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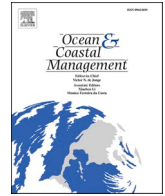
Setting the stage for decision-making on nature-based solutions for coastal climate adaptation

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A B S T R A C T

Nature-based solutions (NbS) are fast becoming the norm for multifunctional coastal climate adaptation to increased sea-level rise. However, informing decision-makers about NbS presents ongoing challenges. This study set out to identify and explore the information requirements at different stages of the decision-making process of coastal NbS. Developing and applying a novel methodological approach, we analysed the values and indicators discussed in four key decision-making stages: the advocacy, political, bureaucratic and provisioning stages. Applied to a mega beach nourishment in the Netherlands, our study identified substantial differences in information requirements across the decision-making stages. Most notably, the values and indicators discussed shifted from being abstract to becoming increasingly specific and concrete as the stages progressed. Our findings emphasize the importance of recognizing the distinct stages of decision-making and tailoring the content and level of abstraction of information accordingly. Additionally, they suggest that future changes in the content and concretisation of the information required for decision-making on coastal NbS can be anticipated and prepared for. By distinguishing and understanding the decision-making stages in NbS, this study bridges a longstanding gap between decision-making and NbS studies, thereby allowing for improving the fairness, implementation, evaluation and comprehension of trade-offs of coastal NbS. This study progresses the understanding of the information required for planning, implementing, evaluating and managing coastal NbS, advancing multifunctional coastal climate adaptation for shores worldwide.

1. Introduction

Nature-based solutions (NbS) are fast becoming the norm for multifunctional coastal climate adaptation but bring increased complexity to decision-making. The global mean sea level may rise 2 meters by 2100 (IPCC, 2023a), when about one billion people are predicted to live within 10 meters of the coastline (Merkens et al., 2016). There is an increasing call for applying NbS for coastal climate adaptation, as these can help to effectively adapt to climate impacts while delivering multiple values to both society and nature (IPCC, 2023b; Seddon et al., 2020). Since the concept came to increased institutional attention, the need to integrate NbS research with decision-making knowledge has only become more prominent (see Editorial, 2017; Nesshöver et al., 2017; Seddon, 2022).

The challenges for informing decision-making on NbS follow their diverse information requirements. The openness of the NbS concept allows it to be regarded and used as a 'boundary object', i.e., it permits stakeholders to project their own beliefs and values, thus connecting stakeholders, scientific disciplines and policy-makers (Hanson et al., 2020). Informing NbS decision-makers of this multitude of values and beliefs requires complex knowledge production and communication, which involves more stakeholders and scientific disciplines (Nesshöver et al., 2017). The ambiguity of the NbS concept makes decision-making prone to reinforce dominant narratives and power structures that lead to unjust and undesired NbS outcomes (Melanidis and Hagerman, 2022; Woroniecki et al., 2020). Moreover, the openness and the multitude of perspectives contrast with the preciseness of information required for other decision-making activities, such as its evaluation (Van Oudenhoven et al., 2018a).

Addressing the diverse information requirements for NbS decision-making can improve its contribution to successful coastal climate adaptation. This implementation is currently challenged by the lack of precise and scientifically valid reporting on multiple outcomes of NbS (Chausson et al., 2020; Key et al., 2022). Additionally, the occurrence of

trade-offs in NbS decision-making for climate adaptation is poorly understood (Seddon, 2022). Moreover, the delivery of appropriate and just NbS must be increased by precisely informing decision-makers on stakeholders' value articulations (Cousins, 2021). Informing decision-makers on NbS for coastal climate adaptation requires understanding their information requirements and, thus, the translation of NbS from an open concept to its concrete implementation and evaluation (Hanson et al., 2020; Langridge et al., 2014; Nesshöver et al., 2017).

Crucial for addressing the diverse information requirements is distinguishing and understanding the different stages in NbS decision-making. Informing decision-makers entails communicating about the statuses or trends that reflect stakeholders' concerns (Ash et al., 2010). By applying a policy science framework, changes in both these trends and concerns can be understood. Veeneman et al. (2009) defined a framework that builds on Bachrach and Baratz (1970). Therein, four stages of decision-making are defined that have distinct information requirements, in which the values of the involved stakeholders change distinctively (Veeneman et al., 2009). As stakeholders' values change, informing decision-makers requires communicating on different indicators (Schröter et al., 2020). Therefore, distinguishing and understanding the change in values and indicators discussed across the stages of decision-making allows researchers to better understand and anticipate information requirements. Yet, these stages of decision-making have thus far not been applied to analyse the information requirements of NbS decision-making.

This study aimed to identify how the information utilized in decision-making on NbS for coastal climate adaptation differs across the four stages of decision-making (sensu Veeneman et al., 2009). We distinguished the decision-making stages for a nature-based solution for Dutch coastal climate adaptation and analysed the information mentioned in formal policy documents for each stage. To the best of our knowledge, this study is the first to distinguish these crucial stages of decision-making concerning NbS and quantitively analyse the values and indicators discussed per decision-making stage. This study allows researchers to analyse and anticipate NbS information requirements of

decision-makers, to make better informed and more just choices on NbS.

2. Methods

2.1. Stages of decision-making, values, indicators and objects

Central to this study is the policy science framework that distinguishes four crucial stages in decision-making, as defined by Veeneman et al. (2009). These stages are the advocacy, political, bureaucratic and provision stages (Table 1). Each stage is concerned with distinct processes and actors involved, who engage in activities that range from creating abstract ambitions to concrete physical interventions and precise evaluations. Bachrach and Baratz (1970) laid the groundwork for distinguishing these stages and demonstrated that in each stage, distinct actors, activities and power dynamics shape the information decision-makers require (Dunn, 2016). Veeneman et al. (2009) applied these stages for theoretically analysing shifts in the understanding of public values per stage in public infrastructure projects.

In the advocacy stage, values are articulated to be placed on the agenda of decision-makers. The advocating stakeholders compete for decision-makers' access, attention, approval and support. Outcomes of this stage, therefore, depend on factors such as lobbying capacity, financial resources, media attention and alignment with shared cultural values – creating a narrative to form a coalition of advocators and obtain decision-makers' support (Bachrach and Baratz, 1970; Bontje and Slinger, 2017; Veeneman et al., 2009). Alignment with cultural values can for instance be achieved by framing the project to encompass culturally agreeable values (Rein and Schön, 1996). In the advocacy stage, the information required is therefore often broad, culturally aligned and concerned with 'win-win' situations relating to influential stakeholders' interests (Veeneman et al., 2009).

In the political stage, a course of action is chosen based on the articulated values. As this must be a single course, it contrasts with the broader value articulations and information requirements in the advocacy stage. Values must be in- or excluded, interpreted and prioritised

Table 1
The four decision-making stages as defined by Veeneman et al. (2009). The definition and descriptions of each stage are followed by examples in the academic literature pertaining to nature-based solutions.

Stage	Definition	Description	Examples in NbS literature
Advocacy	Advocation for articulation and selection of values that the project can bring	Values are *articulated* to be placed on the political agenda. A coalition of advocates is often created. To gather support, the values tend to be simple, abstract, 'win-win', culturally agreeable and in line with the interests of powerful stakeholders.	Boundary object function of NbS (Hanson et al., 2020; Van Oudenhoven et al., 2018a). Institutional push for NbS to be green, natural and sustainable in the EU and UN (Seddon et al., 2021)
Political	Negotiation to designate and prioritise values to decide upon a course of action for the project	*Designation* is deciding which values are considered. *Prioritisation* concerns deciding how values should be weighed against each other. *Interpretations* of the ambition values are made. Support is sought for these political choices. The choices follow from setting a course of action in which not all values advocated for can be met, as resources are limited.	Common trade-offs for NbS occur between social, ecological, economic, biodiversity, climate mitigation and adaptation concerns (Chausson et al., 2020; Seddon, 2022), and the interests of stakeholder groups (Cousins, 2021; Giordano et al., 2020).
Bureaucratic	Operationalisation of the values into concrete actions to be taken in the project	*Operationalisation* concerns transforming a course of action into concrete norms, infrastructure and regulations. This can lead to trade-offs with efficiency concerns. The values are reinterpreted considering the executing organization's culture, regulations, goals, abilities and interests. It may strive to formulate additional goals, e.g., based on private interests. Its technical, local perspective may mismatch with the strategic perspective of earlier stages.	Governance of social, environmental, ecological, biodiversity and resilience by multiple disciplines and policy levels may require forming new collaborations between actors that so far have operated in "disciplinary silos" (Hanson et al., 2020, p. 10).
Provision	Monitoring, evaluation, and assessment of the value provisioning of the project	Delivery of the project values, and monitoring, assessing and reporting of this. Trade-offs may occur with the evaluators' interests, data available, norms, the timescale of delivery and the concreteness of the values. The outcomes can serve as feedback to and potential restart of the earlier stages. The values are understood most concretely.	NbS evaluation is still challenged in assessing uncertainty and robustness (Lallemant et al., 2021), considering unexpected outcomes (Sala and Torchio, 2019) and multiple outcomes (Chausson et al., 2020). Also, NbS outcome indicators may not necessarily reflect the initial project goals (Dumitru and Wendling, 2021).

Note: The definitions and descriptions of the stages follow the definitions and study by Veeneman et al. (2009). The examples from academic literature on NbS are studies that described these characteristics as challenges for NbS decision-making.

(Dunn, 2016). Often, values have distinct and mutually exclusive understandings (Rawls 2009). For instance, when designing an area for nature conservation, some will prioritise conserving specific ecological factors, while others prefer the area's traditional human activities in nature (Geukes et al., 2021; Pike et al., 2015). In western political studies, it is agreed that such political choices do not have objective 'right' outcomes, as values are incommensurable (see Berlin, 2006). Political processes should aim to create legitimacy by fairly considering relevant political actors (Rawls, 2009). For informing political processes, information is thus required on the status of the specific value understandings and prioritisations of relevant stakeholders.

The bureaucratic stage is concerned with operationalising the course of action into concrete interventions, norms and regulations. Bureaucracy is the formal, rule-based, hierarchical and often technical execution of governmental plans (Weber, 2013). In practice, bureaucratic processes are also determined by informal factors, such as the executing organization's culture, power relations, internal relationships and norms (Crozier, 2009). As such, decision-making on bureaucratic operationalisation requires information for executing the negotiated plans, relating to the organisation's formal and informal structure (Stone, 2012).

In the provision stage, decision-making is informed of the monitoring, assessment and evaluation of the delivery of the operationalised values. As evaluators must be able to estimate and communicate on the delivery of a value, information requirements in this stage are steered by further pragmatic concretisation of the ambition values. For instance, effective evaluation is shaped by the perceived legitimacy, credibility, saliency and feasibility of the information available (Cash et al., 2003; Van Oudenhoven et al., 2018b). Such factors are also influenced by societal aspects, which may, for instance, be social, economic or historic (Latour, 1988). The information requirements in the provisioning stage are thus concretised in the context of evaluators' pragmatic concerns and societal factors that enable effective communication.

To evaluate the information discussed in the different stages of decision-making, we distinguished values, indicators and their objects. We define a value (in the Aristotelian sense) as an object or process that a person or society cares about, as these are deemed to contribute to the meaningful well-being of someone or society (Chan et al., 2019; Doorn, 2019; Schröter et al., 2020). The objects or processes that are valued (hereafter referred to as 'objects', Fig. 1) are often not directly observable (e.g., it is hard to directly see the status of 'nature'). To still observe the status of a value, indicators are used. These inform about another object, an observable phenomenon that is logically connected to the value (Hinkel, 2010). For instance, an indicator can inform about the status of nature by reporting the surface area of available habitats. We thus define indicators as funtions from observable variables that have a logical connection to a process or object of concern, so that they reflect their status, cause or outcome (Ash et al., 2010; Hinkel, 2010). The fit of indicators to values is never perfect, as indicators reflect the status of another – but observable and logically connected – variable (Haila and Levins, 1992; Hinkel, 2010; McDermott et al., 2022). Together, values and indicators inform about what information was relevant for decision-making but reflect different aspects of it. If values are discussed, the information pertains more to what is strived towards, or why so. Indicators, on the other hand, inform on the real-world status of a variable logically relating to these goals.

2.2. The Sand Motor as a case study

Our inclusion criteria for a case study encompassed that it was designed to address social, environmental and economic challenges in a coastal area arising from heightened climate impacts, with a multifunctional approach that included delivering benefits to biodiversity (following the definition of NbS by the UNEP (2022)). Further, the case was required to have detailed data available on all four stages of decision-making, to study these in detail and in-depth. Additionally, the
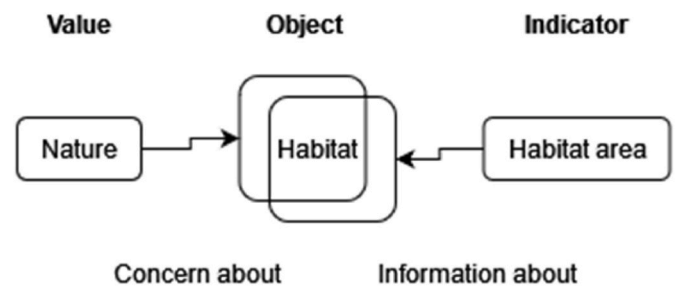

Fig. 1. Conceptual relation between values and indicators. Values signify a concern about an object or process ('object'). Indicators inform about the status or trend of such objects of concern. The objects of values and indicators may overlap but may never fit perfectly. For instance, indicators may change due to other factors or be more specific than the value they refer to.

case had to be relevant for future coastal climate adaptation of sandy shores. These criteria were met by the Sand Motor in the Netherlands. Placed in front of the Delfland coast, this is a mega beach nourishment, consisting of 21.5 million m^3 of sand. It was created with the multifunctional intention to benefit safety, nature, recreation and knowledge production (Luijendijk and van Oudenhoven, 2019). It relied on natural processes to spread the sand longshore and create dunes by wind transport, 'building *with* nature', rather than against it (De Vriend and Van Koningsveld, 2012). Moreover, the project served as an 'innovative' experiment that informed multiple other Dutch multifunctional coastal climate adaptation projects (Aukes et al., 2018; Baltissen, 2015; Bontje and Slinger, 2017).

In policy documents on the Sand Motor, the four stages of decision-making and their characteristics were distinguishable and well described. The advocacy stage was present as stakeholders advocated for the project in multiple documents, which mostly included letters to national and provincial parliaments, and was consolidated in an ambition agreement. The political stage was described in documents that drafted a preferred design of the Sand Motor by designating, interpreting and prioritising the ambition values. Support was sought by consulting local citizens on the finished plan. These citizens engaged politically by offering new value interpretations and prioritisations, and related adjustments (Gerdes et al., 2021; Ministry of Infrastructure and Water Management and Rijkswaterstaat, 2010). The bureaucratic stage consisted of deciding on the construction and management of the Sand Motor. The dredging companies Van Oord and Boskalis constructed the project, and the Province of South Holland and local municipalities managed it afterward. The provision stage consisted of a 10-year multi-disciplinary programme to evaluate the provisioning of the ambition goals (Huisman et al., 2021; Tonnon et al., 2011).

2.3. Data selection and coding

Document collection started in the online archive built for the case by EcoShape, a consortium of Dutch private and governmental actors that promote Building with Nature-design in hydraulic engineering. The inclusion criterium for documents was that they must contain information on the decision-making of the Sand Motor, which includes the ambitions, planning, design, management and evaluation of the project. In these documents, we identified the stakeholders involved in any decision-making stage. If these identified stakeholders had online repositories to publicly store policy documents, we investigated those to gather additional policy documents, utilizing the same selection criterium. As this could lead to the identification of other involved stakeholders and accompanying documents, this was an iterative approach, which continued until we identified no new stakeholders and documents. We compiled 68 policy documents in total. The period of searching for documents ran until July 1st, 2022.

We critically read all compiled documents and assigned them to the

decision-making stages they were most representative of. Following Veeneman et al. (2009), we identified 13 documents as representing the advocacy stage, 15 documents for the political stage, 6 documents for the bureaucratic stage and 34 documents for the provision stage. We then selected the most relevant documents to study in detail, until all characteristics of the decision-making stages were represented in our selection. A document was considered most relevant if it was referred to most often and as essential in other documents. The ambition document was the starting point for this selection as it laid out a formal project roadmap, indicating crucial future decisions and documents, and was recognized as such in later documents. One document mentioned in the ambition document, which concerned the construction and management of the Sand Motor, was not found and not referred to in any later documents. We considered the documents that were referred to instead as the most relevant representation of these processes. We ultimately selected six documents as most relevant and representative of the four decision-making stages (Table 2; Appendix).

For each selected document, we identified and coded the decision-making stages, values and indicators. This coding was performed in ATLAS.ti 22 for Windows, version 22.1.5–22.2.4 (ATLAS.ti Scientific Software Development GmbH, 2022). We coded as detailed as possible, close to *in vivo*, to not exclude any information beforehand (see Haila and Levins, 1992). Selected indicators could be quantifiable and physical, such as the beach width, but also less quantifiable and more procedural, such as the formal structure of stakeholder agreements. Values were coded broadly as objects or processes of stakeholders' concern, including, for instance, recreation, morphological coastal maintenance, local cultural heritage or swimmer safety. The values and indicators were coded and linked to their associated objects. We identified the four stages of decision-making following the definitions by Veeneman et al. (2009) (Table 1).

We coded the information iteratively to assure coherence between the coding over time. We expected that the coding could become more detailed or shift focus with more knowledge of the project obtained. Therefore, all coding was critically assessed at least once again after the first round of coding. In case we were unsure of a certain code, we listed the information to discuss among the authors for inter-coding agreement. For instance, the indicator for management agreements was first one general code but later specified into multiple codes – specifying, for example, management of cleaning the beach or of coast guard supervision. We identified 3659 quotes and 2381 unique codes. These codes consisted of 542 values, 1835 indicators and covered all four decision-making stages.

2.4. Information analysis per decision-making stage

To analyse and explore the information discussed for each decision-making stage, we first created an overview of the type of information discussed per decision-making stage. We calculated the relative number of times that values were utilized compared to the total number of times that indicators were utilized per stage. For this, we exported a list of the indicator and value codes' frequencies and their co-occurrence with decision-making stage codes from ATLAS.ti to Pandas DataFrames (McKinney, 2010; Reback et al., 2022) in Python (Python Software Foundation, 2022; Van Rossum and Drake Jr, 1995). There, we calculated the total number of times that values and indicators were mentioned and calculated the ratios of value to indicator frequencies per decision-making stage.

Then, we categorized and compared the frequencies of values and indicators per decision-making stage. We categorized the values into five groups. We based these groups on the four project ambitions of safety, nature, recreation and knowledge production, and added a miscellaneous category. These ambitions were described in the ambition agreement, EIA and evaluation documents (Fiselier, 2010; Huisman et al., 2021; Ministry of Infrastructure and Water Management and Province of South Holland, 2008; Tonnon et al., 2011). We categorized

Table 2

Policy documents included in our analysis. Summary of the description, representativeness of the decision-making stage and relevance for the decision-making on the Sand Motor.

Decision-making stage	Document name	Document description and representativeness of the decision-making stage	Relevance for the project's decision-making
Advocacy	*Ambitieovereenkomst pilotproject Zandmotor*[a]	The ambition agreement, acknowledging its multifunctional nature-based intentions. It *advocated* for the project as a win-win for nature, recreation, safety and innovation.	The formal project roadmap. It was signed by all essential actors for the project start. In later documents, it was referred to as the project starting point and reflecting its ambitions.
Political	*Projectnota/MER, Aanleg en zandwinning Zandmotor Delflandse kust*[b]	The Environmental Impact Assessment (EIA) on the construction and sand extraction. It choose a project design, for which values were *designated, interpreted, prioritised* and partly *operationalised*.	These documents were referred to in the ambition agreement as critical for the decision-making on the Sand Motor and most often referred to political documents in later documents.
	Nota van antwoord op inspraakreacties inzake MER Zandmotor aan de Delflandse kust[c]	Note of citizen replies and governmental answers to the course of action chosen in the EIA. Citizens *designated* and *prioritised* values.	
Bureaucratic	*Beheersovereenkomst Zandmotor*[d]	The management agreement. It *operationalised* the values into concrete actions, norms, and agreements for the managing stakeholders, focusing on formal responsibilities.	The documents mentioned in the ambition agreement for this stage were not found and later referred to. Instead, the later documents referred to these documents as essential to the management and construction.
	Protocol van beheersmaatregelen, taken en verantwoordelijkheden op de Zandmotor[e]	The protocol of control measures, tasks, and responsibilities. It followed the management agreement in the project *operationalisation* to decide on responsibilities for unanticipated effects.	
Provision	*Evaluatie van 10 jaar Zandmotor: Bevindingen uit het Monitoring- en Evaluatie Programma (MEP) voor de periode 2011 tot 2021*[f]	The summary of the project's *monitoring* and *evaluation* documents and *assessment*.	The formal summary of the 10 years of evaluation and monitoring, concerning the ambition goals as stated in the EIA.

[a] Ministry of Infrastructure and Water Management and Province of South Holland (2008).
[b] Fiselier (2010).
[c] Ministry of Infrastructure and Water Management and Rijkswaterstaat (2010).
[d] Municipality of the Hague (2010).
[e] Protocol van beheersmaatregelen, taken en verantwoordelijkheden op de Zandmotor, 2010.
[f] Huisman et al. (2021).

the indicators into six themes. We based these themes on the information categorization in the summarizing evaluation document, leading to morphology, ecology, recreation, procedural, knowledge production, and miscellaneous themes (Huisman et al., 2021; Tonnon et al., 2011). We assigned the originally utilized management theme to a procedural theme. This theme included all indicators concerned with the project execution. For each theme and group, we identified keywords that categorized the information in one of these themes or groups in the policy documents. We then identified the presence of these keywords in the codes. For this, we created a Python function that searched through the list of codes in the Pandas DataFrames by utilizing the string. _contains_() function and added it to the respective category. Any uncategorized value or indicator that remained was manually categorized. If a code did not fit in any group, it was assigned to a miscellaneous category for values or indicators. We assessed the dependency of the distribution of the categories on the decision-making stages with a χ^2-contingency test.

Next, we analysed the objects of the values groups and indicator themes per decision-making stage. We created a Python function that identified the objects in each code. This identification started by importing the codes as strings. The Python function then split these strings to identify each object individually. Then, it stacked and counted these objects as strings, by utilizing the value_counts() function. This process was repeated for codes of each group or theme and decision-making stage. By this, we composed a DataFrame that contained the objects of the discussed indicators and values, including their frequencies per group or theme and the decision-making stage they were mentioned in. The frequencies of the nouns and adjectives were plotted for the ten most frequent per category, per decision-making stage. This created an overview of the most discussed content of the values and indicators in each decision-making stage.

Lastly, we analysed the shift in information content per ambition value as the project developed through the decision-making stages. We interpreted the changes in coded objects across the decision-making stages to identify potential general patterns. We visualized the frequencies of the most frequently discussed values and indicators of each ambition value in Sankey diagrams. This visualization allowed us to explore the patterns in the development of information utilization across the decision-making stages for each ambition value.

3. Results

3.1. Value groups and indicator themes change significantly per decision-making stage

With the development of the Sand Motor project through the four stages of decision-making, the relative contribution of indicators to the total amount of information increased. The total number of times that values were mentioned remained relatively stable, starting with 326 in the advocacy stage to 485 in the provision stage (Table 3). However, the total number of times that indicators were mentioned increased sharply, from 516 to 2320 from the advocacy to the provision stage (Table 4). In these stages, the relative contribution of indicators to values to the information mentioned thus increased from 37% to 79%.

Across the decision-making stages, the distribution of value groups differed significantly (χ^2 (12) = 77.73, $p < 0.001$) (Table 3). For instance, in the political stage, recreation was the second-most discussed value group (25%), while in the provision stage, values in this group were the least-discussed (15%). Also, values concerning knowledge production occurred mostly in the advocacy (14%) and provision stages (19%), but their relative contribution comprised half in the political (8.0%) and bureaucratic (7.4%) stages. Similarly, for each decision-making stage, the distribution of indicator themes differed significantly (χ^2 (15) = 547.83, $p < 0.001$) (Table 4). In all stages, the most frequently discussed indicators were those concerning morphology (~45% on average). Procedural indicators were the second-most

discussed indicator group up until the bureaucratic stage (21%, 19%, 27% in the advocacy, political and bureaucratic stages), but the least mentioned indicators in the provision stage (5.4%). Ecological indicators rose from being the second-least mentioned to the second-most discussed indicator theme over the stages (rising from 9.3%, 13%, and 12% in the advocacy, political and bureaucratic stages to 23% in the provision stage).

3.2. Divergence of objects of values and indicators with decision-making stage

Across the four stages of decision-making, the objects of the value discussions changed substantially. These objects shifted from being combined with other value groups towards multiple specific concretisations in later stages. In doing so, each value group demonstrated distinct patterns. In the advocacy stage, values concerning safety mostly concerned coastal safety, referring to flood prevention (Fig. 2). In the bureaucratic and provision stages, the local safety concerns for swimmers and recreationists became the most discussed safety values. Values relating to nature also referred to recreation in the advocacy stage, but notably less in the other stages. In the other stages, natural values increasingly discussed habitats, dunes and the Solleveld area, which is a Natura2000 area behind the Sand Motor. Similarly, recreational values referred to nature in the advocacy stage and did so decreasingly in the later stages. Access to the area was a political topic but little discussed in the other stages. Beach cleanliness rose in the bureaucratic stage as a topic of recreational values, and kitesurfing came up in the provision stage. The objects of the knowledge production values were mentioned most frequently in the advocacy and provision stages, and much less in the political or bureaucratic stages, as was the case for innovation, development and nature. As an exception to this trend, knowledge uncertainty was a concern in the political stage but discussed little in the other stages. Some miscellaneous values were brought up in the political stage but were little discussed in the other decision-making stages, such as those about economics and the local character.

The objects that indicators referred to also differed substantially across the decision-making stages. Even though ecological and morphological indicator topics were little discussed in the advocacy stage, they became the most discussed topics in the provision stage (Fig. 3). For instance, this trend occurred for morphological topics such as sediment (mentioned 38 times in the advocacy stage and 211 times in provision stage), dune (29–137 times), transport (24–116 times, referring to sand transport by wind or currents) or the lagune (1–101 times). Exceptions to the trend were sand and its winning. These objects were mostly discussed in the bureaucratic stage, but substantially less in the other stages. Also, the location of impacts was mostly a topic of indicators discussed in the political stage (80 out of 144 in total). Most objects of ecology-related indicators were in majority discussed in the provision stage, such as indicators on the vegetation, benthic animals, birds and animals. Objects of indicators related to recreation came up in

Table 3
Number of times values were mentioned in each decision-making stage, categorized per value group. The decision-making stages are based on Veeneman et al. (2009).

Value group	Advocacy	Political	Bureaucratic	Provision	*Total*
Safety	88 (27)	78 (16)	72 (28)	74 (15)	312
Nature	71 (22)	138 (29)	55 (21)	134 (28)	398
Recreation	52 (16)	120 (25)	49 (19)	71 (15)	292
Knowledge Production	45 (14)	38 (8.0)	19 (7.4)	92 (19)	194
Miscellaneous	70 (21)	102 (21)	62 (24)	114 (24)	348
Total	326	476	257	485	1544

Note: The numbers in brackets indicate in percentages the relative contribution of the group frequencies to the frequencies of all values mentioned in that decision-making stage.

Table 4
Number of times indicators were mentioned in each decision-making stage, categorized per indicator theme. The decision-making stages are based on Veeneman et al. (2009).

Indicator theme	Advocacy	Political	Bureaucratic	Provision	Total
Morphology	224 (43)	669 (49)	483 (34)	1171 (50)	2547
Ecology	48 (9.3)	174 (13)	171 (12)	526 (23)	919
Recreation	43 (8.3)	136 (10)	160 (11)	153 (6.6)	492
Procedural	110 (21)	255 (19)	388 (27)	125 (5.4)	878
Knowledge Production	23 (4.4)	41 (3.0)	80 (5.6)	175 (7.5)	319
Miscellaneous	70 (14)	82 (6.0)	144 (10)	170 (7.3)	466
Total	518	1357	1426	2320	5621

Note: The numbers in brackets indicate in percentages the relative contribution of the theme frequencies to the frequencies of all indicators mentioned in that decision-making stage.

the bureaucratic stage, such as zonation, agreements or coast guard supervision. Other recreational topics were mostly a topic in the evaluation stage, such as those relating to visitors. The objects of procedural indicators were mainly discussed in the bureaucratic stage and hardly

evaluated. These topics included finances, responsibility and agreements between stakeholders. The available information was mostly a topic of political discussion. For knowledge production, monitoring and methods came up in the bureaucratic stage and were often mentioned in the provision stage. Agreements concerning knowledge production were discussed in the bureaucratic stage and less in the other stages. Some objects of the 'miscellaneous' indicators were often discussed in the advocacy stage but little discussed in the other stages, as was the case for the presence of hard defences.

3.3. Value and indicator became more concrete through the decision-making stages

Across the stages of decision-making, the objects of the values and indicators discussed shifted from being abstract to becoming increasingly concrete. In the advocacy stage, the objects of the ambition values were discussed in the broadest sense. In the later stages, these objects became more concrete. In Fig. 4, this trend is visualized for the concretisation of the concept of safety. In the advocacy stage, safety in an abstract sense was discussed the most (18 times). Coastal safety was a notable concretisation of this ambition value (mentioned 7 times in the
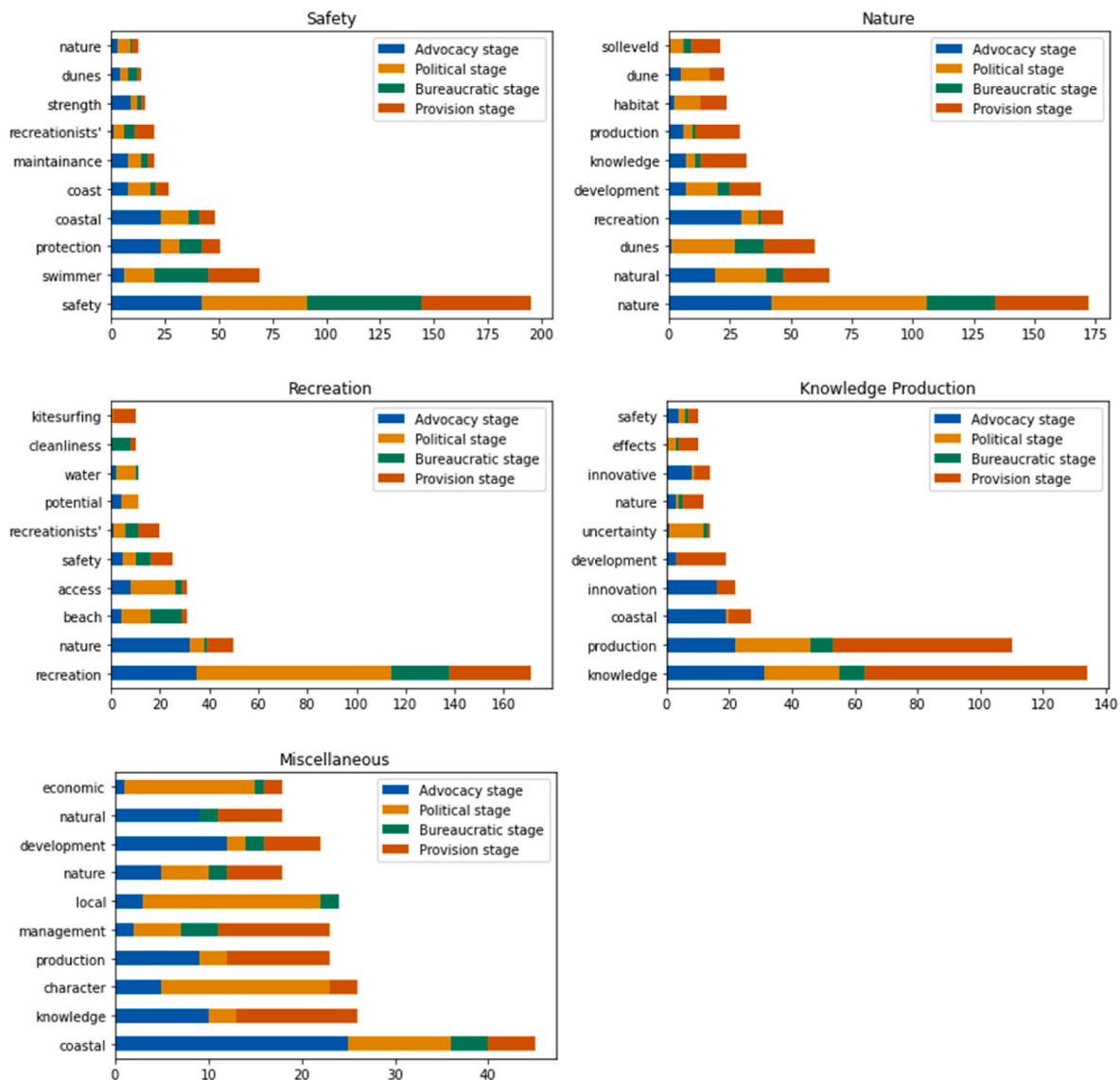

Fig. 2. Number of times (x-axis) that objects (y-axis) were mentioned in values, divided per decision-making stage on the Sand Motor. Results have been grouped into safety, nature, recreation, knowledge production and miscellaneous value groups.
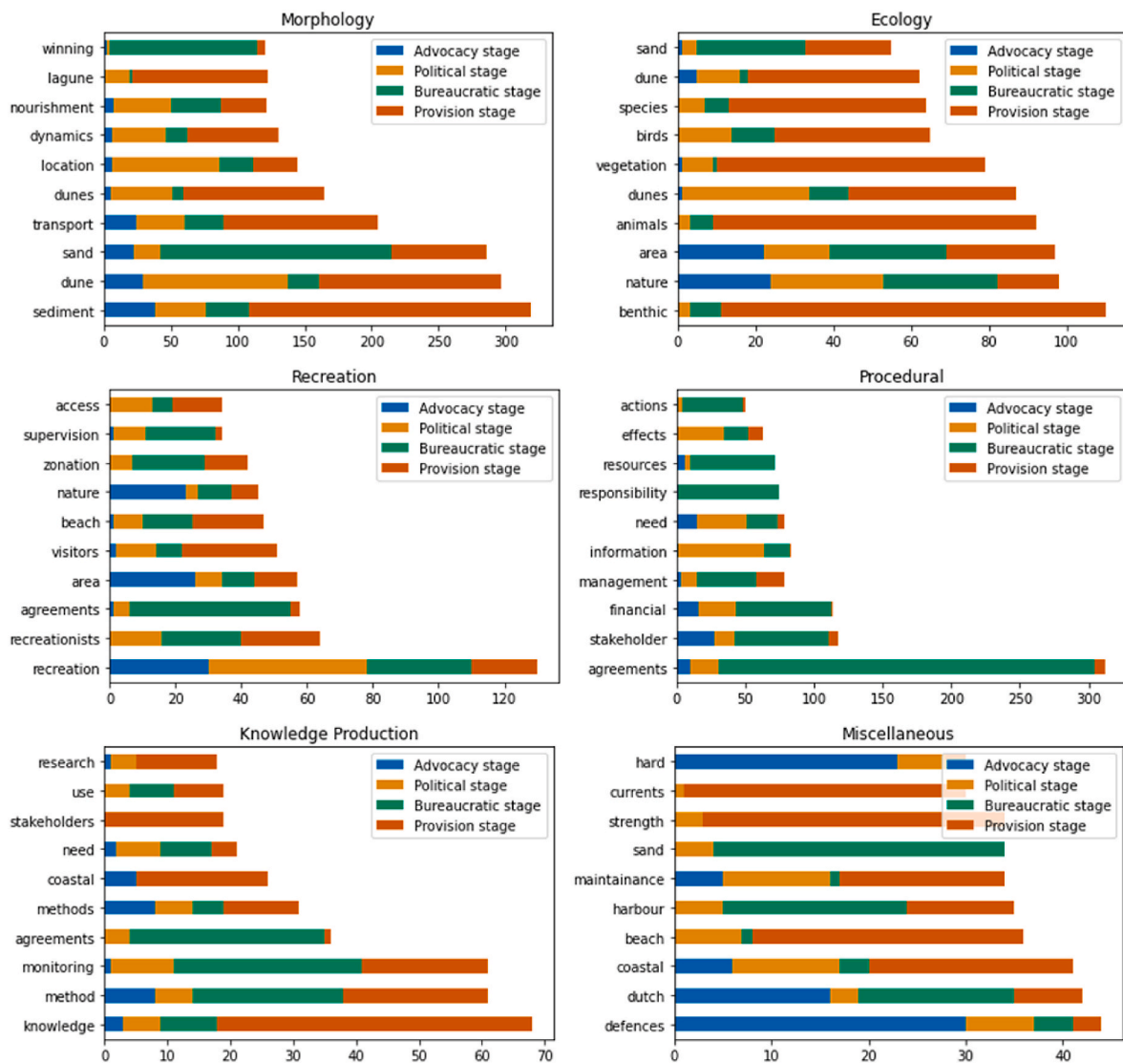
Fig. 3. Number of times (x-axis) that objects (y-axis) were mentioned in indicators, divided per decision-making stage on the Sand Motor. Results have been grouped into morphology, ecology, recreation, procedural, knowledge production and miscellaneous indicator themes.

advocacy stage and 8 times in the political stage, but only 2 times in the bureaucratic and 4 times in the provision stages). Instead, local conceptions of safety came up in the political stage as swimmer safety (12 times) and recreationists' safety (5 times), which were discussed often in the following bureaucratic and provision stages. These concretisations of the ambition values led to the utilization of matching stage-specific indicators, as, for instance, the procedural indicator on agreements on the supervision of swimmer safety by the coast guard was the most discussed safety indicator in the bureaucratic stage (6 times).

The values of innovation also became more concrete throughout the decision-making stages. The broadest conception of knowledge production focused on the 'win-win' with innovation (Fig. 5). Knowledge and innovation was discussed almost solely in the advocacy stages (4 times). It was argued that the Sand Motor was innovative (2 times) as a new type of nourishment for coastal maintenance (4) that could be used internationally (once). The indicators matched these concrete understandings, as they inform about the extent of knowledge being used internationally (2 times), on the use of the Sand Motor as an example of innovative coastal maintenance (4) and discussing the value of innovative monitoring (2) and coastal maintenance (3). In the political and bureaucratic stages, however, innovation was discussed only once.

As the stages developed, values and indicators related to nature

became more concrete and focused less on the 'win-win' with recreation. Similarly, ecological information for indicators became more concrete and specific (Fig. 6). The broadest conception of nature as a value was 'nature and recreation' combined. This broad understanding was discussed 26 times in the advocacy stage and only 5 times in the other stages. The indicator that reflected the scope of this value was mentioned 15 times in the advocacy stage and only once in the later stages. In the political stage, 'nature' was discussed as a value 17 times, separate from recreation, which was discussed 32 times in this stage. Also, the documents mentioned 'natural values' (7 times) or 'habitat types' (7 times) – acknowledging the multiple understandings of nature. From the political to the bureaucratic stage, procedural indicators came up, relating to juridical aspects of these 'natural' areas. For instance, indicators informed on whether the effects of the Sand Motor would be compliant with the Nature Protection Law (10 times in the political and 5 times in the bureaucratic stages) and on what area is part of Natura2000 (2 times in the political and 9 times in the bureaucratic stages). In the provision stage, outcome indicators related to the most specific ecological conceptions were discussed, such as dune vegetation growth (11 times), benthic animals' biomass (9 times) and the amount of sand that was captured by dune vegetation (8 times).
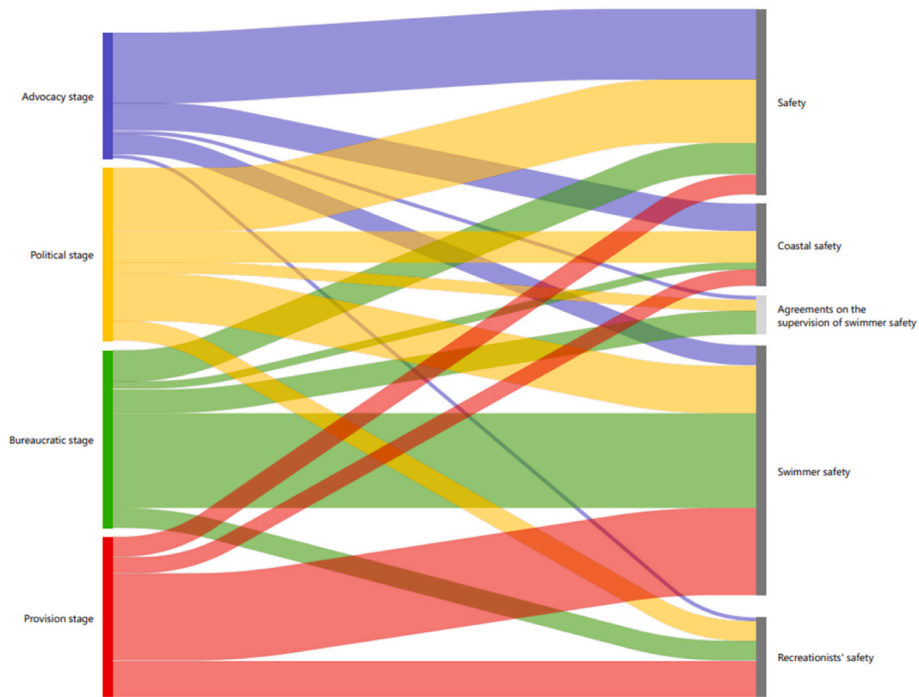
Fig. 4. Sankey diagram visualizing the frequencies of the five most discussed values and indicators related to safety (right), linked to the four decision-making stages (left). The focus of safety shifted from coastal safety (i.e., flood prevention) to local swimmer and recreationists' safety. Values are dark grey, and indicators are light grey.

4. Discussion

We analysed the values, indicators and objects discussed in the four stages of decision-making in a nature-based solution for coastal climate adaptation. We found that the information discussed in each stage differed substantially; as the stages developed, the contributions of indicators to values increased, the categories of information shifted significantly and different objects of concern were discussed, displaying a general trend from abstract to concrete. Our novel methodological approach connects the worlds of decision-making and NbS research. We offer three methodological reflections for NbS researchers who aim to integrate the decision-making stages in their research. Being aware of the decision-making stages allows information to be adapted more precisely to what is needed and when. Moreover, decision-making can
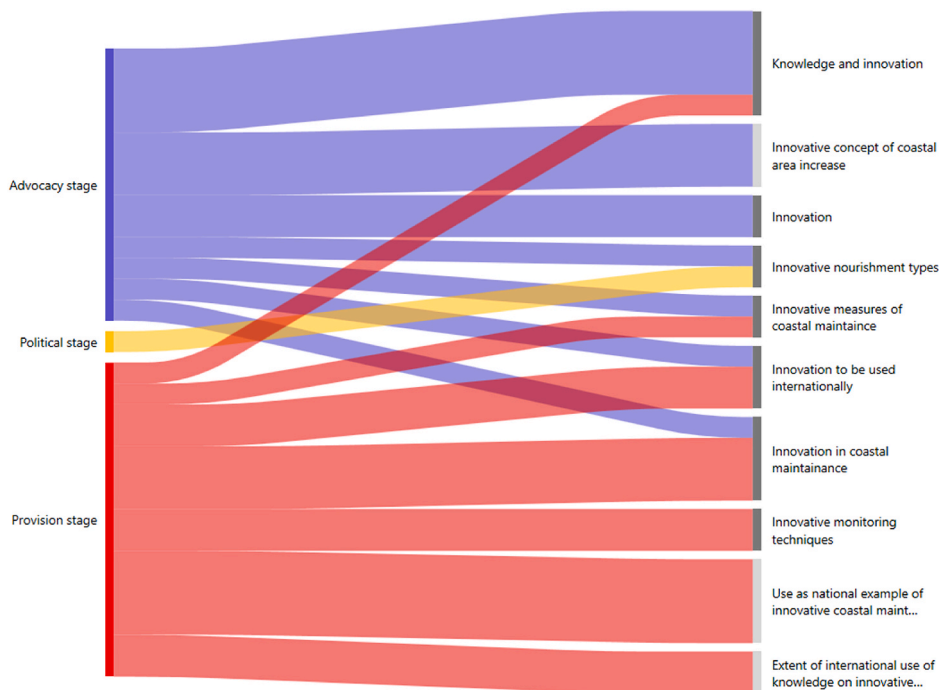

Fig. 5. Sankey diagram visualizing the frequencies of the ten most discussed values and indicators concerning innovation (right), per decision-making stage (left). Innovation was not discussed in the bureaucratic stage and mentioned only once in the political stage. Values are dark grey, and indicators are light grey.
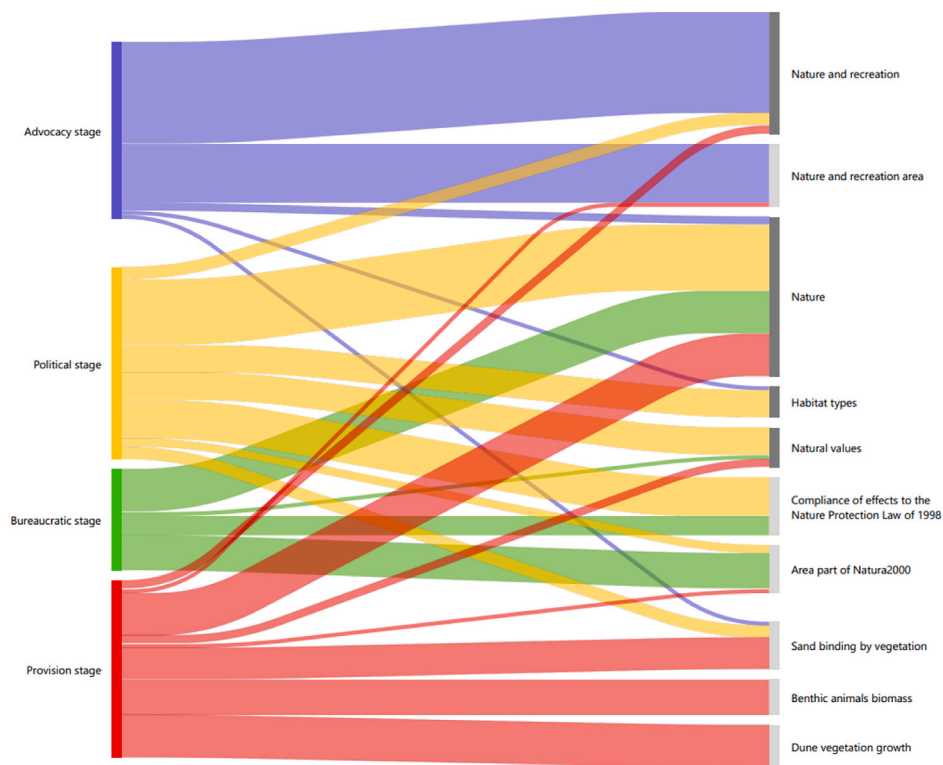
Fig. 6. Sankey diagram showing the frequencies of the most discussed values and indicators concerning nature (right), per decision-making stage (left). Nature and recreation were considered as a common value in the advocacy stage and became increasingly concretised as the stages developed. Values are indicated by the dark grey colour, and indicators are light grey.

be prepared for dealing with future stages by understanding the underlying drivers of the concretisations and the different stages' requirements, for instance by anticipating specific stakeholder interests. Thereby, this study allows researchers to better inform NbS decision-making and improve the proper delivery of multifunctional coastal climate adaptation.

4.1. Addressing four challenges to informing decision-making on nature-based solutions

Distinguishing the four stages in NbS decision-making to study values, indicators and objects connects the fields of decision-making and NbS research. The call for integrating the NbS and decision-making field has been steadfast since the concept came to increased institutional attention (see Editorial, 2017; Nesshöver et al., 2017; Seddon, 2022). This call was partly motivated to prevent a repetition of the limited policy uptake of the ecosystem services concept (Nesshöver et al., 2017; Ruckelshaus et al., 2015). Applying the definitions of Veeneman et al. (2009), we were able to distinguish the four stages of decision-making in formal policy documents on a nature-based solution for coastal climate adaptation. Connecting the stages of decision-making to the discussed values and indicators helps to address four major open questions on informing NbS decision-making.

First, this novel methodological approach allows making the general patterns explicit in the translation of NbS from a boundary object, where multiple broad values are articulated and advocated for to being planned, executed and evaluated. This explicitness had remained a major knowledge gap to the NbS research field (see Editorial, 2017; Hanson et al., 2020; Nesshöver et al., 2017).

Our approach also allows to better understand why and how trade-offs occur in NbS decision-making (see Seddon, 2022). Our results show that each stage has distinct processes that may lead to conflicts within and between stages. For instance, in the political stage,

stakeholder interests, interpretations and priorities may clash. In the bureaucratic state, conflicts may arise between the values that are desired by political decision-makers and the delivery of values that is operationalisable. In the provision stage, trade-offs may occur between informing on processes that can be reliably measured and the information that robustly validates the project's outcomes. As the stages develop, more concrete information is required, which enhances the likelihood of trade-offs between the potential concretisations. For instance, as an evaluator must measure specific processes, she or he cannot measure 'nature' in general (see also Haila and Levins, 1992). Thus, in evaluation, trade-offs may be expected between the provision of information on different measurable aspects that we regard as having natural value and with a general notion of 'nature' that stakeholders advocated for.

Third, our approach helps to better evaluate multiple NbS outcomes (see Chausson et al., 2020). Our research found that the indicators discussed in the provision stage may relate to value discussions in the political stage. Additionally, our results suggest a mismatch between indicators and the object of concern that they inform about. Also, evaluation may entail a concretisation from the abstractly formulated benefits that NbS bring. Evaluation can thus be improved by consciously adapting outcome indicators to the values that were advocated for and negotiated about.

Finally, our approach allows for more just NbS outcomes (see Cousins, 2021). The political stage is the focal point where just outcomes are created (Rawls, 2009). Researchers can recognize where these choices are made, and aim to fairly include relevant stakeholder perspectives and interests (e.g., Bauer, 2022; Cousins, 2021; Hagedoorn et al., 2021). Moreover, researchers and decision-makers can assess how these views are translated into further stages of project execution, management and evaluation. As these processes require new value interpretations and prioritisations, they further affect the justness of NbS outcomes (see Stone, 2012). Informing decision-making about the

justness of NbS outcomes can be improved by evaluating the value interpretations and prioritisations of all relevant, or currently underrepresented, stakeholders.

4.2. Applying the stages of decision-making to analyse values, indicators and objects

We regard our novel methodological approach as a fruitful starting point to increase the understanding of the diverse information needs of NbS decision-making. For this, we offer three main methodological reflections on the challenges we encountered in applying our approach.

First, the inclusion of sources for studying the stages of decision-making should be considered. Studying formal policy documents gave us a coherent understanding of the information discussed therein. This information was articulated and promoted by a wide range of diverse stakeholders, including local and national politicians, news media and concerned citizens. To also understand what information did not make it to the formal decision-making agenda and the mechanisms for the inclusion of information, future research may analyse NbS decision-making stages by including a larger scope of textual sources.

Furthermore, in distinguishing the stages, we note that the advocacy stage consists of two processes in the Sand Motor case. Some values were articulated with an economic spin to represent the interests of influential stakeholders (see Aukes et al., 2018; Bontje and Slinger, 2017). Other value articulations, however, were made by influential science-based institutions (see Deltacommissie, 2008). This second type of articulation received less attention from Veeneman et al. (2009). We, therefore, advise studying value articulations on a broader scale, by also including value advocation by authoritative institutions. The values considered in the advocacy stage may also be grouped in another manner than individually, as we did. Different NbS projects may be compared on what values are advocated for and analysing how these values are understood in the other stages.

Third, when investigating the political and bureaucratic stages, it may be challenging to differentiate between the two. Both stages can be intertwined as executing organisations make political choices themselves, conflicting with bureaucracies' traditional role (as in Weber, 2013). This overlap may follow from bureaucracies with a long-standing practice relating to the NbS, or when the political choices include highly technical or specific elements (Crozier, 2009; Stone, 2012). This overlap may also follow from liberalisations where the executive functions of ministries were outsourced to private companies (Veeneman et al., 2009). The two stages require distinct information and relate differently to justness concerns; private political preferences may not always overlap with the most just NbS outcomes. To effectively inform decision-making and address justice concerns fairly, NbS researchers may thus differentiate between the political choices on the interpretation and prioritisation of values, and their bureaucratic operationalisation.

4.3. Adapt the abstraction level and content of the information to the decision-making stage

The information provided to decision-makers should be adapted to the stage it will be utilized in. To inform decision-makers in the advocacy stage, broad information is required that reflects a common ground between the values brought by NbS and stakeholders' concerns. Our results demonstrate that in the advocacy stage, values and indicators were most abstract and described as mutually beneficial while relatively few indicators were mentioned. The broad value articulations reflected societal trends and related to influential stakeholders' interests such as the need for 'innovation' in the 2008 financial crisis (Aukes et al., 2018;

Baltissen, 2015; Bontje and Slinger, 2017) and the desire for 'green' recreation on a provincial scale in a nature-based narrative (see Pulleman et al., 2022). These findings fit the boundary function of NbS (see Hanson et al., 2020; Van Oudenhoven et al., 2018a). To meet such information requirements, a broad range of information is required, reflecting the mutuality of values, that can be framed to fit the cultural values of influential stakeholders for effective support.

In the political stage, information is required that relates the potential project outcomes to the values and interests of the relevant stakeholders. Our study found that values were articulated more concretely in the political stage than in the advocacy stage. Additionally, in the political stage, new understandings and interpretations of values came up that specifically reflected the interests of local stakeholder groups. Information is thus required on more specific understandings of the ambition values and the potential conflicts between these. Fairly considering all relevant stakeholders' views on value interpretations and prioritisations in the political stage decreases the risk of reinforcing undesired societal power structures (see Haila and Levins, 1992; Melanidis and Hagerman, 2022; Woroniecki et al., 2020). This consideration also increases the justness of NbS outcomes (Cousins, 2021; Kaufmann et al., 2021; Rawls, 2009), the instrumental knowledge on which the decisions are based and the support for them (Cuppen, 2018; Stirling, 2008).

In the bureaucratic stage, procedural indicators are required that relate the negotiated values to the multiple systems in which stakeholders operationalise the NbS. Our results suggest that procedural indicators played a central role in this stage. These indicators reflected juridical, financial and governance concerns for the stakeholders involved in the operationalisation of the nature-based solution. These results are in line with the literature on bureaucratic decision-making (Crozier, 2009; Veeneman et al., 2009; Weber, 2013). Also, they fit the description of NbS implementation as being dependent on a wide array of governance structures (Hanson et al., 2020; Nesshöver et al., 2017) and local policy contexts (Langridge et al., 2014). Interestingly, in our case, procedural indicators mainly addressed management and maintenance, while procedural indicators on project execution were lacking. This discrepancy might be explained by the presence of the legal and governance structures necessary for the project's execution, as this execution largely followed nourishment practices that were performed by similar stakeholders, since the 1970s (Baltissen, 2015).

Informing decision-makers in the provision stage entails communicating outcome indicators that are shaped by practical concerns and reflect the most specific understanding of the project's values. We saw for some indicators that their use depended on their perceived feasibility and legitimacy (see Cash et al., 2003; Van Oudenhoven et al., 2018b). These factors reflect the importance of tradition and social practice in evaluation – which can be addressed to increase the effectiveness of NbS evaluation (cf. Latour, 1988). The outcome indicators discussed in the provision stage reflect the most concrete understandings of the ambition values (see Stone, 2012). Thus, special care must be taken to ensure common ground between the objects that are evaluated and the objects of concern to decision-makers.

4.4. Prepare for the concretisations of values and indicators by understanding their driving processes

Researchers can prepare for future changes in the information requirements of the decision-making stages. This preparation requires awareness of what drives the changes between the decision-making stages. Often, understanding these drivers requires insights into the stakeholders involved in the future stages, their activities, how they understand and prioritise the ambition values, and what trade-offs they

may encounter.

To prepare for value articulation in the advocacy stage, broad societal trends and the interests of relevant stakeholders should be considered. This entails understanding the governance structures required for financing a nature-based solution and investigating the interests of the involved stakeholders. Also, new societal trends and their relations to potentially delivered values may be anticipated. Value framing in the advocacy stage has often been closely linked to major events (e.g., the financial crisis and floods) and cultural values (Aukes et al., 2018; Bontje and Slinger, 2017; Correljé and Broekhans, 2015). NbS values are likely to be articulated parallel to such events and values (Melanidis and Hagerman, 2022; Woroniecki et al., 2020). For instance, nature-based climate adaptation efforts will increase worldwide (IPCC, 2023b) and the European Commission aims to invest sustainably in the coming decades (European Commission, 2021). Also, recently, the EU has focussed on strategic autonomy in crucial policy areas, such as security and resource availability (Damen, 2022). We expect that, in the nearby future, the values that coastal NbS can bring to the EU will be articulated to include – in addition to adaptation and sustainability functions – strategic security benefits, which could bring interesting new research fields and information requirements in the later stages.

Justice concerns and future conflicts can be anticipated and avoided by investigating the underrepresented political views of stakeholders. NbS decision-makers are at risk of giving prominent consideration to the political views of powerful stakeholders, thereby potentially excluding the views of other stakeholders with less institutional power, resulting in unjust NbS outcomes (see Brillinger et al., 2020; Melanidis and Hagerman, 2022; Woroniecki et al., 2020). Such exclusion may result in conflicts in the later stages and the need for ad hoc adjustments (Correljé and Broekhans, 2015). In some cases, these conflicts may lead to the re-prioritisation of values in formal decision-making (Pesch et al., 2017). For instance, the uptake of local safety at the Sand Motor was driven by local citizens, media and politicians who voiced the need for prioritising local safety in managing and evaluating the project (Buitenkamp et al., 2016). However, to prevent or anticipate conflict and inform fair consideration in political decision-making, researchers can identify underrepresented political views in the earlier decision-making stages (Jacobs et al., 2020). Value interpretations and prioritisations of stakeholders may, for instance, be identified along the lines of race, class, gender and species – where representation in decision-making on NbS is often limited (Cousins, 2021; Kaufmann et al., 2021; Pineda-Pinto et al., 2022).

In preparing for the bureaucratic stage, information on procedures is crucial. Anticipating the operationalisation of the relevant values entails a concretisation and refocus of values and indicators in the light of the operationalising actors' technical 'know-how' and culture. Potential discrepancies may emerge between the values discussed in advocacy and political stages and the values and indicators utilized by these operationalising organisations. Such discrepancies decrease the effective translation of the negotiated plans to effective implementation. Research may focus on informing on the formal and informal bureaucratic procedures and aligning these structures with the new values considered.

To prepare for the provision stage, a wide range of concretizations of the relevant values should be considered. In this stage, the objects of information are discussed in the narrowest sense. We observed mismatches between such specific indicators and the objects of interest to decision-makers involved in the earlier stages, in line with Dumitru and Wendling (2021) and Van Oudenhoven et al. (2018a). For example, in the political and advocacy stages, nature was mostly discussed as a

co-benefit of recreation, but in the provision stage, concrete ecological information was produced without a clear link to recreation, such as benthic animals' biomass. To prevent mismatches, evaluators are advised to avoid preparing only single indicators but rather aim to research and communicate information in the widest range possible, reflecting the wide range of stakeholders' interests. For instance, nature may be evaluated by including information on ecosystem functions, biodiversity indexes related to legislation and different perceptions of naturalness that relate to the area. NbS will always affect economic, social and environmental challenges, and influence local biodiversity, resilience, ecosystem services and human well-being (UNEP, 2022). Preparing for NbS evaluation must therefore include this wide set of functions, their potential understandings and their relations to all relevant stakeholders.

5. Conclusion

NbS can bring additional functions and values to coastal climate adaptation, next to improving coastal safety and flood defences. Considering multiple functions will, however, entail more complex decision-making as additional scientific disciplines, stakeholders and types of information must be considered. This study set out to identify and explore the information requirements for decision-making on NbS for coastal climate adaptation. We developed a novel methodological approach to analyse the values, indicators and objects discussed in four crucial stages of decision-making. In relevant public policy documents, we found that each decision-making stage has distinct information requirements. Over the stages, the information required shifts from addressing what is possible and why it should happen, to choosing a specific plan, discussing how it should be operationalised and whether it worked. Thereby, for each stage, the categories and objects of discussion altered significantly. Most notably, the level of abstraction of values and indicators discussed shifted towards concreteness as the stages developed. The principal implication of these findings is that information provided to decision-makers can be adapted to the stage that it will be utilized in. Further, the concretisation of the information required can be prepared for by understanding the driving processes behind these concretisations. This research bridges the fields of decision-making and NbS studies, which allows for improving NbS evaluation, implementation, justness and understanding its trade-offs. This study may provide a solid basis for future research on the interactions between values, indicators, the decision-making stages and the actors involved in those, to improve the delivery of multifunctional coastal climate adaptation for sandy shores worldwide.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix

Table A.1

Description and representativeness for the decision-making stage on the Sand Motor of the documents studied in detail

Decision-making stage	Document name	Document description and representativeness of the decision-making stage
Advocacy	*Ambitieovereenkomst pilotproject Zandmotor, 2008*	The ambition agreement was signed by critical stakeholders for the project start: the province of South Holland, three ministries, three municipalities, the Delfland water board and the provincial environmental organisation. They acknowledged a consortium of actors in the Dutch water sector, academia and government, and the design philosophy of Building with Nature. These stakeholders *advocated* for Sand Motor as a win-win for nature, recreation, safety, and innovation.
Political	*Projectnota/MER, Aanleg en zandwinning Zandmotor Delflandse kust, 2010*	The Environmental Impact Assessment (EIA) on the construction and sand extraction of the Sand Motor. In it, a preferred project design was chosen, based on the ambition values. Values were d*esignated* as innovation and economy were no criteria anymore. They had to *interpret* and *prioritise* nature, recreation, and safety trade-offs in choosing a course of action. A part of the EIA also described the *operationalisation* of this planning, discussing sand winning and transport.
	Nota van antwoord op inspraakreacties inzake MER Zandmotor aan de Delflandse kust, 2010	The note of citizen replies and governmental answers to the course of action chosen in the EIA. Citizens *designated* and *prioritised* values differently, especially regarding local safety, different forms of recreation and nature.
Bureaucratic	*Beheersovereenkomst Zandmotor, 2010*	The management agreement for the stakeholders managing the Sand Motor. It *operationalised* the values into concrete actions, norms, and agreements for the managing stakeholders with a focus on formal responsibilities.
	Protocol van beheersmaatregelen, taken en verantwoordelijkheden op de Zandmotor, 2010	The protocol of control measures, tasks, and responsibilities for stakeholders managing the Sand Motor. It *operationalised* the values into concrete actions, norms, and agreements for the managing stakeholders. This document was built on the management agreement to decide responsibilities for previously unanticipated effects.
Provision	*Evaluatie van 10 jaar Zandmotor: Bevindingen uit het Monitoring- en Evaluatie Programma (MEP) voor de periode 2011 tot 2021, 2021*	The summary of the documents of evaluation and monitoring of the Sand Motor from 2011 until 2021. This document summarized the *monitoring* and *evaluation* documents and *assessed* the project on the ambition values, as also stated in the EIA.

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