



SCORE Project

Structural Capacities for Tackling Wicked Problems

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www.score-eu.org

Result ID: 1

Result Title: State-of-the-art analysis



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Extended summary

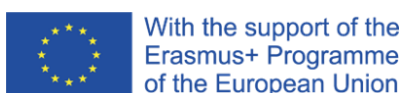
This document reports the work completed for result No1 of the SCORE project and details the main output of this work that is the state-of-the-art literature synthesis report. This task has been led by the University of Ioannina and has been completed with contributions from all the SCORE project partners.

The completed work aimed at addressing a core input requirement to advancing the scientific research and dialogue in HEIs with regard to wicked problems, namely the identification of the state-of-the-art literature on wicked problems. This step is also deemed important for the successful completion of the rest of the SCORE project tasks, i.e., the development of the SCORE model and e-tool. To complete the work for result No1 of the SCORE project the following activities have been completed:

1. The broad literature collection and analysis protocol
2. Compilation of the literature database and availability through open public repository (Zotero)
3. Documentation of the results in the synthesis report presented therein

The results of this work provide the academic community with a rich reference database on wicked problems that brings together high-quality scientific work and an overview of the current landscape of the scientific literature on wicked problems. The open library database provided via the Zotero reference management software contains all the scientific works that have been collected and analyzed for the purposes of result No1 of the SCORE project. To the best of our knowledge, this is a first-time contribution to the academic community. The library is available here: https://www.zotero.org/groups/4795632/wicked_problems_public/ and can be exported, i.e. easily downloaded and used by the HEIs.

The synthesis and analysis of the state-of-the-art literature on wicked problems shows that while the existing stock of works offers a good understanding of the characteristics and aspects that define wicked problems, they offer limited systematic approaches and insights to the solutions. The definitions repeat the use of key words such as “social”, “complex”, “urgent”, “system”, “hard” or “incomplete”. Several works note that wicked problems are usually ill-defined and cannot be solved with a standardized process. Most of the works agree that there is no single solution to a wicked problem, and many stakeholders and decision makers are involved in the process of identifying solutions. The synthesis results identify arguments in favor of the importance of bridging different stakeholders and disciplines, of education systems and political systems, of business environment, and technological transformations to solving wicked problems.

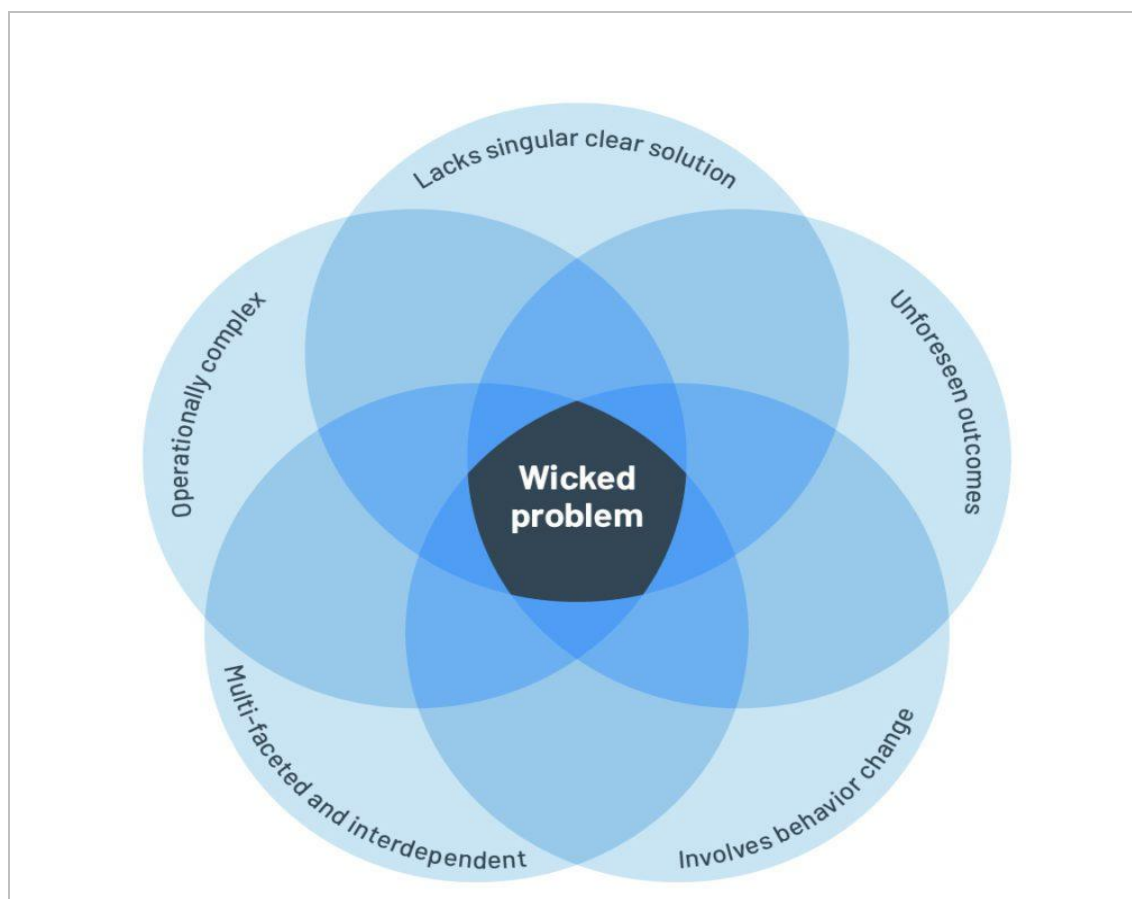


Wicked problems: A state-of-the-art analysis

1. Introduction

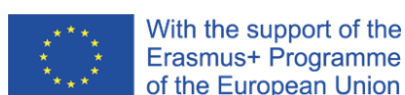
Wicked problems can be broadly defined as problems that are difficult to resolve due to incomplete, complex, and ever-changing conditions that are hard to identify. As problems with no single solution, wicked problems come with origins to no single source, planning, or solving approach. Wicked problems come with technology, social, economic, policy, and environmental dimensions, to name a few, embedded in their sources and in their solutions (Figure 1). As such, they require interdisciplinary and system approach to analysis and addressing.

Figure 1: Wicked problems: Some defining terms and characteristics



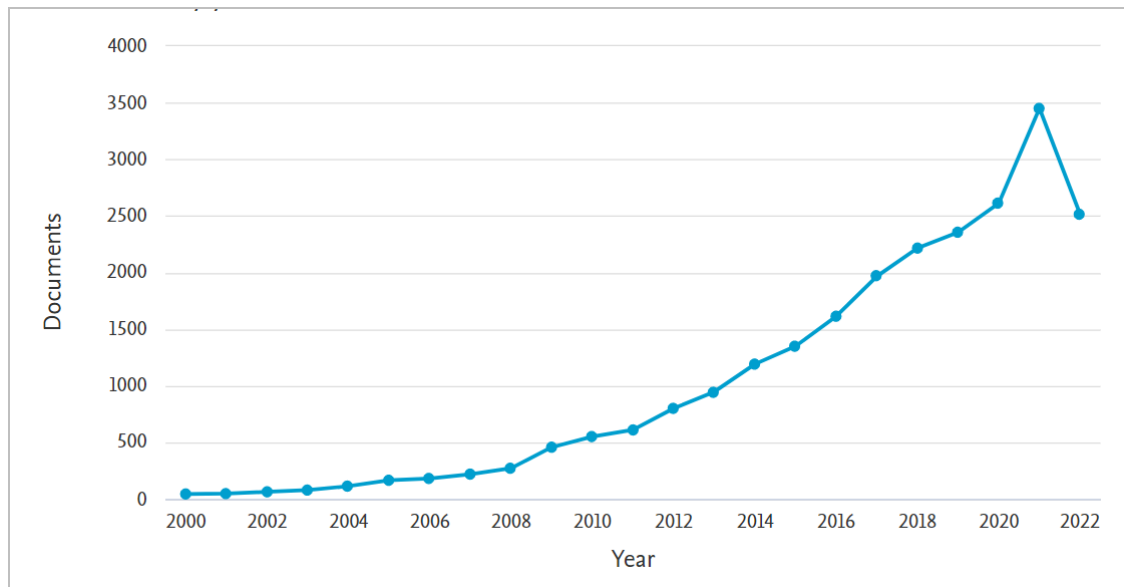
Source: Authors' compilation

The term wicked problem can be originally attributed to Rittel and Weber and their seminal paper “Dilemmas in a General Theory of Planning” Published in Policy Sciences volume 4, issue 2 (1973), pages 155-169. Since the work of Rittel and Weber (1973), the scientific literature on the subject has increased significantly in numbers, in scope, and in depth. Figure 2 shows



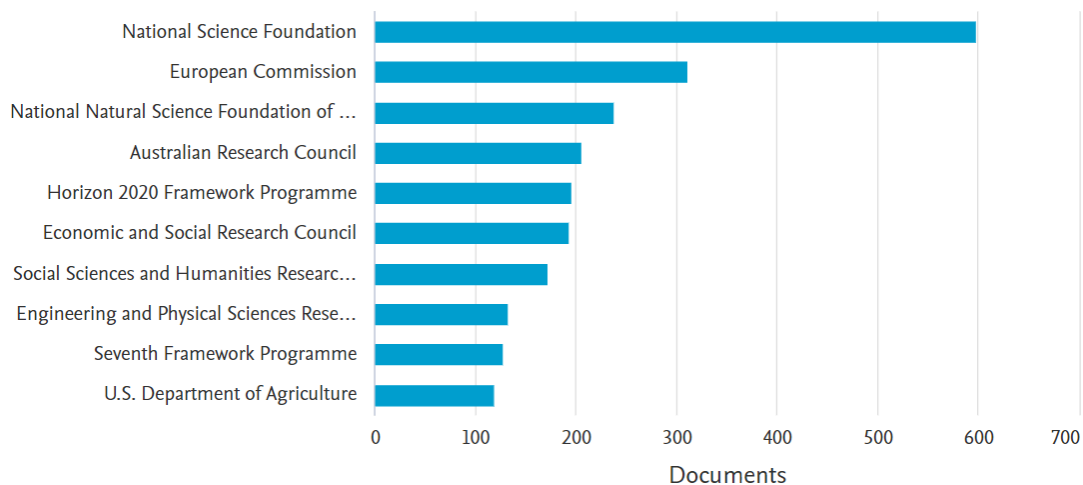
an overtime development of the number of articles that have 'wicked problem' in their title, abstract and keywords indicating the significant increase in interest in the topic. These results result from a simple query on Scopus. Figure 3 illustrates the collection of articles by funding sources. The National Science Foundation and the European Commission are identified as the leading funding bodies of research on wicked problems.

Figure 2: Published articles per year related to wicked problems during 2000-2022

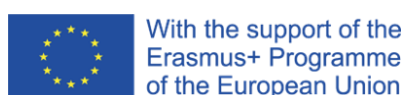


Source: Scopus

Figure 3: Published articles per year related to wicked problems during 2000-2022 by sponsor



Source: Scopus



In the light of the above it appears contributing to the ongoing research on the subject, but also to the development of training and research tools on the subject, to provide a fresh synthesis of the state-of-the-art literature on wicked problems. The working team of the SCORE project has completed this step, the results of which are presented next. Toward this end, methodological alternatives have been explored in the literature review and the systematic review has been selected on the basis of its comparative advantages. For example, with the use of systematic review, it can be determined whether an effect is constant across studies and identified what future studies should look into in order to demonstrate the effect. Techniques can also be used to discover which study level or sample characteristics have an effect on the phenomenon being studied, such as whether studies conducted in one cultural context show significantly different results from those conducted in other cultural contexts (Davis et al., 2014). Next, more on the advantages and approaches related to systematic literature review are discussed. The methodology used has led to the (final) collection of 107 papers that are briefly presented and discussed next¹. This compilation is made available through the Zotero SCORE library.

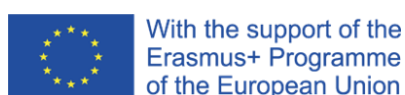
The remainder of the report develops as follows. Section 2 presents the methodological steps and approach used for the development of the reference database and the collection of the analyzed paper. This section also provides information on the search steps and results. Section 3 presents the synthesis and brief analysis of the state-of-the-art literature. Section 4 presents some bibliographic cluster modelling results. The last section concludes with some useful remarks for next steps and prospective work on wicked problems.

2. Methodology

The review of the literature is one of the most important tools for any research activity. Literature review can lead to meaningful summaries of the existing stock of knowledge on a subject, highlight the missing parts or links between different streams of work, and indicate future directions of work that are worthwhile to explore further. On the downside, large stocks of existing literature can lead to a long process of retrieving the desired information or to difficulties in navigating between works of relevance. Collection and analysis of the literature is not a random process. In contrast, it should follow rigorous methodological steps and checks to ensure that the result meets high scientific standards and complies with approaches widely accepted and tested in the scientific world. Existing works in the field and the significant number of studies that employ the different methodologies provide a good guide on the methodological approach to state-of-the-art literature synthesis and analysis.

Researchers have developed and employed alternative methodological approaches to literature review. These can generally be categorized into traditional review, systematic review, and scoping review; Table 1 provides a summary of the main characteristics of the different approaches to literature review as discussed by Munn et al. (2018). As the traditional literature review lags in several considered aspects, for the purpose of SCOPE the team has narrowed the selection focus between the scoping and systematic literature review. Both methodologies have an a priori review protocol, a critical point of the process for the purposes

¹ The final list included 121 works. Access was possible to 107 (PDFs files missing for 14 papers).



of the present project. In addition, both have peer-reviewed search strategies and a standardized data extraction process. On the other hand,

Table 1 Characteristics of traditional, scope and systematic literature review according to Munn et al. (2018)

	Traditional Literature Reviews	Scoping Reviews	Systematic Reviews
A priori review protocol	No	Yes (some)	Yes
Explicit, transparent, peer reviewed search strategy	No	Yes	Yes
Standardized data extraction forms	No	Yes	Yes
Mandatory Critical Appraisal (Risk of Bias Assessment)	No	No ^b	Yes
Synthesis of findings from individual studies and generation of 'summary' findings	No	No	Yes

Source: Munn et al. (2018)

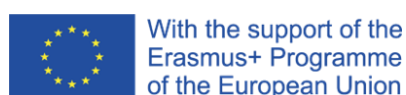
For the purposes of the SCORE project, a systematic literature review has been preferred. This choice follows application, advantages, and shortcomings of each method as discussed next in Section 2.1. The application of the systematic review follows a predefined and agreed protocol. The use of protocol is preferred as it can provide a clear identification of the goal, a homogeneous result among a team of many researchers, and a clear step by step guide for everyone to follow. Section 2.2. presents the protocol employed in the SCORE project. The setup and implementation of the protocol naturally follow the selection of the methodological approach to the review of the literature.

2.1 Scoping versus systematic literature review

2.1.1 Scoping Review

According to Arksey and O'Malley (2005, p. 21) scoping studies 'aim to rapidly map the key concepts that underpin a research area and the main sources and types of evidence available, and can be undertaken as standalone projects, especially where an area is complex or has not been reviewed comprehensively before'. Grant and Booth (2009) (p. 101) propose a different definition, approaching the field review as 'a preliminary assessment of the potential size and scope of available research literature that aims to identify the nature and extent of research evidence'.

The four main reasons to make a field bibliography are summarized as follows according to Arksey and O'Malley (2005, p. 21):

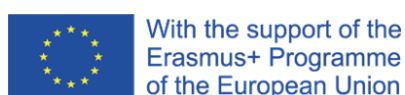


1. To examine the extent, scope, and nature of research activity
2. To determine the value of undertaking a complete systematic review
3. To summarize and disseminate research findings
4. To identify research gaps in the existing literature.

From the four different reasons, two approaches to the purpose of a field study emerge: According to the first approach, the field study is a process of analysis with the main goal of a systematic review. According to a second approach, it can lead to publications in a specific field of research, as it can be perceived as a method itself. The methodological framework of the scoping review of Arksey and O'Malley (2005) is represented in detail by Levac et al. (2010). Additionally, they provide recommendations for clarification or additional steps. The framework is provided next in Table 2.

Table 2: Scoping review framework

Framework Stage	Challenges	Recommendations for clarification or additional steps
#1 Identifying the research question	<ol style="list-style-type: none"> 1. Scoping study questions have a wide range. 2. Establishing the scoping purpose of the study is not associated with a framework stage. 3. Objectives of scoping studies lack clarity. 	<ol style="list-style-type: none"> 1. Clearly state the main question that the study aims to address, which will guide the scope of investigation. Consider the concept, the target population, and the health outcomes of interest to clarify the focus of the scoping study and establish an effective search strategy. 2. Consider mutually the objective of the scoping study with the research question. Envision the desired outcome (<i>e.g.</i>, framework, a list of recommendations) to ease the process of determining the purpose of the study. 3. Consider the rationale for conducting the scoping study to help clarify the purpose.
#2 Identifying relevant studies	<ol style="list-style-type: none"> 1. Balancing the quantity and inclusiveness of the scoping study with the feasibility of resources can be challenging. 	<ol style="list-style-type: none"> 1a. The research question and the purpose of the study should guide decision-making about the scope of the study. 1b. Assemble a suitable team with content and methodological expertise that will ensure successful completion of the study. 1c. When limiting scope is unavoidable, justify decisions and acknowledge the potential limitations of the study.
#3 Study selection	<ol style="list-style-type: none"> 1. This stage seems simple, but it is not 2. The process of decision making for study selection is often time-consuming. 	<ol style="list-style-type: none"> 1. This stage should be considered an iterative process that involves searching the literature, refining the search strategy, and reviewing articles for inclusion in the study. 2a. At the beginning of the process, the team should meet to discuss decisions surrounding the inclusion and exclusion of the study. At least two reviewers should independently review abstracts for inclusion. 2b. Reviewers should meet at the beginning, midpoint,



		and final stages of the abstract review process to discuss challenges and uncertainties related to study selection and to go back and refine the search strategy if needed. 2c. Two researchers should independently review the full articles for inclusion. 2d. When disagreements on study inclusion occur, a third reviewer can determine the final inclusion.
#4 Charting the data	1. The nature and extent of data to extract from included studies are unclear. 2. The 'descriptive analytical method' of charting data is poorly defined.	1a. The research team should collectively develop the data-charting form and determine which variables to extract in order to answer the research question. 1b. Charting should be considered an iterative process in which researchers continually extract data and update the data-charting form. 1c. Two authors should independently extract information from the first five to ten included researches using the data-charting form and discuss to conclude whether their method of data extraction corresponds to the aim and question of the study. 2. Process-oriented information may require additional planning for analysis. A qualitative content analysis approach may be appropriate.
#5 Collating, summarizing, and reporting the results	1. Little detail is provided, and multiple steps are summarized as one framework stage.	Researchers should break this stage into three clearly stated steps: 1a. Analysis (including descriptive numerical summary analysis and qualitative thematic analysis); 1b. Reporting the results and producing the outcome that refers to the overall purpose or research question; 1c. Consider the meaning of the findings as they relate to the overall study purpose; discuss implications for future research, practice, and policy.
#6 Consultation	1. This stage is optional. 2. There is a lack of clarity on when, how, and why to consult with stakeholders and how to integrate the information with the study findings.	1. Consultation should be an essential component of the scoping study methodology. 2a. Clearly establish a purpose for the consultation. 2b. The preliminary findings can be used as a basis to inform consultation 2c. Clearly articulate the type of stakeholders to consult and how data will be collected, analyzed, reported, and integrated within the overall study outcome. 2d. Incorporate opportunities for knowledge transfer and exchange with stakeholders in the field.

Source: Levac et al. (2010)

Colquhoun et al. (2014) argue that scoping review is a methodology that is gaining popularity, especially among researchers that synthesize data that can influence policy makers and researchers for both theoretical and empirical studies. They also emphasize the need for consistency and devotion in the methodologies associated with scoping review as it will have



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many benefits, such as methodological progress, less confusion, and better representation of the findings of the review. Authors also note that this approach can accommodate collaborations among researchers. They also mention that consistency in the proposed areas and scoping review methodologies will facilitate methodological progress, reduce confusion, facilitate collaboration, and improve the representation and interpretation of knowledge of scope review findings. Weeks and Strudsholm (2008) argue that, despite the many advantages, scoping review also has many weaknesses. The main argument is that the scoping review lacks in quality assessment. They do not include a quality evaluation; therefore, there is a high possibility that the results will be biased. Subsequently, this method is not recommended for policy making. Despite potential limitations, it can be noted that the scoping review methodology is gaining popularity, especially since 2000, with more than 500 published reviews currently available (Peterson et al., 2017).

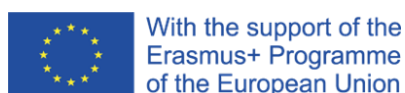
2.1.2 Systematic literature review

A systematic review of the literature identifies, selects, and critically evaluates research to answer a clearly stated question. The key points in a systematic literature review according to Kitchenham and Charters (2007) are:

- Summarize the available data on any topic
- Recognize gaps in current research to suggest areas for further examination
- Provide a framework for the proper placement of new research activities

According to Okoli (2015), a systematic literature review should follow the following steps:

1. **Identify the purpose:** The very first step in any review, such as the systematic review of the literature, is to set and clearly state the intended goals and purpose. This step requires reviewers to clearly identify the purpose and intended goals of the review, which is necessary for the review to be explicit to its readers.
2. **Create a draft of the protocol,** then properly educate, and train the members of the team: Any review that accommodates a team of reviewers, more than one, requires a clear procedure that every team agrees to follow. It is important that the team is in alignment. This can be achieved through a detailed written protocol, which all team members agree to, and training for the execution of the review.
3. **Practical screening:** In this step, the reviewers determine which studies should be included in the research and which are excluded. For studies that are not included in the research, the reviewers must state the reason for the exclusion and justify why the elimination of these articles will not negatively impact the result.
4. **Search for literature:** Reviewers must be precise in the literature research and the process they follow. Also, they need to be explicit and justify how they ensure the quality and completeness of the research.
5. **Extract data:** The reviewers need to first pin down the studies which will be included and then extract the relative information from them.
6. **Appraise quality:** The team of reviewers needs to identify and state the criteria which they use to evaluate the quality of the studies, and subsequently exclude the ones



that do not meet the criteria. In addition, they need to evaluate the quality of the included studies according to the methodology they used.

7. **Synthesize studies:** In this step, the team decides the appropriate technique (quantitative, qualitative, or both) to synthesize the information from the selected studies and then proceed to do so.
8. **Write the review:** Reviewers need to first follow the standard principles for a research paper, and then, for a systematic review, the process needs to be presented in such detail that an independent reviewer or a team of reviewers is able to reproduce the same results.

The advantages of the systematic review of the literature are summarized as follows.

- The result of the review is less likely to be biased due to explicitly defined methodology. On the other hand, publication bias is still likely to occur in primary studies.
- It can provide data for the effects of a phenomenon on a wide range of settings and empirical methods. If studies give consistent results, systematic reviews provide evidence that the phenomenon is strong and transferable. If the studies give inconsistent results, sources of variance can be studied.
- Specifically for the case of quantitative studies, systematic literature review methodology provides tools to increase the possibility of detecting real effects. This is less likely to occur in smaller studies, as meta-analytical techniques, useful for this purpose, cannot be used.

The main disadvantage of the systematic review method is that it is laborious and requires more effort from the research team, in contrast to other literature reviews methodologies that researchers traditionally follow. Moreover, the use of meta-analytical techniques may also detect minor biases as well as real effects, which can be considered as a disadvantage (Kitchenham and Charters,2007).

2.2. Selection of method and setting of the protocol

Table 3 summarizes the main characteristics and approaches that best describe the scoping and systematic review of the literature. According to Arksey & O'Malley (2005) the main differences between a systematic and a scoping literature review can be narrowed down to two main points. First, a systematic review concentrates on specific questions that have been determined a priori and uses study plans according to the objectives of the study. On the other hand, a scope study accommodates questions in a broader spectrum leaving room for the implementation of various research plans. Second, the objective of a systematic review is to answer questions from a limited range of studies that have been carefully evaluated. On the other hand, a scope study does not focus on a specific question or the quality of the studies that have been included. Consequently, the systematic review lacks flexibility. It appears that a systematic review is not the best option when the research calls for answering a wide range of questions that are not closely related.

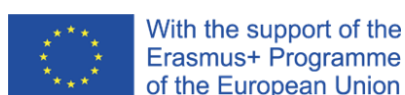


Table 3 Indications for systematic and scoping reviews

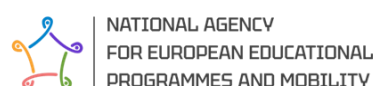
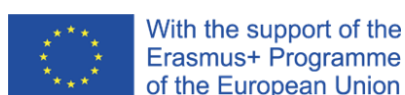
Systematic Review	Scoping Review
<ul style="list-style-type: none"> ● Pinpoint relative data from all over the world. ● Confirm current practice/ address any variation/ identify new practices ● Recognize the limitations of the field and suggest specific areas for future research ● Point out any conflicting results and investigate them ● Conclude with statements to guide decision-making 	<ul style="list-style-type: none"> ● To recognize the types of available data in each research field ● To analyze and resolve any confusion around key concepts/ definitions in the literature ● To investigate how research is implemented on a certain topic or field ● To identify key characteristics or factors related to a concept ● As a preliminary process to a systematic review ● To acknowledge and break down any knowledge gaps

Source: Munn et al. (2018)

Given the above and the aims of the SCORE project, the state-of-the-art synthesis proceeds with the selection of systematic literature review as the preferred method. To ensure robustness of the steps, the PRISMA protocol has been further employed. Protocols are used in systematic and scoping review methodologies. They consist of elaborate documentation of the steps and the methods that will be followed in a review. A protocol is very important for the scoping and systematic review of the literature. First, it provides careful planning for every research and team member to follow and thorough documentation of the process. Researchers foresee potential problems and obstacles, before the implementation of the method, and every team member has a clear guide to follow. In this way, top quality homogenous output is ensured. The detailed documentation of the plan allows researchers to compare the planned version of the process and the steps that were ultimately followed. This comparison may reveal any weaknesses of the plan and allows for replication by other researchers. The protocol also encourages collaboration and prevents arbitrary decision making that will deviate the research from the goals that have originally been set (Shamseer et al. 2015).

2.2.1 Prisma Protocol

For the purposes of SCORE, the Prisma protocol has been adopted. The Prisma protocol was developed in 2009 to ensure the quality of systematic reviews. The protocol provides explicit guidelines for this purpose. Since then, many versions of the protocol have been developed, with the latest being Prisma 2020 which can be found at the Prisma website: www.prisma-statement.org. The Prisma protocol has many advantages. First of all, it is a complete set of guidelines that ensures the transparency of the process implemented. Researchers document every part of the process, which is then available for evaluation. Moreover, the Prisma protocol provides the tools necessary to include all the articles related to the question that the research aims to address. This process results in a complete synthesis, a valuable tool for



policy makers. Indicative works that illustrate the use of Prisma protocols include: Rosenstock et al. (2016), Lawal et al. (2014), and Maguire & Guérin (2020).

The Prisma protocol contains the following steps, as detailed in Moher et al. (2015):

- Administrative Information
- Introduction
- Methods
- Study records

Each step is essential for the review and plays an important role for the planning, the result of the project, and the comprehensiveness of the final product.

The administrative information aims to introduce all the actors that were involved in the project. In this section, the authors are presented and the contribution that each had, as well as the financial resources, funding, and sponsors that supported the research. The introduction aims to present to the reader the research question and the outline of the process. This segment includes the research question that the project aims to address, all the participants that were involved, the potential interventions, and finally, the results. Methods, on the other hand, aim to introduce to the reader all the tools that were implemented to produce the final product of the research. Finally, the study records present the data collection and data synthesis process, a step that ensures the transparency of the research.

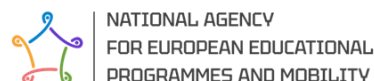
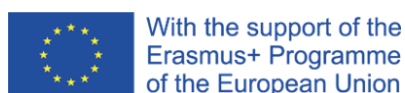
For the purposes of the SCORE project, the following approaches/definitions have been employed.

A. Administrative Information

1. **Registration number**
2. **Authors:** Name, institutional affiliation, e-mail address of all protocol authors
3. **Contributions:** Describe the contributions of the protocol authors and identify the review guarantor.
4. **Amendments:** *If* the protocol represents an amendment of a previously completed or published protocol, identify as such and list changes; otherwise, state plan for documenting important protocol amendments
5. **Support:** Describe Sources, Sponsor and the Role of sponsor or funder

B. Introduction

The SCORE project focused on case-specific knowledge. In particular, there were three areas of knowledge that were targeted. The first was about social issues, and the key words that were used were inequality and poverty. The second one was about global health. The key words that were implemented were one health and planetary wealth. Finally, the last area was environmental changes that affect the population, such as climate change and air pollution, which were also used as keywords.



C. Methods

Eligibility criteria:

1) The keywords that were selected were: Air pollution, inequality, poverty, one health, one health and complexity, one health and wicked problems, one health and policy making, determinants of one health, suggestions for future implementation of one health, surveys on one health, empirical applications of one health

2) The time frame within the SCORE project aims has been set to 2000-today because this is a new field of study, and an older article with a significant contribution will be visible through the most recent review.

3) The language that was chosen was English, however articles that are in languages known to the team members could easily be incorporated into our analysis.

4) The publication status of the articles that were included were peer-reviewed articles to ensure the scientific robustness of the reviews. Only scientific articles retrieved from the following databases have been considered, with the aim of maintaining focus on top scientific quality work.

1. ScienceDirect (<https://www.sciencedirect.com/>)
2. Web of Science (<https://www.webofscience.com/wos/woscc/basic-search>)
3. PubMed (<https://pubmed.ncbi.nlm.nih.gov/>)
4. Scopus (<https://www.scopus.com/home.uri>)

Data management:

For data management the Zotero program was used. Zotero is an open-source management program, that aims to ease the process of data management and research materials.

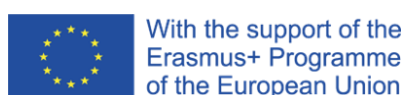
Selection process: The selection process can be described as follows:

- Screening
- Eligibility criteria
- Inclusion in meta-analysis

D. Study records

Data collection process: This section includes data deriving such as demographic information, methodology, intervention details, and all reported important outcomes about research question. We suggest the use of a standardized form such as excel to have uniformity among all team members

Data items: At this stage, all variables (qualitative and / or quantitative) will be defined. we can also list key assumptions, and more generally, all the features we are interested in focusing on to draw useful conclusions and policy practices.



Outcomes and prioritization: In this section, the primary outcomes are summarized. Also, we create a list of the most important outcomes related to the research questions and the central idea of the article.

Risk of bias in individual studies

Data synthesis:

- Describe the criteria under which the study data will be quantitatively synthesized.
- If the data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data, and methods of combining data from studies
- For the data synthesis we suggest being investigated in a second time as we will have reached the main articles according to the flow diagram.

Meta-bias: Authors should pre-specify any methods used to explore the possibility that the data identified are biased due to non-study related processes. Such bias may result from non-publication of studies and the reporting of a subset of measured outcomes and analyses within studies.

For these reasons, we suggest an intuitive evaluation of the data to see if there are extreme deviations from the results of some other research. Also, in empirical studies if the data is available and something deviating from the theory is observed, we can estimate again and re-evaluate it.

Confidence in cumulative evidence: Authors should describe which approach they plan to use to summarize the confidence they have in the resulting body of evidence, ideally using an established and validated approach.

2.2.2 Compilation of bibliographic references database

The first step of the work completed for result No1 of the SCORE project has been the identification of the relevant literature in Scopus, ScienceDirect, Pubmed, and Web of Science. Figure 4 provides an illustration of the methods and the steps as foreseen by the PRISMA protocol.

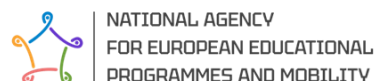
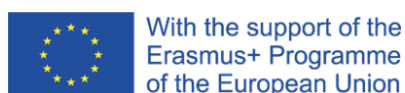
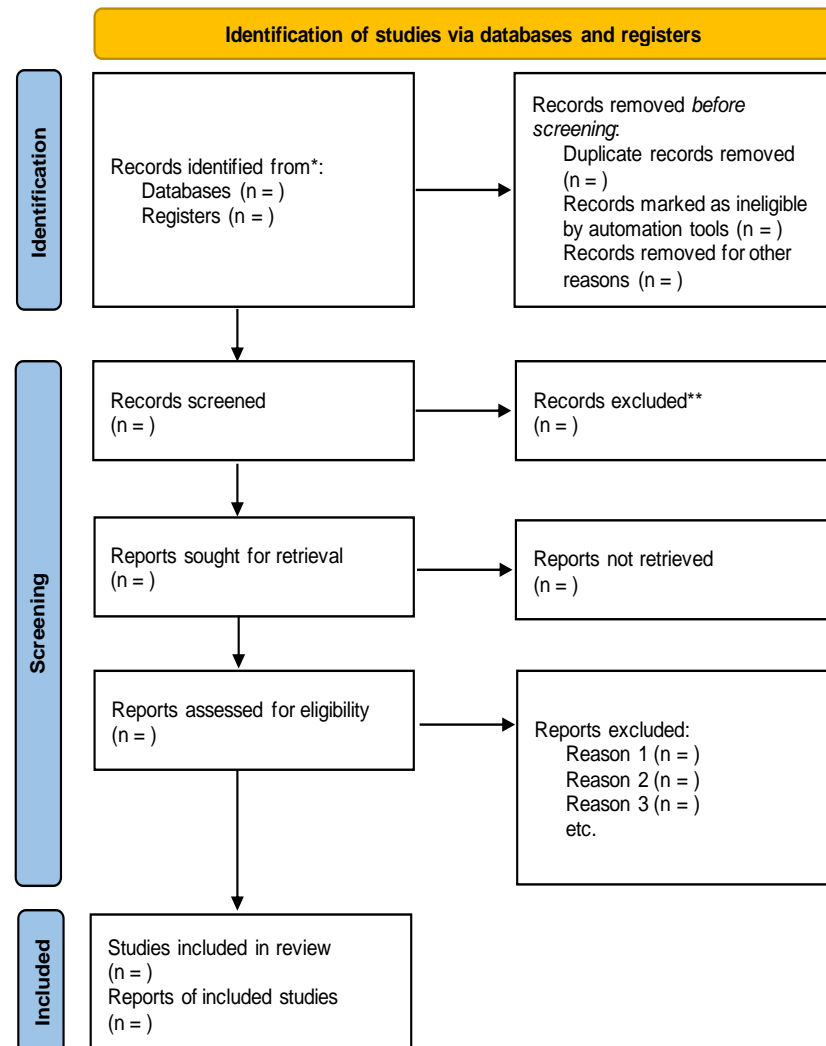


Figure 4: Illustration of protocol and Score database.



Source: <https://prisma-statement.org/prismastatement/flowdiagram.aspx>

- In Zotero for the option "Title, creator, year" search for the word "wick". This resulted in 634 papers in total
- In Zotero for the option "All fields and tags" search for the word "environment". This resulted in 158 papers in total. Following the above steps, the SCORE team has continued with the screening of the titles. If the title is found not to be related to the constraining option, eg, "environment", the document is removed from the list. In the end, the list contains only scientific works related to:
 - Environment
 - Pollution
 - Climate
 - Ecological systems

- Sustainability
- Complex systems
- Security in nature
- Security in food
- Health
- SDGs

These specific topics were selected because the specific keywords summarized the dominant wicked problems. Through a preliminary search, the research team found that wicked problems are mostly about the environment, the pollution (air, water, etc.), climate, ecological systems, and sustainability. Moreover, complex systems have been categorized as wicked problems, as well as security in nature and security in food. Health has also occupied the literature on wicked problems. Specifically, health related issues have been categorized by many as wicked problems. Finally, sustainable development goals involve many wicked problems which require a multidimensional and multidisciplinary approach. Sustainable development goals are a topical issue as the coexistence of environment and economic development is necessary. This selection has resulted in a final Zotero reference library which consists of a total of 107 papers.

Compilation of the reference library has been followed by systematic analysis of the works included therein. The work has focused on identifying literature contributions and developments with regard to:

- Definition of wicked problems
- Characteristics of wicked problems
- Factors that influence wicked problems (regulations, policies, institutions, etc.)

This part of the work consisted of the following steps:

- Step 1: Incorporating the bibliography
In this step, an excel file has been compiled including columns for each element to be analyzed in the works reviewed. The compiled file is attached to this report. In this file, all the bibliography gathered from the preliminary research is imported. All entries are also included in the Zotero library
- Step 2: Definition of wicked problems
 - A. The first part in this step consisted of efforts to locating the definition of wicked problems in the text. For these two different approaches have been used in a complementary manner.
 1. Use of the “search” option in the pdf application. Search for the following keywords and their modifications: “definition”, “defined”, “wicked problem is”, “problem is”, or other that are deemed as appropriate.
 2. Scanning of the paper. Go through the paper and identify where the authors try to give a definition or explain what a wicked problem is. The definition may not be presented as: “definition is...” or “is defined...” but it may be written as “wicked problem is...” or something similar.
 - B. Incorporating the definitions detected in the text



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- Where available, definitions have been incorporated in the excel file as it is in the text, without any changes. If there are more than one definition, all of them have been included in the summary excel file by adding each definition in a new row.
- Step 3: The main characteristics of wicked problems
 - A. Locating the specific characteristics
 - Use of the “search” option in the pdf application. Then search for the following keywords and their modifications: “characteristics”, “explained”, “elements”, “aspect”, “attribute” or other that are deemed as appropriate.
 - Scanning of the document. Go through the paper and identify where the authors try to present the characteristics of the wicked problems. Sometimes they can be given in a table or as bullets, but sometimes they can be discussed/presented in the main body of the paper.
 - B. Incorporating the characteristics detected in the text
 - Where available, characteristics have been incorporated in the excel file as identified in the text, without any changes. Term/name changes of the characteristics are not advised; a copy-paste option is proposed to make sure that we stay as close to the source as possible. If there are more than one definition, all of them have been included in the summary excel file by adding each definition in a new row.
- - Step 4: Factors that influence wicked problems
 - A. Locating the factors.
 - Use of the “search” option in the pdf application. Then search for the following keywords and their modifications: “model”, “factors”, “influence”, “relations”, “hypothesis” or other that are deemed as appropriate.
 - Scanning of the paper. This process involves going through the article and identifying where the authors attempt to present the factors that influence the wicked problems. In some papers, the authors will have created a model that includes the factors that influence the wicked problem. Other authors might just list a factor and explain it in a paragraph or a sentence. Most likely, the factors are mentioned in the methods, findings, or discussion section, thus we suggest searching those parts more carefully.
 - B. Incorporating the factors detected in the text
 - After finding the factors, we copy and paste them into the excel file. We suggest not changing the name of the factors; just copying it and adding it as it is without change. If there are more factors, copy all and add each definition in a new row.
 - If the factors are grouped in a model (that is, a figure) in the excel file, we suggest writing the page number where this figure is. The page number is added as it is written in the manuscript, not the page number that is shown in the pdf application.

3. Synthesis of the state-of-the-art literature and analysis

This section provides a synthesis of the results of the state-of-the-art literature review on wicked problems with a focus on the three dimensions of interest to the SCORE project, i.e.



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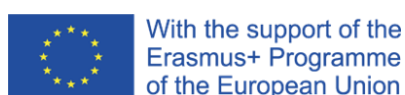


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definition, characteristics, and factors of influence for wicked problems. Most of the research papers build their definitions on the work of Rittel and Weber's (1973) or employ the definition that the latter have derived for wicked problems. This definition lists 10 characteristics of wicked problems, namely: 1. There is no definite formulation of a wicked problem, 2. Wicked problems have no stopping rules., 3. Solutions to wicked problems are not true-or-false, but better or worse, 4. There is no immediate and no ultimate test of a solution to a wicked problem., 5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly, 6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan, 7. Every wicked problem is essentially unique, 8. Every wicked problem can be considered to be a symptom of another [wicked] problem, 9. The causes of a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the resolution of the problem. 10. [With wicked problems,] the planner has no right to be wrong (Rittel and Webber, 1973)).

A common agreement among authors is the "social" nature of wicked problems and their planning extensions (See Table 4). Acey (2016) notes that "wicked problems are social problems, and all planning problems are wicked". As such they can be defined as problems that require multi-stakeholder approach to solutions (Alexander et al., 2022). A significant number of works defines wicked problems as "complex". Indicative are the definitions identified in the work of Alexander et al. (2022), Artman, (2015), Dwyer and Gill (2019). Everingham et al. (2020), Goel. (2019), Bruggemann, et al (2012), Hartman(2017), Hughes et al. (2013), Virtanen (2022), Kämpf and Haley (2014) and Webster (2021). Other key words that are used to define wicked problems are "system" (see Davidson et al. (2021), Arroyave et al. (2021), Davidson et al. (2021), Palmer (2012), Markowska et al. (2020), Seager et al. (2012), Thompson and Whyte (2012), Weaver et al. (2022), Zia (2018), Gilligan and Vandenberg (2020), Goel (2019), Goldsmith (1969), Jung et al. (2022), Kirschke et al. (2022), Hukkinen et al. (2022).), "hard" (Artmann (2015) & Gleeson et al. (2016)), "challenge" (see Dronova (2019), Duprey et al. (2017), Maron et al. (2016), Reinecke and Ansari (2016), Tatham and Houghton (2011), Goldstein (2017), Hargrove and Heyman (2020), Head (2014), Hughes et al. (2013), and Kraak (2022)), "incomplete" (see Arroyave et al. (2021), Barkemeyer et al. (2015), Palmer (2012), Pyykkoe et al. (2021), Inghelbrecht et al. (2014)).

Many works refer to the role of policies in the very definition of wicked problems (see for instance Auld et al. (2021), Patterson et al. (2015) and Hukkinen et al. (2022)). Several works note that wicked problems are usually ill-defined, cannot be solved with a standardized process, only be managed (see for instance Arroyave et al. (2021), Palmer (2012), FitzGibbon and Mensah (2012), Alexander et al. (2022), Duprey et al. (2017), Parrott (2017), Pederneiras et al. (2022), Muller (2016), Salvia et al. (2021), Zia, A. (2018), Zijp et al. (2016), Gleeson et al. (2016), Hargrove and Heyman (2020), Hartman (2017), Hughes et al. (2013), Kelley and Dietl (2022), Kirschke et al. (2018), Liou and Rao-Nicholson (2021)). The stance that there is no single solution to a wicked problem and many stakeholders and decision makers are involved in the process is repeated in the literature (see for instance, Murphy (2012), Bouma and McBratney (2013), Palmer (2012), Lidskog et al. (2018), Mikhailovich (2009), Potting et al.



(2022), Sun and Yang (2016), Tatham, P., and Houghton, L. (2011), Galappaththi and Nayak (2017), Garcia et al. (2016), Head (2014)). Also, a wicked problem requires an open mind approach to be managed. Any attempt to solve them by implementing a strategy that is straightforward and generalized would be ineffectual (Colding et al. (2019), Dronova (2019) and Levin et al. (2012)). Finally, wicked problems are difficult to solve because solving one part of it may create another problem in a different area of the problem (Chan (2016), Tatham and Houghton (2011) and Kirschke et al. (2018)).

Table 4 Definitions of wicked problems as identified in the collected references for the SCORE project

Source	Definition
Acey (2016)	Wicked problems, according to the paper, social problems and all the planning problems are wicked.
Alexander et al (2022)	Wicked problems are complex problems that require multiple stakeholders to manage them.
Allen (2013)	A wicked problem is difficult to clearly define the boundaries of the issue, as it is characterized by many interdependencies and has multiple causes.
Arroyave et al (2021)	Wicked problems reflect our incomplete understanding of interdependent global systems and the systemic risk they pose; such problems escape solutions because they are often ill-defined, and thus mis-identified and under-appreciated by communities of problem solvers.
Artmann (2015)	The concept of wicked problems was first introduced by Rittel and Webber (1973) who argued that problems of social policy cannot be analyzed and solved by common, scientifically linear, analytical methods because they are hard to define and comprise underlying complex and changing requirements.
Auld et al (2021)	Super wicked problems are denoted by four features we originally formulated to describe the climate crisis: time is running out, no central authority, those causing the problem also want to solve it, and policies irrationally discount the future.
Barkemeyer et al (2015)	Wicked problems are highly challenging to address, largely due to incomplete, contradictory, and dynamic requirements that make them both complex and multi-factored. Wicked problems also suffer a lack of clarity in terms of a route towards an optimal solution
Block et al (2018)	Wicked problems are characterized by uncertainty regarding the knowledge base on which to solve these problems and disagreement on norms and values.
Blok et al (2015)	Wicked problems are complex, ill-structured and public problems. Some examples are international terrorism, climate change and poverty.
Bouma and McBratney (2013)	Wicked problems have no single, logical solutions but only a series of options. Each balances the key elements of sustainable development, which are the economic, environmental, and social requirements.
Caron and Serrell (2009)	Wicked problems are multifactorial in nature and do not have a clear resolution due to the participation of numerous community stakeholders.

Chan (2016)	Wicked problems are problems where both the definition and the solution to the problem are uncertain and controversial. Moreover, solving the problem at one level exacerbates the problem at another level
Chapin et al (2008)	Wicked problems are social problems (e.g., poverty) so complex that people disagree about how to define and solve them; in addition, efforts to solve the focal problem generally create unanticipated secondary problems (e.g., dependence on transfer payments that are provided to alleviate poverty), so the problem can never be fully solved.
Chen et al (2019)	Wicked problems are interpreted as a framework of competing values rather than viewing the problems as knowledge gaps
Chester and Allenby (2019)	A wicked problem is one where one does not understand the problem until the solution is discovered.
Colding et al (2019)	Wicked problems lack simplistic solutions and straightforward planning responses are not sufficient to solve them.
Cross and Congreve (2021)	Wicked problems arise through a complex set of social, environmental, and economic processes which are closely interrelated.
Davidson and Wei (2012)	Wicked problems are ill defined and are intractable. This happens the social, political, economic, and biophysical processes involved are intertwined.
Davidson et al (2021)	Wicked problems are understood as complex, incorrigible and contested problems found at the intersection of natural and social systems.
de Abreu et al (2019)	Wicked problems are dilemmas in social and political planning that resist clear definitions and predetermined solutions.
de Oliveira et al (2021)	Wicked problems are complex social problems such as the covid-19 pandemic.
Dewulf and Termeer (2015)	Wicked problems are ‘a class of social system problems that are poorly formulated, the information involved is confusing, and there are many clients and decision makers with conflicting values. Finally, the ramifications of a wicked problem in the whole system are thoroughly confusing’
Dronova (2019)	Wicked problems are complex challenges that cannot be solved in a predictable, straightforward way. Moreover, they lack generalizable approaches to test for potential solutions, requiring more comprehensive, strategic, and multi-scale tackling.
Duprey et al (2017)	Wicked problems are complex challenges that require the efforts of multiple stakeholders to manage them.
Dwyer and Gill (2019)	Wicked problems are very complex policy problems, highly resistant to resolution



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Everingham et al (2016)	Wicked problems are highly complex, and the information associated with them is inadequate. Moreover, they are nebulous, usually they are inter-related with one another and reflect a conflict of value-laden perspectives.
Nygren et al (2017)	Wicked problems are difficult to solve. There is no single truth to learn, but instead there is a need to acknowledge the points of view of different stakeholders, which means not learning that one's view is the only true view of the problem.
Okeke-Ogbuafor et al (2020)	Wicked problems are difficult to define.
Osmundsen et al (2017)	Wicked problems are difficult to define and delineate from other problems; there is rarely consensus as to their interpretation and solutions. They persist and rarely have a final solution.
Palmer (2012)	Wicked problems reflect our incomplete understanding of interdependent global systems and the systemic risk they pose; such problems escape solutions because they are often ill-defined, and thus mis-identified and under-appreciated by communities of problem solvers
Parrott (2017)	The term "wicked problem" was first proposed by Rittel and Webber (1973) in the context of planning, and has since been widely adopted in the natural resource management and sustainability science literature.
Patterson (2016)	Wicked problems are complex, uncertain, ambiguous, contested, unstable, and historically contingent. Moreover, they are consequently evasive to traditional planning and management approaches.
Patterson et al (2013)	Wicked problems are multi-actor, multi-scalar, dynamic, uncertain, and present unclear route towards an optimal solution.
Patterson et al (2015)	Wicked problems involve multiple actors, scales, and levels, diverse policies, goals, and interests. Moreover, they presented uncertainty, and evolving situations.
Pederneiras et al (2022)	Wicked problems are complex and cannot be resolved through finding right 'answer' or 'solution', but rather they must be managed.
Kreuter et al (2004)	Wicked problems are illusive and difficult to pin down. They are influenced by a constellation of complex social and political factors, some of which change during the process of solving the problem.
Kuhmonen (2018)	Wicked problems are open to divergent and conflicting arguments for resolutions and have causal relationships with other problems. Various stakeholders generally disagree on both the nature of the problem and the best solution. Wicked problems are complex junctures that escape univocal definitions and agreed solutions, unlike tame problems.
Lehtonen et al (2018)	The wicked sustainability problems of today can be understood as the results of ignorance of the consequences of consumption, inattention to human dependence on ecological realities and the exceeding of planetary boundaries (Steffen et al., 2015).
Levin et al (2012)	The paper refers to Rittel and Webber's (1973) characteristics to define wicked problems. Also, the paper expands Rittel and Webber's (1973) conceptualization of "wicked problems" that lack simplistic or straightforward planning responses, by introducing the term "super wicked" to characterize a new class of global environmental problems.
Lidskog et al (2018)	Wicked problems are difficult to understand and resist a definite solution.

Lintern et al (2020)	Diffuse 94 nutrient pollution is truly a 'wicked problem'
Liou and Rao-Nicholson (2021)	Wicked problems (as opposed to "tame" problems) refer to "poorly formulated, boundary-spanning, ill-structured issues with numerous stakeholders who bring different perspectives to the definitions and potential resolution of the issue or problem".
Lundström et al(2016)	Wicked problems do not have right or wrong answers. They can be defining as negative externalities where corporations provide goods and services with unintended negative side effects.
Mampuys (2022)	Wicked problems (Rittel and Webber 1973) involve conflicting facts and values, lack a shared problem definition, and are famously difficult to solve.
Markowska et al (2020)	Wicked problems are multi-faceted, complex problems, which amplify with a changing situation (conditions). Moreover, they seem unsolvable through classic, rational analysis. Wicked problems involve intertwining systems and disciplines. Specifically, social, and economic systems, biological requirements and ecological processes
Maron et al (2016)	Wicked problems are contentious issues related to biodiversity offsetting. They are categorized as ethical, social, technical, or governance challenges.
Marshall and Sterett (2019)	Wicked problems are complex and not readily named. Also, in many cases they are not limited to one jurisdiction.
Mason et al (2018)	Wicked problems lack clear solutions due to divergent values of stakeholders. Also, they embedded within wickedly complex environments making them even more complicated to solve.
McGrath and McGonagle (2016)	Wicked problems, also known as social messes (Horn, 2001), refer to highly complex social issues with innumerable and undefined causes, which are difficult to understand and articulate (Rittel & Webber, 1973).
Mikhailovich (2009)	Wicked problems are social problems that evoke considerable conflict and involve multiple perspectives about an issue. Also, many actors take place while the solution is uncertain.
Muller (2016)	Wicked problems are policy and management dilemmas that are intractable using historically conventional methods applied by engineering, planning and related professions
Munneke et al (2007)	Wicked problems are a subset of ill-structured problems with unique features.
Murphy (2012)	Wicked problems involve many stakeholders, often with conflicting values. Also, in many cases there is a tension between sustainability and development, between environmental requirements and sociocultural needs and desires, between needs of the present generation and those of future generations.
Potting et al (2022)	Wicked problems are complex problems in which borders between facts and values are fading and contested. In these cases, stakeholder participation is put forward to adequately deal with those controversies. Unstructured, wicked or complex problems are usually understood as those where stakeholders (strongly) disagree about whether and how they see a problem. Moreover, there is also strong disagreement about solution directions and the robustness of involved knowledge. Wicked problems are typically viewed as surrounded with controversy around facts, norms, and values.



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Pyykkoe et al (2021)	The paper refers to Rittel and Webber's (1973) characteristics to define wicked problems. Consequently, as shown, climate change has arguably been a problem that is significantly difficult to solve, be it for incomplete knowledge, differing views, or a variety of complex interactions that make it seem subject to endless discussions. This is because the topic spans many, if not most, different dimensions such as scientific, economic, social, ethical, political, and religious. While sustainable development has often been defined "as a form of development which meets the needs of the present without compromising the ability of future generations to meet their own needs [46]", this concept can be seen as a wicked problem as well. Sustainability transition (ST) of supply chains (SCs) has wicked problem characteristics.
Rae and Wong (2012)	Wicked problems were introduced by Rittel and Webber (1973) and spatial planning can be characterized as one, embedded in a dynamic social context, which makes each problem unique but also difficult or impossible to solve.
Reinecke and Ansari (2016)	The question of responsibility attribution has been posed for many complex social issues, such as extreme poverty, pandemics, and climate change, described as 'wicked problems' (Conklin, 2006; Rittel and Webber, 1973) or 'grand challenges' (Ferraro et al., 2015). Wicked problems are large scale social challenges caught in causal webs of interlinking variables spanning national boundaries that complicate both their diagnosis and prognosis. First, wicked problems are complex social problems for which there may be no 'directly traceable causes' (Ferraro et al., 2015; Gioia, 1992, p. 381). Wicked problems such as climate change are often 'back-of-the-mind' issues with which people do not identify in their everyday experiences (Giddens, 2009).
Riley (2017)	It might better be conceived of as a wicked problem, that is, a problem that is inordinately complex, constantly evolving, and lacking in a concrete stopping point. Wicked problems like climate change are, in other words, problems that resist resolution because of their ability to outpace scientific research and ethical responses.
Sahin et al (2020)	The COVID-19 pandemic has emerged as a problem of wicked complexity for policy makers internationally.
Salvia et al (2021)	Waste management is a wicked problem characterized by multilayered interdependencies, complex social dynamics, and webs of stakeholders.
Seager et al (2012)	Wicked problems are beyond the scope of normal problems. Wicked problems typically test the limits of ethical analysis in business-as-usual and systems engineering approaches, which are concerned primarily with the actions of individuals in the context of professional groups. Wicked problems should not be thought of as problems to be solved, but conditions to be governed.
Sharma (2020)	Rittel and Webber (1973) have coined two terms to describe social problems; 'tame' problems are those that are solved and halted by policy intervention, and 'wicked' problems are those that continue to persist despite policy intervention.



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Sharp et al (2021)	Wicked problems have been thought of as a way of seeing the world: As aspects of a complex, multivalent or even malevolent world that needs taming. The idea of “wicked” problems emerged out of planning scholarship (Rittel & Webber, 1973) where conventionally used policy was not able to capture or solve the complexity – of multiple and dynamic causes, non-linear mechanisms, and associated human threats – of policy problems
Signal et al (2013)	Rittel and Webber (1973) first coined the term ‘wicked problems’ to refer to a category of public policy issues, not with moral wickedness, but with a high level of complexity.
Stahl and Cimorelli (2013)	Rittel and Webber (1973) refer to ‘wicked problems’ as a category of public policy issues, not with moral wickedness, but with a high level of complexity.
Stahl (2014)	The paper utilizes Rittel and Webber’s (1973) definition, in which wicked problems can be synthesized as values-centered problems. Another way to think about values-centered problems is to consider them priorities-centered problems where each stakeholder in a group may have their own views to the importance of each aspect of the problem. Wicked problems are those that are difficult to define (i.e., context or problem formulation is a matter of stakeholder perspective), have no single right answer, have no objective measures of success (i.e., no standardized, objective set of indicators), have no stopping rules, and often require discovering the solution.
Sun and Yang, (2016)	The notion of wicked problems is an approach to understanding the dynamics of a major proposed change with multiple and conflicting inputs and multiple possible outcomes, all of which play over time against, or occasionally with, each other. Wicked problems occur at the interface of human/environmental interaction and are characterized by the fact that solutions create a ‘plethora of new problems’ [4] (p. 183). Rittel and Webber (1973) used ‘wicked’ as a term “akin to that of ‘malignant’ (in contrast to ‘benign’) or ‘vicious’ (like a circle) or ‘tricky’ (like a leprechaun) or ‘aggressive’ (like a lion, in contrast to the docility of a lamb)” (p. 160).
Tatham, P, and Houghton, L (2011)	Rittel and Webber (1973) introduced the term “Wicked Problem” to describe the challenges of urban planning and design in the early 1970s. They concluded that the existing framework for analyzing and solving such problems, based as it was on the application of scientific method, or on the traditional linear method was bound to fail. Such problems are multi-faceted, and it is only through exploration of potential “solutions” that one can develop an improved understanding of the issues that one is faced with (Houghton and Metcalfe, 2010). Furthermore, there are a plethora of individuals, groups and organizations involved in the problem and, inevitably, each will have a different perspective of its nature and, hence, what is an acceptable solution.



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Thompson and Whyte (2012)	Wicked problems ill-structured and to which it is impossible to respond successfully using top-down tactics or the methods belonging to any one discipline Wicked problems occur within complex social systems. They “are ill formulated,” contain high degrees of uncertainty, involve puzzling information, have multiple decision-makers and impacted parties whose values are in conflict, and promise “ramifications for the whole system” that “are thoroughly confusing”.
Weaver et al (2022)	Wicked problems can be defined as a “class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing.” (Rittel and Webber (1973)
Webster (2021)	Wicked problems are complex and, in many cases, intractable while there is no definitive answer. There are better or worse alternatives” (Grint, 2005, p. 1473). - Rittel and Webber (1973) capture this issue: “The formulation of a wicked problem is the problem!” (1973, p. 161, emphasis in original).
Woodford et al(2016)	The paper refers to Rittel and Webber’s (1973) characteristics to define wicked problems. Also, they refer to Conklins (2005) 6 criteria for wicked problems, a condensed version of the 10 characteristics of Rittel and Webber (1973) .
Zia, A (2018)	Rittel and Webber (1973) mentioned problems of long-term planning and management as examples of wicked problems, and contrasted these with the “benign” or “tame” problems of mathematics and science. Wicked problems, on the other hand, have no determinate solution; even the correct formulation of the problem is contested, and there is no “stopping rule”. Rittel and Webber (1973) argued that many benign problems in planning and environmental protection, such as designing adequate sewer systems or timing traffic lights, have been solved by formal modeling and technological innovation but that many of the remaining problems faced by municipalities and agencies must be understood as wicked problems. The analysis of Rittel and Webber was prescient, for today’s decision scientists readily admit that correct problem formulation is the most difficult and least understood aspect of public decision making (Keeney 1996; Keeney and Raiffa 1976; Winterfeldt and Edwards 1986; Corner et al. 2001; Coenen et al. 1998; Gregory et al. 2001; Gregory 2002; Hanne 2001; Yu 1979; Wooley and Pidd 1981; Mintzberg et al. 1976; Abaulsamh et al. 1990; Perry and Moffat 1997; Taket and White 1997). Rittel and Webber hypothesize that wicked problems have no definitive solution—and no agreed-upon formulation—because disagreements involve multiple competing interests. For wicked problems, we cannot expect “optimal” and final solutions; rather, we can only expect a negotiated and balanced outcome, a resolution that will be acceptable for a time but always open to re-negotiation as the context and power relations change in society. The question remains: how should we “resolve” wicked environmental design problems? It is a question that has intrigued Norton (2005, 2015) over many years of scholarship and research.



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Zijp et al (2016)	Wicked problems are multi-faceted and deriving of a management solution requires an approach that is participative, iterative, innovative, and transparent in its definition of sustainability and translation to sustainability metrics.
Zywert and Quilley (2018)	Wicked problems resist simplistic definitions and their “solutions” are invariably contingent, involving trade-offs, balances, socially defined values, and “sweet spots” (innovation spaces that can meet multiple goals simultaneously). Many wicked problems are nested within broader paradoxical dilemmas, and every attempt at intervention has real-world consequences, some of them intended and some unintended, unforeseeable in advance. The higher-up one goes in scale, the more likely one is to meaningfully address the root of the problem, and yet the more difficult it is to effect change (Rittel and Webber 1973; Meadows 2008).
Galappaththi and Nayak (2017)	Following Jentoft and Chuenpagdee (2009) we define wicked drivers as those for which there is no known technical solution, it is not clear when and how they create impact, and there are no right or wrong methods that can be determined scientifically to respond to these drivers.
Garcia et al (2016)	Wicked problems have no clear solution.
Gilligan and Vandenberg (2020)	Wicked problems are technically complex problems, ill-formulated, where the information associated with them is confusing. Many clients and decision makers are involved with conflicting values, and the ramifications in the whole system are thoroughly confusing. Wicked problems are societal problems in general that belong in the wicked category.
Gleeson et al (2016)	Wicked problems are unstructured policy problems that governments find hard to manage and resolve,
Goel (2019)	Wicked problems are complex, open-ended, and intractable. Moreover, they are inherently resistant to a clear definition and agreed solution. Finally, they have multiple elements constituting a complex system.
Gold et al (2017)	Corporations have been accused of exacerbating social and environmental conditions in developing world regions where they operate, for example by aggravating poverty and social displacement, backing authoritarian regimes, exploiting workforce and polluting the environment. ...these intractable ‘wicked’ social problems poverty, a ‘wicked’ problem that is complex and multi-dimensional in nature Kajiado West is one of the regions in Kenya with high levels of poverty, illiteracy and related persistent social and environmental problems which may be labelled as “wicked problems”
Goldsmith (1969)	Wicked problems refer to that class of social system problems which are ill-formulated and the information about the problem is confusing. Moreover, there are many clients and decision-makers with conflicting values and the ramifications in the whole system are confusing. Community air pollution is considered a wicked problem.



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Goldstein (2017)	Wicked problems have many variables, and each suggested solution changes the conditions and produces new challenges.
Gutierrez (2020)	Wicked problems cannot be resolved to the extent that every involved party is satisfied.
Hargrove and Heyman (2020)	The label “wicked” was first assigned to urban policy challenges by Rittel and Weber and shortly thereafter applied to water resources planning and management by Liebman. Gallagher further demonstrated how the label applies to climate change and water resources management
Head (2014)	Wicked problems are complex, intractable, and messy problems rather than simple problems with linear technical solutions. Moreover, they are inherently resistant to a clear and agreed solution. Wicked problems involve many other linked problems, and none of them can be solved separately. The short-term and long-term calculations of impacts, costs, and benefits of specific interventions are likely to be diverse, and may shift over time. The impacts are also global, national, regional, and local simultaneously. The scientific knowledge related to the problem have been contested in public debate, with sceptical dissent being fanned by some industry sectors. Finally, there is the prospect of economic nationalism and protectionism, and a reduced appetite for shouldering new economic adjustment costs, in the wake of the global financial crisis since 2008. there are several reasons why climate change response policy can be termed a field of ‘wicked problems’. Firstly, the challenges are actually a series of linked problems, none of which can be resolved in isolation, leading to what Gamaut (2008a) has termed a ‘diabolical’ challenge for science and for politics, and what Lazarus (2009) has termed a ‘super-wicked’ problem for political and legislative resolution.
Bruggemann et al (2012)	Wicked problems are value driven, complex, multi-scale, persistent or reoccurring, and challenging to solve.



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Hartman (2017)	The terminology of “wickedness” originated in the planning literature of the 1970s; from there it spread to many different disciplines (Rittel and Webber 1973). In its original formulation, this “wicked” quality is contrasted with “tame” problems. “Tame” problems have clear and obvious solutions and may be tackled using standard tools and approaches (Ibid. 160). “Wicked” problems are vexingly complex, bleeding across disciplines, tauntingly unmanageable, and frustratingly immune to any standard problem-solving protocols. Such problems call out for new approaches—not simply extensions of older approaches (Riley and Bauman, this volume, 1–2). Horst Rittel and Melvin Webber, scholars of design and city planning respectively, first set out their understanding of wicked problems in a conference of the American Association for the Advancement of Science in 1969. The influential article that they then composed explains the concept in some detail, using examples such as poverty or crime in cities. Rittel and Webber admit that other terms besides wicked may be more appropriate to describe the complexity facing the flummoxed city planner. They suggest “‘malignant’ (in contrast to ‘benign’) or ‘vicious’ (like a circle), or ‘tricky’ (like a leprechaun), or ‘aggressive’ (like a lion, in contrast to the docility of a lamb)” (1973: 160). Building on Rittel and Webber’s brainstorm, then, I argue that perhaps such problems, in contrast to “tame,” should be called “wild” or “feral” or “bewildering,” to recognize human incapacity to comprehend and control them.
Hoffman (2020)	Wicked problems are serious global problems facing the human condition that require collective actions and international cooperation.
Holgate and Stokes-Lampard (2017)	Air pollution is an example of wicked problem.
Hughes et al (2013)	A wicked problem by definition is complex and involves multiple sets of players (e.g., the general public, industries, governments, scientists, nongovernmental organizations, and multiple sovereign states). It has no single or optimal solution, and partial solutions invariably cause new, often unforeseen, problems and conflicts among players. Here, we applied the wicked-problem paradigm to the social and ecological challenges of sustainably managing coral reefs in rapidly developing countries, exemplified by the sub-tropical reefs of mainland China and the disputed South China Sea, where 6 countries claim sovereignty over off-shore reefs and atolls.
Hukkinen et al (2022)	Policies have become wicked, i.e., characterized by urgency, path-dependence, complexity, uncertainty, value conflicts, indeterminate solutions, and high demand for expertise, often of inter-disciplinary nature political decisions increasingly involve complex issues or systems that require competences beyond the traditional political realm high level of conflict, discord and complexity
Inghelbrecht et al (2014)	“A problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognise. The term ‘wicked’ is used, not in the sense of evil, but rather its resistance to resolution. Moreover, because of complex interdependencies, the effort to solve one aspect of a wicked problem may reveal or create other problems”



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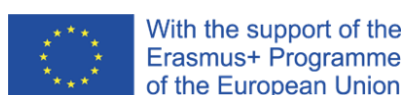
Jung et al (2022)	Wicked problems are poorly defined, messy situations with high uncertainty, and with highly divergent perspectives, worldviews, and value systems among relevant stakeholders (Rittel and Webber, 1973; Head, 2008; Xiang, 2013). By definition, inquiries into wicked problems cannot arrive at conclusive truths (Rittel and Webber, 1973). Instead, they can help us transform situations by reexamining how to make sense of them (Waddock et al., 2015). Engaging with wicked problems requires coherent action and relationship building rather than looking for incremental or disconnected solutions (Head, 2019).
Kämpf and Haley (2014)	Wicked problems are problems that are unstructured, complex, irregular, interactive, adaptive, and novel. Wicked problems are problems that are unstructured, complex, irregular, interactive, adaptive and novel. The concept of wicked problems has contributed to the understanding of complex projects since the 1960s. They exist in any aspect of societal life marked by complexity and interdependencies of stakeholders with differing views and values, be they technological, cultural, economic, environmental, political or legal. The use of the terms – wicked problem and wicked projects – occurs interchangeably in this paper, employing Shurville and William’s characteristics of a wicked project: these projects are difficult to define and are embedded in a complex social and political milieu.
Kelley and Dietl (2022)	Many, if not most, environmental problems are “wicked problems” (Rittel and Webber, 1973). These problems are deeply embedded in disagreements among stakeholders, who often have opposing views on a problem and its causes; wicked problems lack clear solutions, and attempts to solve them can lead to unexpected consequences.
Kirschke et al (2018)	The label of wicked problems generally hints at the challenges of defining and solving a problem, given the existence of diverse interests and values of stakeholders, as well as numerous interconnected factors that, if not sufficiently considered, may result in various negative side-effects of actions. research on wicked problems generally emphasizes that there are several dimensions, such as goal diversity, non-solvability, or delayed side-effects of actions
Kirschke et al (2022)	Wicked problems relate to problems that are particularly difficult to address as problems and solutions are not clearly defined, among others (Rittel & Webber, 1973). Following more recent developments in the wicked problems literature (e.g., Head, 2008; Kirschke et al., 2019; Termeer et al., 2019), we define wickedness along the three dimensions of goal conflicts, system complexity, and uncertainty. Goal conflicts or divergence relate to antagonistic interests of actors. This dimension mainly relates to diverging values shaping different understandings of problems and of their solutions. System complexity describes the number of dynamic and interconnected variables in social-ecological systems, implying (delayed) side-effects of actions when addressing wicked problems. Uncertainty indicates the lack of data, information, and knowledge for addressing problems. In case of wicked problems, such uncertainty cannot be addressed through enhanced data collection and analysis but requires means to cope with the uncertainty inherent in complex systems.

Kraak (2022)	A wicked challenge is a problem about the nature and framing of which there is no agreement among actors; the causes and solutions to address the challenge vary and are judged by many actors; there are no best practices to guide policy decisions; and solutions are determined by a specific policy context.
FitzGibbon and Mensah (2012)	Wicked are social and environmental situations that overwhelm existing practices and persist even after the application of best-known practices; The term wicked problems were originally coined by Rittel and Weber (1973) as the opposite of “tame problems,” where the latter can be resolved with traditional methods because it is easy to define cause-and-effect relationship of the problem as well as the solutions. Conversely, wicked problems are social planning problems that defy traditional methods because they are “ill-defined, ambiguous and associated with strong moral, political and professional issues”

Source: Authors' compilation

With regards to the characteristics (Table 5), the state-of-the-art literature review shows that that wicked problems are characterized by pervasiveness, political and economic contexts that are detrimental to their occurrence, unpredictability, social, environmental, and economic complexity (Davidson and Wei (2012), Okeke-Ogbuafor et al. (2020), Kreuter et al. (2004),Lundström et al.(2016), Stahl and Cimorelli (2013), Zijp et al. (2016) and Gilligan and Vandenberg (2020), Allen (2013), Bouma and McBratney (2013), Sahin et al. (2020), Gold et al. (2017), Goldstein (2017), Bruggemann et al. (2012),Alexander et al. (2022), Allen (2013), Chester and Allenby (2019), Palmer (2012), Patterson et al. (2013), Pederneiras et al. (2022), Muller (2016)). Authors note the uncertainty regarding the knowledge base on which wicked problems can be solved as well as the non-agreement on how to best address them. Many works note that there is often no single solution, but rather a series of options to address wicked problems. These need to be multifactorial, dynamic in nature, and resistant to resolution (Caron and Serrell (2009), Block et al. (2018), de Abreu et al. (2019), Palmer (2012), Mikhailovich (2009), Weaver et al. (2022), Head (2014), Hukkinen et al. (2022), Kirschke et al. (2022), Caron and Serrell (2009), Patterson et al. (2015), Riley (2017) and Hoffman. (2020). The applicability and efficacy of the solution is often viewed differently by different stakeholders, and this often adds to the complexity of wicked problems. The complexity of the characteristics is linked by many authors to the difficulty in identifying appropriate management and policy paradigms that can solve wicked problems.

Complexity also renders traditional or tested and tried approaches inadequate to solve wicked problems, thus calling for innovative multi-dimensional, multi-stakeholder approaches to overcoming wicked problems (Chester and Allenby (2019), Dewulf and Termeer (2015), Dronova (2019), Dwyer and Gill (2019), Lidskog et al. (2018), Riley (2017), Zijp et al. (2016). Some authors highlight the inadequacy of purely scientific solutions to wicked problems that has to do with the closely linked to society nature of wicked problems. As noted in Gilligan and Vandenberg (2020) "natural science and engineering can very accurately describe the behavior of physical systems under controlled conditions but cannot answer normative and political questions regarding what goals a policy ought to aim for; and second, while science can describe the behavior of a system, if the system is complex, it may not be feasible to predict its future behaviour; contained an irreducibly normative or political component”.



Complementary to this argument, authors note that solutions to wicked problems cannot be true-or-false, but good-or-bad, i.e., solutions are only subjective based on the perception of each stakeholder (Goel, 2019). The results of the collection on the characteristics of wicked problems is presented next in Table 5.

Table 5 Characteristics of wicked problems as identified in the collected references for the SCORE project

Source	Characteristics
Acey (2016)	Wicked problems are pervasive and are global. Specifically, they may occur in every part of the world across varied social, political, and economic context.
Alexander et al (2022)	Wicked problems are unstable and occur under unpredictable circumstances. A wicked problem often implies an underlying complexity and difficulty solving them. Moreover, they have a complex scope and nature. Finally, multi-stakeholders are involved, and partnerships usually are forming to address the problem.
Allen (2013)	Wicked problems are characterized by social, environmental, and economic complexity. An inherent complexity, while there is an urgent need to bridge across agencies, jurisdictions, and constituencies to effectively manage these problems.
Arroyave et al (2021)	Wicked problems are difficult to address, are ill-defined and difficult to identify them. Finally, they are appreciated by communities of problem-solvers.
Artmann (2015)	Wicked problems are difficult to define and solve. There are no objective criteria evaluating a solution to a wicked problem as right or wrong but as being better or worse. Finally, wicked problems have no given alternative solutions
Auld et al (2021)	The paper refers to Rittel and Webber's (1973) characteristics of wicked problems as a definition.
Barkemeyer et al (2015)	Wicked problems are highly challenging to address and lack clarity in terms of a route towards an optimal solution.
Block et al (2018)	Wicked problems present: (1) uncertainty regarding the knowledge base on which to solve these problems; and (2) disagreement on norms and values, fuzzy boundaries, urgency, no single right answer to these problems,

Blok et al (2015)	Wicked problems are highly complex and difficult to pin down. Moreover, they have no definitive formulation, and multiple stakeholders are involved with each one their point of on the root of the problems. Wicked problems have no simple solution and cannot be solved in traditional ways or by simple solutions
Bouma and McBratney (2013)	Wicked problems have no single logical solutions but only a series of options, each of which balancing economic, environmental, and social requirements, the key elements of sustainable development.
Caron and Serrell (2009)	Wicked problems have no definitive resolutions, they are multifactorial, dynamic in nature, and resistant to resolution, the feasibility of numerous solutions may be viewed differently due to the varied perspectives and interests of many stakeholders, there are multiple stakeholders who define the problem differently and who possess uncoordinated solutions
Chan (2016)	Wicked problems are unclear and lack a stable definition. Also, there is no definitive solution. Finally, the paper refers to Rittel and Webber's (1973) characteristics.
Chapin et al,(2008)	Wicked problems have no optimal solutions, and they are difficult or impossible to solve within current management and policy paradigms. Finally solving them may result in unanticipated secondary problem, making them even more complex.
Chen et al (2019)	Wicked problems cannot be resolved through the traditional analysis of vast amounts of data or conventional statistical analyses. They resist the analytical definition, and each problem appears to be a symptom of other problems and the cause-effect relations of and solutions to them are largely unclear and unstable. Moreover, it is impossible to know when it can be solved, they defy resolution due to enormous interdependencies, uncertainties, and even circularities satisfactorily. At best it is only resolved repeatedly
Chester and Allenby (2019)	The paper refers to Rittel and Webber's (1973) characteristics as a definition. Moreover, wicked problems require fundamentally different approaches than what we've historically used. Finally, they present technical complexity and social complexity.
Colding, J et al (2019)	Wicked problems lack simplistic solutions and straightforward planning responses, and they are difficult to detect before they occur.



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Cross and Congreve (2021)	Wicked problems are difficult to define and linked to other problems. Addressing the challenges of wicked problems requires the integration of different bodies of knowledge and diverse skills. Also, the paper refers to Rittel and Webber's (1973) characteristics.
Davidson and Wei (2012)	Wicked problems are unresolvable by applying pure science, closely linked with social issues, and for which there are no optimal solutions. They have causes and effects that are difficult to identify, separate and model, no clear cause and effect, no optimal solution, no path to follow and no way of resolving the social, political effects they have. The cause and effect of a wicked problem are difficult to separate. Finally, they often result in economic and biophysical mess.
Davidson et al (2021)	Wicked problems are complex, incorrigible, significant harm, complexity, urgency and contestation, solving such problems requires coordination across boundaries of different kinds and cooperative effort from all affected by a particular problem
de Abreu et al (2019)	Wicked problems are persistent, complex, and unpredictable. They have not a definite solution, therefore they are open-ended and intractable. Moreover, they present institutional complexity and scientific uncertainty, while conceptual difficulties are persistent.
de Oliveira et al (2021)	Wicked problems can be characterized as complex crises and they require a multi-sectoral and multi-level approach to manage them.
Dewulf and Termeer (2015)	Wicked problems defy traditional governance approaches based on issuing policies, specifying procedures and consulting stakeholder. Moreover, a wicked problem is multifaceted and presents itself as a confusing mess of interrelated problems. Also, different aspects appear to be triggers, root causes, effects, priorities, side effects which makes it difficult to pin down the causes. Conclusively, there is no final solution for them.
Dronova (2019)	Wicked problems have no sustainable solutions. Moreover, they do not have straightforward solutions, and require innovative approaches to manage them.
Duprey et al (2017)	Wicked problems do not have definite solutions, as the suggested solutions often create new conflicts.
Dwyer and Gill (2019)	Wicked problems are difficult to resolve. They challenge the existing mindsets or at least managing them requires a reassessment of some of the traditional 'business as usual' approaches.



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Everingham et al (2016)	The consequences of a wicked problem are characterized as 'irreversible'. They are often associated with issues of equity in public, uncertain knowledge, multiplicity of interests and complex interconnections. The process of managing them require strict policy and planning.
Nygren et al (2017)	Wicked problems in socio-ecological systems
Okeke-Ogbuafor et al (2020)	The paper lists the below characteristics of wicked problems (1) Wicked problems are difficult to define. There is no definitive formulation. (2) Wicked problems have no stopping rule. (3) Solutions to wicked problems are not true or false, but good or bad. (4) There is no immediate or ultimate test for solutions. (5) All attempts to solutions have effects that may not be reversible or forgettable. (6) These problems have no clear solution, and perhaps not even a set of possible solutions. (7) Every wicked problem is essentially unique. (8) Every wicked problem may be a symptom of another problem. (9) There are multiple explanations for the wicked problem. (10) The planner (policy-maker) has no right to be wrong (11) Wicked problems involve multiple actors and are socially and politically complex (12) "Time is running out. (13) There is no central authority, or only a weak central authority, to manage the problem. (14) The same actors causing the problem seem to solve it. (15) The future is discounted radically so that contemporary solutions become less valuable
Osmundsen et al (2017)	To describe a wicked problem involves acknowledging how different stakeholders (i.e., politicians, bureaucrats, NGOs and industry) have competing perspectives of what the problem is. It is important to acknowledge that there are ambiguities and disagreements as to the cause of the problem, and measures may not have the intended effect.
Palmer (2012)	A proposed typology of incertitude which may typically characterize wicked.Problems is strict uncertainty, indeterminacy, ambiguity and ignorance. In sum, there are various qualities of complexity and uncertainty inherent to a wicked problem. When present together, these epistemological phenomena might be viewed as the quintessential characteristics of wicked problems, collectively rendering the tasks of identifying and interpreting relevant knowledge and evidence hugely difficult.
Parrott (2017)	Wicked problems have several key characteristics, first identified by Rittel and Weber (1973). These are: 1) the formulation and existence of the problem is deeply embedded in the perspectives of the stakeholders; 2) there is no optimal solution, and no right or wrong solution; 3) there are innumerable possible solutions; 4) each wicked problem is unique and so solutions cannot be taken from previous experience; 5) every wicked problem is a symptom of other wicked problems (Rittel & Webber 1973; Whyte & Thompson 2012; Norton 2012).

Patterson (2016)	Wicked problems are difficult to determine, inherently unstable and ambiguous. Wicked problems have many environmental, social, and institutional consequences.
Patterson et al (2013)	In general, features of wicked problems include: unclear, unstable and cross-sectoral issues; social complexity and shared responsibility; historical contingency; and systemic interconnectedness . Moreover, wicked problems are often inseparable from deeper “issues of values, equity, and social justice”, and power. (Pritchard and Sanderson, 2002).
Patterson et al (2015)	Wicked problems are resistant to traditional policy interventions, which are implemented on a single level or at a short timeframe.
Pederneiras et al (2022)	Wicked problems can be characterized by structural complexity, knowability, knowledge fragmentation and knowledge framing. Structural complexity: It relates to aspects of the problem, not to stakeholders. Knowability: There is not enough knowledge for the issues of the problem. This comprises multiple complex variables, and operation requires efforts to discover causal relationships and likely results. Knowledge fragmentation: Knowledge is divided between several actors, and the connection is a barrier. Knowledge framing: Understanding can be distorted by the disproportionate attention of knowledge between stakeholders.
Kreuter et al (2004)	No agreement exists about what the problem is. Each attempt to create a solution changes the problem. The solution is not true or false—the end is assessed as “better” or “worse” or “good enough.” Many stakeholders are likely to have differing ideas about what the “real” problem is and what its causes are. The end is determined either by stakeholders, political forces, and resource availability or a combination thereof. Solution(s) to problem is (are) based on “judgments” of multiple stakeholders; there are no “best practices.” Every problem is unique and solutions must be tailored.
Kuhmonen (2018)	The paper refers to the following list to refer to the characteristics of Rittel and Weber (1973)
Lehtonen et al (2018)	Wicked problems are difficult to solve and can't be solved with the same strategies of knowing that has resulted in problems
Levin et al (2012)	Super wicked problems comprise the following four key features: 1. limited time. 2. the actors that caused the problem also seek to provide a solution. 3. the central authority needed to address them is weak or non-existent. 4. irrational discounting that pushes responses into the future.



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Lidskog et al (2018)	Wicked problems are characterized by the inability to reach a general understanding of a problem – to define it and spread the definition to a wider circle of stakeholders and decision makers Wicked problems also have no definitive formulation and solution; that is, there is no single best approach to tackling the problem. This kind of problem is complex, spanning different sectors, regulatory frameworks, and policy targets. It is new in the sense that there is limited experience about how to handle and solve this kind of an issue. It is uncertain, with a deficit of knowledge both about the problem's character and also, in a more strategic sense, about to what extent and in what ways actors will respond. Lastly, the problem is value-laden; involved stakeholders have different goals for their activities and therefore differ in their normative evaluation of the severity of the problem. Finally, Wicked problems cannot be solved by simple, rational-technical approaches, although this does not mean that they are impossible to tackle (Head and Alford, 2015; Roberts, 2000).
Lundström et al(2016)	Wicked problems are unique and symptoms of another problem, usually a larger-scale one. Typically, such issues are social or political, and subject to what can be termed the non-stopping rule (see Conklin, 2006).
Mampuys (2022)	. Wicked problems are characterized by facts and value that contradict one another and, lack a clear agreed up on definition, and are difficult to solve
Markowska et al (2020)	The characteristics of wicked problems can be concluded to the list below. Wicked problems are: 1. difficult to define 2. ambiguously bounded 3. temporally exacting .4. Repercussive 5. doubly hermeneutic and 6. morally consequential.
Maron et al (2016)	Wicked problems can be summarized to philosophical/ethical, social, technical and governance challenges. Also, the paper refers to Rittel and Webber's (1973) work to pinpoint characteristics of wicked problems.
Marshall and Sterett (2019)	Wicked problems are complex, therefore they are not easily categorized. They cannot be “named” in existing scientific communities or policy circles. In the absence of simple formulations, wicked problems have no simple solutions. Any proposed solution must draw on a range of different forms of knowledge and expertise, which often place conflicting demands on a society. Finally, wicked problems present long-term challenges because the underlying conditions causing the problems are constantly changing
Mason et al (2018)	The paper refers to Rittel and Weber’s (1973) work to pinpoint the characteristics. Also, it is important to note that wicked problems involve multiple actors which have varying levels of power.



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McGrath and McGonagle (2016)	Wicked problems do not have clear definitions. They have multiple interdependencies and causal levels, continually evolving. They are socially complex, and rarely sitting within the boundaries of any organization or discipline. Furthermore, the suggested solution to wicked problems typically involves multiple stakeholders who are equally equipped, interested and entitled to judge any potential solution.
Mikhailovich (2009)	Wicked problems present multiple perspectives about an issue, have many actors involved, and have high uncertainty about solutions
Muller (2016)	The paper refers to Rittel and Webber's (1973) work to list the characteristics of wicked problems.
Munneke et al (2007)	Wicked problems have no right or wrong solutions that can be tested and revised. Also, they are problems with many stakeholders with each one holding their own views on both the problem and the solutions.
Murphy (2012)	Wicked problems often displace the blame onto attempts at sustainability for a host of social ills.
Potting et al (2022)	Unstructured (or Wicked) problems and moderately structured problems with debate (mainly) about norms and values need higher degrees of (two-directional) interaction (trust about norms and values at stake). Controversy about norms and values was not a core condition though for wickedness according to Rittel and Webber (1973), who coined the term 'wicked problems', but rather a consequence of a problem-solving attitude in which professionals assumed their problem diagnoses were of a generic nature and therefore shared by the public.
Pyykkoe et al (2021)	There is no definite formulation of a wicked problem. Wicked problems do not have a "final solution" because the resolution can always be improved. Solutions to wicked problems are not true-or-false, but good or bad. There is neither a final test nor an immediate solution to a wicked problem. Each solution tentative to a wicked problem is a one-time operation and each attempt counts significantly. Wicked problems do not have enumerable sets of potential (or exhaustively descriptive) solutions. Each wicked problem is essentially unique. Each wicked problem can be considered a symptom of another problem. The existence of discrepancies in the representation of a wicked problem can be explained in several ways. Choosing an explanation determines the nature of the problem resolution. The existence of discrepancies in the representation of a wicked problem can be explained in several ways. Choosing an explanation determines the nature of the problem resolution.
Rae and Wong (2012)	Wicked problems are complex problems which require an adaptive model in order to manage them.



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Reinecke and Ansari (2016)	Wicked problems cannot be conclusively “solved” as there are no formulas or objective criteria to judge a solution as right or wrong. However, narrowing a wicked problem’s scope can reduce fatalism, make the problem appear tractable, and spur action by providing hope for a possible resolution. Finally, wicked problems tend to have a global scope.
Riley (2017)	Wicked problems are constantly changing and resistant to single-solution thinking. With no clear stopping point and no clear solutions, the wicked problem of climate change is perhaps best addressed by open-ended ethical approaches such as White’s. As he warned, changes in ideas and values, and especially changes in actions and practices, were often stymied by unintended and unforeseen consequences that only exasperate environmental problems. The problem of climate change, then, requires adaptive ethics that are open-ended in their solutions and flexible enough to cope with complex, evolving problems.
Roche et al (2021)	Wicked problems typically involve multiple stakeholders with different perspectives, include complex interconnections, and have no single solution or one “right” answer; this wickedness defies normal problem-solving processes and attempts at resolution can reveal or even generate additional problems (Rittel and Webber, 1973; Balint et al., 2011).
Sahin et al (2020)	Wicked problems, such COVID-19 pandemic have consequences that transcend many boundaries (e.g., health, communities, science, politics, environment, and economics).
Salvia et al (2021)	Wicked problems are complex, have social and endless causal chains, that link stakeholders and interacting systems. Finally, they are difficult to solve.
Seager et al (2012)	Wicked problems are difficult to define. They have multiple but incomparable solutions. Open-ended timeframes. Novelty (or uniqueness). Competing value systems and objectives. Open-ended timeframes are an essential characteristic of wicked problems that must be addressed both by anticipation and adaptation.
Sharma (2020)	Rittel and Webber have articulated that the most significant wicked characteristic is that it cannot be precisely formulated. Meanwhile, Rittel and Webber note that only after the ‘is’ and the ‘ought to be’ conditions are recognized by policymakers can a relative solution to the problem be derived; ‘to find the problem is thus the same thing as finding the solution, the problem can’t be defined until the solution has been found’ Yet, the wicked complexity of social problems may not be apparent throughout the distinct phases of the traditional policy planning approach, which consists of first, understanding the problem, then gathering information to conduct an analysis on it, to finally forming definitive solutions to it.



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Signal et al (2013)	Wicked problems are characterized as policy issues that: are continually evolving; have many causal levels; have no single solution that applies in all circumstances. Finally, solutions can only be classified as better or worse, rather than right or wrong.
Stahl and Cimorelli (2013)	The paper refers to the following characteristics of wicked problems: "Multidimensional context - Cannot be easily defined so that all stakeholders agree on the problem. Multiple stakeholder perspectives - Can be defined in many ways, including spatial and temporal scales; require complex judgment about the level of abstraction at which to define the problem. Reflects nonoptimality - Have no clear stopping rules. Trade-offs among conflicting goals - Have better or worse conditions, not right and wrong ones Subjective, values-driven - Have no objective measure of success. Learning-driven - Require iteration—every trial counts. Stakeholder-driven learning - Have no given alternative solutions—these must be discovered. Multidimensional legitimacy - Often have strong moral, political, or professional dimensions".
Sun and Yang, (2016)	The paper refers to Rittel and Weber’s (1973) work to list the attributed characteristics of wicked problems.
Tatham, P, and Houghton, L (2011)	The paper refers to Rittel and Weber’s (1973) work to list the attributed characteristics of wicked problems. Finally, the paper points out that when stakeholders deal with wicked problem understand the problem only when the solution has been developed. Making them difficult to solve and comprehend.
Termeer et al (2016)	The characteristics of wicked problems in the paper can be summarize as followed: Reflexivity - Reflexivity addresses the wicked problem feature of problems being hard to pin down because people disagree about the formulation of the problem (Rittel & Webber, 1973, p. 161). Resilience - Resilience addresses the inherent uncertainties and interconnectivities surrounding wicked problems, as “every wicked problem can be considered to be a symptom of another problem” (Rittel & Webber, 1973, p.65). Responsiveness - Responsiveness addresses the feature of wicked problems having no stopping rule. Revitalization - Revitalization addresses the feature that wicked problems can be overwhelming (Weber & Khademan, 2008) and “frustrating as hell” (Roberts, 2000). In such stressful situations, actors may revert to more defensive strategies (Termeer & Kessener, 2007) that run the risk of becoming part of the problem (Rittel & Webber, 1973). Rescaling - Rescaling addresses the wicked problem feature of interconnectivity across scales and the lack of “a natural level” (Rittel & Webber, 1973, p. 165).
Thompson and Whyte (2012)	The paper refers to Rittel and Weber’s (1973) work to list the attributed characteristics of wicked problems.



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van Bueren et al (2014)	The paper refers to Rittel and Weber's (1973) work to list the attributed characteristics of wicked problems.
Wade et al(2020)	Wicked problems don't have definitive formulation and clear-cut solutions. Moreover, their complexity demands new modes of inquiry in order to manage them.
Weaver et al (2022)	Some characteristics of wicked problems are the unclear definition, and the various stakeholders that are involved each with their own values, often conflicting with each other. Moreover, they lack clarity on the problem's parameters or solutions. Also, wicked problems are characterized by complexity of elements, subsystems and interdependencies, also by the uncertainty around associated risks and consequences of actions (and non-action). Finally, wicked problems and their stakeholders present divergence in viewpoints, values, and strategic goals.
Woodford et al(2016)	Wicked problems are complex problems where the cause-and-effect relationships between components are unordered and thus have solutions that are not obvious. Solving these problems require collaboration among stakeholders to determine appropriate actions. Finally, the paper refers to Concklin's (2005) criteria for wickedness problems, which adds to the characteristics of wicked problems as mentioned above.
Zellner and Campbell (2015)	The paper refers to Rittel and Weber's (1973) work to list the characteristics of wicked problems.
Zia, A (2018)	The analysis of Rittel and Webber was prescient, for today's decision scientists readily admit that correct problem formulation is the most difficult and least understood aspect of public decision making - Various decision theorists have tackled the problem of problem formulation from three broad perspectives. First, Keeney (1988, 1992, 1996) emphasized value-focused problem formulation. Second, Simon (1955, 1982), von Neumann and Morgenstern (1944) emphasized a focus on alternatives in problem formulation. Finally, many decision scientists focused on the process of deliberation involved in problem formulation



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<p>Zijp et al (2016)</p>	<p>The paper refers to Rittel and Webber’s (1973) and Stahl and Cimorelli (2013) work to list the characteristics of wicked problems. Stahl And Cimorelli (2013) mention that wicked problems have:- Multidimensional context. The problem context cannot be easily defined and agreed on by all stakeholders. - Multiple stakeholder perspectives. The problem can be defined in many ways, including variation in the spatial and temporal scales. The problem requires complex judgments about the level of abstraction at which to define the problem. - Reflects non-optimality. There are no clear rules to finalize a multi-metric assessment. There is no single optimum. - Trade-offs among conflicting goals. There are better or worse conditions, not right or wrong ones. - Subjective, values-driven. There is no objective measure of success. - Learning-driven. Solving the problem requires iteration – every trial counts. - Stakeholder-driven learning. There are no given alternative solutions – these must be discovered. - Multidimensional legitimacy. The problem often has strong moral, political, or professional dimensions - To cover the incremental learning aspect of dealing with wicked problems, characteristics of adaptive management approaches (e.g. Linkov et al. (2006); Kingsford et al. (2011) and Robinson and Levy (2011)) were incorporated in the SfSA framework.</p>
<p>Frame (2007)</p>	<p>Wicked problems are often a symptom of deeper problems, they are also unique opportunities that cannot easily be reversed. Wicked problems don not have clear, predefined solutions nor alternative solutions. Moreover, they are characterized by contradictory certitudes and contain redistributive implications for entrenched interests. Finally, they are persistent and insoluble.</p>
<p>Gilligan and Vandenberg (2020)</p>	<p>Natural science and engineering can very accurately describe the behavior of physical systems under controlled conditions but cannot answer normative and political questions regarding what goals a policy ought to aim for; and second, while science can describe the behavior of a system, if the system is complex, it may not be feasible to predict its future behavior; contained an irreducibly normative or political component; 1. There is no definite formulation of the problem, so different stakeholders have different criteria for what the goals of a response should be. 2. There is no stopping rule. 3. Solutions are not true or false but better or worse. 4. There is no immediate or long-term test for evaluating solutions. 5. Any possible response to the problem is a “one-shot operation” that may fundamentally and irreversibly change the nature of the problem. 6. There is not a manageable set of possible responses to compare and choose from; the domain of possible responses is large and possibly infinite. 7. Every wicked problem is essentially unique, so there is no opportunity to learn from experience with other problems. 8. Every wicked problem may be the symptom of another problem, so responses are doomed to managing symptoms rather than root causes. 9. There are multiple competing explanations for what causes any wicked problem. 10. The political context is sufficiently fraught such that the public will not tolerate mistakes or failures by the planner.²⁸</p>

Gleeson et al (2016)	Wicked problems are complex and difficult to solve. They require technical skills and knowledge but in many cases are not sufficient.
Goel (2019)	WPs involve multiple stakeholders with diverging values and cannot be reduced to measurable and objective goals. Ten characteristics of WPs provided by Rittel and Webber (1973)
Gold et al (2017)	Wicked problems are complex and multi-dimensional in nature. Moreover, wicked problems seem to have “no definitive formulation and no conclusively ‘best’ solutions”. Finally, the various economic, social, and ecological problems seemed to constantly shift them.
Goldsmith (1969)	Wicked problems are tricky to solve because many try to solve them only by addressing the manageable aspect of them, ignoring the others. This was of solving it, results in more problems.
Gutierrez (2020)	Wicked problems are difficult to solve.
Hargrove and Heyman (2020)	In the context of water resources, wicked problems can be characterized by the following statements: (1) they involve multiple definitions as to their nature; (2) they are the object of multiple and conflicting criteria for defining solutions; (3) the “solution” to one interested party is a “problem” for others; and (4) there are no obvious stopping rules that define when enough has been accomplished. Wicked problems are difficult to explain, unique and impossible to plainly define. This happens because they are often the result of other indefinable problems and have no one true solution. Finally , wicked problems cannot be solved, but only managed
Head (2014)	The ‘wicked’ and complex features of climate change response policy have been deliberately inflamed for partisan reasons to undermine the possibility of consensus formation. Wicked problems are characterized by complex and interconnected issues where past experience provides only incomplete guidance about future changes. Wicked Problems seem intractable because they generate uncertainty. Wicked problems such as climate change adaptation are managed, debated, and constantly renegotiated rather than solved. Ten characteristics of wicked problems were suggested (Rittel and Weber (1973).
Bruggemann et al (2012)	Wicked problems, such as ecological conditions, are both difficult to fully understand and solve because of the inherent social ecological complexity and constant change. These types of problems are value driven, complex, multi-scale, persistent or reoccurring, and challenging to solve; not just local but embedded and linked in broader social, economic, environmental, and policy issues and associated values, which can create a set of nested problems within problems.
Hoffman (2020)	Wicked problems have a insidious and malevolent nature that impact significantly larger global populations and have proven to be resistant to any type of a single solution.



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Holgate and Stokes-Lampard (2017)	Public health crisis
Hughes et al (2013)	Wicked problems and their solution are characterized by inadequate governance, missing institutions, and a shortage of time before the problem becomes even harder to address. Finally, wicked problems, have a narrowing window of opportunity to prevent an irreversible consequence.
Hukkinen et al (2022)	Wicked Problems are characterized by urgency, path-dependence, complexity, uncertainty, value conflicts, indeterminate solutions, and high demand for expertise, often of inter-disciplinary nature Socio-ecological disruptions, should they become chronic, threaten to normalize authoritarian powers initially intended for exceptional situations alone. Sustainability and democracy face three challenges (Barry, 2008; Heidenreich, 2018): 1) securing a requisite level of expertise in sustainability decisions without defaulting into meritocracy; 2) securing citizens' participation and deliberation without losing the effectiveness of organized decision making; and 3) reconciling the need for urgent strategic decisions with the slow pace and short time span of decisions in today's democracies.
Inghelbrecht et al (2014)	Wicked problems cannot be solved, but only managed. Wicked problems, like complex problems, tend to be non-linear and solutions to address them easily generate other problems. These types of problems are not solvable by a reductionist or sequential approach. However, wicked problems are a particular type of complex problem as they have no 'closure' - because there is no definite problem statement and thus no definite solution. Every attempt to address a wicked problem is in fact a 'one-shot operation', as every attempt is likely to cause (unintended) consequences which may spawn new wicked problems. Wicked problems are difficult to define clearly. They have no clear problem statement, especially because the nature and the extent of the problem are not clear. Wicked problems have multilevel actor involvement with many interdependencies. There are multiple conflicting goals at stake that all emphasize different risks. Wicked problems are often multi-causal, meaning that different stakeholders put forward different causes to define the problem. Wicked problems have no clear solution. Effective solutions require coordinated action by a range of stakeholders, and they involve changes at all the levels of society. They are not the responsibility of a single organization. Attempts to address a wicked problem often led to unforeseen consequences. Solutions for tackling a wicked problem often create unforeseen side effects and introduce new problems. Wicked problems are often unstable, as the available evidence and constraints to fully understand the problem are evolving by themselves - which makes the problem even harder to solve.
Jung et al (2022)	Wicked problems seem to be intractable and messy. They involve many stakeholders with high divergence.

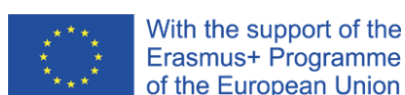
Kämpf and Haley (2014)	Arctic offshore development fits the definition of a wicked problem in three characteristic respects: (1) uniqueness, social and technical complexity, (2) changing requirements and constraints to solutions and (3) multiple stakeholders with different views and values.
Kirschke et al (2018)	Wicked problems present severe complexity. Moreover, the information associated with them is limited and uncertain.
Kirschke et al (2022)	Specific dimensions of wicked problems: inputs, activities, outputs, and outcomes of management processes each relate to goal conflicts, system complexity, and uncertainty
FitzGibbon and Mensah (2012)	Wicked Problems present linkages to other issues evolving in a dynamic social context, and tackling one often leads to unintended consequences of generating new sets of wicked problems. Moreover, they seem to have no stopping rule. Every wicked problem is essentially unique and often is a symptom of another problem.

Source: Authors' compilation

With regards to factors (i.e. policies, regulation, enabling conditions, etc.) that relate to wicked problems, the synthesis results are shown in in Table 6. The state-of-the-art literature review identifies arguments in favor of the importance of bridging different stakeholders, i.e., bridging government agencies, engage partners outside of government in collaborative efforts, and foster different ways of “doing business” (Allen, 2013). Policies and regulations evolve from solving individual problems to solving system problems (Carron and Serrell, 2009).

The role of education systems and the development of adequate skills is also identified as a factor impacting on wicked problems emergence and solution provision (Table 6). Cross and Congreve (2021) argue that education has an important role to play in developing appropriate skills that will enable young people to contribute meaningfully to the societal challenges of wicked problems. Political systems and organizational structures (authoritarian or liberal democracies, unitary or federation, levels of government) are also identified to be factors linked to wicked problems (de Oliveira et al., 2021).

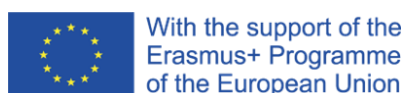
Multiple stakeholders take place in decision making and the process of managing the problem. This significantly influences the problem as it becomes even more complex, while the different stakeholders hold their own view about the problem and the possible approach to solve it (Kreuter et al. (2004), Pederneiras et al. (2022), Mikhailovich (2009) & van Bueren et al. (2014). Some papers mention that a holistic view of the issue, and subsequently a holistic approach, may contribute significantly in the process of managing the problem (Patterson (2016), Lehtonen et al. (2018)). Some works refer to the knowledge about the problem and the flow of it as an important factor that affects wicked problems (Markowska et al. (2020), van Bueren et al. (2014), & Guimarães et al. (2018))



Socio-economic and cultural sustainability, and long-term paradigm shift also are identified as factors impacting on wicked problems emergence and solution ability (Dronova, 2019). Other works touch upon the importance of demography, globalization, business environment, and technological transformations to wicked problems (Salvia et al. (2021), Seager et al. (2012), & Frame (2007) Rae & Wong (2012)& Reinecke & Ansari (2016) .

Table 6 Characteristics of wicked problems as identified in the collected references for the SCORE project

Source	Factors
Alexander et al (2022)	Complex socially embedded factors.
Allen (2013)	Approaches that bridge government agencies, engage partners outside of government in collaborative efforts, and seek to foster different ways of “doing business” among groups and individuals that can harness the respective strengths of public and private sector organizations and align resources towards systemic solutions.
Bouma and McBratney (2013)	Some suggestions to manage the wicked problem are: Effective policies and the understanding of the complexity of the wicked problem. Scientists are used to examine and solve simple linear problems; wicked problems require a different approach to effectively solve than well-defined problems. Wicked problems require a different approach and an open mind to effectively manage them.
Caron and Serrell (2009)	Engaging the public sphere (to help build a community’s capacity to address the wicked problem), forming an academic–community partnership and (2) developing a place-specific strategy grounded in the cultural–experiential model of risk.
Chan (2016)	Appropriate framing of the problem may be helpful in managing a wicked problem. Also bias that are associated with it may influence the process of solving it.
Chester and Allenby (2019)	Wicked problems can be managed, not solved, a shared understanding of the complexity is helpful. Moreover, an open mindset which focuses on “what can be” over “what is”.
Cross and Congreve (2021)	Education systems have an important role to play in developing appropriate skills that will enable young people to contribute meaningfully to the societal challenges of wicked problems.
de Oliveira et al (2021)	Firstly, the form of the state (unitary or federation, and levels of government) and the political system (authoritarian or liberal democracies) in place determine the type of intergovernmental relations which exist in a particular order of government.
Dewulf and Termeer (2015)	The paper suggests governmental policies as a way to manage the wicked problem.
Dronova (2019)	Some suggestion to manage the problem are enhancing the policies that promote cultural sustainability, engaging economic and policy instrument to implement policies and longer-term paradigm shift.



Duprey et al (2017)	Coordinated efforts from both the government and scientists to address the research priorities and knowledge gaps.
Dwyer and Gill (2019)	Some suggestions to manage the wicked problem are to implement policies from government instrument and an effort to a shift the collective mindset in order to become more open.
Parrott (2017)	Knowing the system well is key to gaining the trust and confidence of stakeholders in the ability of the modeler and the entire research team to contribute meaningfully to the issue. Identifying the most important stakeholders in the study area (those who are most knowledgeable and/or who have the most influence in the community or relative to the issue at stake) is a crucial next step. In some communities, there may already exist some level of coordination amongst stakeholders to solve the problem at hand. Arriving at an acceptable solution requires bringing together the network of stakeholders in a neutral space where diverse viewpoints can be freely expressed. Arriving at an acceptable solution requires bringing together the network of stakeholders in a neutral space where diverse viewpoints can be freely expressed. Arriving at an acceptable solution requires bringing together the network of stakeholders in a neutral space where diverse viewpoints can be freely expressed. When participating with stakeholders in the search for solutions to a wicked problem, the modeler's key role should be to provide information that can be beneficial to informing the decision-making process.
Patterson (2016)	Key analytical themes characterizing how local responses to NPS pollution arise in practice are inductively analyzed to explore and compare three local catchment cases. An inductive approach is required because the scope and boundaries of wicked problems are by definition complex, uncertain, and ambiguous (Head 2008). These analytical themes are: 1. Contextual factors (human–biophysical setting, drivers of change, management arrangements). 2. Forms of collective action (types, mechanisms, and modes of collective action). 3. Outcomes and adaptation needs (environmental, social, institutional).
Patterson et al (2015)	A particular issue within catchments that exemplifies the challenge of practical action is the wicked problem of managing nonpoint source (NPS).
Pederneiras et al (2022)	In a wicked problem, the more different stakeholders are involved, the more complex it becomes socially.
Kreuter et al (2004)	1. Disagreement about problem definition. 2. Involvement of multiple stakeholders. 3. Lack of a “stopping rule. 4. Unique nature of wicked problems
Lehtonen et al (2018)	Ecological intelligence has an important role on the wicked problem. Moreover, a holistic awareness of interconnectedness and systems thinking is suggested to manage the problem.



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Levin et al (2012)	Understanding how “path-dependent” policy interventions might be generated to affect future policy requirements and, ultimately, behavior.
Lidskog et al (2018)	The problem is perceived differently by different stakeholders also, the problem occurs in different ways according to the contexts and the situations that generate new sets of challenges.
Liou and Rao-Nicholson (2021)	Market failure exists when firms do not supply quality goods that people want or can afford. Lacking responsibility to eliminate negative externalities. Insufficient creation of positive externalities. Systemic challenges to form a coalition of multiple societal actors.
Lundström et al(2016)	Stakeholders subjectively define the best solutions. No one has the power to decide an answer is right or wrong, because solutions will usually be based on value judgments, such as political or ideological preferences.
Mampuys (2022)	Scientific, societal, and legal factors should be taken into consideration when managing wicked problems while the politics have an explicit role in decision-making.
Markowska et al (2020)	The aspects that influence the quality of the process are: 1. the flows of information and the control over these flows, 2. the evolution of the planned involvement of participants over time, 3. managing the participants of the process (determining interaction).
Maron et al (2016)	Supporters and opponents of offsets broadly agree on the suite of technical and governance challenges.
Marshall and Sterett (2019)	The changing climate significantly impact the problem, while there is a raising need for adaptation to manage it.
Mason et al (2018)	Distributed decision-making, Creative practice, Diverse expertise, Predictive management, Pattern-based evidence, Outcome-focused, Trade-offs in objectives, Sharing failures
McGrath and McGonagle (2016)	Wicked problems cannot be classified as right or wrong only better or worse (Grint, 2010; Rittel & Webber, 1973). The growth in both the number and diversity of wicked problems can be seen as an inevitable consequence of increasingly pluralistic societies where what satisfies one may be abhorrent to another, and what comprises a problem solution for one group is a problem generator for another (Rittel & Webber, 1973).
Mikhailovich (2009)	The factors that play an important role on the wicked problem are multiple and often have competing discourses which makes the problem even more complex.
Muller (2016)	It has been demonstrated that interactions and feedbacks among users, and between users and landscapes significantly ease the process to manage the problem.



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Munneke et al (2007)	Arguing about the wicked problem does not lead to more understanding of the issue. the relationships between argumentation and collaborative learning processes are neither simple nor predictable and thorough consideration of task characteristics and learning tools is necessary to provoke and support argumentation in the context of collaborative learning. This
Murphy (2012)	Consequences of unsustainable practices in both time and in space. Scale impasse. Urgency dilemma.
Pyykkoe et al (2021)	The factor that influences the wicked problem according to the paper are the climate change and the main suggestion is the promotion of sustainable development.
Rae and Wong (2012)	Urban vision. Additional commercial floorspace developed. Additional new homes completed. Interregional and intraregional transport infrastructure capacity and connections. Change of working age people in employment (%).Change in level of commuting independence (%).Loss of protected land (SSSI, ESA, etc.).Change in carbon footprint (%).Change in commuting mode (public transport, %).Change in total resident population (%).Change in population who live in the 10% most deprived areas (%).Change in derelict land stock (%).Percentage of appeals allowed against refusal of planning permission. Change in total number of VAT registered businesses (%). Change in job density. Residents surveyed satisfied with their neighborhood as a place to live (%). Change in area of parks and green spaces per 1000 head of population (%). Congestion: average journey time per mile during morning peak Percentage of residents surveyed finding it easy to access key local services. Percentage of households that can afford to purchase the average first time buyer's property in the area. Supply-side over-qualification index.
Reinecke and Ansari (2016)	Some factors that influence the wicked problem are: Humanitarian crisis, the state's fragility and failure, human rights abuse, corporate business's irresponsibility. However, focusing on chains of influence in the global supply chain, NGOs argued that 'actors who have the highest potential for influence are those who have the buying power' (NGO7).
Riley (2017)	Some factors that influence the wicked problem are social justice, Race, Sex, Gender, Violence, nationalism and shifts in economic practices. Also changes in science and technology may positively impact the problem.
Sahin et al (2020)	Reinforcing loops will lead to the creation of an exponential growth or decay in the system, whereas balancing loops will balance a system until an equilibrium has been achieved. The dominance of reinforcing loops in this system indicates that there are more sources of growth, erosion, and failure which decision makers need to address and minimize. Misinformation and confirmation bias.
Salvia et al (2021)	Some factors that influence the wicked problem are social norms, political influences, financial availability, infrastructural and technological implementation.



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Seager et al (2012)	Ultimately, technological progress under the business-as usual paradigm could exacerbate wicked problems, rather than contribute to their resolution.
Sharp et al (2021)	Limited factors as the paper treats wicked problems indirectly, more focused on teaching and learning methods: (1) Students engage better and learn more effectively when they are active participants, and agents, of their own learning (and peer-teaching). (2) Learning environments need to be sites of inclusive and equitable learning for effective teaching to take place. (3) In teaching wicked problems, it is often better to start slow, simple, and local, and then build in complexity and scale
Signal et al (2013)	The drivers of obesity, nutrition and physical activity are recognized to be multiple, diverse, and complex (Hammond, 2009), including both personal behaviors and aspects of the physical, economic, socio-cultural, and political environments that shape them (Egger and Swinburn, 1997; Shiell, 2008; Vandebroek et al., 2008; Kopelman, 2010).The ANGELO Framework is a commonly cited tool used to analyze influences on obesity and opportunities for action. ANGELO enables a comprehensive analysis of the obesity environment by classifying the environment into four types: physical (what is available), economic (costs), socio-cultural (attitudes and beliefs) and political (the rules) (Swinburn et al., 1999). This research identifies the need for action to influence a range of physical, economic, socio-cultural, and political factors within those social systems by many different government and community actors.
Stahl and Cimorelli (2013)	Tame problem strategies do not work well with wicked problems because wicked problems cannot be more clearly defined through simplification. Vermeij et al. (2006) and other experts in wicked problem analyses refer to the strategies to solve wicked problems as clumsy solutions. Elegant solutions optimize around a single definition of the problem through a process that silences voices that represent other solutions (and other definitions of the problem). In contrast, clumsy solutions recognize the “essential contestation” that makes every solution and definition of the problem an essential part of the problem (Soderbaum 2006; Vermeij et al. 2006).
Stahl (2014)	They are multi-criteria because describing them require the consideration of many factors including those that are environmental (e.g., impacts on air or water quality or human health), economic (e.g., costs of implementation), and social (e.g., impacts on community integrity and identity). Environmental problems are also multi-objective because we seek to attain or maintain environmental goals (e.g., clean air) while balancing the attainment of economic and social goals (e.g., plentiful jobs, robust communities).



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<p>Sun and Yang, (2016)</p>	<p>The debate on climate change is inherently political. It takes place in the political arena, is shaped by networks of power, and it is impacted by political maneuverings. These include strategic inconsistency, which are contradictory rules created in the hope of undermining other rules in other agreements; forum-shopping—the selection of an international venue most beneficial to their own policy; and regime shifting, where loyalties are shifted to parallel regimes that will acquiesce in their policy priorities [18]. It can be argued, therefore, that such complexity makes it more difficult to understand causality. Social mess and fragmentation are constituents of super-wicked problems and pose, perhaps, the greatest challenges as to how human beings learn and how they process information. It may be the case that these dynamic, fluidly interacting aspects of the wicked problem of climate change are interfering with stakeholders’ ability to think through the various interrelated components of the climate change issue, thereby preventing them from addressing the problem effectively.</p>
<p>Tatham, P, and Houghton, L (2011)</p>	<p>The substantive dimension relates to the gaps and conflicts in one’s understanding of the knowledge base surrounding the problem which, in turn, results in the absence of a clear and/or agreed understanding of the nature of the problem itself. Indeed, in many senses, this dimension reflects the essence of a wicked problem The strategic element reflects the numbers individuals and organizations involved in the problem and their associated perspectives and preferences, and the inevitable difficulty associated with the achievement of a common understanding of the problem. As will be discussed later in this paper, this aspect of the problem presents a particular challenge to the humanitarian logistician in view of the plethora of organizations (and, hence, supply networks) that respond to many disasters. Finally, the institutional aspect of the problem recognizes that the actors belong to many different organizations and, hence, there is a multiplicity of decision-making processes which may be uncoordinated or incompatible. This tripartite view of the attributes of wicked problems has been similarly adopted by van Bueren et al (2003), albeit they refer to cognitive uncertainty instead of substantive.</p>
<p>Termeer et al (2016)</p>	<p>To analyze these specific challenges of wicked problems, we developed the theoretical framework of the Five R Governance Capabilities (Termeer, Dewulf, Breeman, & Stiller, 2015; Termeer & Dewulf, 2014).</p>
<p>van Bueren et al (2014)</p>	<p>In moderately structured problems, science can act as analyst of problems, advocate problem perceptions and solutions, or act as mediator, by showing consequences of alternative decisions for different stakeholders. In ill-structured problems, science can merely contribute to problem solving by identifying the various problem definitions and possible solutions but cannot deliver ultimate answers [44]. - Wicked, contested problems thus typically are problems that require interaction and negotiation between actors involved to come to a mutual understanding of the nature of the problem and how the problem could be solved [47,48]. - multiple levels thus also provide multiple venues for addressing the multiple dimensions of sustainability, for approaching the sustainability from different frames [50] - organized irresponsibility in his work on the risk society -</p>



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	- The first concerns governance aiming to reduce risk and uncertainty, and usually is blind to trade-offs and resulting risks. A second approach to governing risk, trade-offs and the resulting uncertainty and ambiguity is by acknowledging these characteristics, or even exploit them. Strategies for addressing wicked problems tend to take the institutional constellation of interdependent relationships and resource dependencies between stakeholders as given, and aim to construct a mutual understanding of the problem that can guide joint effort to cope with wicked problems.
Wade et al(2020)	The paper suggests deep integration across fields and transcendence of disciplinary boundaries (Harris et al., 2010; Irwin et al., 2018).
Weaver et al (2022)	Effective engagement is impeded by the classic wicked problem parameters of complexity, uncertainty and perspective divergence - Transformative governance is therefore gaining traction for its potential to achieve resilience in complex systems against climate change and affiliated wicked problems. - A major impediment, however, is the popularity of ‘hard’ transformative governance that demands radical and immediate change in concert with the perceived urgency of the attendant crises. Our results, in contrast, demonstrate the salience and feasibility of ‘soft’ transformative governance that privileges evolutionary change over impractical revolutionary change to achieve needed reform through the accumulation of innovative incremental changes. - Minimally, awareness that a particular problem is wicked gives clarity as to why conventional modes of problem solving and decision- making have failed, are likely to fail, or induce unanticipated consequences, and therefore why new ways of thinking and doing are merited. Roberts (2000) contributes to the discourse by proposing “authoritative”, “competitive” and “collaborative” approaches to wicked problem resolution, while Daviter (2017) focuses on taming or coping in con- tending that “We do not so much solve wicked problems as make progress towards improving them or towards better managing them” (p. 400).
Wiering et al (2020)	In conclusion, dealing with a serious wicked problem, such as diffuse pollution and nutrients with a discretionary and experimentalist governance approach [29] might produce informed, nuanced and tailor-made programs of measures, perhaps combined with all kinds of voluntary and subsidized measures, which could work.
Woodford et al(2016)	Where the problem becomes wicked (as opposed to being complicated in terms of resource allocation) is if the management goal is not eradication per se, but island restoration.

<p>Zellner and Campbell (2015)</p>	<p>Approaching wicked problems as complex requires a way of thinking that is closer to playing than to optimizing or forecasting. By “play” we do not mean frivolous, non-essential behaviour. Games are work; they are the productive, open-ended, and interactive exploration of co-evolving processes. Games encourage participants to tackle challenging problems in diverse, tangible, creative ways. Playing allows for learning and recovery from failure, mid-course intervention, and innovation necessary to transparently address the surprises inherent in complexity (Kapp, 2012; McGonigal, 2011). Games are “the voluntary attempt to overcome unnecessary obstacles” (Suits, 1978, pp. 54–5) – and one can cautiously substitute the term “wicked problems” here for “unnecessary obstacles.” Our field has yet to fully develop the strategies to train practitioners to use these tools creatively.</p>
<p>Zia, A (2018)</p>	<p>Through these research projects, we discovered that many wicked problems surrounding environmental management persist in the field settings due to the stakeholder power asymmetries, conflicting values, politics of scale across different space time horizons and institutional inertia. - Repeatedly, Norton argued that conflicting values lie at the heart of wicked problem formulation, making goal-finding “an extraordinarily obstinate task.” Norton (2005) laid out following three important characteristics of “adaptive management” to resolve wicked environmental problems: 1. Experimentalism: adaptive managers respond to uncertainty by undertaking reversible actions and studying outcomes to reduce uncertainty at the next decision point. 2. Multi-Scalar Modeling: adaptive managers model environmental problems within multi-scaled (“hierarchical”) space-time systems. 3. Place-Orientation: adaptive managers address environmental problems from a “place” which means problems are embedded in a local context of natural systems but also of political forces. - I propose that institutional designs and governance processes operating at different levels of the space-time hierarchy—ranging from a person’s ambit to their community, city, state, country and planetary scales—must also be examined and addressed for adaptive management in social ecological systems.</p>
<p>Zijp et al (2016)</p>	<p>- Authoritative. A selection of people is asked to solve the problem; they get the necessary means. Advantage: reducing # of stakeholders reduces process complexity as (some) competing points of view are eliminated from the start. Disadvantage: relevant perspectives on problem and solutions may lack.</p>
<p>Zywert and Quilley (2018)</p>	<p>- Relationships between individual society, people and landscape, formal informal market,</p>



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<p>Frame (2007)</p>	<p>. Resource availability: in the global context, New Zealand has good current and future access to water and renewable energy though there are issues concerning demand and supply. However, most supplies are outside the Auckland Region and therefore create a large ecological footprint for the region (McDonald and Patterson, 2003); . Demographics: the ageing and more ethnically diverse New Zealand population may become under pressure to accept a much higher number of immigrants with climate change and resource scarcity; . Worldviews: Auckland's ethnically diverse population is currently strongly dependent on international trade and tourism; . Globalization: Auckland is New Zealand's largest business center with many local and internationally owned companies; . Technological transformations: Auckland's ability to innovate and embrace new technologies is critical to its future success. Aquaculture-led factors contributing to the process of losing commons in Chilika are: large-scale, individually owned aquaculture operations; encroachment of customary fishery commons; loss of commons rights (access and entitlements); breakdown of commons institutions; policy changes; caste politics and resource conflicts; ecological disturbances; change in fishing practices. In Sri Lanka, aquaculture related factors contributing to making commons are: coordinating discharge; built-in incentive for stewardship; multi-level commons institutions; collective decision-making; bottom-up management approach; mixed commons regime; and small-scale operations.</p>
<p>Galappaththi and Nayak (2017)</p>	<p>Nayak and Berkes (2011) capture these two viewpoints on shrimp aquaculture's contribution to ecosystem health and human wellbeing as processes of commonization and decommissionisation. "Commonization is understood as a process through which a resource gets converted into a jointly used resource under commons institutions that deal with excludability and subtractability, and 'decommissionisation' refers to a process through which a jointly used resource under commons institutions loses these essential characteristics" (Nayak and Berkes 2011: 132). Decommissionisation helps understand the adverse effects of aquaculture as a driver that eventually contributes to the decline of customary capture fishery commons with immense social, economic, political, and ecological consequences. Inversely, the concept of commonisation is a lens to examine conditions in which aquaculture positively contributes to human wellbeing without causing significant harmful effects on the environment. This paper aims to address this gap by examining the two faces of aquaculture: its decommissioning and commonising roles. We use two cases from South Asia (Sri Lanka and India) which offer evidence that shrimp aquaculture activities can potentially contribute to either a process of commonisation or decommissionisation depending on the context and the influences of cross-scale drivers. In the case of the Bay of Bengal coast of India, we discuss an example of aquaculture-led privatisation, i.e., de facto control of customary capture fishery commons through their systematic encroachment in Chilika Lagoon for more than three decades to explain how it caused decommissionisation. Using the case of Northwestern Sri Lanka, we discuss collective action (Ostrom, 2014) initiatives around small-scale shrimp aquaculture to consider aquaculture's role in creating the</p>



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ground for commonisation that promises to reverse the process of decommissionisation due to previously undertaken industrial shrimp aquaculture. We argue that aquaculture can strengthen the existing collective action to adapt to the changes in lagoon system or it can enable new forms of collective action fostering learning and innovation. Collective action is an effective means of confronting commons problems. Large-scale aquaculture makes high returns on investment during the first few years, with the expectation that the shrimp farmers abandon their farming areas, move to new areas, and set up farms rather than establish sustainable practices and remain in one area. In contrast, small-scale community-based aquaculture farmers do not have the option of relocating. They cannot afford to act in unsustainable ways, as they are accountable to the community in which they live and do not have huge investment capacity (Galappaththi and Berkes, 2014, 2015a). Enclosure and privatization in aquaculture are two of the main factors causing decommissionisation. Globally, there are widespread examples of aquaculture contributing to the breakdown of customary commons institutions that oversaw fishery management. Aquaculture can cause both commonisation and decommissionisation; however, the scale at which their outcomes and impacts are felt is significant. While aquaculture's decommissioning effects are undesirable from the ecosystem and human wellbeing perspective (Nayak and Berkes, 2010, Nayak and Berkes, 2011), positive outcomes associated with a process of aquaculture-led commonisation are desirable (Galappaththi and Berkes, 2015a). Commonisation can occur when the process of farmers cooperates with each other by working collaboratively and collectively using commons institutions instead of competing, to solve commons problems. Our Sri Lankan case study provides an example of commonisation, i.e., how aquaculture farmers regulate themselves under a commons arrangement (e.g., collective action, and institutional and rule systems) to overcome challenges such as diseases, water distribution, pollution, conflict resolution and external linkages including policy and market. However, our Chilika case study depicts a process of decommissionisation, i.e., how aquaculture triggers the disintegration of existing institutional, economic, social and cultural arrangements surrounding customary fishery commons. Here, aquaculture-led decommissionisation took shape through the synergistic impacts of multiple factors such as global market trends, the global shrimp price, the creation of protected (restricted-access) areas, a change in government policy, a culture of encroachment, the erosion of fisher institutions and a change in fishing practices (Nayak and Berkes, 2010, 2011). The commonisation process in Northwestern Sri Lanka is driven by multiple factors (Table 3). The zonal crop calendar system coordinates the discharge of pond wastewater. This mechanism is coordinated by the shrimp farmers' associations together with government institutions. The multi-level institutional structure of shrimp farmers' associations is collaboratively working with the government in decision making related to shrimp aquaculture management. A bottom-up management approach with government support is the distinguishing functional feature of this integrated institutional structure. A built-in financial and non-financial incentive



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	<p>for membership is a motivational driver for stewardship. Shrimp farmers develop this multi-level commons management system in cooperation with the government to effectively manage aquaculture CPR — an interconnected lagoon body of water. Sri Lankan small-scale shrimp aquaculture is run by the mixed commons regimes of private, communal and government (Galappaththi and Berkes, 2015a). An amalgamation of these factors makes a unique resource management system: aquaculture commons. In reverse, the Chilika case offers insights into decommissioning led by a series of factors associated with shrimp aquaculture (Table 4). ... As a direct consequence of shrimp aquaculture-led encroachments, the lagoon witnessed an extensive loss of fishers' access and entitlement rights (see Table 1 above). There was a breakdown of multi-level fishery institutions (e.g., village cooperatives, the fisher federation, the regional fish marketing federation) and collective decision-making arrangements. Influenced by rampant shrimp aquaculture, these changes became direct drivers of decommissioning. State policy changes in favour of shrimp aquaculture, caste politics (e.g., fishers and non-fishers based on their position in the Hindu caste hierarchy) and growing resource conflicts pushed the ongoing processes of decommissioning. This has resulted in the occupational displacement of customary fishers and out-migration by more than one-third adult fishers. On the ecological front, shrimp aquaculture had a deleterious effect on the biophysical, hydrological and geochemical processes of the lagoon, not only challenging its long-term sustainability but also jeopardizing its status as a commons (e.g., a commons does not exist if there is no physical resource present). Thus, a combination of these factors provides evidence of the possibility of shrimp aquaculture-led decommissioning. Collaboration, cooperation, and collective action are essential elements of successful commons management (Poteete et al., 2010). However, collaboration over competition, and cooperation over contestation, are not easy to achieve without engaging in processes of negotiation, partnership, relationship and institutional linkages across multiple levels. Linked to global trade and international industrialized capitalism through resource extraction. Linked to the contemporary global economy.</p>
Garcia et al (2016)	Investments in creating expertise in technologies; establishing a manufacturing base and associated supply chains; and training a skilled workforce to produce, distribute, install, operate, and maintain the new technologies.
Gilligan and Vandenberg (2020)	Public sector experience and theoretical knowledge; capacity to analyze and manage the wicked problems 'environmental factors (the 'givens', outside the control of the workers), and factors in the policy processes (generally, those where the worker had some influence but not command-and-control authority) dominated.
Gleeson et al (2016)	WPs are multi-levelled and people tend to tackle them with solutions targeted at lower level. Public has low tolerance to failed solutions/experiments of WPs thus denying a second chance to problem solver
Goel (2019)	The paper argues that corporations can play a key role in addressing complex societal problems unrelated to their core business and that they can thereby improve their own business environment by



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	<p>adopting a collective action approach to community development in their locales rather than a corporate-centric approach that might have negative consequences for the corporation (e.g. high transaction costs) and to the community (e.g. dependency, powerlessness). Dynamic dependencies between all players involved need to be modelled... Therefore, the system dynamics modelling is applied ... that can treat multiple non-linear relationships between many variables.</p>
<p>Gold et al (2017)</p>	<p>This paper develops a model of collective action for development... to examine the changing corporate-community interaction and the role of different stakeholders in advancing corporate community development in the region. The participatory community development capacity (PCDt) is a core element of the presented model. PCDt is increased by build-up of PCD capacity (BPCDt) for example, through training and awareness creation, and decreased by the erosion of self-help capacity (ESCt). BPCDt is mainly influenced by the PCDt-Δt, the PCD share (PCDs) and we-feeling (WfT). The corporate CSR State (CCSRt) is specified ... under consideration of the CCSREt, the erosion of state (ER), and the CDEt. The importance of the cultivation of “we-feeling” among actors can galvanize action by all; additionally, the use of systems dynamic modelling suggested in this paper can help societies achieve their intended aim of a systems approach to be able to understand the dynamic dependencies (PCDt, WfT, etc.) and to identify unanticipated side effects, e.g., a low PCDs will lead to a complete erosion of WfT and interestingly the CCSRt is reduced as well. The traditional instrumental motives/agenda for company-oriented CSR in terms of public relations, image and reputation building could easily erode the we-feeling, i.e., the explicit past self-interest agenda by any stakeholder can destroy the we-feeling. This is in line with Olson's (1971) theory of collective action underlining the essential importance and difficulty to appropriately incentivize all individual actors to join their forces for the common goal. The indispensability of collaborative action for facilitating long-term community development This paper critiques the effectiveness of traditional corporate-driven CSR that responds reactively rather than proactively to wicked social problems among deprived local communities ..., and advocates a collaboratively driven model of community development. Such model shows how corporate-centric social responsibility activities—i.e. traditional CSR—can be transformed into “participatory” and “inclusive” CSR / community development models that create sustainable (mid- and long-term) development through establishing appropriate governance and accountability mechanisms, backed by comprehensive stakeholder engagement In “participatory” and “inclusive” social responsibility models, the company is often the initiating actor, playing a convenor role and then deliberately steps back and acts as one partner among a group of equal partners in development. The integrated relational approach requires the consideration of corporate-community interaction and sustainable community development from a systems approach where actors are interlinked and together, they engage in action that improves the socio-economic, ecological, human, political and cultural capitals of these communities of place. Corporations</p>



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	cannot run a one-size-fits-all approach regarding CSR but headquarter CSR activities need to be carefully adapted to subsidiaries' institutional environments and socio-economic situations The implementation of the epidemiologic approach to challenge some of the wickedness of the air pollution problem. Epidemiology applies to the total nexus of these "wicked" problems, and not only to the health and disease aspect of it
Goldstein (2017)	Understanding the complexity of the problem to be dealt with; impact of the quantity of actors; location, interaction between resource units and network structure; Wicked problems (i.e., wicked conservation conflicts) are those that are large, complex, have high scientific uncertainty, and divided public opinion that result in impasse among conflict parties .
Guimarães et al (2018)	Freeman identified four research challenges in addressing the wickedness of water problems: (1) the challenge of becoming more interdisciplinary; (2) the challenge of integrating two types of knowledge, scientific and local site-specific knowledge; (3) the challenge presented by multiple levels of analysis, in our case from global climate to binational agreements to federal governments to state and local entities to the individual citizen or water user; and (4) the challenge of individual rationality and common property resources, i.e., water is viewed and treated both as a property right and as a common resource property by various stakeholders, and at various points in space and time, resulting in a conflict between individual and community rationality.
Gutierrez (2020)	Our objective was to develop a systematic approach to identifying and classifying water stakeholders, and to engage them in a discussion of water futures as a foundation for a participatory modeling research project to address the wicked water resource problems of the Middle Rio Grande basin... a methodology for identifying, classifying, and engaging all types of stakeholders in the context of a research project, enabling us to compare views of different types of stakeholders



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Hargrove and Heyman (2020)

Identifying and classifying all water stakeholders and engaging them in a discussion of water futures as a foundation for a participatory modeling research project...We used this stakeholder knowledge base to inform and guide our participatory modeling approach Highly successful stakeholder participatory approaches to water quality improvement and participatory modeling Environmental stakeholders are often included in participatory management or modeling activities, but social justice stakeholders are seldom if ever included. Sustainable water resources management. The Spiral of Climate Change, Prolonged Drought, Groundwater Depletion, and Salinization ... With warming trends projected to continue, identifying, and quantifying the impact of future climate scenarios, including the depletion of groundwater reserves, is a prerequisite to planning and managing for prolonged drought. Agricultural Intensification, Urbanization, and Conjunctive Management. While supplies are dwindling, demands for water are rising due to a few factors, including warmer temperatures, expanding acreage of high consumption perennial crops (like pecan trees and alfalfa), urbanization, and increasing demands for environmental flows and other environmental-related uses of water. The Complexity and Obsolescence of the Water Governance Framework. The water governance framework for this binational and multi-state region, which draws on common surface (the Rio Grande) and groundwater resources (Mesilla and Hueco Bolson aquifers), was developed over 100 years ago and is ill-equipped to address the dwindling supplies and growing demands ... Land Ownership, Water rights, and Threats... unique to the agricultural stakeholders: a readily apparent feeling of ownership of water rights as part of land ownership, coupled with the concomitant sense of threat to those water rights emanating from the current situation of dwindling supplies and competing demands. In summary, the region faces pressing wicked challenges stemming from: (1) changing climate and prolonged drought; (2) growing and competing demands, due to the production of high use perennial crops, growing population and urbanization, and the growing political voice of environmental advocates; (3) an outdated, complicated, multijurisdictional governance system that is ill-equipped to address the pressing challenges; and (4) strong feelings of tension and conflict, stemming from threats to water rights from other users and the proclivity to make "the other" responsible for actions to reduce use or conserve water. Addressing the wicked problems and their associated transboundary conflicts require integrative thinking, considering surface and subsurface water jointly (conjunctive use), using dynamic scenarios of climate change and human water use, and utilizing basin scale integrated management. Furthermore, time is running out, due to groundwater depletion, to come up with a solution; there is lack of institutional authority to make decisions on how to proceed; and the same people who are trying to solve the problem are creating it, a common scenario in river basins facing wicked problems Local adaptive initiatives rather than central controls are likely to be best able to respond to the specific and diverse biophysical and socioeconomic contexts found in each region. ...local efforts need to be supported by the coordinated provision of information and ideas,



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	<p>strategic direction, regulatory facilitation, and funding resources. Central governments will need to develop multilevel strategic frameworks, invest in science and monitoring activities, encourage cooperation, coordinate equitable access to resources, and facilitate trust building and networking across diverse groups. Solutions to such problems are highly provisional and need continual renegotiation</p>
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<p>Head (2014)</p>	<p>The behavioral unit to be targeted by designers of environment policies will likewise range from individuals, households, neighborhoods, and suburbs through to larger regional and global scales. The interconnections between these levels are also important to consider, raising great difficulties both for clear analysis of causality and for devising practical interventions to tackle the problems. Time scales are also important—the disjunction between short-term costs for some stakeholders and long-term benefits for future generations can exacerbate opposition by strong political and economic groups. In a rational policy-making process to address climate change risks, rigorous scientific knowledge would be seen to provide expert foundations for evidence-based solutions ... Investing in more scientific evidence (eg, research about climate variability and cost-effective interventions for mitigation and adaptation) would be seen as helping to reduce risks and uncertainties in decision making. However, in actuality, scientific research is only one of several inputs into the policy process at national and international levels. There are important forms of political, managerial, and professional knowledge that shape decision making, while taking account of industry interests, advocacy groups, and public debates generated through the media. Substantive differences in climate change policy preferences are not able to be resolved through research findings alone; hence, the need for policy leadership and engagement processes through which divergent interests at local and regional levels, and across industry sectors, may have ‘voice’ on key issues. The complex policy domain of climate change response is likely to require ongoing interplay between regulatory, market, and community-based approaches. developing policy responses that integrate opposing perspectives regarding the nature of the problems and how they should be resolved. ... tackling complex problems requires flexible combinations of these various approaches to problem solving. The collective experience of inclusive processes for participation and discussion has been identified as important for building stakeholders’ capacities to develop informed and effective solutions... Such processes benefit from the interplay of a broad base of expertise, both scientific and professional, and from engaging the practical lay knowledge of stakeholders. Processes for consultation and dialogue should not rest on lowest common agreement, but seek to raise levels of information and analysis for tackling intractable problems ... Such inclusive approaches—at appropriate local, regional, and national scales—can help to build planning capacity and problem-solving capacity. This is a constructive way to address the insecurities arising from uncertainty, complexity, and divergence. Embedded and linked in broader social, economic, environmental, and policy issues and associated values, which can create a set of nested problems within problems.</p>
<p>Bruggemann et al (2012)</p>	<p>“Morally objectionable for the planner to treat a wicked problem as though it were a tame one, or to tame a wicked problem prematurely, or to refuse to recognize the inherent wickedness of social problems”</p>



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<p>Hartman (2017)</p>	<p>“Researching and responding to wicked ecological problems depends on those problems becoming sites that reconnect cultural imaginations with the environmental sciences and that stimulate culture reform” (2013: 178). The wicked problem, then, hosts cultural creativity cum problem solving. Among other solutions, such sites of cultural creativity should foster additional explorations of the commons as a way for individuals to solve collective problems by working together (Nagarajan, this volume, 52). “Environmental humility” ... refers to an awareness of the importance of environmentally responsible behaviors that all community members share and a recognition of the collective impact (both positive and negative) that our behaviors have on the viability and future of natural ecosystems. Environmental humility also more generally refers to an individual respect and appreciation of the finite effects of the natural environment and the impact it has on interpersonal relationships and psychological well-being. Two specific problems or obstacles that have historically prevented environmental change: governments (i.e., large bureaucratic institutions that often lack accountable behavior) and individual human behaviors that are driven by greed, entitlement, fear, selfishness, and fear ...A primary issue in addressing and preventing serious environmental problems is providing individual access to accurate information and helping communities gain access to a variety of basic resources that can provide for a more universal and sustainable environment.</p>
<p>Hoffman (2020)</p>	<p>Behavioral changes are most efficiently addressed through three sequential processes: access to information and education that facilitate an understanding of environmental issues, motivating individual behaviors, and behavioral changes that are designed to reduce threats to the environment Information, Motivation, Behavioral Changes (IMB) Organizations and larger institutions (i.e., primary and secondary educational systems) have an advantage in the development of creating a successful culture of change that can embrace greener and more sustainable practices through the development of intentional educational programs that embrace the values and promote healthier and sustainable behaviors. This study examined how providing different types of community service and environmentally sustainable programs influenced perceptions of community connectedness, environmental humility, and proenvironmental attitudes. When volunteers were provided with opportunities to participate in different types of green and environmentally sustainable activities, they reported a stronger sense of community connectedness that was significantly correlated with an increased likelihood to engage in recycling behaviors....These findings support previous research where behaviors are more likely to change when individuals are presented with opportunities to participate collaboratively in environmentally sustainable projects (i.e., signing a petition that supports renewable energy initiatives). the relationship between exposure to outdoor green space environments and the belief that positive changes in the natural world were possible through the development of community service activities (i.e., recycling programs and participation in community gardening programs) ($r = 0.447$; $p < 0.01$.) When provided with opportunities of</p>



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	<p>collective engagement with other individuals sharing a common (i.e., proenvironmental) cause, participants reported a stronger belief system that these goals (i.e., reducing waste through increased recycling and increased use of public transportation systems) were indeed possible and attainable through organized group efforts. ...modern air pollution, with emissions consisting of small particulates (PM10, PM2.5, and PM0.1), oxides of nitrogen (especially NO2), volatile organic chemicals, and ozone. These pollutants are major risk factors for the development of human diseases, especially cardiovascular disorders such as heart attacks, arrhythmias, and stroke and respiratory diseases such as asthma, chronic obstructive pulmonary disease, pneumonia, and cancer. Chronic exposure [to air pollution] impairs lung growth of the fetus and throughout childhood, increasing the risk of developing asthma and contributing to impaired cognition, type 2 diabetes, various cancers, and skin ageing and even serving as a risk factor for obesity.</p>
<p>Holgate and Stokes-Lampard (2017)</p>	<p>China's ongoing economic expansion has exacerbated many wicked environmental problems Without systematic monitoring, the status of coral reefs in China and the South China Sea will remain poorly understood and the decline in coral cover we document here will be easier to miss, ignore, or deny. Therefore, monitoring the condition of coral reefs and understanding why they are changing are critical aspects of addressing the wicked problem of loss of reef habitat and the decline in ecosystem services they provide.</p>
<p>Hughes et al (2013)</p>	<p>Climate change is adding to the wicked problems of sustaining the world's coral reefs ..., but ongoing overfishing, pollution, coastal development, and other human activities that affect reefs are much more prevalent in many densely populated regions like China societal norms and attitudes in China are major aspects of the wicked problem of sustaining coral reefs. ...Rapidly growing wealth and rising consumption of seafood, combined with poor governance and management of fisheries, has led to unsustainable harvesting of targeted species In the longer term, changing public perceptions in China is at least as important as shifts in state, provincial, and municipal policies and laws for confronting the wicked problem of sustaining coral reefs. maintaining marine ecosystems in good condition is a much better management approach than attempting to rebuild them after they have been severely damaged Partial solutions to wicked problems typically disadvantage some players while benefiting others and often generate new problems ...The challenge therefore is to initiate partial solutions to wicked problems that do not preclude future incremental improvements. Governing wicked problems becomes more challenging as they increase in extent from local to regional or global scales, particularly where institutions are weak or nonexistent There is no quick fix to a wicked problem as complex as securing a sustainable future for coral reefs in China and the South China Sea. We suggest that governance of China's coastal reefs can be improved by increasing public awareness, by legal and institutional reform that promotes progressive change, by providing financial support for training of reef scientists and managers, expanding monitoring of coral reef status and dynamics, and by enforcing existing regulations that protect reef ecosystems. The loss of coral</p>



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	<p>reef habitat in China ..., as in other nations, is caused by a failure of governance. ... Governance includes formal laws and regulations, but also more diffuse and often unrecognized components that influence decision making, such as the media, religion, commerce, and public opinion We propose a test bed – the Policy Operations Room (POR) – to practice and analyze urgent decision-making with path-dependencies. POR is a situation room for interactive decision-making among policy-makers, managers, and experts to deal with wicked issues. ... We suggest that the control room model of high reliability management, which successfully maintains reliable operations despite a wicked operating environment, is transferable to a strategic policymaking context involving urgent decisions with long-term lock-in effects. We show that simulation exercises based on analogous application of decision principles from a high reliability control room, or the POR framework, can help policymakers to consider the long-term path-dependence (be it desirable or not) of urgent decisions made during wicked socio-ecological disruptions under high uncertainty. We argue that in long-term strategic policymaking settings it is possible to benefit from the same operational procedures with which control room operators stabilize critical infrastructures and ensure reliability. To address the tensions in decisions over wicked problems, we constructed an analytical framework made of three variations of POR that cover decision situations with variable knowledge and variable emphasis on crisis preparedness versus response (Fig. 2). Bayes-POR focuses on decisions made with probabilistic knowledge of risks, such as those taken to increase preparedness. Crisis-POR focuses on decisions made with poor knowledge of the situation, such as those taken during crisis response. Path-POR is located between Bayes-POR and Crisis-POR and focuses on strategic decisions made as an urgent response to a policy crisis with a combination of risk knowledge on some aspects of the situation and ignorance on others.</p>
<p>Hukkinen et al (2022)</p>	<p>Highly reliable management in control rooms shares the following features: it is non-fungible, i.e., efforts to maximize techno-economic efficiency erode reliability; it results from hazard-driven adaptation, which necessitates a constant preparedness for multiple hazards and awareness of errors; and it relies on improvisation, experimentation, and highly variable operations to manage the real-time contingencies emerging in critical infrastructure operations. Obviously, none of the above would be possible without a high level of expertise among control room operators Crisis-POR aims to investigate decision-making over sudden socio-ecological crises characterized by poor knowledge and the need to rapidly construct situational awareness. ...The novelty of the Crisis-POR that we propose is to magnify the degree of wickedness in the disruption scenarios to be managed in a crisis exercise. As a result, multiple expertise is needed in the emergency response exercise. Precluded policy consequences define the boundaries of the decision space by specifying the intolerable consequences, or “policy errors.” Precluded emergency management defaults define the boundaries of the decision space by specifying the unacceptable management actions – the “easy- ways-out,” such as calling the emergency rescue services – that fail to address the wicked</p>



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	<p>long-term path-dependencies. All risk and resilience management decisions rely on human capability to construct a realistic picture of the ongoing situation. This situational awareness under uncertainty can be conceptualized as a Bayesian probabilistic phenomenon, composed of two main elements: 1) prior experiences and expectations based on such experiences, and 2) currently available information concerning the situation and how reliable the participants think this information is in a probabilistic sense. A wicked problem requires multi-stakeholder engagement (from industry, amongst others) to reach a shared understanding of a common problem. In theory, there are three strategies to tackle a wicked problem: authoritative, competitive, and collaborative strategies.</p>
Inghelbrecht et al (2014)	<p>Managing a wicked problem is a shared responsibility of multiple stakeholder groups. Companies' strategies to address a wicked problem should in fact be fourfold. Nevertheless, the core insights from this paper have already contributed to a better understanding of these social practices, in relation to economic activities, political arrangements, private governance and supply chain governance arrangements.</p>
Jung et al (2022)	<p>Cross-disciplinary research creation can provide collaborative opportunities to foster more nuanced understandings of wicked problems. Strategies for navigating wicked projects:</p>
Kämpf and Haley (2014)	<p>Strategies for navigating wicked projects: - First, the risk manager must use systems thinking theory to identify and understand different aspects of wicked problems. - After identifying a problem as wicked, a participatory, deliberative process, such as a risk workshop, can facilitate diverse stakeholder representation to assess and mitigate risks collectively. The objective here is to engage stakeholders and integrate collective intelligence to forge equitable solutions that mitigate risks and balance risks and benefits. - To assist stakeholders with conceptualizing the problem collectively, risk managers can use problem structuring tools such as mind maps or Rich Pictures, including the exploration of differences in risk perceptions such as conceptual models, data sources and risk attitudes. - Lessons from high reliability organizations (HROs). The growing literature on high reliability organizations (HROs) examines the failures in organizations and processes which lead to catastrophic consequences such as major nuclear radiation releases or a fatal aircraft carrier crash. This literature offers concrete steps to avoid catastrophic errors in wicked projects. Key benefits of this wicked problem framework as a methodology to approach risks in complex projects include mitigating biases, conflict reduction and building trust and relationships. The wicked problem framework creates awareness of cognitive biases among team members and experts and encourages participation from team members and stakeholders who have diverse backgrounds (i.e. experience level, functional areas, organizations and industries). ... for wicked problems such as resource development in the Alaska Arctic offshore, better risk management solutions are reached through extended, face to face, facilitated dialogue involving diverse stakeholders.</p>



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<p>Kelley and Dietl (2022)</p>	<p>As a solutions-oriented discipline, conservation paleobiology (CPB) aims to address the wicked problem of biodiversity loss (Game et al., 2014) by generating knowledge from the geohistorical record (fossils, sediments, and other natural archives) to inform and shape the policies and practices that protect biodiversity (Dietl et al., 2015). This goal is laudable; however, in a fractal-like way, it also creates a wicked problem of its own for conservation paleobiologists. We have argued (Kelley et al., 2018, 2019) that the traditional disciplinary academic experience of most of today's conservation paleobiologists constrains our ability to prepare students to solve conservation problems. Our conventional background in the science of paleontology has not prepared us to train students for conservation careers other than research based academic appointments. Yet, the wicked nature of many conservation problems demands an evolution in the way we train students. Like CPB, sustainability is an emerging academic field that confronts wicked problems (e.g., climate change, water scarcity, extreme poverty, COVID-19 pandemic), but it has expanded much more rapidly; as of 2016 there were nearly 2,400 programs focused on sustainability in the United States alone (Engle et al., 2017). The rapid proliferation of academic programs and the interest in sustainability beyond academia have spurred efforts (e.g., De Haan, 2006; Barth et al., 2007) to develop a framework of competencies to guide pedagogical approaches.</p>
<p>Kirschke et al (2018)</p>	<p>Factors Substantiating Wickedness - Conflicts related to resource allocation and management in the context of various overarching goals; in theory no prioritization of resources; the need for negotiation - A large amount of highly dynamic and strongly interconnected factors, including solution options (e.g., technical, management) as well as social (e.g., governance, actors, interests) and bio-physical conditions (e.g., climate, quantity and quality of resources) - Lack of adequate, reliable and timely data with regards to solution options, as well as bio-physical and social factors; limited means to gather/share information Research suggests that highly wicked problems come along with specific challenges for management. Based on Kirschke and Newig and psychological literature on complex problem solving, these challenges refer to the need for solving conflicts, gathering, and sharing information, modeling, prioritizing, deciding under uncertainty, and being adaptive and flexible. In addressing problems, relevant actors must come to terms with these specific needs of wicked problem-solving. In terms of conflict solving, they must address varying values and interests, including often diverging perceptions of problems. Further, financial, technical, and political means should be established to gather and share data as well as to model respective complexities. Given that there is no possibility to gather all relevant data, managers must prioritize their data generating efforts. This results in a need to decide under uncertainty, and thus also to adapt flexibly to changing conditions such as climate and demographic changes.</p>



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Kirschke et al (2022)

Researchers often emphasize that wicked problems cannot be solved, as there are diverging interests of stakeholders, negative side effects of interventions, and deep uncertainties, among others (e.g., Dewulf & Biesbroek, 2018; Hoppe, 2011; Rittel & Webber, 1973). Consequently, adaptive management approaches typically emphasize flexible processes to address challenges emerging from wicked environmental problems (Allan & Watts, 2018; Allen & Garmestani, 2015; Pahl-Wostl et al., 2012; Schoeman et al., 2014; Williams & Brown, 2014). Such a process-orientation in management can, however, be problematic. From a scientific perspective, the process orientation hampers the analysis of effective instruments in generating outcomes such as effective policies for addressing wicked environmental problems (Howlett & Lejano, 2015). This problem is well-known in the wicked problems literature (e.g., Head, 2014) and there are ongoing attempts to overcome evaluation challenges of wicked problems through defining “small wins” (Termeer & Dewulf, 2019) or “imperfect responses” (Bannink & Trommel, 2019). From a practical perspective, the process orientation is not solution-oriented, given that public authorities must demonstrate results. The effectiveness of management processes in dealing with wicked problems can be measured systematically along 12 indicators representing four steps of planning and three dimensions of wicked problems. Research has shown that wicked problems need to be addressed adaptively (e.g., Allan & Watts, 2018; Pahl-Wostl et al., 2012; Plummer & Baird, 2013; Schoeman et al., 2014; Williams & Brown, 2014; Zedler, 2017), creating small wins rather than grand solutions when addressing wicked problems (e.g., Bours et al., 2021; Termeer & Dewulf, 2019). However, what exactly are small wins when addressing wicked problems? How can these small wins be operationalized further? Our conceptual approach adds to operationalizing small wins, by disclosing relevant inputs, activities, outputs, and outcomes for three acknowledged dimensions of wicked problems. Wicked problems are coined by diverging views and complex side-effects, adding to the uncertainty of data, information, and knowledge often associated with environmental problems (e.g., Dewulf & Biesbroek, 2018). Managing wicked environmental problems is a major duty towards sustainable development. However, while adaptive management approaches have been put forward, there has been a lack in systematically considering the different dimensions of wicked problems at different stages of the management process. By combining the results-based management (RBM) approach with a three-dimensional conceptualization of wicked problems, we identified 12 indicators for effectively managing wicked problems along four steps of planning (inputs, activities, outputs, and outcomes) and three dimensions of wicked problems (goal conflicts, system complexity, and uncertainty). Based on these 12 indicators, the effectiveness of management processes in dealing with wicked problems can be measured and addressed systematically. The 12 indicators particularly advance the “small wins” thinking in wicked problems by presenting these wins as specific and measurable inputs, activities, outputs, and outcomes related to three dimensions of wicked problems.



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Kraak (2022)	1) Confusing marketing landscape for the public; 2) diverse views and varying acceptance among consumers about the health and environmental benefits of these products; 3) inadequate education and labeling provided by federal agencies to enable consumers to understand how these may support healthy sustainable diets; and 4) slow federal policy and regulatory actions to address the range of AP products and provide industry guidance. Factors that influence the wicked problem: Human health, equity, animal welfare, and economic viability goals Sustainable diets and sustainable eating patterns aspire to balance many goals to promote human health and well-being; support biodiversity and environmental stewardship and respond to climate change challenges; ensure social equity and fair trade; encourage eco-friendly, locally, regionally, and seasonally produced foods; accommodate cultural heritage and cooking skills; and meet the food and nutrient needs of populations while promoting food and nutrition security . If populations were to adopt healthy sustainable dietary patterns on a large scale, countries would be better positioned to align their national food systems to produce health and environmental benefits consonant with their international commitments, including the 2030 UN Sustainable Development Goals, 2015 Paris Agreement to reduce the impact of human-induced climate change on planetary health, and 2017 Aichi Convention on Biodiversity (). The World Wildlife Fund described the need to shift global food systems toward plant-based diets to reverse biodiversity loss, encourage people to live within a global carbon budget, reduce greenhouse gas emissions (GHGE), feed people on existing land, and optimize crop yields.
FitzGibbon and Mensah (2012)	Strongly stakeholder dependent, dynamism of the drivers of change such as human behavior, ecological factors, and scale of interaction of the processes

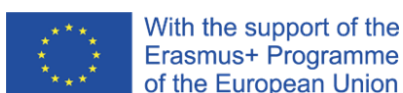
Source: Authors' compilation

4. Cluster modelling

The VOSViewer software was used for cluster modeling and two publications samples were taken with a minimum number of articles for analysis (121 articles) (scenario 1), that are classified as relevant to the task of analysis, and a larger sample of bibliographic data (1240 articles) (scenario 2).

It is worth noting that to operate with a smaller number of articles, it was decided to take the minimum number of occurrences of a term equal to 5, which increased the number of terms that fell within the clusters and made the network more branched. Logical relationships were built around the dominant terms, with an emphasis on thematic branching on wicked problems. Thus, 9 subject clusters were identified (Figure 5):

- orange cluster - problems concern ecosystem functions and their violation;
- yellow cluster - problems of implementation of sustainable development goals;



- dark blue cluster - problems related to the impact on society of the Covid-19 pandemic;
- blue cluster - water pollution and water resource management.
- brown cluster - problems of environmentally-oriented education and its implementation in practice;
- purple and red clusters are in the pre-forming stage, which is probably connected with the lack of a clear definition of the problems.

It is worth noting that a significant dominance of super-wicked problems can be traced in the blue cluster, which indicates that in the context of the subject of research, this term is often found in connection with the development of research and interdisciplinary problems of managing the manifestations and effects of the Covid-19 pandemic in different spheres of society at the global level.

Fig. 5. Cluster modelling. General network visualization (constructed via VOSViewer v.1.6.15): 9 clusters, 3335 links, 18041 total link strength (scenario 1)

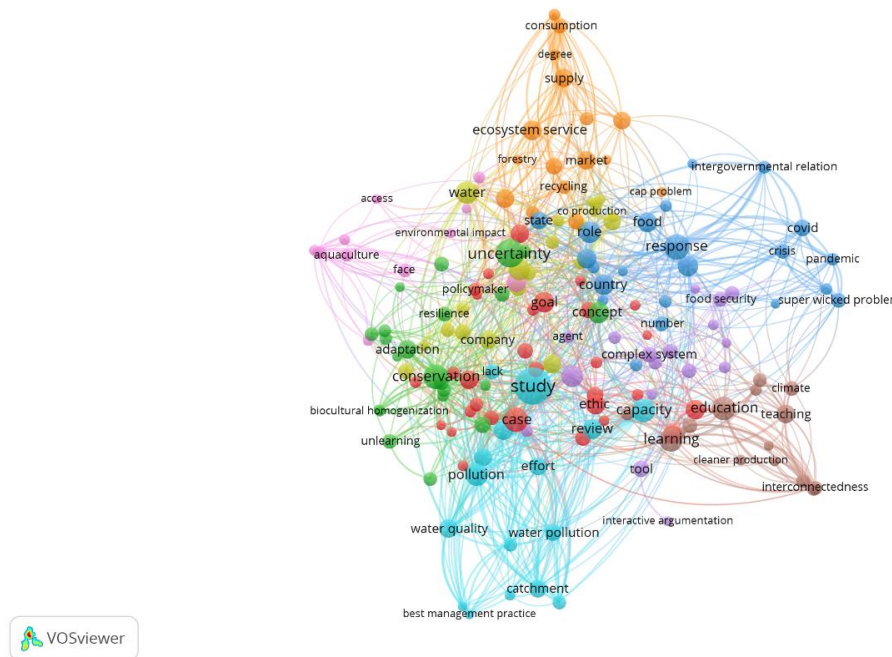


Figure 6 shows the result when working with a large number of samples of publications on the topic of the research. As can be seen from the cluster analysis of network visualization, a total of 8 clusters were automatically grouped, which is one less than for a more specialized sample with a smaller number of articles. However, the clusters have more completeness in the formation of the subject area.



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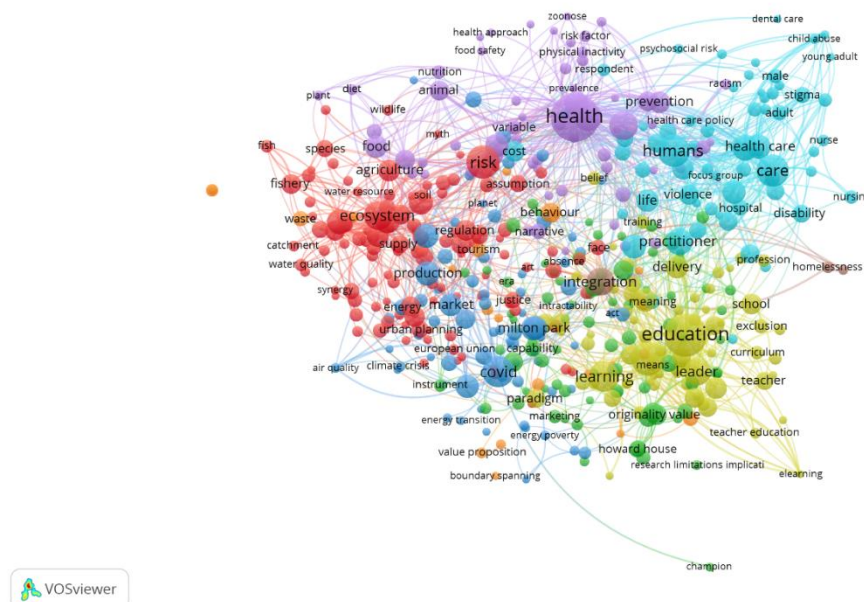


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- Yellow cluster - wicked problems in the context of the development of environmental education.
- Blue cluster - concerns the medical sphere and perinatal care.
- Red cluster - problems of ecosystem services and their management, in particular in the processes of recycling, energy and water management.
- Purple cluster - influence of environmental factors on human health, in particular problems of atmospheric and hydrospheric pollution and health risks.
- Blue cluster - related to possible directions of climate change and its impact on society.

The orange cluster remains unformed, which is the most insignificant in terms of the number of terms included in it and therefore has no strong interpretation.

Fig. 6. Cluster modelling. General network visualization (constructed via VOSViewer v.1.6.15): 8 clusters, 25445 links, 126988 total link strength (scenario 2)



From the comparative analysis of visualization cluster modeling with a larger (scenario 2) and smaller (scenario 1) sample of articles, we can draw the following conclusions: scenario 2 has greater statistical significance of the results, but their distribution across clusters is more general than under scenario 1. Scenario 1 provides more interest in terms of specifying wicked problems along environmental pathways, which is more convenient for analysis. However, it has two unformed clusters, which, although they are allocated automatically in the program as separate clusters, overlap with other clusters, and are not defined as separate clusters.

5. Concluding remarks

The review of the state-of-the-art literature identifies complementarities and divergences in the works that look at wicked problems. These can be explained by the similarities in methodological approaches or the different conceptual or disciplinary approaches to the subject. An additional factor that may explain the plethora of results may be linked to methodological differences or geographic focus in the identified works. For instance, the local approach to wicked problems limits the ability to identify commonly applied or accepted approaches to definitions and solutions. A main conclusion that derives from the present synthesis of the literature on wicked problems is that the existing works offer a good understanding of the characteristics of wicked problems but limited systematic approach and insights to the solutions. This provides some indication for future research paths pursued in HEI.



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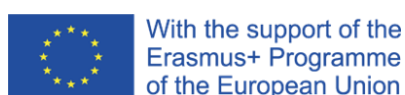
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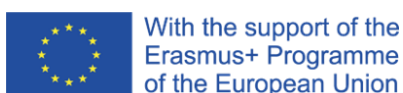
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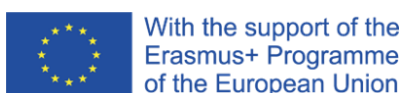
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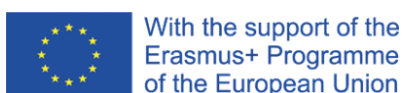
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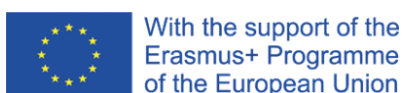
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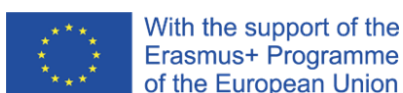
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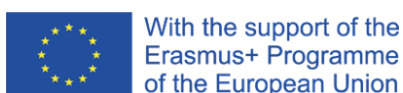
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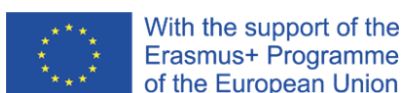
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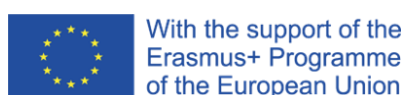


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