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Reflections on the ecosystem services of whales and valuing their contribution to human well-being

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ABSTRACT

Although whale ecosystem services have been scarcely explored in the academic literature, they illustrate many of the threats, trade-offs and decision-making dilemmas common to marine ecosystem services in general – climate change impacts, the ongoing need to provide remote communities with forms of sustenance, and the potential development of new economic sectors which are prosperous but undermine traditional ways of life. In this paper, the first evaluation is carried out of the ecosystem services specific to whales, involving (a) their classification using the established Common International Classification Ecosystem Services (CICES) framework, (b) an assessment of the most suitable methods for their valuation, and (c) implications for decision-making. Our findings are that whale ecosystem services belong to all three categories of the CICES classification and cultural services are the most common type. The most suitable approach for the respective valuation of each service depends on the local socio-cultural context, a fundamental ingredient in value formation, which can formulate on either an individual or collective basis. In the case of individual value formation, this paper recommends the use of economic information derived from non-market valuation techniques; for collective, non-monetary techniques are advised. Given the complexity of human-environment interactions, a pluralist approach to valuation is likely to be required, whereby decision-makers are informed about impacts to whale ecosystem services through a mixture of economic and non-monetary information. A logical consequence of value pluralism is the need for decision-support platforms which can satisfactorily integrate different types of information concerning ecosystem service impacts, evaluating these against multiple marine management objectives. The paper briefly reflects on the potential of Multi-Criteria Decision Analysis to fulfil this ambition, before discussing some of the current challenges and barriers which have limited the uptake of ecosystem services research in marine planning and decision-making.

1. Introduction

Ecosystem services (ES) relate to the gains in human well-being secured, either directly or directly, from the natural environment (Costanza et al., 1997; Daily, 1997; MEA, 2005; Haines-Young and Potschin, 2010). Determining the physical links between the processes and functionality of ecosystems and valuing their contribution to human well-being is of considerable importance to a broad range of decision-making contexts (MEA, 2005), including spatial planning, conservation policy formation, and evaluations of the trade-offs associated with economic development. The oceans on a collective scale represent the largest ecosystem on the planet, providing the world's largest carbon sink and a source of protein for more than one billion people (Blasiak et al., 2015). The overall scale of marine ES is likely considerable, approximated by Costanza et al. (2014) as constituting over 65% of the total value of the world's ES. The United Nations has

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also recognized the importance of marine resources in terms of their contribution to the support and advancement of human well-being, with Goal 14 of the Sustainable Development Goals, 'Life Below Water', emphasizing the need to "conserve and sustainably use the oceans, seas and marine resources for sustainable development" (UN General Assembly, 2015, p. 23).

Despite an increase in the number of ES valuation studies in a marine context, the evidence demonstrating their actual use in decision-making contexts is currently sparse (Guo and Kildow, 2015; Hanley et al., 2015). A number of publications have observed an information deficit relating to marine ES (Halpern et al., 2012; Maes et al., 2012; Villasante et al., 2016; Nahuelhual et al., 2017). The location of many marine ES – especially those derived from the remote high seas – presents particular challenges for ES practitioners (Blasiak et al., 2015; O'Garra, 2017). However, their geographical remoteness should not distract attention from the importance of their physical quantification and valuation across the full spectrum of marine resource contexts, which might otherwise be overlooked or underestimated (Magnussen and Kettunen, 2013; Hasler, 2016; Gunderson et al., 2017). Others have reported on a need for greater collaboration between scientists, decision-makers and environmental economists in order for marine ES valuation studies to be better understood by those surveyed and, ultimately, more widely used by decision-makers (Börger et al., 2014). Torres and Hanley (2016) explain that communication issues have prevented the widespread adoption of non-market valuation studies in a marine context, particularly emphasize the importance of improved cooperation as a means of furthering transdisciplinary work.

The focus of this paper concerns the marine resource context of whales, which have been lightly studied in ES research (Malinauskaite et al., 2020). This is despite obvious socio-ecological interactions, particularly connected to many coastal communities (Torres and Hanley, 2017), and the delivery of multiple benefits to human well-being, such as primary production, nutrient cycling, recreation (including ecotourism), education, food provision, and carbon sequestration (Roman et al., 2014). As far as the authors are aware, the study by Roman et al. (2014) remains the only publication to date to begin to outline, in a thematic rather than location-specific sense, the ES human beings derive from whales. No authors have yet taken the next step, which is to consider how such benefits should be valued, which is necessary in order to better understand the various trade-offs associated with changes to whale populations, such as development pressures, expanded eco-tourism, and climate change. This literature gap was restated in a Workshop Report by the Society for Conservation Biology, which opined that the valuation of whale ES represents an important step towards improved marine policy-making (Roman and Galletti, 2017). The three aims of this review paper are as follows: (1) identify an inventory of whale ES, (2) consider how the respective whale ES could be valued and review the likely threats and trade-offs affecting whale ES, and (3) discuss the likely implications for decision-making, given the potential presence of value pluralism, the idea that there may be several equally valid and fundamental values in conflict with each other.

This paper is structured as follows. Section 2 classifies an inventory of whale ES using the Common International Classification for Ecosystem Services (CICES) typology. Section 3 constructs a framework for valuing the respective whale ES, linking these to the various economic and non-monetary techniques available, and outlines some of the likely threats and trade-offs of economic developments and environmental change. In addition, existing valuation studies in the context of whale ES are outlined and the implications of value pluralism analysed in terms of the need for decision-support tools that can integrated multiple values of the environment. Multi-Criteria Decision Analysis (MCDA) is explored as an example of one possible integrated valuation technique that could be applied in a whale ES context. Section 4 then discusses the challenges of conducting economic, non-monetary and integrated valuation studies in a whale ES and general marine context, before reflecting on opportunities for further whale ES research.

2. Ecosystem services of whales

2.1. Defining and classifying ES

A wide range of definitions exist for ES, all of which derive from an understanding that ES relate to human well-being benefits obtained from ecological phenomena. Perhaps the most widely cited definition has been set out by the Millennium Ecosystem Assessment (MEA), which articulates ES as the benefits that people obtain from ecosystems (MEA, 2005). This understanding has been further advanced through the delineations of Fisher et al. (2009), who contributed three main points: (1) that ES are ecological phenomena sourced from biotic and abiotic processes, (2) they do not have to be directly consumed, and (3) ES frameworks should be developed to avoid the potential for double counting of benefits. With regards to (2), this perspective ensures that ES also encompass many indirect benefits to human welfare, such as the passive gains in well-being obtained from regulation services, including carbon sequestration and water purification.

Classifying ES is an important first step in the valuation process, clarifying and providing transparency concerning the links between changes in ES and changes in human welfare, and, linked to point (3) of Fisher et al. (2009), lowering the risk of double-counting in assessment (MEA, 2005; Fisher et al., 2009; Kumar 2010). A wide range of ES typologies exist in the academic literature, including those published in the MEA (MEA, 2005), The Economics of Ecosystems and Biodiversity (TEEB, 2010), UK National Ecosystem Assessment (UK NEA, 2011) and the Common International Classification for Ecosystem Services (CICES) (Haines-Young and Potschin, 2010).

In recent times, CICES has helped to resolve some of the subtle structural and theoretical differences between the classification schemes and has become an increasingly important frame of reference for various lines of ES research (Paracchini et al., 2014; Hastik et al., 2015; Cook et al., 2017; La Notte et al., 2017). CICES is based on the cascade framework (Haines-Young and Potschin, 2010), and endeavors to link underlying ecological structures and processes to the well-being benefits received by human beings (La Notte et al., 2017). A key distinction between the CICES and the MEA typologies concerns the omission of the 'supporting' category of ES in the former. These are considered to be a function rather than a service. In addition, CICES merges TEEB's underlying category of 'habitat services' with 'regulating services' in a category entitled 'regulation and maintenance services'. Due to the ways in which it has sought to resolve the complexities of earlier classification frameworks and its straightforward approach to linking ecological infrastructure to human well-being benefits, CICES has become widely used in ecosystem services research for designing indicators, mapping and valuation (Haines-Young and Potschin, 2018), and is thus an ideal typology for the commencement of analysis in the context of whale ES.

2.2. Whale ES and CICES classification

Although the analysis in this paper is thematic rather than location-specific, an important first step on the road to classifying whale ES concerns the formation of an inventory of likely services following an extensive literature review. These are grouped according to version 5.1 of the CICES classification scheme (Table 1) (Haines-Young and Potschin, 2018), and are then briefly discussed in turn.

Note that this classification specifically excludes the ES of nutrient cycling and primary production, which are not included in CICES as these are supporting ES necessary for the provision of services in the provisioning, regulation and maintenance, and cultural categories.

2.2.1. Provisioning ES

2.2.1.1. Food products (meat, blubber, skin and intestines). Although less common in the modern era, whale meat has been consumed around the

Table 1
CICES classification of whale ES.

Section	Division	Group	Class	Class type	Service
Provisioning (biotic)	Biomass	Animals for nutrition, materials or energy	Wild animals	By amount of product	Food products (meat, blubber, skin and intestines)
Provisioning (biotic)	Biomass	Animals for nutrition, materials or energy	Wild animals	By amount of product	Whale bones, teeth and baleen
Provisioning (biotic)	Biomass	Animals for nutrition, materials or energy	Wild animals	By amount of product	Oil-based products deriving from blubber
Regulation and maintenance (biotic)	Regulation of physical, chemical and biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats (including gene pool protection)	By amount and source	Enhanced biodiversity and evolutionary potential
Regulation and maintenance (biotic)	Regulation of physical, chemical and biological conditions	Water conditions	Regulation of chemical composition of atmosphere and oceans	By type of living system	Climate regulation (carbon sequestration)
Cultural (biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	By type of living system or environmental setting	Tourism (whale watching)
Cultural (biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems used for entertainment or representation	By type of living system or environmental setting	Music and arts (entertainment)
Cultural (biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems used for entertainment or representation	By type of living system or environmental setting	Sacred and/or religious
Cultural (biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable education and training	By type of living system or environmental setting	Educational
Cultural (biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable aesthetic experiences	By type of living system or environmental setting	Aesthetics
Cultural (biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that are resonant in terms of culture or heritage	By type of living system or environmental setting	Community cohesiveness and cultural identity
Cultural (biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an existence value	By type of living system or environmental setting	Existence
Cultural (biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an existence value	By type of living system or environmental setting	Bequest

world, and this has not always been restricted to coastal communities. Today, whale meat is consumed by many indigenous communities for the purposes of subsistence and as a cultural practice, as well as by countries such as Iceland, Norway, the Faroe Islands, Japan, South Korea and China. The International Whaling Commission has delineated three types of whaling: (1) commercial, (2) aboriginal subsistence, and (3) research focused (Freeman, 1993). Of these, only the first two are relevant to the concept of provisioning ES.

Commercial whaling can be any type of whaling that is not research focused or limited to subsistence objectives. Although the majority of nations have banned commercial whaling following the International Whaling Commission's "indefinite moratorium" in 1986, the nations continuing to do so have maintained that sustainable stocks are now possible and that culling can contribute to maintaining a healthy and balanced marine ecosystem (Swartz and Pauly, 2008). The ultimate beneficiaries of harvested whale meat are not necessarily the residents of the whaling nation. Among Icelandic people, for instance, there has been fairly limited consumption of whale meat in the period since the second world war, apart from as an occasional specialty food (Bertulli et al., 2016). Rather, whale meat has been increasingly promoted to tourists as a novelty food product, and the majority of recently harvested whale meat has been exported to Japan.

Aboriginal subsistence whaling is whaling *"for purposes of local aboriginal consumption carried out by or on behalf of aboriginal, indigenous or native people who share strong community, familial, social and cultural ties related to a continuing traditional dependence on whaling and on the use of whales"* (Donovan, 1982, p.80). A wide range of places continue to practice aboriginal subsistence whaling. These include the Inuit of Greenland, the Chukchi people of Siberia, and indigenous peoples in Indonesia, the United States, Canada and Besquia, an island in the Caribbean.

For several indigenous groups, the consumption of blubber, skin and the internal organs of whales is as important a cultural practice as the eating of meat (NAMMCO, n.d.). Due to the high energy content of blubber, it has formed a central part of the traditional diets of the Inuit and other northern peoples (Kenny and Chan, 2017). When combined with whale skin, whale blubber is often consumed in the frozen meal of muktuk, which has formed a traditional dish in Inuit and Chukchi communities (Kenny et al., 2018). Some peoples, such as those located in the Wakamaya Prefecture, Japan, have consumed the internal organs of whales, including the liver, kidneys, lungs, stomach and small intestines (Simmonds et al., 2002).

Although this paper focuses on the ES of whales, it is important to point out that consumption of whale meat has often been associated with health risks due to the bioaccumulation of toxins (Weihe et al., 2008; Wise Jr. et al., 2019). This is a potential ecosystem disservice of whales.

2.2.1.2. Whale bones, teeth and baleen. In earlier centuries, whale bones and teeth satisfied a number of uses. These included the use of whalebone in children's toys, corsets and umbrellas, and utilisation of teeth in items of art, chess pieces and piano keys. Whale baleen has been used in the past as a construction material and in the manufacturer of fashion products, especially corsets. In modern times, the uses of these items are very limited, apart from in antiques.

2.2.1.3. Oil-based products deriving from blubber. Beyond whale meat, historically a number of whale-based products have constituted provisioning ES, especially those relying on oil inputs deriving from blubber. Although since the latter half of the twentieth century, vegetable and petroleum oils have replaced nearly all uses of whale oil, traditional uses have included lamp oil, cooking oil, and an important ingredient in margarine, candles, soaps, perfumes and cosmetics. Similarly to whale bones, teeth and baleen, modern uses of these products are limited, apart from as antiques and heirlooms.

2.2.2. Regulation and maintenance

2.2.2.1. Enhanced biodiversity and evolutionary potential. The ES of enhanced biodiversity and evolutionary potential, and enhanced primary production, are interrelated. Via the supporting ecosystem service of nutrient cycling, through abundant releases of iron from whale faeces and nitrogen from urine and faecal plumes, enhanced primary production occurs, including extended phytoplankton blooms (Lavery et al., 2010; Lundsten et al., 2010; Roman and McCarthy, 2010; Roman et al., 2014). In addition to ocean currents meeting and upwelling, the physical movement of animals in the water column, especially larger animals such as whales, contributes to the wider distribution of nutrients and oxygen in the water, leading to greater primary production (James et al., 2017). Areas rich in primary production also tend to be associated with an abundance of prey, and are thus often more biodiverse. In contrast, marine areas which have suffered losses of great whales have been associated with trophic cascades, leading to the associated stock decline of many other species, such as sea otters, kelp forests and birds of prey (Wilmers et al., 2012; Roman et al., 2014). In addition, the sunken carcasses of great whales, of whale falls, provide an important deep-sea habitat for more than 100 species that may be considered whale-fall specialists (Smith et al., 2019). The loss of these habitats as a result of commercial whaling is likely to have had a big impact on the diversity of whale-fall specialists in areas where whales have been hunted for centuries.

2.2.2.2. Climate regulation (carbon sequestration). Over their lifetime, whales contribute to the removal of carbon from the atmosphere through the accumulation of large amounts of carbon in their bodies (Smith and Baco, 2003; Roman et al., 2014; James et al., 2017). After death, whales sink to the ocean floor. So-called 'whale falls' result in the locking in of organic carbon content on the sea floor. Smith and Baco (2003) reported that the carcass of a 40-tonne grey whale can contribute a level of organic carbon content equivalent to around 2000 years of the background flux. In addition, a study by Pershing et al. (2010) reported that restoring baleen whale stocks to pre-whaling levels would remove 1.6×10^5 tons of carbon each year through whale falls.

2.2.3. Cultural

2.2.3.1. Tourism – whale watching. For the purposes of this paper, the tourism ES deriving from whale watching shall be defined in accordance with the understanding set out by the International Whaling Commission. Whale watching is distinguished as "*any commercial enterprise which provides for the public to see cetaceans in their natural habitat*" (IWC, 1994). Given the natural habitat qualification, this definition excludes any tourism activities relating to whales held in sea pens or pools. The vast majority of whale watching activities involve opportunities to see whales and are boat-based, however, some may take place from land-based or aerial vantage points (Parsons, 2012). There are also sub-sets of recreational activities linked to whale watching tourism, such as sea swimming in their presence or feeding (Walker and Weiler, 2014).

In recent years, the whale watching industry has become a significant revenue generator. A study in 2009 estimated that the global value of the industry was US $ 2.1 billion per year, involving the employment of over 13,000 people in 119 countries, with over 13 million tourists taking trips to see cetaceans in their natural habitat (O'Connor et al., 2009). Moreover, a subsequent study estimated that the industry could be worth an additional US $ 400 million per year and an additional 5700 jobs if nations with cetacean populations, but no related tourism industry, were to initiate such activities (Cisneros-Montemayor et al., 2010).

2.2.3.2. Whale music and arts (entertainment). Since the 1970s, whale music deriving from their vocalizations – "songs" – has become increasingly popular (Ritts, 2017; Stafford et al., 2018). A study by Burnett (2012) estimated that over 150 items of popular music had sampled or thematized whale music since 1970. Ritts (2017) contends that part of the popularity of whale music is its capacity to evoke different emotional responses in human beings, ranging from the joyous squeals of Songs and Sounds by Orcinus Orca (1979) to the mournful moans of humpbacks in the beginning of Common Ground (1976).

Whales have also been the focus and formed the inspiration for a wide variety of other artistic ventures, including sculpture, painting, drawing, printing and film-making (Thomasson, 2005). The great whales have also formed the centerpiece of movies such as *Free Willy* and *Whale Rider*, and books such as *Moby Dick* and *The Lost Whale*.

2.2.3.3. Educational. Educational benefits linked to whales can take many forms. They can accrue via a somewhat informal process of cognition, involving biological and cultural knowledge gained from the whale watching experience. Alternatively, benefits can be acquired more formally, based upon planned activities aimed at knowledge-gathering. These may include visits to whale museums and visitor centers. Equally, educational benefits can derive from science-based research linked to whales, including field and desk-based studies. Interest in whales, particularly when occurring at a young age, has often stimulated wider interest in their conservation (Russell and Hodson, 2002; Anderson and Miller, 2006).

2.2.3.4. Sacred and/or religious. Particularly among many indigenous communities, whales continue to represent a resonant feature of cultural identity and a source of spiritual enrichment. In New Zealand, they are of significance to the Maori peoples, with whales frequently depicted in traditional narratives and mythology (Wehi et al., 2013). In this culture, whales have often been compared to chiefs due to their large-scale capacity to provide sustenance to communities, with stranded whales considered to be gifts from the great god of Tangaroa. Meanwhile, legends about their capacity to aid navigation during ocean voyages from Hawaiki to New Zealand have led many Maori peoples to view whales as guardians (Levine, 2016). Popular spiritual narratives and associations concerning whales have also been to the fore in Inuit communities, mostly unfolding from the perception of whales as beings of special reverence. The Inuit have traditionally believed that all animals have souls which, if mistreated, could transform into monsters (Bodenhorn, 1988). They also consider hunted mammals to be deliberately sacrificing themselves for the benefit of human beings. In so doing, an obligation of duty and respect is conveyed to the whale hunter. Through veneration for the killed mammal, the Inuit believe that it will be reborn to be hunted again. These beliefs have been expressed most prominently in connection to the bowhead whale, considered by many Canadian and Greenlandic Inuit to be the largest and most powerful animal in Arctic waters (Stern, 2010; Hastrup et al., 2018).

2.2.3.5. Community cohesiveness and cultural identity. Whales have long played a central role in the forging and development of community cohesiveness and cultural identity. Especially during earlier eras of limited communication and transportation opportunities, local communities developed diets based on scarce resources, skills and knowledge (Nuttall et al., 2005). The whale, rich in energy and protein, was fundamental to the subsistence of many communities, and its cultural significance is testified by appearances in myths, legends and indigenous traditions (Wichert and Nussbaum, 2017). Equally, the whale continues to play a central role in the cohesiveness and cultural identity of modern communities. Einarsson (2009) reported on how the growth of whale watching in Húsavík, a small, coastal community in North Iceland, had been pivotal in reversing a drain of human capital following the decline of the local fishing and fish processing industries. This was particularly the case with regards to the younger and educated generation, who would otherwise have left the town to cultivate their talents in the capital city of Reykjavík or abroad. Equally, the development of tourist infrastructure linked to whale watching, in traditional fishing communities such as Húsavik and Reykjavík, adds to the embedding of whale watching as an authentic component in the maritime culture of these places.

2.2.3.6. Aesthetics. Aesthetics relate to the enjoyment or appreciation of the beauty of whales. In recent years, whales have been depicted as 'charismatic megafauna', large animal species with more popular appeal than others (Einarsson, 2009; Hausmann et al., 2017). Perceptions of their majesty, rarity, intelligence and distinctness have been a fulcrum underpinning the popularity of whales. Their aesthetics have also been cited by environmentalist organizations as an argument in favour of their conservation (Einarsson 2003, 2009).

2.2.3.7. Existence and bequest. With regards to existence, individuals value whales simply for knowing that they (or particular species) exist and are conserved. Bequest values are similar, but relate to values held in relation to opportunities for future generations to benefit from whale ES. This is often labelled as non-use value, which is underpinned mainly by existence and bequest concerns, and is distinguished from the welfare benefits human beings receive from direct interactions with a resource or environment (Harris and Roach, 2017).

The relative rarity, intelligence, distinctness and aesthetically pleasing qualities of whales ensures that their preservation is often valued, even though human-cetacean interactions may occur remotely without a human presence in the environmental setting (Edwards, 1986; Loomis and Larson, 1994).

3. Valuing whale ES and common trade-offs

3.1. Valuing ES and concept of value pluralism

The importance of marine ecosystems to human welfare and the public goods characteristics of the many ES sourced from such environments adds weight to arguments in favour of gaining better understanding of these benefits (Hattam et al., 2015; Torres and Hanley, 2017). Studies such as TEEB (2010) have helped to highlight the importance of ES in terms of their contribution to marketed and non-marketed economic activities, and human well-being. They have also underscored the need to embed ES valuation into decision-making processes, particularly those connected to the trade-offs associated with managing ecosystems differently.

Valuing ES and marginal changes to ES can occur through the use of economic and/or non-monetary information. Arguments in favour of economic valuation have largely focused on its capacity to increase the likelihood of conserving highly valued ES, both through knowledge accumulation about the economic value of their losses and integration into decision-making apparatus, such as cost-benefit analysis (Myers, 1997; Atkinson and Mourato, 2008; Dixon et al., 2013). Critics who have argued against the use of economic valuation have tended to voice three main contentions: (1) that valuing impacts to ES using economic information has not led to increased conservation of resources (Heal, 2000; Simpson, 2014); (2) that economic information does not furnish decision-makers with sufficient information to make coherent and consistent choices about the environment (Vatn and Bromley, 1994; Spash and Hanley, 1995; Primmer and Furman, 2012) and (3) that economic information is unsuitable in certain societal contexts due to the specifics of value formation (Chan et al., 2012; Martín-López et al., 2014). Often the debate about the merits of economic valuation has been heated and seemingly driven by ideological fervor (Cook et al., 2017). However, there also exists an increasingly popular middle-ground perspective which is pluralist and maintains that coherence in decision-making tools, such as cost-benefit analysis, can be retained provided that economic data is complemented with non-monetary information where necessary given the sociocultural context and character of value formation (Fisher et al., 2009; Wegner and Pascual, 2011; Bark et al., 2016; Chan et al., 2016).

3.2. Non-market valuation methods and existing economic valuation studies

Despite certain limitations, the use of a monetary metric can reveal human preferences and estimate the relative value of different development options (Fisher et al., 2009; Dixon et al., 2013; Martín-López et al., 2014). A widely applied heuristic for organizing the economic value of ES in different resource contexts/localities is the Total Economic Value (TEV) framework. As Fig. 1 portrays, economists have typically split the total economic value of natural resources into two main components: use and non-use value (Tietenberg, 1988; Hanley et al., 2013). Use value includes direct use, indirect use and option value.

In the case of direct use value, individuals undertake a planned demand for an ecosystem service. Their demand may take the form of consumptive use, whereby they extract provisioning services from an ecosystem. Alternatively, direct use can be non-consumptive in character and thus not involve a drawing down on resource stocks, such as during the receipt of recreational or sacred and/or religious benefits. Consumptive forms can generally be traded in a market while non-consumptive cannot.

Indirect use value represents a form of vicarious consumption mainly relating to regulation and maintenance ecosystem services (Cook et al., 2017).

Option value relate to the retention of the possibility to gain benefits from using a resource in the future, either directly or indirectly (Hanemann, 1989).

Non-use value is derived purely from the knowledge that a resource is preserved intact for the future (Harris and Roach, 2017).

Apart from certain provisioning ES and some tourism activities, which are traded in markets, economists use non-market valuation techniques to estimate use and non-use types of value. These are generally split into direct market valuation, revealed or stated preference methods.[1]

Direct market valuation approaches include cost-focused techniques such as avoided, replacement and damage cost methods, market pricing and the production function method.

[1] In this paper, there is insufficient space to provide a detailed description of each non-market valuation technique. However, there exist numerous such analyses in the academic literature. Readers are pointed towards the publication by Tinch et al. (2019) for a recent review.

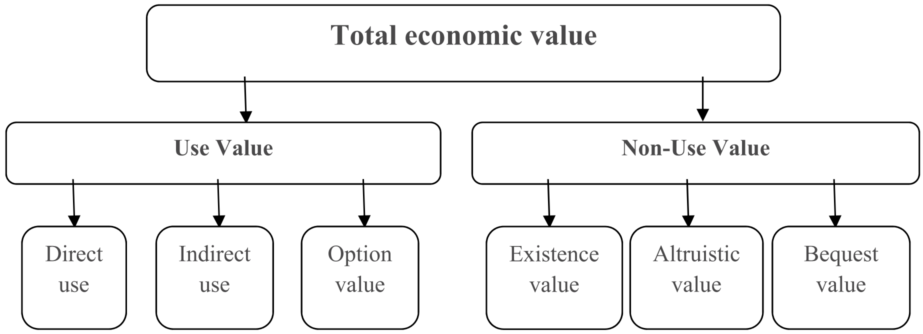

Fig. 1. Total economic value framework (source: Cook et al., 2017).

Revealed preference methods involve the gathering of economic data concerning individual preferences for marketable goods related to the non-market good (Harris and Roach, 2017). The approaches assume that consumer behaviour is always rational and seeking to maximise utility, and that actual preferences can be revealed by the direct observation of responses to complementary or substitute goods. The group of revealed preference methods includes techniques such as hedonic pricing; and the travel cost method.

Stated preference methods rely on the use of carefully designed questionnaires to elicit individual preferences for a change in the level of provision or quality of an environmental resource (Harris and Roach, 2017). Unlike revealed preference methods, which can be applied to estimate use value, stated preference methods can also be used to estimate non-use value. Stated preference methods include the contingent valuation method and discrete choice experiments.

The focus of existing non-market valuation studies linked specifically to whales has been on highlighting their conservation value, often in the broader context of biodiversity conservation. Due to the presence of non-use value, stated preference techniques have dominated the literature. The authors discovered one travel cost study focused on the economic value of whale watching (Loomis et al., 2000), although this paper acknowledged the particular challenges for researchers of dealing with multi-destination and multi-purpose trips in this context. A recent publication by O'Garra (2017) applied the benefit transfer method to approximate the existence value of beluga whale populations in the Arctic, calculating a mean value of US $ 29.44 billion per year (2016 prices).

Early non-market valuation studies were based exclusively on the contingent valuation method. Hagemann (1985) estimated the economic value of preserving various marine mammal species, including the grey-blue whale. Samples and Hollyer (1990) conducted a study broadly similar in methodological approach, estimating the economic value of preserving the humpback whale and comparing their outcome to values for the monk seal. The study by Loomis and Larson (1994) reported that if a particular whale species was held constant in number, visitors valued the resource more than residents. The authors also estimated willingness to pay for preservation given two different scenarios of stock expansion – a 100% increase or a 50% expansion – and found much higher outcomes in association with the former.

In recent times, discrete choice experiments have been more commonly applied (Johnston et al., 2015; Lew, 2015; Wallmo and Lew, 2016). The advantage of this approach is that preferences and willingness to pay for different attributes of marine resources can be estimated, with a view to informing trade-offs and management strategies. Wallmo and Lew (2016) formed three estimates of willingness to pay for different species in a survey and found spatial variations for protecting threatened and endangered marine species.

3.3. Non-monetary valuation methods

Emotional, aesthetical, symbolic, community-based and sacred values connected to an ecosystem or resource are typically very poorly captured by non-market valuation techniques, which include commodity metaphors, payment mechanisms and money metrics (Chan et al., 2012; Martín-López et al., 2014). Many academics have asserted that non-market valuation techniques are ill-suited to valuing impacts to certain cultural ES which relate to non-material gains (Wilson and Howarth, 2002; Cook et al., 2017). In these contexts, where a particular ecosystem service is considered 'beyond money', it is likely that participants would either not engage in the valuation process or willingness to pay for a particular service would be zero, and yet these individuals still hold a deep preservation value (Cooper, 2009; Christie et al., 2012; Martín-López et al., 2014).

A variety of non-monetary techniques can be applied to estimate values which extend beyond utilitarian associations and motives. These include largely qualitative approaches (e.g. surveys and semi-structured interviews), participatory and deliberative tools (e.g. citizens' juries and focus groups), and Delphi panels. However, there also exist quantitative approaches, such as preference assessments, time use studies and Q-methodology (Christie et al., 2012). Socio-cultural valuation, which integrates insights from multiple non-monetary techniques, is also increasingly popular as a means of informing preferences for the preservation of stakeholder-identified ES in protected area contexts (García-Llorente et al., 2016; Maestre-Andrés et al., 2016).

3.4. Valuing ecosystem service impacts – choosing economic or non-monetary information

When multiple value domains and thus multiple valuation languages are necessary, ES researchers may apply the concept of value pluralism (Gómez-Baggethun and Barton, 2013). When value pluralism is applied, Fisher et al. (2009) contend that it is up to ES researchers to determine the cases where non-market valuation techniques are appropriate informatives to decision-making. Often this selection process appears to be carried out by researchers in an arbitrary way. However, the recent paper by Cook et al. (2017) attempted to address this issue by setting out three general criteria to assist researchers when determining whether economic information could be utilised[2] to value a specific ES, or marginal change to an ES. These criteria are as follows:

1) Establishing a scientific relationship – can a physical function be determined which links the particular ecosystem (and changes to it) to a flow change in an ES, in terms of quality and quantity of supply? This is particularly relevant to provisioning and regulation and maintenance ES.
2) Value commensurability – does the particular ES relate to material benefits, and/or preferences formed on an individual basis? Where

[2] The aim was not to determine whether monetary data was *more* suited than non-monetary information to value a particular ES, but rather whether a rationale could be established for its utilisation.

non-material benefits are formed collectively, non-monetary sources of information should be preferred.
3) Reliability – does a market or non-market valuation technique exist that can be effective in eliciting preferences and willingness to pay/ accept in a particular resource context?

Table 2 considers these criteria in the context of whale ES, determining, in a thematic sense, the ES that are potentially suited to valuation using economic information. Where applicable, links between the ES, non-market valuation techniques and components of the TEV are denoted. Note, though, that non-monetary valuation techniques could be applied to value all of the services.

3.5. Threats and trade-offs involving whale ES

Although not reliant on an ecosystem services perspective, the academic literature contains many examples of impacts to whale ES. There is insufficient space available in this paper to conduct an exhaustive analysis, however, Table 3 provides a summary of recently reported examples where the quality and/or quantity of whale ES was impacted in some way. Impacts to whale ES are considered in two ways:

(1) Threats to whale ES from economic activities and environmental change;
(2) Trade-offs between whale ES, with increased provisioning of one service leading to diminishment in the quality/quantity of the service itself or another.

3.6. Integrated valuation and decision-making

It is evident from Table 3 that multiple value domains may be relevant to an impacted whale resource – for example, indigenous peoples may embrace the income opportunities proffered by the tourism sector through whale watching (utilitarian motives), yet the development of the industry may have a negative collective effect on community cohesion, identity and culture (non-utilitarian benefits). In addition, economic developments involving seismic activities, such as oil and gas exploration in Arctic environments, may induce whale stranding, which undermines food and community security within indigenous populations reliant on these resources for subsistence. In these cases, decision-makers must be aware of how best to ensure that the monetary advantages of economic advancement are evaluated alongside the various non-monetary impacts to human well-being.

The preceding analysis in Table 2 may infer that decision-making processes should be informed through a straight-forward collection and comparison of economic and non-monetary information. However, this approach would constitute merely a hybrid rather than integrated form of analysis. Integrated valuation seeks to advance hybrid valuation through four core forms spanning (1) knowledge systems; (2) quantitative and qualitative information; (3) values emerging across different societal domains; and (4) value articulating institutions (Gómez-Baggethun et al., 2014).

Although a thematic form of analysis, it is evident from this paper's review of whale ES and potential trade-offs from economic developments and environmental changes will lead to human well-being consequences which vary according to the local socio-cultural context. This is due to the multiple values that underpin the formation of ES. A logical consequence of these complexities is the need for environmental managers to consider multiple and conflicting types of values (Martín-López et al., 2014; Jacobs and Burkhard, 2017). This is a direct implication of value pluralism, necessitating integrated valuation tools to support decision-making.

One decision-support tool that has gained considerable traction in recent years is Multi Criteria Decision Analysis (MCDA), a framework describing approaches which attempt to account for multiple criteria and stakeholder objectives in decision-making (Pascual et al., 2017). In the context of ES assessments in general, MCDA has generally been perceived in three different ways: (1) as an alternative to economic valuation; (2) as a complementary approach to cost-benefit analysis; and (3) as an integrative decision-support system involving economic and non-economic values (Saarikoski et al., 2016). With respect to values held in connection to whales and their marine resources, viewpoint (3) is most applicable to decision-making. MCDA methods enable information to be incorporated from non-market valuation studies and the outcomes from deliberative research (Chan et al., 2012). They are integrative forms of evaluation, since they combine information about different policy and development outcomes with respect to scoring against criteria, based upon subjective weightings of the relative importance of the evaluation criteria (Saarikoski et al., 2016).

An understanding of ES in the context of whales and their valuation is only commencing through this publication. It is therefore unsurprising that there are not yet any related MCDA studies in the academic literature. However, a paper by Wenstøp (2012) began to conceive of the various criteria that could be assessed in relation to whaling projects, and how MCDA could be applied to formulate rational analysis of trade-offs. Among the potential objectives of relevance to decision-making were the following:

- Sustenance of indigenous populations, measured as the size of populations sustained by whaling;
- Sustenance of coastal populations, measured in terms of annual income from whaling;
- Health improvements from diets based on increased uptake of marine fatty acids, measured in terms of life years;
- Scientific information concerning the sustainability of the ecosystem, using the number whales killed compared to a sustainable threshold as an indicator;
- Commercial hunting, measured in terms of profit;
- Suffering of whales killed, measured in terms of time endured in the killing process;

A broader MCDA study, with an ES perspective and evaluation of trade-offs at its core, would also seek to evaluate impacts to additional services, especially those relating to the cultural, ecological, biodiversity and climate components. This would be essential in order to understand the sustainability and human well-being implications of different marine development permutations. As an informative to environmental decision-making, MCDA has already been applied in diverse marine contexts including, in recent times, marine current energy generation (Ramachandran and Takagi, 2015), climate change risk assessments (Rizzi et al., 2014), a sustainability evaluation of marine fuels (Ren and Liang, 2017), marine protected area planning (Portman et al., 2016), and determining the optimal location for fish farming (Dapueto et al., 2015).

4. Discussion

4.1. Challenges of valuing whale ES and conducting ES valuation in marine contexts

The challenges involved in conducting ES assessments involving whales have many parallels with the difficulties of conducting such studies in other marine contexts, and indeed in general. An important consideration relating to Table 2 is that although specific non-market valuation techniques *may* be available for valuing many whale ES, the particular study context will be a determining factor in their ultimate suitability. In the case of provisioning resources such as whale meat, market pricing data is likely to represent useful proxy data for estimating consumer surplus in study locations where commercial whaling takes place. For those locations where whale meat remains a subsistence aspect of the local diet or the act of whaling forms part of a spiritual or indigenous tradition, the use of economic information will be

Table 2
Whale ES – valuation using economic or non-monetary information.

CICES classification of ecosystem service impact	Value impacts economically?	Justification (numbers relate to criteria)	Likely valuation method(s)	Component of the TEV framework (if applicable)
Provisioning				
Food, oil-based, bone, baleen and teeth-based products	Yes/no	(1, 2 and 3) in non-indigenous context; may violate (1) and (3) in indigenous setting	Market pricing; non-monetary valuation techniques – qualitative and/or quantitative	Use (direct) or N/A
Regulation and maintenance				
Climate regulation (carbon sequestration)	Yes	(1, 2 and 3)	Marginal abatement costs; marginal damage costs	Use (indirect)
Enhanced biodiversity and evolutionary potential	Yes	(1, 2 and 3)	Production function or contingent valuation	Use (indirect) and non-use
Enhanced primary production	Yes	(1, 2 and 3)	Production function or contingent valuation	Use (indirect)
Cultural				
Tourism (whale watching)	Yes	(1, 2 and 3)	Market pricing or travel cost method	Use (direct)
Whale music and arts (entertainment)	Yes/no	(1, 2 and 3)	Market pricing or contingent valuation	Use (indirect)
Education	Yes/no	(1, 2 and 3)	Market pricing or travel cost method	Use (direct and indirect)
Sacred and/or religious	No	Violates (2) since non-material benefits are formed collectively	Non-monetary valuation techniques – qualitative and/or quantitative	N/A
Community cohesiveness/ cultural identity	No	Violates (2) since non-material benefits are formed collectively	Non-monetary valuation techniques – qualitative and/or quantitative	N/A
Aesthetics	Yes/no	(1, 2 and 3)	Contingent valuation	Use (indirect) and non-use
Existence and bequest	Yes/no	(1, 2 and 3) in non-indigenous context; very likely to violate (2) in indigenous setting	Contingent valuation or discrete choice experiments; non-monetary valuation techniques – qualitative and/or quantitative	Non-use or N/A

inappropriate and deliberative techniques should be preferred. Equally, in both indigenous and non-indigenous communities, whaling and whale watching is often one of the central features of community cohesion and cultural identity, the development of which occurs collectively. In some cases, the context of the valuation study will determine the practicality of conducting non-market valuation techniques for specific ES, and thus several services are listed as yes/no in terms of their suitability. For whale music and artistic contributions, a market setting or estimate of willingness to pay may not be appropriate, especially if these form elements of spiritual rituals or practices. The same is apparent in the case of aesthetics and associations linked to non-use value. In the case of education sourced from whales, this ES may be delivered to recipients at the same time as recreational benefits, for example, during a whale watching tour. Therefore, it would be erroneous to value both services using the travel cost method, as this would result in a partial double counting of benefits. In other cases, where education is delivered in a formal setting, such as in a whale museum, then a combination of market pricing and the travel cost method could be applied – the former in relation to ticket sales; the latter linked to the travel and opportunity costs of the educational experience.

In addition, non-monetary valuation techniques applicable to whale ES, including deliberative techniques such as semi-structured interviews, focus groups and citizens' juries, have pros and cons. These techniques are capable of inferring subjective well-being by eliciting how stakeholders define well-being components in the context of whales, and the locally relevant issues of importance. They offer particular advantages in articulating values and responses to potential management decisions e.g. economic developments, and can potentially increase social support and engagement and help to provide transparency concerning outcomes (Kelemen et al., 2014). However, the outcomes of deliberative techniques depend on the skills and capacity of the researchers in surveying a broad array of affected stakeholders, the willingness of affected communities to engage in the research process, and the ultimate utilisation of the information gleaned from the valuation exercise(s) in local decision-making. There are challenges in ensuring that deliberative valuation techniques are tailored to fit the particular institutional contexts pertaining to the study location (Bunse et al., 2015). In addition.

Outcomes from non-monetary techniques are much harder than non-market valuation studies to transfer between sites. These have to be undertaken for each individual site and are thus much less efficient than their economic alternatives, which once undertaken can be transferred to a wide range of sites.

Integrated forms of valuation and decision-support frameworks such as MCDA entail higher information costs than forms of valuation focused on single value domains (bib_citation_to_be_resolved Martinez-Alier and Muradian, 2015; Jacobs and Burkhard, 2017). Cost is therefore a major barrier to the wider deployment of such approaches and platforms. However, as this paper has illustrated, single value approaches are liable to inefficiency and ineffectiveness, failing to capture the deeper complexities of human-nature interactions. In addition, single value approaches are likely to involve the risk that certain stakeholder groups are marginalized in decision-making (Jax et al., 2013; Martín-López and Montes, 2015), and this is possibly even more likely in indigenous communities. However, inclusivity is not in itself a guarantor of eventual fairness in the process of informing decision-making. Fairness demands the consideration of equity aspects throughout the research and evaluation process, from the identification of stakeholders to the choice of valuation methods, to the eventual MCDA objectives and weightings (Garmendia and Pascual, 2013). Otherwise, power asymmetries may emerge, in terms of research design, analysis and, ultimately, decision-making protocols.

There are also many challenges associated with the gathering of economic and non-monetary information to inform decision-making. Undertaking non-market valuation techniques – typically stated preference techniques – linked to whales is feasible in non-indigenous contexts, where there exists an identifiable coastal population to survey. There will remain challenges when the ES of whales occur in remote locations without human populations, such as the high seas. Currently, there remains a general dearth of information concerning marine ES supplied in the high seas, which support economically significant species that may then migrate thousands of kilometers. It is therefore very difficult, if not impossible, to estimate the contribution made by high-sea ecosystems to ES providing benefits to human beings elsewhere.

Table 3
Threats and trade-offs involving whale ES.

Issue	Location and study	Issue(s) discussed
Threats to whale ES		
Economic threats		
Unsustainable and/or illegal whaling	Japanese whaling in the Southern Ocean, which has been claimed to be for commercial rather than scientific purposes (Brierley and Clapham, 2016)	Japanese whaling in the Southern Ocean violated the zero-catch limit set by the International Whaling Commission by setting a self-determined quota, reducing the potential for stocks to recover and diminishing benefits from the cultural and regulation and maintenance categories of whale ES. Roman et al. (2014) and Smith et al. (2019) also reported on how unsustainable whaling could increase the likelihood of extinctions of deep-sea species reliant on whale falls.
Oil and gas exploration and production – seismic issues	Population of western grey whales at Sakhalin Island, Russia (Weller et al., 2002) Scotian Shelf population of northern bottlenose whales, Canada (Allen, 2015) Canada and Greenland (Heide-Jørgensen et al., 2013)	Seismic activities linked to oil and gas activities have been shown to significantly reduce the number of whales and pods present compared to the pre-seismic condition. Heide-Jorgensen et al. (2013) report on the circumstantial links between seismic surveys and the ice entrapments of narwhals in Arctic Canada and Greenland, a problem for local indigenous peoples whose subsistence is reliant on these resources.
Oil and gas exploration and production – oil spills	Gulf of Mexico (Wise et al., 2018)	The Deepwater Horizon oil spill resulted in increased metal levels in sperm whales, including (1) genotoxic metals at concentrations higher than global averages previously reported and (2) patterns for MC252-relevant metal concentrations decreasing with time from the oil spill.
Increased shipping	Six islands in the Caribbean Sea (Heenehan et al., 2019)	Vessel traffic was found to adversely affect marine soundscapes, masking sounds by humpback whales, potentially changing their typical behaviour and raising the risk of ship strikes.
Increased marine-based tourism	Barrow, Alaska (Hillmer-Pegram, 2016) Sasi Laut, Misool, Indonesia (Prasetyo et al., 2019) Arctic in general (Veijola and Strauss-Mazzullo, 2019)	Diminished sense of local community and indigenous identity due to increased presence of more 'Western' forms of tourism, often via cruise ships, which does not seek to integrate traditional ecological knowledge (TEK) concerning marine resources, including whales; absence of opportunities for storytelling. Equally, Veijola & Strauss-Mazzullo (2019) discuss how the economic benefits of 'last-chance' tourism have helped to sustain remote Arctic communities and cite several examples whereby TEK has been integrated into the tourist experience.
Environmental threats		
Plankton communities – increased abundance	Northern Patagonian Gulfs, Península Valdés, Argentina (D'Agostino et al., 2018)	Increased abundance of phytoplankton and mesozooplankton found to be associated with peaks in whale biomass values. Salinity and phaeopigments linked to plankton production were related with copepod abundances.
Climate change	Alaska (Walch et al., 2018; Huntington et al., 2019)	Climate change is affecting the migratory pattern of whales and where they feed and breed, sometimes increasing the vulnerability of communities reliant on the presence of whale resources for subsistence. Food security challenges are already increasing, exacerbating community stress and increasing the likelihood of community breakdown.
ES trade-offs		
Increased commercial whaling (minke and fin whales)	Faxaflói Bay, Reykjavík (Bertulli et al., 2016)	Greater provisioning services but study reports negative effects among tourists on whale watching, reducing the likelihood of visitors going on such trips. Also see section above on 'unsustainable whaling'.
Increased whale watching	Faxaflói Bay, Iceland (Christiansen et al., 2013; Higby et al., 2012) Bocas del Toro, Panama (Sitar et al., 2016)	Disruption of feeding activities of minke whales in Faxaflói Bay due to whale-watching boat interactions and vessel noise, including reduced foraging activity and less likelihood of witnessing surface feeding events, thus reducing the quality of the whale watching experience; in case of Bocas Del Toro, failure to follow national guidelines for whale watching, including surrounding marine mammals with more than 15 boats, presents a long-term threat to populations.

4.2. Future research – whale and marine ES

A logical progression of the ideas in this paper concerns the commencement of quantification (in terms of service flows) and valuation studies – economic, non-monetary and integrated – which inform the debate concerning the contribution of whales and their ecosystems to human well-being. This is necessary in order for decision-makers to better understand the well-being impacts to affected societies and the various trade-offs of economic developments, climate change affects, and potential conservation strategies. Through such studies, there is the potential for ecosystem-based principles to become embedded into decision-making concerning whale ecosystems.

A further consideration related to the valuation of whale ES concerns their role as contributors to marine ES in most cases, with the obvious exception of whale watching tourism. The valuation of whale ES needs to occur in context, often with whales serving as an "umbrella species" for the supply of marine ES. The protection of whale habitats can allow provision of the ES from that habitat, and thus future research in this area should investigate the changes in the full range of marine ES that occur in response to changes in whale populations. This will require extensive ecological modelling.

5. Conclusion

Whale ES are diverse and provide an example of human well-being benefits that have been largely ignored in the ES literature, which contains neither a detailed thematic review of services nor consideration of how these can best be valued in order to inform decision-makers. The example of whale ES highlights issues common to the valuation of marine ES in general, whereby different types of values – utilitarian and socio-cultural – may underpin the sourcing of human well-being. Through this paper's thematic review of the most suitable methods for valuing whale ES, it is evident that a pluralist approach to ES assessment is very likely to be necessary in practice, one that incorporates and integrates economic and non-monetary information. MCDA was suggested as an example of an integrative form of decision-making apparatus that could potentially be applied to evaluate the relative merits of different marine management scenarios linked to whale ecosystems. Due to its capacity to evaluate economic and non-monetary information against multiple criteria, tools such as MCDA have potential in terms of their ability to induce reasoned, rational compromises in decision-making, considerate of various ES threats and trade-offs. They can also play a central role in embedding ecosystem-based principles into the management of marine resources. Future research concerning whale ES could involve the quantification of biophysical flows of services belonging to the regulation and maintenance category, the conducting of valuation studies concerning cultural whale ES in indigenous and non-indigenous contexts, and, where applicable, the practical deployment of integrated valuation techniques.

Declaration of competing interest

I wish to confirm that we have read, understood and fully complied with the journal's ethical guidelines. This manuscript is our own work and has not been submitted for review to another journal. There are no conflicts of interest that impinge on the publication of this paper.

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