or expert involvement may be available. For example, IPA managers may calculate the values of selected NCPs provided by their protected area by combining publicly available GIS data for that specific protected area, with values calculated from ecosystem services meta-studies (Costanza et al., 2014; Pandeya et al., 2016; Reynaud & Lanzanova, 2017; Varcoe et al., 2015).

The calculated annual runoff values of 180GL–549GL across the IPA provide a baseline to assess changes to runoff driven by human activities (e.g., agriculture, climate change) and the consequent impact on NCP and ecosystem health. Runoff across the IPA is highly dependent on monsoon rainfall which fluctuates considerably. Actual yearly runoff values calculated by the Australian Water Balance Model (between 52GL and 436GL from 2009 to 2016) may therefore be relevant should IPA management attempt to establish thresholds for runoff that lead to healthy and functioning NCPs (Finn & Jackson, 2011). Using specialized hydrological modeling programs (e.g., eWater Source) could assist the assessment process through consideration of surface and groundwater interaction but this cannot be achieved with current data (CSIRO, 2009; Wright, George, Paul, & Raper, 2016). Significant capital investment in data collection (e.g., drilling of new test bores across a wide area) would be required, as was the case for Wright et al. (2016) in their study of the adjacent LaGrange aquifer. This kind of investment may not be forthcoming without the economic potential of agricultural development to drive interest from the state government.

If using available data to estimate the value of NCPs, managers must consider the limitations resulting from data scale or scope deficiencies. For example, the CSIRO (2009) did not make a localized calculation for runoff on Roebuck Plains, citing insufficient data. The Australian Landscape Water Balance hydrological modeling also relied on low resolution data, leading to possible overestimates of runoff. Our calculation of average annual runoff of between 180GL and 549GL across the IPA demonstrates the difficulty of making precise calculations in data deficient areas.
Despite the above limitations, the estimated total runoff across the IPA and its watershed can provide a benchmark useful to management in determining environmental flow assessments. In combination with groundwater data, runoff calculations will be important to the quantification of IPA cultural flows under existing local and national policies. As the IPA has no major river systems (Yawuru RNTBC, 2014), the jila, inflow-dependent, and groundwater-dependent ecosystems are reliant on runoff for surface inflow and groundwater maintenance (Semeniuk & Semeniuk, 2000; Yawuru RNTBC, 2014). Environmental flow assessments should also take account of other data, especially floral/faunal transects, and indigenous knowledge of acceptable ecosystem condition to calculate the optimum runoff required to sustain healthy ecosystems and indigenous cultural practices (Finch & Jackson, 2011). Combining indigenous and nonindigenous knowledge would allow the impact of changing levels of runoff on the IPA’s NCPs to be quantified and the consequences to be analyzed from both perspectives. Managers then have a baseline from which to assess the potential impacts of external threats such as climate change or agricultural development (Yawuru RNTBC, 2014) on the IPA. Mitigation strategies could then be targeted more precisely and communicated more effectively to the indigenous community and nonindigenous stakeholders.

We believe the way IPA managers in Australia incorporate NCPs that are valuable to indigenous and nonindigenous stakeholders can serve as a template for protected area managers internationally. There are several trends in favor of this, including governments becoming increasingly interested in measuring ecosystem services (Polasky et al., 2015); the realization that indigenous perspectives can underpin management strategies in areas where research is difficult (e.g., marine protected areas) (Townsend et al., 2018); and the improved social, ecological, and economic outcomes associated with indigenous involvement in protected area governance (Oldekop, Holmes, Harris, & Evans, 2015). We acknowledge that the control exercised by indigenous Australians over IPAs contrasts with many other parts of the world (e.g., Brazil) (Gullison & Hardner, 2018; Jackson & Palmer, 2015). Despite this, we believe that in countries such as Canada, where change is occurring, evaluation of NCPs will be invaluable in helping managers communicate their objectives to policy makers and funders.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

DATA ACCESSIBILITY STATEMENT

All data used is publicly available from sources noted in the text.

AUTHOR CONTRIBUTIONS

All authors were involved in the conception of the idea for the paper. J.M., D.M., and M.W. provided relevant data from the Yawuru IPA. B.N. conducted the data analysis and wrote the paper with assistance from G.D.I. and K.A.W. All authors provided edits and feedback.

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