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LETTER

A multidisciplinary framework to assess the sustainability and acceptability of wildlife tourism operations

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ABSTRACT

Wildlife tourism is growing in popularity, diversity of target species, and type of tours. This presents difficulties for management policy that must balance the complex trade-offs between conservation, animal welfare, and pragmatic concerns for tourist satisfaction and economic value. Here, we provide a widely applicable, multidisciplinary framework to assess the impacts of wildlife tourism focusing on industry tractability, socioeconomic values, and their effects on conservation, animal welfare, and ecosystem impacts. The framework accommodates and quantifies the complexity of factors influencing wildlife tourism management, including direct and indirect effects on target and nontarget species, and identifies priorities for future biological, socioeconomic, and cultural heritage research. When applied to white shark cage-diving as a case study, the output demonstrates the utility of the framework for researchers, managers, and policy makers, and highlights the benefits of undertaking the assessment as an inclusive workshop to facilitate a more multidisciplinary assessment of wildlife tourism industries. The use of a universally applicable assessment framework will enable the identification of relevant factors to account for when managing wildlife tourism, provide an inventory of current knowledge, identify research needs, and semiquantitatively compare categories and target and nontarget species, leading to improved conservation outcomes for species and ecosystems.

KEYWORDS

cage-diving, conservation, ecology, ecotourism, management, nonlethal consumptive use, provisioning, sustainable tourism

1 | WILDLIFE TOURISM GLOBAL POLICY AND MANAGEMENT

The importance of sustainable tourism practices, when visiting protected areas or interacting with wildlife, is increasingly emphasized in international policy (Center for Responsible Travel [CREST], 2017; Koprowski & Krausman, 2019; Spenceley, 2017). Recommendations to ensure the sustainability of wildlife tourism is now incorporated

in the Convention on Biological Diversity (CBD, 2004), the IUCN (Spenceley, 2017), and the United Nations (UN Resolution A/RES/69/233). The creation of organizations such as the Global Sustainable Tourism Council (GSTC) and Centre for Responsible Travel (CREST), and the inclusion of tourism in IUCN, UN, and CBD recommendations showcases the recognition by policy makers of the role wildlife tourism plays in both species exploitation and conservation. The GSTC states (D3.4 d): "Direct interactions, in particular feeding, should not be permitted, unless specifically sanctioned by internationally accepted standards or, where standards are not available, guided by independent wildlife expert advice" (Global Sustainable Tourism Council [GSTC], 2016). However, in the absence of global standards or consensus amongst wildlife experts, this holds limited real-world applicability, showcasing a disconnect between international policy, regional management, and scientific research. Implementing the policies recommended in these conventions to ensure sustainable wildlife tourism at the global, national, and community level requires a comprehensive understanding of the impacts of tourism on the organisms, environment, and community (Buckley, 2009; Higham, Bejder, Allen, Corkeron, & Lusseau, 2016; Newsome & Rodger, 2013; Newsome, Dowling, & Moore, 2005).

Wildlife tourism practices are globally diverse, targeting a multitude of taxa across all biomes, and uses a range of methods to observe and attract species. The industry has a history of affecting species and ecosystems (Higham et al., 2016; Trave, Brunnschweiler, Sheaves, Diedrich, & Barnett, 2017), but can also provide a positive alternative to lethal wildlife use, owing to a number of conservation and economic benefits (Huveneers et al., 2017; Macdonald et al., 2017). Balancing the impacts on species and benefits to the community has prompted a paradigm shift in how we view wildlife tourism from "nonconsumptive use" to "nonlethal consumptive use" (Higham et al., 2016). However, industry practices often predate appropriate policies or impact assessments, with the evolution and diversification of wildlife tourism outpacing location-specific research and management. Additionally, policy and management is sometimes driven by industry best practice (Mau, 2008). This leaves research teams to piece together an understanding of the myriad of potential context-specific impacts, while managers balance the complex trade-offs between animal welfare, conservation, tourist satisfaction, and economic benefits (Agyeiwaah, Mckercher, & Suntikul, 2017; Dubois & Fraser, 2013; Leung, Spenceley, Hvenegaard, Buckley, & Groves, 2018). Specifically, the intersection between industry tractability and socioeconomic benefits showcases the challenge managers and tourism operators face, as congested tourism sites risk species conservation and welfare, and tourists satisfaction (Steven & Castley, 2013; Steven, Pickering, & Castley, 2011). This challenge is not limited to wildlife tourism, as managers of marine protected areas, or those conducting broad ecological impact assessments must also conceptually balance disparate impacts and benefits (Brown et al., 2001; Glasson & Therivel, 2013).

A number of *ad hoc* management and assessment frameworks have been developed to conceptually balance impacts and benefits and facilitate effective management. The scope of such frameworks include managing marine protected areas (Brown et al., 2001), evaluating wildlife tourism sustainability (Agyeiwaah et al., 2017; Rodger, Smith, Newsome, & Moore, 2011), assessing the acceptability of wildlife feeding (Dubois & Fraser, 2013), and negative impact mitigation (Higginbottom, Green, & Northrope, 2003). However, in the case of wildlife tourism these frameworks focus almost exclusively on the direct impacts on target species, which exclude the consideration of nontarget species, and overlooks broad concerns for the ecosystem, indirect impacts on species, cultural heritage, and future research and planning. Given the inclusion of wildlife tourism in global policy recommendations (Koprowski & Krausman, 2019; Spenceley & Snyman, 2017), scientists, managers, and policy makers require an inclusive, multidisciplinary framework to assess and manage local wildlife tourism operations as nonlethal consumptive wildlife use. Thus, we aim to:

1. Build a semiquantitative, multidisciplinary framework to assess the impacts of wildlife tourism by including direct and indirect impacts on target and nontarget species, and identifying priorities for future biological, socioeconomic, and cultural heritage research.
2. Apply the framework to white shark cage-diving activities at the Neptune Islands Group Marine Park, South Australia, to demonstrate the utility of the framework for researchers, managers, and policy makers.

2 | FRAMEWORK DEVELOPMENT

The framework (Table 1) includes factors within five discrete categories (tractability, socioeconomic values, conservation outcomes, animal welfare, and ecosystem impacts; Figure 1), incorporating previous management and assessment frameworks, international policy recommendations, and concerns detailed in the literature (factors defined in Table S1). The framework uses the existing Dubois and Fraser framework (2013) as a scaffold to incorporate broader, multidisciplinary considerations underpinning effective adaptive management policy (Figure 2), expanding the 13 factors from three categories,

TABLE 1 Framework evaluating white shark *Carcharodon carcharias* cage-diving practices in south Australia, assessed by 26 factors within the categories of tractability, impacts on socioeconomic values, and their effects on conservation, animal welfare, and ecosystem impacts. Factors are scored based on previous studies when available or expert opinion. Scores are very high (+ +), somewhat high (+), somewhat low (–) or very low (– –) from Dubois and Fraser (2013), null impact (Ø), and unknown (U). Green highlight indicates indirect effects, and purple knowledge gaps. Grey boxes are proportion scores calculated as the number of positive (++ = 1) and negative scores (– – = –1) divided by the count of potential scores for each category (see Supplementary Material for more information). Factors are defined in Table S1

Factors	Target	Nontarget
Tractability		
Practice linked to conventions and guidelines[2,6]	+ + Industry management includes activity limits[101]	+indirect Industry guidelines indirectly manage nontarget species [101]
Feasible to regulate/monitor/intervene[1,6]	+ Small industry with limited operator licences & an industry management plan[101]	+ Small industry with limited operator licences, an industry management plan, & activity contained within a regulated marine protected area[101]
Public & political support[2,7,9]	+/– Polarized support	+indirect
Natural area stewardship[2,7]	+ +	+ +
Safe for the public[1]	+	– Provisioned fish can be aggressive toward divers
Proportion score	+0.70 –0.10	+0.50 –0.10
Socioeconomic values		
Economic benefits[1,2,5] to the local community[2,5,6,7]	+ + $15 Million to the regional economy[106] + + Operators, supporting industries locally owned and operated[106]	+ Inclusive wildlife experience[106]
Contributes to public education[1,2,7,130]	+ 122, 123,130	+ 122
Supports traditional and cultural values[2,5,7]	**U**/+ 122 + Contributes to global cultural values	**U**/+ 122 **Ø**
Enhances public perception of species	+ Contributes to changing positive public perception of white sharks[122, 123]	+ Marine park enhances perception of seals, rays and some fish[122, 123]
Proportion score	+0.80 –0	+0.38 –0
Conservation outcomes		
Contributes to understanding the species[1,2]	+ + History of providing opportunities for research[121, 123, 124, 127, 129]	+ Providing opportunities for research[127]
Contributes to population sustainability[1,2,5,6]	**Ø**	+ + Marine protected area, fish-based attractant nutritionally supports numerous species[102]
Does not facilitate illegal use (i.e., poaching)[1,6]	+ Presence of operators provides area surveillance	+ + Supports the marine protected area, presence of operators provides area surveillance
Proportion score	+0.50 –0	+0.83 –0

(Continues)

TABLE 1 (Continued)

Factors	Target	Nontarget
Animal welfare		
Effects relatively few individual animals[1,6]	+ Relatively few sharks interact with the industry[116]	– – Many fish interact with the industry[102]
Does not cause physiological stress to animal[1,3,4,6,8]	**U/Ø**	**U/–** Large aggregations potentiate stress from increased competition, or predation risk
Does not physically harm wildlife[1,2,3,6,8]	– Occasional collisions with cages may cause injury	– Collisions with cages may cause minor injury
Does not facilitate harm to conspecifics[8]	– Rare aggressive competition	– Some fish are aggressively competitive
Does not facilitate disease[1,4,8]	**U/–** Aggregations potentiate higher parasite load and disease transmission	**U/– –** Large aggregations potentiate higher parasite load and disease transmission
Maintains normal migration and movement[4,8,10]	– Increased residency[116]	**U/–**
Does not facilitate predation[8]	+ Few white shark predators, with a single incident of predation by an orca at this site	**U/–** No observed successful predations around diving boats increased shark residency potentiates natural predations on pinnipeds & benthic elasmobranchs
Maintains natural foraging & energy budgets[1,4,6,8,10]	+ + No change in diet or nutritional condition[102]– Increase energy expenditure[129]	– – Altered diet from consuming attractant[102]
Impacts from conditioned behavior[8]	**U/–** Potential reduced foraging range, reduced threat avoidance Potentially conditioned to human interaction, but unlikely[125]	**U/–** Conditioned fish are more aggressive Reduced threat avoidance, including approaching boats, fishers & divers
Does not impact on mental state[8]	**U/–** Potential frustration with failure to capture bait, may compromise natural learning opportunities **U/+** Increased residency at rich hunting grounds	**U/–** Increased fear of predation and stress from competition
Proportion score	+0.29 –0.29	+0 –0.75
Ecosystem impacts		
Maintains suitable environment[3,4,8]	+ Minimal traffic (3 boats max)[101]	+ Minimal traffic (3 boats max)[101] – Light pollution can attract nocturnal birds and squid **U/–** Potential noise pollution **U/–** Potential for nutrification from fish aggregations and attractant

(Continues)

TABLE 1 (Continued)

Factors	Target	Nontarget
Does not strain natural resources[5]	– Longer residency[116] potentiates more predations ++ Attractant is waste from local aquaculture	Provisioned fish may strain resources when operators are absent[102] +/– Attractant is waste from local aquaculture
Maintains ecosystem services[7]	Forage naturally[126]	Unbalanced pelagic fish assemblages[126]
Does not competitively exclude species	– Mid-trophic level elasmobranchs excluded	+ Unaltered benthic fish assemblages – Trevally and leatherjacket dominance likely to affect other species
Does not facilitate invasive species	Ø	Ø
Proportion score	+0.33 –0.17	+0.21 –0.21

Citations for factors

[1]Bushell and McCool (2007), [2]Dubois and Fraser (2013), [3]Higginbottom et al. (2003), [4]Cox and Gaston (2018), [5]Agyeiwaah et al. (2017), [6]Higham et al. (2016), [2017], [10]Heinrich et al.,20Citations for assessment

[101]DEWNR (2016); [102]Meyer et al. (2019b); [106]Bruce and Bradford (2013); [116]Huveneers et al. (2017); [122]Apps et al. (2019); [123]Apps et al. (2018); [124]May et al. (2019); [125]Gallagher and Huveneers (2018); [126]Meyer, Whitmarsh, Nichols, Revill, and Huveneers (2020); [127]Huveneers et al. (2018c); [129]Huveneers et al. (2018b); [130]Apps et al. (2017)

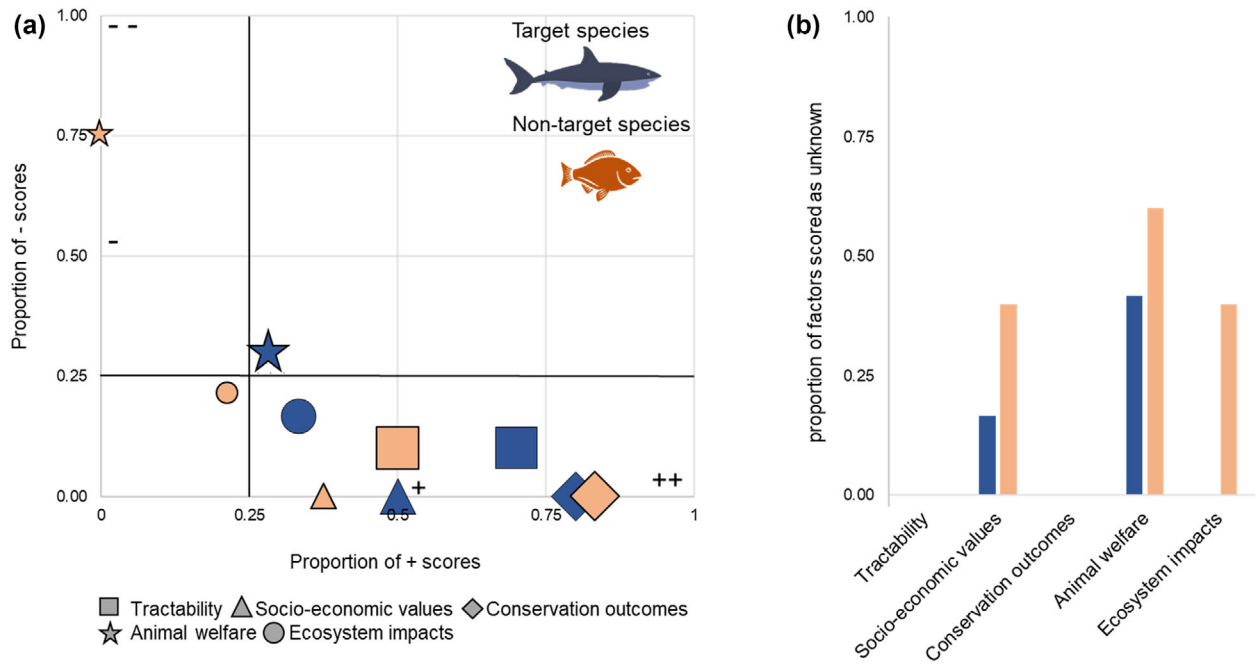

FIGURE 1 (a) Proportion of known positive impacts (+ scores) and negative impacts (– scores) for eachmanagement category (represented by different symbols) and for the target species (blue) and the nontarget species (orange). Threshold lines at 0.25 indicate 50% of positive or negative proportionate scores. + and – at 0.5 indicate where the average is a single positive or negative. The size of the marker represents the number of factors scored at "unknown" in Table 1 (Figure 1b), with smaller markers indicating a higher proportion of unknown scores. (b) Percent of factors within each category scored as unknown. Blue is target species and orange is nontarget species

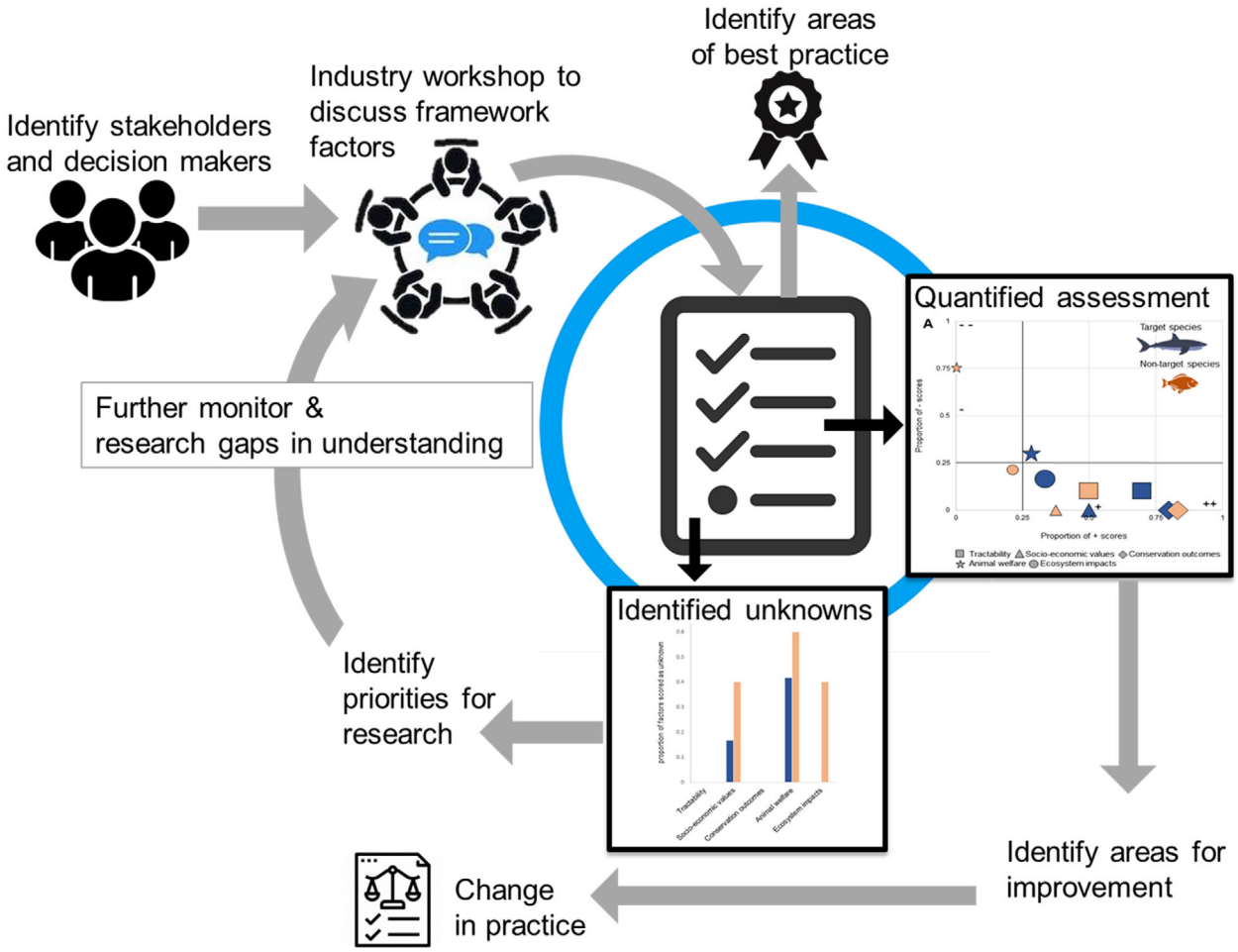

FIGURE 2 Schematic diagram of the management cycle, where findings from applying the framework is being communicated back to the stakeholders to address shortcomings identified through the process

into the 26 factors in five categories here (see "Factor Selection" section of the Supplementary Material). The number of factors were expanded to include those detailed in other management frameworks, reviews, and policy recommendations, including Reynolds and Braithwaite (2001); Buckley (2009); Bushell and McCool (2007); Higginbottom et al. (2003); Agyeiwaah et al. (2017); Cullen-Knox, Haward, Jabour, Ogier, and Tracey (2017); Global Sustainable Tourism Council (2016); Higham et al. (2016); Mellor (2017); Spenceley and Snyman (2017); Cox and Gaston (2018); and Leung et al. (2018) (detailed in Table S1). Further, important factors known to the authors, but not explicitly detailed in the published literature were included based on author expertise. In an effort to ensure the framework and factors were sufficiently broad and pertinent to industry managers, ecologists, biologists, social scientists, and included animal welfare and ethics concerns, authors for this work spanned the aforementioned expertise.

1. Industry tractability

This category examines the ability to manage the industry and tourist behavior, and mitigate impacts (Figure 1). Often overlooked in assessments, this has a major influence on the success of managing industries ranging from consumptive to nonlethal wildlife use, including tourism, fishing, and marine protected areas (Bushell & McCool, 2007; Dubois & Fraser, 2013; Higham et al., 2016; Leung et al., 2018). Tractability includes the presence of formal management and community support (e.g., social license Cullen-Knox et al., 2017), both of which underpin successful adaptive management policy (Bushell & McCool, 2007; Cullen-Knox et al., 2017).

2. Socioeconomic values

Wildlife tourism often provides substantial education opportunities and economic benefits (Huveneers et al.,

2017; Macdonald et al., 2017; Steven, Morrison, & Castley, 2017), which require inclusion to enable managers to balance the complex and challenging trade-offs of the industry, similar to frameworks such as Brown et al. (2001) balancing marine protected area management options. Furthermore, sustainable wildlife tourism should ensure that economic benefits remain, at least in part, within the local community (Agyeiwaah et al., 2017; Brown et al., 2001; Leung et al., 2018). Location or species-specific cultural values, including traditional, global popular culture, and religious importance have not been detailed in wildlife tourism policy frameworks to date, yet are highlighted when managing sustainable tourism more broadly (Spenceley, 2017). In some instances, traditional and cultural values may be exploitative (Steven & Castley, 2013; Steven et al., 2011), yet the impact of the industry on these values should be scored independently of conservation concerns and popularized ideals of wildlife use, which are incorporated in other factors (see Table S1 in Supplementary Material).

3. Conservation outcomes

Touted by proponents of wildlife tourism as a primary benefit of the industry, the opportunity for conservation from area and species protection, increased public support for conservation measures, and opportunities for research require inclusion within the framework (Higginbottom et al., 2003; Higham et al., 2016; Koprowski & Krausman, 2019; Steven et al., 2017). However, ensuring the industry contributes to population survival and does not facilitate illegal poaching are often overlooked and difficult to prove, despite their importance to wildlife conservation (Dubois & Fraser, 2013; Higham et al., 2016; Steven & Castley, 2013).

4. Animal welfare

Following the numerous reported impacts of wildlife tourism on animal welfare (Dubois & Fraser, 2013; Trave et al., 2017), welfare is a primary concern voiced by scientists, policy makers and the public (Koprowski & Krausman, 2019), and is featured in most existing wildlife tourism management frameworks (Higginbottom et al., 2003). Specifically, factors impacting animal welfare include extent of physiological and physical harm (Dubois & Fraser, 2013; Higginbottom et al., 2003; Mellor, 2017), and disruptions of natural behavior including foraging success and energy expenditure, predation likelihood, migration, reproduction (Dubois & Fraser, 2013; Higham et al., 2016; Rizzari, Semmens, Fox, & Huveneers, 2017; Meyer, Pethybridge, Beckmann, Bruce, & Huveneers, 2019; Senigaglia, Christiansen, Sprogis, Symons, & Bejder, 2019; Heinrich et al., 2021), and impacts from conditioned behavior (Mellor, 2017). Mental state is a key consideration in Mellor's (2017) five domains model for assessing animal welfare, often used in the context of zoos and aquariums. It is included, here, as the emotional response to the combination of animal welfare and ecosystem impacts. We acknowledge it is challenging to assess for most taxa, especially teleosts and elasmobranchs.

5. Ecosystem impacts

Existing policies and frameworks focus on target species, with little attention paid to the broad ecosystem that these species and industries rely upon (Higginbottom et al., 2003). As such, we have included specific ecological factors to detail the impacts on natural resources, ecosystem services and habitats, as well as ensuring a natural balance of native species, similar to ecological criteria used to assess the management of marine parks (Brown et al., 2001). Environmental suitability includes habitat modification and anthropogenic pollution, such as ambient noise (e.g., boat motors), light, and waste (Mellor, 2017; Popper, Hawkins, & Thomsen, 2020; Steven et al., 2011).

2.1 | Target versus nontarget species

Management assessments and impact mitigation traditionally focus on target species, while calls within the literature detail the need to include nontarget species (Gallagher & Huveneers, 2018; Higginbottom et al., 2003; Rizzari, Semmens, Fox, & Huveneers, 2017; Meyer et al., 2020; Trave et al., 2017). To facilitate their inclusion, we have extended the same framework factors developed for target species to nontarget species (Table 1). This enables the direct comparison between these groups, which aids managers and policy makers in balancing the positive and negative effects of wildlife tourism.

2.2 | Factor assessment

Assessing the continuum of wildlife tourism impacts necessitates the inclusion of null impacts, multiple scales of impact, and indirect effects, when evaluating factors. Here, we evaluate each of the factors included in our framework (Table 1), scoring them as very high (+ +), somewhat high (+), somewhat low (–) or very low (– –), as initially described by Dubois and Fraser (2013) (see Supplementary Material). This evaluation included an assessment workshop, whereby the multidisciplinary group of authors met to discuss and asses each factor based on group consensus and available literature (Supplementary

Material). This work expands the +/– evaluation used to include "null impact" (Ø), and indirect effects (highlighted in green) to better accommodate the complexity, or lack of impact the industry has on species, environment, and socioeconomic values. We also included "unknown" (U, purple highlight), that when paired with +/– from expert knowledge, allows researchers and managers to use the framework output as a completed assessment.

The framework scores (+ and –) enable a semi-quantitative comparison between target and nontarget species, and between the five categories (Table 1, Figure 1A), with the potential to compare quantitatively across industries. The proportions of positive and negative impacts are calculated separately and plotted on different axis (Figure 1a) to emphasize that effects of each factor do not cancel out one another. The proportions are calculated as the total positive (+ = 0.5, ++ = 1) and negative scores, divided by the count of potential scores for each category, excluding those scored as unknown (see Supplementary Material for more information). The proportion of "unknown" can be similarly calculated, providing a quantitative value for which categories, target and nontarget species (Figure 1b), and industries can be compared to highlighting key areas of future research needed to facilitate management.

3 | WHITE SHARK CAGE-DIVING IN SOUTH AUSTRALIA

Cage-diving with white sharks (*Carcharodon carcharias*) is a globally popular tourism industry with many associated challenges for industry, managers, and policy makers (DEWNR, 2016; Meza-Arce et al., 2020). White shark cage-diving in South Australia has been the focus of numerous studies on the socioeconomic benefits of the industry (Apps, Dimmock, Lloyd, & Huveneers, 2017, 2018, 2019; Huveneers et al., 2017) and its ecological impacts on target white sharks (Bruce & Bradford, 2013; Huveneers et al., 2013; Meyer et al., 2019) and nontarget species, including trevally (*Pseudocaranx* spp.), yellowtail kingfish (*Seriola lalandi*), ray spp., and other teleosts (Gallagher & Huveneers, 2018; Meyer et al., 2020; Rizzari, Semmens, Fox, & Huveneers, 2017) is an ideal case study to demonstrate the use of the assessment framework (Table 1, Figure 1).

In South Australia, white shark cage-diving operates at the Neptune Islands Group (Ron and Valerie Taylor) Marine Park, hosting >10,000 passengers across three operators running ~260 days per year (DEWNR, 2016; Huveneers et al., 2017). The industry is limited to maximum 200 kg/day of fish-based attractant (Southern Bluefin Tuna *Thunnus maccoyii*) including minced tuna chum edible to sharks, and tuna heads and gills used to coax sharks within view of divers, then retracted prior to being eaten, as operators are explicitly prohibited from feeding sharks (policy 7.3, DEWNR, 2016). The Neptune Islands Group is also a Marine Protected Area, providing protection for unique offshore island habitats (DEWNR, 2012) and supporting hundreds of invertebrate, fish, marine mammal, bird, and elasmobranch species. The *tractability* of South Australia's white shark cage-diving industry is very high for target species (+0.70), and somewhat high (+0.50) for nontarget species (Table 1, Figure 1a), as this is a small (three operators), highly-regulated industry with area camera surveillance and mandatory daily-activity logs, leading to a history of compliance with temporal closures and restrictions on attractant type, quantity, and use (DEWNR, 2012; DEWNR, 2016). The polarized local and global public view of white shark cage-diving remains an ongoing challenge (Apps, Dimmock, Lloyd, & Huveneers, 2016; Gallagher & Huveneers, 2018), which limits *tractability*, *socioeconomic values*, and potentially the extent of *conservation outcomes* (Figure 1). Similar to *tractability*, the *socioeconomic values* from the target white shark is very high (+0.80), contributing ~$8 million AUS annually to the local economy (however the potential for additional educational opportunities has been discussed; Apps et al., 2017, 2019, Huveneers et al., 2017). The contribution to public education and awareness is considered high. The socioeconomic values are somewhat high (+0.38) for the other wildlife, which contribute to the experience as a whole, but do not carry the same charismatic draw, notoriety, or historically-damaged public perception as white sharks (Apps, Dimmock, & Huveneers, 2018, 2019; Macdonald et al., 2017). The Barngarla and Naou people are the traditional custodians of the Eyre Peninsula, yet the cultural and spiritual role of the Neptune Islands, white sharks, and nontarget species is unknown to industry managers. While visitors to the site may acknowledge the presence of these values (Apps, Dimmock, Lloyd, & Huveneers, 2019), the impact the industry may have on the relationship to Country is not well understood. The lack of knowledge in relation to traditional values was identified during the assessment workshop and is now being explored by industry managers. Historically, the industry has played an evolving role in popular culture, from contributing to the filming of Jaws at Dangerous Reef in 1974, to now avoiding interactions which appear "aggressive," with operators, managers, and passengers advocating for revised perception of these top predators (Apps et al., 2018; DEWNR, 2016).

The *conservation outcomes* for both target (+0.50) and nontarget species (+0.83) are very high as the industry provides extensive opportunities for research (e.g., Apps et al., 2018; Huveneers, Watanabe, Payne, & Semmens, 2018b; Huveneers et al., 2018c; May, Meyer, Whitmarsh, &

Huveneers, 2019), supports the MPA, and offers additional surveillance preventing illegal use. The trade-offs with *animal welfare* are less known, but where assessed animal welfare scores are predominantly negative (−0.29 target, −0.75 nontarget) (Bruce & Bradford, 2013; Gallagher & Huveneers, 2018; Huveneers et al., 2018b). Many factors warrant additional research, owing to the challenges of researching potentially dangerous large free-swimming predators (Huveneers et al., 2018a) and nontarget species in this remote location. The framework reveals several research priorities to better understand the impacts on *animal welfare*, particularly the potential for physiological stress, disease facilitation and the extent of conditioned behavior (Gallagher & Huveneers, 2018; Huveneers et al., 2018a; Heinrich et al., 2021). Similarly, the assessment of *ecosystem impacts* highlights the need for a better understanding of the industry's effect on nontarget species in the ecosystem, abundance, and the flow-on changes in natural resources, ecosystem structure, and habitat (Gallagher & Huveneers, 2018; Rizzari, Semmens, Fox, & Huveneers, 2017; Meyer et al., 2020). The unknown effect of using noise to attract white sharks was identified from this framework and led to discussions of the need to review the effects of noise pollution on the Neptune Islands ecosystem.

White shark cage-diving scored highly positive overall, with only two categories scoring below +0.25 (indicate less than 50% of positive scores), and only two negative scores above −0.25 (Figure 1a). *Conservation outcomes*, *tractability*, and target species *socioeconomic values* are all very positive (ranging from +0.50 to +0.83), with only a lack of public support contributing to the −0.10 target species *tractability* score. In contrast, *animal welfare* and *ecosystem impacts* have the most shortcomings that warrant further consideration by managers. Categories with the most factors scored unknown (small symbols Figure 1a, Fig. 1b), are the least positive, suggesting that where information is available for managers to act on, policy appropriately mitigates impacts resulting in positive industry outcomes. Target and nontarget species face incongruent impacts and benefits, mandating that managers carefully balance the trade-offs unique to each group.

4 | GLOBAL FRAMEWORK USE

The application of the framework and semiquantitative assessment (Table 1, Figure 1) demonstrates the utility for researchers, managers, and policy makers to form multidisciplinary teams and work together to balance the complex trade-offs to manage wildlife tourism. The assessment included workshop-style meetings with the multidisciplinary group of co-authors, whereby each factor was discussed and assessed on group consensus and available literature (Supplementary Material). This process proved particularly valuable and we strongly recommend inclusive workshops using the framework as a scaffold to structure assessments of tourism industries. Following the geographic expansion, growing popularity, and increasing diversity of wildlife tourism industries, we provide a universally applicable, multidisciplinary framework including direct and indirect impacts on target and nontarget species, and identify priorities for future biological, socioeconomic, and cultural heritage research (Figure 2). This framework facilitates a semiquantitative, comprehensive assessment of existing and proposed wildlife tourism operations, enabling better management with the potential for improved conservation outcomes for species and ecosystems. This semiquantitative framework approach also enables cross-industry comparisons (e.g., between different shark tourism industries), highlighting industry-specific risks, or best practice approaches.

This type of framework, including the semiquantitative approach developed here, could be modified for managing other industries that also balance trade-offs between disparate impacts and benefits, including general tourism (CREST, 2017), marine protected areas (Brown et al., 2001), or environmental impacts (Glasson & Therivel, 2013).

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AUTHOR CONTRIBUTIONS

LM conceived the idea. LM with the support of CH led the writing of the manuscript. LM, SW, TC, and CH developed the quantitative approach and designed the figures. All authors contributed to refining the concept of the manuscript, determining the factors, and scoring the white shark cage-diving industry, and approved the final version for submission.

ETHICS STATEMENT

Ethics approval was not required for this study, as no new data were created.

DATA ACCESSIBILITY STATEMENT

Data sharing is not applicable to this article as no new data were created.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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