



MASTERARBEIT | MASTER'S THESIS

Titel | Title

Invasive Alien Species and their impact on the Sustainable
Development Goals

verfasst von | submitted by

Julia Fugger BSc

angestrebter akademischer Grad | in partial fulfilment of the requirements for the degree of
Master of Science (MSc)

Wien | Vienna, 2025

Studienkennzahl lt. Studienblatt | Degree
programme code as it appears on the
student record sheet:

UA 066 879

Studienrichtung lt. Studienblatt | Degree
programme as it appears on the student
record sheet:

Masterstudium Naturschutz und
Biodiversitätsmanagement

Betreut von | Supervisor:

Univ.-Prof. Mag. Dr. Franz Essl

Contents

Acknowledgements.....	2
Abstract.....	3
Zusammenfassung	4
Introduction	5
Methods.....	10
Results.....	13
Discussion.....	18
Conclusion.....	24
References:	25
Supplementary materials.....	33

Acknowledgements

First, I would like to express my gratitude to my supervisor, Franz Essl, for his support and valuable feedback throughout the course of this thesis. Next, I want to thank my colleague Bernd Lenzner for all his input, guidance and feedback during the conceptual and writing process, as well as the analysis and graphical representation. Their expertise and encouragement have been instrumental in shaping both my research and academic growth.

Special thanks to my colleagues and friends, whose insightful discussions, support, and camaraderie made this journey both intellectually enriching and personally fulfilling.

Finally, I am deeply grateful to my family and partner for their love, patience, and encouragement.

Abstract

Background: Biodiversity is the fundamental building block for life on Earth. Intact ecosystems provide the essential services humans rely on for health, societal and economic prosperity. This essential role is recognized by the community of nations and its various conventions and frameworks. Consequently, biodiversity is recognized as a central pillar for sustainable development and thus the achievement of the UN Agenda 2030 and its Sustainable Development Goals (SDGs). Nature's functions and services can be investigated within the Nature's Contributions to People (NCP) framework, that identifies different domains, including 18 material, non-material and regulating NCPs. Understanding how SDGs and NCPs are linked is crucial given the increasing impact of anthropogenic pressures on biodiversity. In this thesis, I am focusing on the effect of one specific driver, invasive alien species (IAS), on the SDGs via their effect on different NCPs.

Methods: Using a 2-step procedure, I established a connection between the NCPs and SDG targets based on their definitions and evidence in the scientific literature. Subsequently, in the second step I investigated the impact of a set of six IAS (*Rattus rattus*, *Felis catus*, *Solenopsis geminata*, *Robinia pseudoacacia*, *Pontederia crassipes*, *Dreissena polymorpha*) on the SDG targets via their impact on different NCPs. Impact information was obtained from the Global Impacts Database of IAS (GIDIAS; Bacher *et al.*, 2025). Using the reference literature provided in GIDIAS, I then investigated whether the impacts on the SDG targets through their connection with the different NCPs was supported by the scientific literature.

Results: Overall, I established a link between more than half of the SDG targets (53%) and at least one NCP. Targets within SDGs 1 – *No Poverty*, 2 – *Zero Hunger*, 3 – *Good Health and Well Being*, 8 – *Decent Work and Economic Growth*, and 15 – *Life on Land* showed most links to NCPs. Looking at IAS impact on SDGs through NCPs, impacts to 12 SDGs could be identified and SDGs 1, 2 and 8 showed links to all six focus species. Links of IAS impact to 43 SDG targets were identified, with most impacts to targets within SDGs 1 and 2.

Conclusion: Linking IAS impacts on SDGs targets through NCP provides insight into how changes in NCPs affect the development of the SDGs and their targets. I could establish a substantial number of such impacts supported by scientific literature, however, for several plausible links no literature support was available. Nevertheless, missing literature evidence for links does not imply incorrectly established links but could in turn imply gaps in the scientific literature or not yet materialized impacts. Hence, my approach might provide a useful tool to identify knowledge gaps and potential threats of IAS to sustainable development. Based on this information decision-makers and managers could proactively monitor IAS impacts and direct often scarce resources.

Keywords: Sustainable Development Goals, Agenda 2030, Nature Contributions to People, Invasive Alien Species, Impacts

Zusammenfassung

Hintergrund: Die biologische Vielfalt ist der Grundbaustein für das Leben auf der Erde. Intakte Ökosysteme erbringen wesentliche Leistungen, auf die der Mensch für seine Gesundheit und seinen gesellschaftlichen und wirtschaftlichen Wohlstand angewiesen ist. Diese wesentliche Rolle wird von der Staatengemeinschaft und ihren verschiedenen Konventionen und Rahmenwerken anerkannt. Folglich wird die biologische Vielfalt als zentraler Pfeiler für die nachhaltige Entwicklung und damit für das Erreichen der UN-Agenda 2030 und ihrer Ziele für nachhaltige Entwicklung (SDGs) anerkannt. Die Funktionen und Leistungen der Natur können innerhalb des Rahmens der ‚Nature's Contributions to People‘ (NCP) untersucht werden, in dem 18 materielle, nicht-materielle und regulierende NCPs unterschieden werden. In Anbetracht der fortschreitenden Auswirkungen des anthropogenen Drucks auf die biologische Vielfalt ist es von entscheidender Bedeutung zu verstehen, wie die SDGs und die NCPs miteinander verbunden sind. In dieser Arbeit untersuche ich die Auswirkungen eines spezifischen Treibers, der invasiven gebietsfremden Arten (IAS), auf die SDGs über ihre Auswirkungen auf die NCPs.

Methoden: In einem zweistufigen Verfahren habe ich eine Verknüpfung zwischen den NCPs und den SDGs hergestellt, die auf deren Definitionen und Belegen in der wissenschaftlichen Literatur beruht. Anschließend habe ich im zweiten Schritt die Auswirkungen einer Auswahl von sechs invasiven Arten (*Rattus rattus*, *Felis catus*, *Solenopsis geminata*, *Robinia pseudoacacia*, *Pontederia crassipes*, *Dreissena polymorpha*) auf die SDGs anhand ihrer Auswirkungen auf verschiedene NCPs untersucht. Informationen zu den Auswirkungen wurden der Global Impacts Database of IAS (GIDIAS; Bacher *et al.*, 2025) entnommen. Anhand der in GIDIAS zur Verfügung gestellten Referenzliteratur habe ich dann untersucht, ob die Auswirkungen auf die SDGs durch ihre Verbindung mit den verschiedenen NCPs von der wissenschaftlichen Literatur unterstützt werden.

Ergebnisse: Insgesamt konnte ich eine Verbindung zwischen mehr als der Hälfte der SDG-Ziele (53 %) und mindestens einem NCP herstellen. SDGs 1 – *No Poverty*, 2 – *Zero Hunger*, 3 – *Good Health and Well Being*, 8 – *Decent Work and Economic Growth*, und 15 – *Life on Land* zeigten die meisten Verbindungen zu NCPs. Betrachtet man die Auswirkungen von IAS auf die SDGs über die NCPs, so konnten Auswirkungen auf 12 SDGs identifiziert werden, und die SDGs 1, 2 und 8 zeigten Verbindungen zu allen sechs Fokusarten. Es wurden Verbindungen zwischen den Auswirkungen von IAS und 43 SDG-Zielen festgestellt, wobei die meisten Auswirkungen mit Zielen innerhalb der SDGs 1 und 2 verbunden sind.

Schlussfolgerung: Die Verknüpfung der Auswirkungen von IAS auf die Ziele der SDGs durch die NCPs gibt Aufschluss darüber, wie sich Veränderungen der NCPs auf die Entwicklung der SDGs und ihrer Ziele auswirken. Ich konnte eine beträchtliche Anzahl derartiger Auswirkungen feststellen, die durch die wissenschaftliche Literatur gestützt werden, für viele plausible Verbindungen war jedoch kein wissenschaftlicher Beleg verfügbar. Das Fehlen von Literaturnachweisen für Zusammenhänge bedeutet jedoch nicht, dass die Zusammenhänge nicht korrekt hergestellt wurden, sondern könnte wiederum auf Lücken in der wissenschaftlichen Literatur oder noch nicht eingetretene Auswirkungen hindeuten. Daher könnte mein Ansatz ein nützliches Instrument sein, um Wissenslücken und potenzielle Bedrohungen für die nachhaltige Entwicklung durch IAS zu ermitteln. Auf der Grundlage dieser Informationen könnten Entscheidungsträger und Manager die Auswirkungen von IAS proaktiv überwachen und die oft knappen Ressourcen gezielt einsetzen.

Introduction

Humankind is facing a multitude of challenges including the climate and biodiversity crises that put increasing pressures on global natural systems, the economy and humanity (Steffen *et al.*, 2015; IPBES, 2019a). To address these challenges, the Community of Nations has adopted the United Nations Agenda 2030 on Sustainable Development. Building on the previous Millennium Development Goals (United Nations, 2015), the Agenda 2030 was adopted in 2015 by the UN General Assembly, formulating 17 goals and 169 targets towards sustainable development across the biosphere, society, and economy (United Nations, 2015).

While the 17 SDGs can be divided into 5 groups, i.e., “*People, Planet, Prosperity, Peace and Partnership*” (United Nations, 2015), they are tightly interlinked and the achievement of one SDG can be supported or hampered by progress towards another one (Nilsson, Griggs and Visbeck, 2016; Pothén and Welsch, 2019; Barbier and Burgess, 2019). For example, the achievement of *SDG 2 - Zero Hunger*, is dependent on achieving *SDGs 1 - No Poverty*, *3 - Good Health and Well-Being* and *4 - Quality Education* (Nilsson, Griggs and Visbeck, 2016). On the other hand, progress towards SDG 2 might for example impede progress in *SDGs 13 - Climate Action*, *14 - Life below water* and *15 - Life on Land* due to increasing pressure on natural ecosystems to ensure food security (Nilsson, Griggs and Visbeck, 2016; Pothén and Welsch, 2019; Barbier and Burgess, 2019). In a comprehensive assessment of such synergies and trade-offs across all targets, Pradhan *et al.* (2017) identified goals with largely synergistic, e.g., *SDGs 1 - Zero poverty* and *3 - Good Health and Well-Being*, or antagonistic effects, e.g., *SDGs 8 - Decent work and economic growth*, *9 - Industry, Innovation and Infrastructure*, *12 - Responsible consumption and production*.

A central pillar to achieving the UN Agenda 2030 and its vision is the achievement of the biosphere-related targets, particularly *SDG 6 - Clean Water and Sanitation*, *SDG 13 - Climate Action*, *SDG 14 - Life Below Water* and *SDG 15 - Life on Land* (United Nations, 2015). In its Global Assessment, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) highlighted nature’s importance as indispensable to achieve sustainable development across all other domains (IPBES, 2019a) through the provisioning of essential contributions that nature can have to human life and well-being including regulating and provisioning functions – so called Nature’s Contributions to People (NCP; Díaz *et al.*, 2018). These functions can be organized into 18 NCPs associated with regulating, material and non-material contributions (Brauman *et al.*, 2019). Regulating contributions include NCPs associated with the regulation of climate, air and water quality, freshwater quantity, ocean acidification, formation of soils, detrimental organisms and hazards (Brauman *et al.*, 2019). Material NCPs deal with the production of food and feed, energy, medicines and materials (Brauman *et al.*, 2019) and non-material NCPs capture cultural and psychological importance, such as supporting cultural identities,

learning and inspiration (Brauman *et al.*, 2019). Despite nature and NCPs being considered essential for achieving the SDGs, their role in the definitions of the targets is hardly acknowledged, if at all (Butchart *et al.*, 2019; Hole *et al.*, 2022). 53% of the targets in this study are linked to at least one NCP, which is similar to the results of Hole *et al.* (2022), who identified nature as relevant for the achievement of half of the SDG targets.

Consequently there have been previous attempts to link NCPs and SDGs concepts (Anderson *et al.*, 2019; Butchart *et al.*, 2019; Adhikari *et al.*, 2022). For example within Chapter 3 of the IPBES Global Assessment Report on Biodiversity and Ecosystem Services (IPBES, 2019a), the authors used a clustering approach to examine SDG targets with direct links to nature and NCPs and also referred to interactions between NCPs and SDGs (Butchart *et al.*, 2019). Adhikari *et al.* (2022), firstly classified drivers that influence NCP trends and secondly grouped the results of a literature review according to ecosystems and their effect on NCPs and assigned those results to each SDG target associated with the NCP. Anderson *et al.* (2019) used a survey conducted among experts to prioritize NCPs that are necessary for achieving an SDG. A common characteristic of these studies is that not every possible NCP-SDG target combination was assessed.

Evidenced by the multitude of approaches and their different outcomes, linking NCPs and SDGs is not a straight-forward process with room for interpretations. The formulation of Goal and Target definitions is often very specific, e.g. SDG 1.1 *By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than \$1.25 a day* ignores dimensions of poverty that can be reduced, for example through subsistence. Target 1.1 could be linked to 15 NCPs; the links are largely based on the NCPs' contribution to income generation through the provision of wild species and material e.g. building materials, timber, firewood, meat, fish, fruit or mushrooms, which can be sold (IPBES, 2019b, 2022).

Even though nature is crucial for human existence, nature and its contributions to people are under pressure globally, their condition is deteriorating (IPBES, 2019a). This loss of biodiversity and degradation of ecosystems is caused by 5 major drivers, which are land and sea use change, exploitation of organisms, climate change, pollution and invasive alien species (IPBES, 2019a). Invasive alien species (IAS) are species that are either intentionally or accidentally transported by humans beyond their native range and that have documented negative impacts in the alien range (Blackburn *et al.*, 2014; IPBES, 2023). The spread of non-native species is due to human activity and involves several stages, starting with transportation from the region of origin to a new region where the species would not have made it without human intervention. There are different pathways of introduction (CBD, 2014; Turbelin *et al.*, 2022), e.g. species are released into nature for hunting (*Cervus nippon*, Lammertsma, Bruinderink and Griffioen, 2012) or erosion control (*Lupinus polyphyllus*, Ramula, 2015), they escape from confinement

(e.g. American mink *Neovison vison*, Palazón and Roy, 2014) or are transported as stowaways or contaminants (CBD, 2014). Following their introduction to the new region, the species must first establish themselves and form a viable population. If the species is successful, it is referred to as an established alien species and only a small proportion of these species spread further and influence biodiversity, ecosystems and native species and become invasive alien species (IPBES, 2023). Globally there are around 3,500 known invasive alien species with documented impacts (IPBES, 2023). They can cause environmental and socio-economic impacts (Pyšek *et al.*, 2020), including the loss of biodiversity but also economic damages such as crop losses (Paini *et al.*, 2016), reduced access to fresh water and the transmission of diseases to animals and humans (Bacher *et al.*, 2023). Globally, IAS contribute to or are directly responsible for the extinction of native species (Blackburn, Bellard and Ricciardi, 2019), and consequently also impair the protection of native biodiversity (Pyšek *et al.*, 2020; Dueñas *et al.*, 2021) and threaten nature conservation areas (Hulme *et al.*, 2014; Bacher *et al.*, 2023). Impacts from IAS affect all 18 categories of NCPs, with NCP 12 - Food and Feed, NCP 1 - Habitat creation and Maintenance and NCP 13 - Materials, Companionship and Labor being particularly affected (Bacher *et al.*, 2023). Invasive alien species such as the zebra mussel (*Dreissena polymorpha*) are known for altering ecosystems and communities through predation, competition and changes to nutrient regimes of freshwater ecosystems (Global Invasive Species Database, 2025c). *Felis catus*, the feral cat, is known as a predator of small mammals and birds and is held responsible for the decline of endangered species, especially from islands (Global Invasive Species Database, 2025d). The black rat (*Rattus rattus*) is known for its contribution to the extinction of several animal and plant species as well as being a transmitter of *Yersinia pestis*, the plague bacteria (Global Invasive Species Database, 2025e). Invasive species thus also have substantial negative impacts on human health through poisoning, illness, allergies and in the worst case, death. The invasive mosquitoes *Aedes aegypti* and *Aedes albopictus* are known vectors of chikungunya virus, dengue virus, yellow fever virus and Zika virus (Näslund *et al.*, 2021; Global Invasive Species Database, 2025b). In 2023, the WHO registered 6.5 million cases of dengue fever worldwide with a death toll of 7300 (WHO, 2024). Furthermore, IAS can contribute to inequity and marginalization of indigenous peoples, due to impacts on their cultural identity through changes in their cultural landscape and autonomy (Brauman *et al.*, 2019). Additionally, inequalities can also arise due to economic disadvantages resulting from decreased livestock production and expenses for the management of invasive species (Bacher *et al.*, 2023; Shackleton *et al.*, 2015). In 2019, economic costs of IAS are estimated to be US\$423 billion globally (Bacher *et al.*, 2023) and since 2000 global economic costs have increased by 700% (Turbelin *et al.*, 2023). While 85% of invasive species have negative ecological and socio-economic impacts (Bacher *et al.*, 2023), there are also beneficial impacts, such as use for firewood, food, shade and revenue (Shackleton *et al.*, 2015).

Aforementioned impacts and threats posed by IAS can be related to the Sustainable Development Goals. When looking at literature covering the impact of IAS on the SDGs there is a bias in the literature towards the environment SDGs (SDG 13, 14 & 15) with regard to the impact of invasive species on the SDGs and showing that people and prosperity SDGs are underrepresented (Lenzner *et al.*, 2024). A comparison of the literature with the impact of the IUCN 100 Worst Invaders (Global Invasive Species Database, 2025a) on the SDGs shows a different picture, with *SDGs 3 - Good Health and Well-being* and *2 - Zero Hunger* showing an association with 98 and 92 of the 100 IUCN Worst Invaders respectively (Lenzner *et al.*, 2024).

Within *SDG 15 – Life on Land* which focuses on terrestrial ecosystems, there is target 15.8 related to reducing the impacts of biological invasions: “By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species”; this target is accompanied by a single proposed indicator to measure its implementation. However, invasive species not only affect SDG 15 and the biodiversity of terrestrial ecosystems but are also closely linked to agriculture and food (*SDG 2 – Zero Hunger*) (Shackleton *et al.*, 2017), health (*SDG 3 – Good Health and Well-Being*) (Lazzaro *et al.*, 2018), infrastructure (*SDG 9 – Industry, Innovation and Infrastructure*) (Booy *et al.*, 2017) and other aspects of good quality of life (Bacher *et al.*, 2023).

To illustrate this with an example, a single invasive species might have different impact on the development of the overall SDGs – the water hyacinth (*Pontederia crassipes*) has positive and negative impacts on several SDGs (Ayanda, Ajayi and Asuwaju, 2020). While the water hyacinth potentially provides animal feed (*SDG 2 – Zero Hunger*) (Dersseh *et al.*, 2019), fibers and compounds for bioenergy production (*SDG 7 – Affordable And Clean Energy*) (Cherwoo *et al.*, 2024; Nega *et al.*, 2024), it has negative effects on water quality and usage (*SDG 6 – Clean Water and Sanitation*) (Dersseh *et al.*, 2019), provides nesting places for pests (*SDG 3 – Good Health and Well-Being*) (Degaga, 2019), loss of native species (*SDG 15 – Life on Land*) (Degaga, 2019) and prevents fishing (*SDG 1 – No Poverty, SDG 8 – Decent Work and Economic Growth*) (Degaga, 2019).

The objective of this master-thesis is to analyze how IAS can affect progress towards the SDGs indirectly through their impacts on Nature’s Contributions to People. This way it will be possible to evaluate positive and negative impacts of IAS on individual targets and potentially identify areas of conflicts of interest, where IAS might benefit some SDGs but simultaneously hamper others. In this thesis, I am going to develop a conceptual framework of how impacts (positive and negative) of IAS can be connected to the SDGs and investigate the following research questions:

- Which NCPs can be associated with which SDGs to inform on their progress?
- How can impacts caused by IAS be connected to the SDGs through their impact on Nature’s

Contributions to People?

Finally, I will provide a proof-of-concept application of the developed framework using six IAS of global relevance - *Dreissena polymorpha*, *Felis catus*, *Pontederia crassipes*, *Rattus rattus*, *Robinia pseudoacacia*, and *Solenopsis geminata*.

Methods

Understanding impacts of invasive alien species on the SDGs was done through a 2-step procedure. In the first step, I linked NCPs to the SDG targets based on the respective definitions and rationales. Subsequently, the second step involved connecting the documented impacts of IAS on the different NCPs for six focal species.

Connecting Nature's Contribution to People and Sustainable Development Goals

The connection between the NCPs and SDGs was done based on their respective definitions. For the NCPs, I used the ones provided in the IPBES Global Assessment (Chapter 2.3, Table 2.3.1; Brauman *et al.*, 2019) and their detailed extensions on the individual production mechanisms of each NCP provided in the supplementary document to the chapter (see table S1 in the supplementary material). SDG definitions for both, the goals and targets, were taken from the UN Agenda 2030 (United Nations, 2015; see S2). Each NCP x SDG target link was established based on available literature to justify the connection.

Each of the 18 NCPs was assessed against the 169 targets of the 17 SDGs and a link was established or not following a set of criteria (Figure 1). Established links were further classified into strong and weak based on the contribution of the NCPs to the SDG targets. For a detailed description on the procedure and discussion including examples for strong and weak links between NCPs and SDG targets please see box 1.

Box 1: Examples of strong and weak links from NCPs to SDG targets

Links between NCPs and SDGs were identified based on their definitions and qualitatively classified into weak and strong links. This qualitative assessment identified strong links as those where a specific NCP with its definition, production mechanisms and products can be directly linked to the SDG target or a component of it. A weak link was established when the literature did not indicate a direct effect on the target or its components by a causal indirect connection could be justified. I acknowledge that this assessment can be somewhat subjective related to the cut-off for indirect connection between NCPs and SDGs. Below I provide two examples of the scoring and a decision tree (Figure 1) of the procedure.

Example 1: Linking NCP 11 – Energy to targets of SDG 2 – Zero Hunger

NCP 11 – Energy is a necessary factor in food production and establishing food security (for example through powering irrigation technology; (GEA, 2012)), therefore the link between NCP 11 and SDG 2.1 - “*end all forms of malnutrition*” is classified as a strong link. However, I did not identify literature proposing a direct benefit of NCP 11 on SDG 2.2 which focusses on ending hunger and malnutrition of adolescent girls, pregnant and lactating women and older persons which was therefore scored as a weak link.

Example 2: Linking NCP 6 – Regulation of Freshwater Quantity to targets of SDG 7 – Affordable and clean energy

Another example is NCP 6 and SDG 7 targets 7.1 *By 2030, ensure universal access to affordable, reliable and modern energy service* and 7.2 *By 2030, increase substantially the share of renewable energy in the global energy mix*, the link to SDG 7.1 was classified as a weak link since the target focuses on policy to ensure access to renewable energy sources (e.g. hydropower) (United Nations, 2015). In contrast, 7.2 aims to increase the share of renewable energy (United Nations, 2015) and therefore greatly benefits from the quantity of freshwater available for hydropower generation (Hidalgo González, Medarac and Magagna, 2020), thus it was rated as a strong link to NCP 6. The established links are based on the NCP description (IPBES, 2019b), which highlights the NCPs relevance for hydropower production.

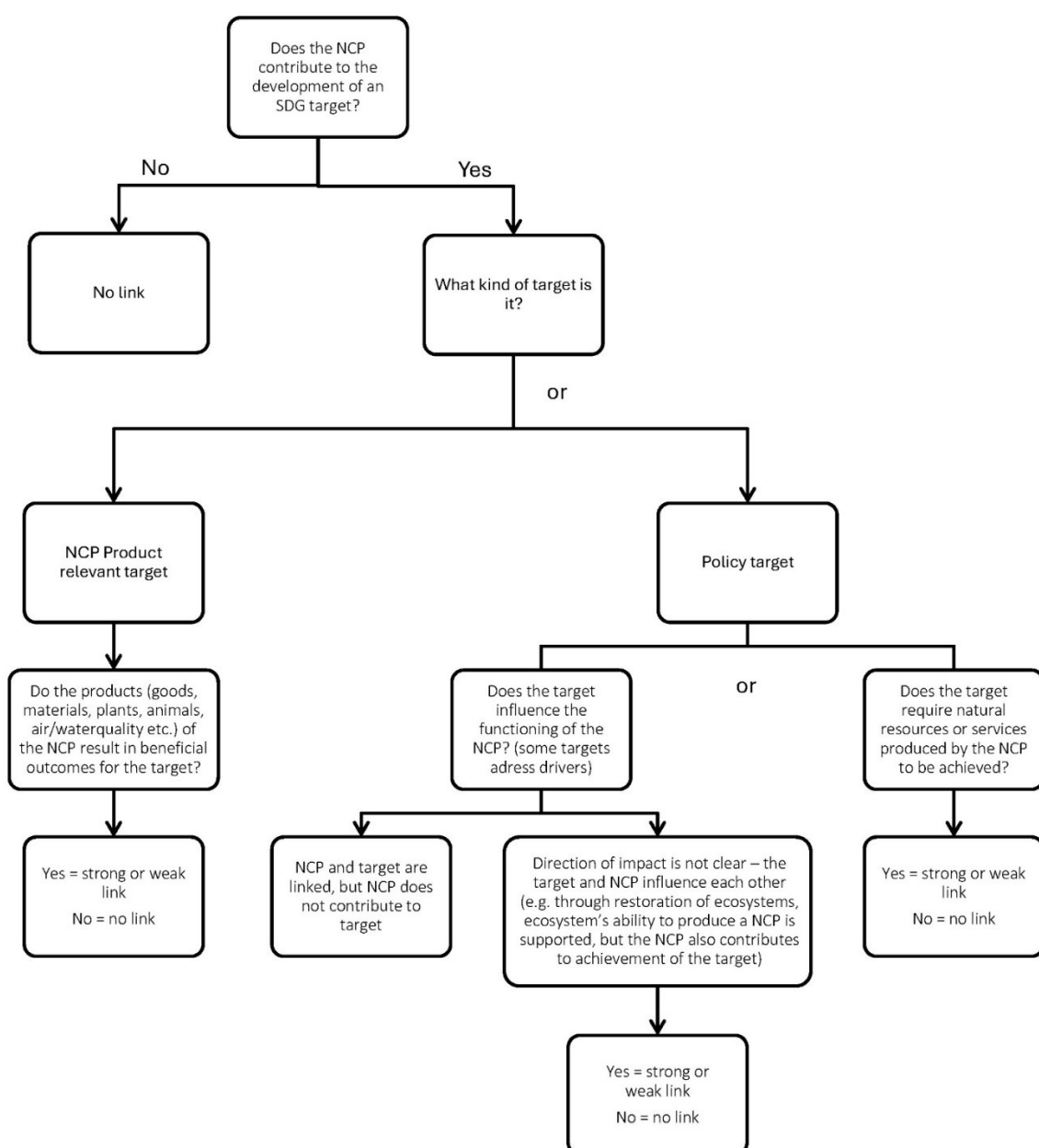


Figure 1: Pathway to decide link strength of the NCP and SDG target connection (field size does not indicate importance of field)

Connecting invasive alien species impacts to the SDGs

A subset of species included in chapter 4 of the IPBES-IAS Assessment (Bacher *et al.*, 2024, 2025) was selected to test whether the identified connections between NCPs and SDGs is supported by the scientific literature on the impacts of the species. Species selection followed three criteria: (i) species had documented positive and negative impacts on nature's contributions to people, (ii) species covered different taxonomic groups, and (iii) species covered both, terrestrial and freshwater realms. As reference species list, I focused on chapter 4 of the IPBES IAS Assessment (Bacher *et al.*, 2023) and identified the following six species to be included in this study for proof-of-concept implementation of this framework: Fire-ant (*Solenopsis geminata*; invertebrate, terrestrial), zebra mussel (*Dreissena polymorpha*; invertebrate, freshwater), feral cat (*Felis catus*; vertebrate, terrestrial), black rat (*Rattus rattus*; vertebrate, terrestrial), black locust (*Robinia pseudoacacia*; plant, terrestrial), and water hyacinth (*Pontederia crassipes*; plant, freshwater). All study species fulfill the above mentioned three criteria and are also listed among "the top invasive alien species with most documented negative and positive impacts on nature's contributions to people" (*sensu* Bacher *et al.* 2023). The database underlying Chapter 4. (GIDIAS, Bacher *et al.*, 2025) provides scientific references on the species-specific impact associated with each NCP. I focused on the provided references to assess whether there is evidence that the specific IAS impacts the previously established SDG x NCP connections.

Data handling and visualization

Descriptive analyses and visualizations were done in R Version 4.4.2 (R Core Team, 2024) using the packages "tidyverse" (Wickham *et al.*, 2019) and "ggplot2" (Wickham, 2016).

Results

Links of Nature's Contributions to People to Sustainable Development Goals and their targets

Five SDGs - *SDG 1 – No Poverty*, *2 – Zero Hunger*, *3 – Good Health and Well Being*, *8 - Decent Work and Economic Growth*, and *15 - Life on Land* - are linked to the largest number of NCPs ($n \geq 14$; see Figure 2 and table S3). *SDG 3 – Good Health and Well Being* is linked to all 18 NCPs, while *SDG 16 - Peace Justice and Strong Institutions* & *17 - Partnerships for the Goals* don't have links to any NCPs. Fewest links were identified for *SDG 4 - Quality Education* ($n = 3$), *5 - Gender Equality* ($n = 3$) and *10 - Reduced Inequalities* ($n = 2$) (see figure 2 and table S3).

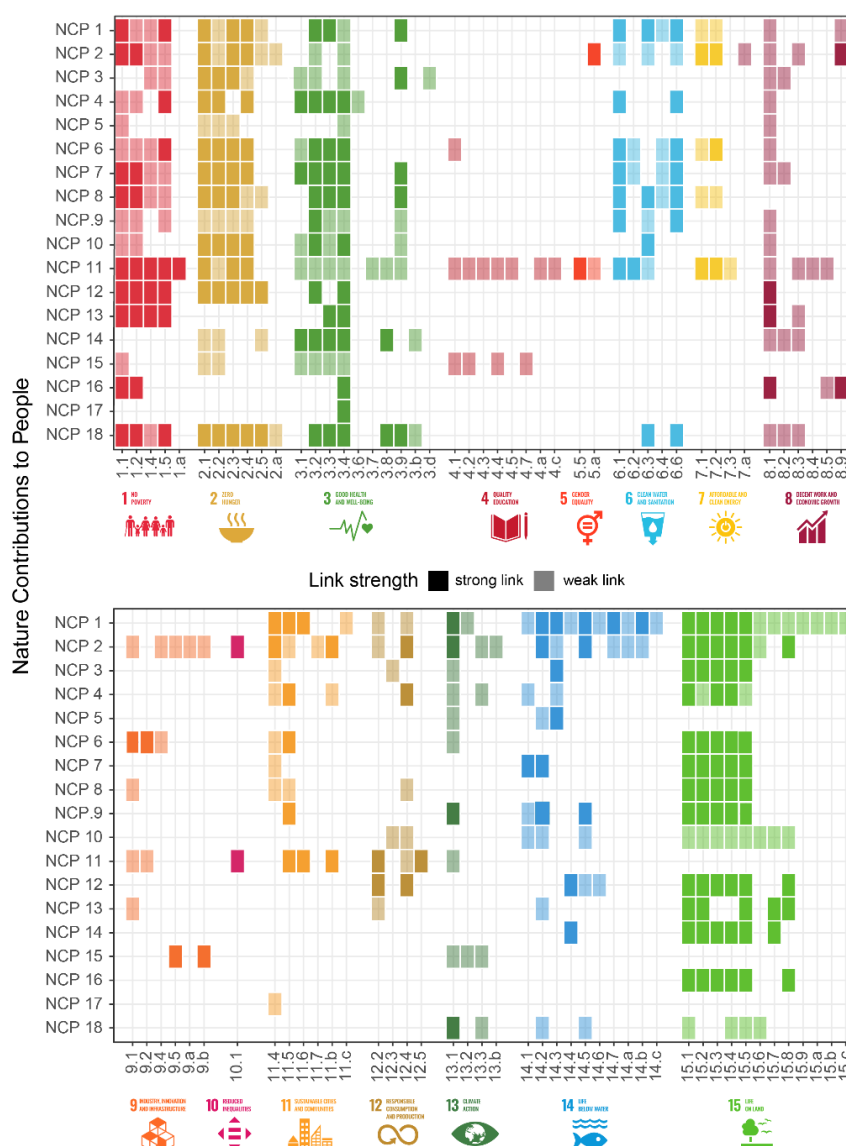


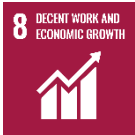
Figure 2: Heatmap showing the established links of NCPs to SDG targets. Solid fields indicate a strong link, transparent fields indicate a weak link.¹

¹ Icons were obtained from the official UN communications material © United Nations, used in accordance with the guidelines for educational purposes. Retrieved from: <https://www.un.org/sustainabledevelopment/news/communications-material/> (24.01.2024)

Of 3042 possible NCP to SDG target connections, 8% were identified as strong links and 7% as weak links, while 84% showed insufficient evidence to be linked. Across all 169 SDG targets, 53% (n = 89) of the targets showed links to at least one of the NCPs. Looking at the SDG target level, highest numbers of linked targets were observed for NCP 1 – Habitat Creation and Maintenance (n = 51), NCP 2 – Pollination and dispersal of seeds and other propagules (n = 50) and NCP 11 – Energy (n = 45) as shown in table S4.

Table 4 shows the targets with the most connected NCPs (threshold 15 connections), with 3.4 being the single target linked to all 18 NCPs, with 11 strong and 7 weak identified links. The complete table can be found in S5 in the supplementary material.

Table 4: Top 5 targets with most links to NCPs.

	SDG Target	Number of linked NCPs
	3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being	18
	1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than \$1.25 a day	15
	2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round	15
	2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons	15
	8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	15

Links of reference IAS impact on NCPs and SDG targets

The IPBES impacts evidence database (Bacher *et al.*, 2024, 2025) links the six reference species to 15 of 18 NCPs (the unlinked NCPs are 3, 15, and 17). NCP 12 is linked to 5 of 6 species, NCPs 10, 13, 16 and 18 are each linked to 4 of the reference species (see S6).

Dreissena polymorpha and *Pontederia crassipes* are the species with the highest number of linked impacts on NCPs (11 and 12 respectively). Table 5 shows the results for the study species.

Table 5: Number of negatively or positively impacted NCPs per sample species based on their impact assessment in Bacher et al. (2024, 2025)

Species name	Number of impacted NCPs		
	total	negative impact	positive impact
<i>Dreissena polymorpha</i>	11	11	3
<i>Felis catus</i>	2	2	-
<i>Pontederia crassipes</i>	12	9	8
<i>Rattus rattus</i>	2	2	-
<i>Robinia pseudoacacia</i>	8	4	7
<i>Solenopsis geminata</i>	5	5	-

As shown in Table 6, a total of 1363 links were examined for literature support, of which literature support could be found for 24% of the links. *Pontederia crassipes* was the species for which the largest number of supported links was examined for literature support.

Rattus rattus and *Pontederia crassipes* are the species with the highest proportion of literature support (37% and 33% respectively). For *Solenopsis geminata* only 10% of the NCP-SDG target links are supported by the given literature.

Table 6: Number of NCP-SDG target links assessed for literature support per sample species. “Yes” indicates, that the established NCP-SDG target link can be supported with the reference literature from (Bacher et al., 2024, 2025)

Species name	Number of links assessed for literature support	Literature support	
	total	no	yes
<i>Dreissena polymorpha</i>	349	275 79%	74 21%
<i>Felis catus</i>	45	34 76%	11 24%
<i>Pontederia crassipes</i>	492	331 67%	161 33%
<i>Rattus rattus</i>	52	33 64% ¹	19 37% ¹
<i>Robinia pseudoacacia</i>	262	218 83%	44 17%
<i>Solenopsis geminata</i>	163	147 90%	16 10%
Total number	1363	1038	325
Percentage		76%	24%

¹ Discrepancies due to rounding

Analyzing the literature support of the IAS-NCP-SDG target links from the perspective of the NCPs, NCPs 12 - Food and Feed (n = 184), 10 - Regulation of detrimental organisms (n = 182) and 11 - Energy (n = 179) had the most links evaluated. The largest numbers of links with literature support were identified for NCP 12 (n = 73) and NCP 7 (n = 65). Results for all NCPs can be found in table S7.

When analyzing the IAS-NCP-SDG target links for literature support from the perspective of the SDG targets, 88 targets were assessed for literature support of IAS impact. Of the 88 assessed targets, literature support for IAS-NCP-SDG target links could be found for 43 targets (~25% of total SDG targets). Most links with literature support were found for the targets within SDG 1 (n = 83) and 2 (n = 77). Most links were examined for the targets within SDG 15 (n = 285), but just 10% were rated “yes” for literature support (Table S8). Table 7 shows the top ten targets with the highest numbers of links supported by literature.

Table 7: Top ten targets with the highest numbers of literature supported IAS-NCP links

SDG Target	Number of links with literature support		Number of links assessed for literature support
	no	yes	
SDG 1.1	26	23	49
	53%	47%	
SDG 1.2	25	23	48
	52%	48%	
SDG 8.1	28	21	49
	57%	43%	
SDG 1.5	16	19	35
	46%	54%	
SDG 2.1	21	19	40
	53% ¹	48% ¹	
SDG 2.2	22	18	40
	55%	45%	
SDG 1.4	16	17	33
	49% ¹	52% ¹	
SDG 2.3	20	17	37
	54%	46%	
SDG 2.4	20	17	37
	54%	46%	
SDG 3.4	34	17	51
	67%	33%	

¹ Discrepancies due to rounding

Finally, the water hyacinth has most identified connections (n =12) to SDGs, followed by black locust (n = 10) zebra mussel (n = 9) fire ant (n = 6), feral cat and black rat (both n = 4; Figure 3).

Species with positive impacts on the SDG	SDG	Species with negative impacts on the SDG
<i>Pontederia crassipes</i> , <i>Robinia pseudoacacia</i>		<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Felis catus</i> , <i>Robinia pseudoacacia</i> , <i>Solenopsis geminata</i> , <i>Rattus rattus</i>
<i>Pontederia crassipes</i> , <i>Robinia pseudoacacia</i>		<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Felis catus</i> , <i>Robinia pseudoacacia</i> , <i>Solenopsis geminata</i> , <i>Rattus rattus</i>
<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i>		<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i> , <i>Solenopsis geminata</i>
		<i>Pontederia crassipes</i>
<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i>		<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i>
<i>Pontederia crassipes</i> , <i>Robinia pseudoacacia</i>		<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i>
<i>Pontederia crassipes</i> , <i>Robinia pseudoacacia</i>		<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Felis catus</i> , <i>Robinia pseudoacacia</i> , <i>Solenopsis geminata</i> , <i>Rattus rattus</i>
<i>Robinia pseudoacacia</i>		<i>Pontederia crassipes</i>
<i>Pontederia crassipes</i>		<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i>
<i>Pontederia crassipes</i>		<i>Dreissena polymorpha</i> , <i>Rattus rattus</i>
<i>Pontederia crassipes</i> , <i>Robinia pseudoacacia</i>		<i>Solenopsis geminata</i>
<i>Pontederia crassipes</i>		<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Felis catus</i> , <i>Robinia pseudoacacia</i> , <i>Solenopsis geminata</i>

Figure 3: This graphic shows the 12 impacted SDGs with the target species for which literature support was found for the impact of the species through NCP.

Discussion

Overall, 89 SDG targets could be linked to at least one NCP based on their definitions and support from the literature. This number of links indicates a strong connection between the provisioning of NCPs to achieve sustainable development particularly for SDG 1 – *No Poverty*, 2 – *Zero Hunger*, 3 – *Good Health and Well Being*, 8 – *Decent Work and Economic Growth*, and 15 – *Life on Land*. Through this linkage it was possible to assess the impact (positive and negative) of invasive alien species on the SDG targets via their documented impacts on individual NCPs. I found literature support for ~ 25% of the links where the focal IAS impact a specific NCPs and subsequently the SDG target. While this support is substantial, there are still many unsupported links indicating either an absence of these impacts in the literature or caveats within the framework, further explored below.

Linking NCPs to SDGs

There is ample evidence in the scientific literature that NCPs and SDG targets can be linked supporting the notion that NCPs underpin sustainable development (Anderson *et al.*, 2019; Butchart *et al.*, 2019; Smith *et al.*, 2021; Adhikari *et al.*, 2022; Moreira *et al.*, 2025). My results support previous findings showing that NCPs contribute substantially towards SDGs 1 and 2, but not to SDGs 16 – *Peace, justice and strong institutions* and 17 – *Partnerships for the Goals* (Adhikari *et al.*, 2022). While Adhikari *et al.* based their NCP-SDG linkages on a literature review, the NCP-SDG target links in this study are based on the NCP descriptions and available literature. Furthermore, I distinguished strong and weak links of NCPs and SDG targets. Following the flowchart (see Figure 1 in Methods), I checked if the target depends on natural resources (e.g. do the products of the NCP result in a beneficial outcome for the target?) or if the target requires a policy change and if natural resources are required to achieve it. To explain this by using an example, NCP 2 – Pollination can be linked with a strong link to SDG 15 targets 15.1 – 15.5, as the NCP provides key ecosystem functions related to revegetation or recolonization after disturbances and thus supports restoration efforts (Traveset and Rodríguez-Pérez, 2008). However, while seed dispersal contributes to genetic diversity (Traveset and Rodríguez-Pérez, 2008), a component of SDG 15.6 – *Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed* (United Nations, 2015), it does not ensure fair and equitable access to resulting resources and can therefore only be classified as a weak link.

Another example is NCP 6 – Regulation of freshwater quantity and SDG 7 targets 7.1 – *By 2030, ensure universal access to affordable, reliable and modern energy services* and 7.2 – *By 2030, increase substantially the share of renewable energy in the global energy mix*, the link to SDG 7.1 was classified as a weak link since the target focuses on policy to ensure access to renewable energy sources (e.g.

hydropower) (United Nations, 2015). In contrast, 7.2 aims to increase the share of renewable energy (United Nations, 2015) and therefore greatly benefits from the quantity of freshwater available for hydropower generation (Hidalgo González, Medarac and Magagna, 2020), thus it was rated as a strong link to NCP 6.

One difficulty during the process of linking NCPs and SDG targets was the context dependency of NCP contributions to SDG targets. While one NCP might contribute to the achievement of a SDG and its targets substantially in one region or for a specific group of people, it might not do so in another region. Looking at the SDG target 8.1 - *Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries* and NCP contribution, while NCP 12 – Food and Feed, which includes contributions such as production of crops, feed and livestock, can support economic development, its relevance for SDG 8.1 varies significantly across regions. In particular, its contribution is more pronounced in developing countries, where agriculture remains a central pillar of the economy and employment (Alston and Pardey, 2014).

Aside from context dependencies, a further challenge in linking NCPs to SDG targets lies in the narrow definition of what constitutes a NCP and how it is produced or what its products are. For example in the case of NCP 11 – Energy, while energy from biomass fuels contributes to the amount of energy needed for sustainable economic growth (Hosen *et al.*, 2024), other forms of renewable energy are more relevant to the economy (GEA, 2012). However, energy production from solar, wind or water is not included in the definition of NCP 11 (IPBES, 2019b).

To illustrate the interactions between SDGs and the role of nature, concrete examples showing how certain SDGs are closely linked to nature's contributions can be highlighted. The following text box (Box 2) uses SDGs 3, 4 and 7 to show how NCPs contribute to achieving the SDGs and their targets.

Box 2: Selection of SDG linkages to NCPs

Drawing on the flowchart from Figure 1, the following examples demonstrate the pathways through which *SDG 3 - Good Health and Well-being*, *SDG 4 - Quality Education*, and *SDG 7 - Affordable and Clean Energy* are linked to Nature's Contributions to People (NCP), elucidating the dependencies of sustainable development on ecosystem-derived benefits.

SDG 3 – Good Health and Well-being

In the developed database SDG 3 is the singular SDG showing a link to all 18 NCPs, in particular SDG 3.4 *By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and*

treatment and promote mental health and well-being. Mental health and well-being benefits from NCPs through reduction of stress and improved cardiovascular function (Butchart *et al.*, 2019; Marselle *et al.*, 2021; WHO, 2021), e.g. the availability of green spaces in urban areas is linked to decreased morbidity and mortality from cardiovascular and respiratory related diseases (Butchart *et al.*, 2019). The regulation of air quality supports the reduction premature death and diseases linked to air pollution, which is a major cause of premature deaths and non-communicable diseases (e.g. stroke, lung cancer, COPD) worldwide (IPBES, 2019b; Rentschler and Leonova, 2023; Compendium of WHO and other UN guidance in health and environment, 2024). Through regulation of climate and extreme weather events (IPBES, 2019b) the NCP can contribute to the target. E.g. exposure to heat caused more than 60,000 deaths in Europe during the summer of 2022 (Ballester *et al.*, 2023).

However, NCPs contribute to human health in a number of ways, e.g. through provision of nutrition (WHO, 2021), medicinal compounds (IPBES, 2019b), clean air (IPBES, 2019b; Rentschler and Leonova, 2023; Compendium of WHO and other UN guidance in health and environment, 2024) and water (WHO, UNICEF and World Bank, 2022), regulation of natural disasters and hazards (EEA, 2024) and by providing green spaces for recreation (Twohig-Bennett and Jones, 2018; White *et al.*, 2019).

Nature provides resources (e.g. biomedical compounds) for the production of medicines (Butchart *et al.*, 2019; IPBES, 2019b), for example traditional medicines with the use of wild plants (IPBES, 2022) or anti-inflammatory medicines from marine species (Malve, 2016; Banday *et al.*, 2024).

NCPs 6 – Regulation of freshwater quantity and 7 – Regulation of freshwater quality contribute to reduction of health impacts caused by water-borne diseases and pollution. Poor water quality is linked to diarrheal disease, e.g. cholera and typhoid fever, in children - one of the major causes of child death (WHO, UNICEF and World Bank, 2022). Also in Europe ~20% of infectious diseases outbreaks are linked to insufficient access to water and sanitation (WHO, 2021), access to water for sanitation also decreases maternal health risks e.g. of infection during delivery (Cameron, Chase and Contreras Suarez, 2021).

NCP 12 – Food and Feed contributes to reduction of starvation and malnutrition of children, study by Golden *et al.* (2011) found that the loss of access to wildlife leads to almost 30% increase of anemia in children.

Through the regulation of pests and pathogens in agriculture there is less need for pesticides and chemicals, because natural enemies reduce the abundance of pests (Saleh *et al.*, 2017; IPBES, 2019b). The use of pesticides is linked to child and adolescent mortality in South Africa (Davies, Hlela and Rother, 2023), and residential proximity to maize is linked to respiratory issues (Simões *et al.*, 2022), asthma (Bukalasa *et al.*, 2018), leukemia in children (Park *et al.*, 2020).

SDG 4 – Quality Education

SDG 4 is linked to 3 NCPs. While NCP 15 – Learning and inspiration contributes to education, the SDG targets within SDG 4 focus on structural changes and policy decisions that ensure free and equitable education for all. Nature, while providing a space for learning, does not solve the underlying structural and societal issues. If the capability approach is used, access to energy improves the educational situation, especially for girls and women, as they are responsible for collecting firewood or threshing grain in developing countries, and can

spend more time on education through the availability of energy (GEA, 2012; Adom *et al.*, 2021). However, the benefits of energy to education largely relate to the availability of modern energy (Adom *et al.*, 2021), e.g. access to electricity improves teaching and learning materials (GEA, 2012).

The third NCP linked to SDG 4 is NCP 6 - Regulation of Freshwater quantity, access to water and sanitation can reduce school dropout rates (Redhu *et al.*, 2023) especially for girls and women (United Nations, 2024).

SDG 7 – Affordable and clean energy

SDG 7 is linked to 5 NCPs (see Figure 2). All linked NCPs relate to the provision of resources for energy production from biomass or hydropower.

The links from NCPs 1, 2, 8 and 11 to SDG 7 relate to the functions of ecosystems, e.g. to provide raw materials for the production of biofuels or firewood (Butchart *et al.*, 2019; IPBES, 2019b). NCP 6 contributes to the SDG 7.1 and 7.2 through the provision of water quantities needed for production of energy (e.g. hydropower or cooling of production sites) (Hidalgo González, Medarac and Magagna, 2020).

Linking IAS impacts on NCPs to SDGs and targets

In this study, all 6 species could be linked to impact on SDGs 1, 2 and 8. The degree of connection between SDG targets impacted through NCPs varies, however, SDG targets linked to 15 or more NCPs in general were more heavily dependent on the availability of natural resources for income (IPBES, 2019b, 2022), nutrition (Butchart *et al.*, 2019), or good health and well-being (Butchart *et al.*, 2019; Marselle *et al.*, 2021; WHO, 2021). Also, IAS impacts on connected NCPs, such as NCP 12 – Food and Feed, are well recorded. For example the effects of rats on NCP 12, are well documented in GIDIAS (Bacher *et al.*, 2025), as the species impacts food production, harvests and agriculture (Bergman, 2000; Pimentel *et al.*, 2000; Makundi and Ogue, 2014; Dossou *et al.*, 2020), resulting in loss of income and economic damages (Pimentel *et al.*, 2000; Dossou *et al.*, 2020) as well as reduced availability of food (Olson, 2006; Makundi and Ogue, 2014; Dossou *et al.*, 2020), linking the species to SDGs 1, 2 and 8. Similarly, *Solenopsis geminata* is associated with negative impacts on agriculture through seed predation and destruction of crops (e.g. rice) (Litsinger *et al.*, 2009; Herrera *et al.*, 2020). These impacts on agriculture have a negative impact on the subsistence and income of smallholder farms and poor communities (Motzke *et al.*, 2013) and therefore support the links to targets of e.g. SDG 1 and 2.

Comparably, black locust negatively impacts SDGs 1, 2 and 8, due the species' impairment of livestock grazing capacities (Chikowore *et al.*, 2021) indicating a negative impact on income and food from livestock production. However, positive impacts are associated with production of honey (Vítková *et al.*, 2017). Furthermore, black locust can be used as construction material (NCP 13) (Vítková *et al.*, 2017; Martínez and Manzano-García, 2019) and biomass fuel (Rédei, 1999; Vítková *et al.*, 2017) relevant for SDG 7, but other literature does not indicate a significant contribution to peoples livelihoods (Chikowore, Chidawanyika and Martin, 2022).

However, not all impacts of IAS on SDGs can be linked through the species' impact on NCPs, since some impacts caused by IAS directly affect SDG targets and are not linked through NCPs, e.g. rats are known transmitters of diseases (GISD, 2025e), but the GIDIAS database (Bacher *et al.*, 2025) does not record an impact on NCPs linked to SDG 3 and its targets. Looking at the example of SDG 15, all six target species have impacts on ecosystems and biodiversity (Bacher *et al.*, 2023) and while five of them can be linked to SDG 15, only ~10% of the NCP-SDG target links examined could be confirmed with literature. But this does not mean impacts to SDGs are not there, they are just not linked through a NCP or that a target is not affected. For example, the water hyacinth is known to impact ecosystems (EPPO, 2021) and the species is listed as one of the IUCN 100 Worst Invaders (Global Invasive Species Database, 2025a), but the impact on SDG 15 targets does not occur through impact on NCP 12 – Food and Feed, which the species is linked to in GIDIAS (Bacher *et al.*, 2025). Furthermore, aquatic species, like *Pontederia crassipes* and *Dreissena polymorpha*, can't be linked to impacts on targets related to e.g. forest ecosystems.

Challenges and caveats

For some NCPs, like NCP 11 – Energy the process of finding literature support within the IPBES database was not straight forward. One reason for this might be the mismatch of NCP interpretations. During the process of establishing literature support for IAS impact on SDG targets through the NCPs, I noticed a mismatch of IPBES definition of the NCPs and recorded impacts in GIDIAS (Bacher *et al.*, 2025) as well as some of the reference literature not discussing impacts relevant for the NCP. Most likely reasons for that could be the use of different definitions and interpretations of the NCP scope between assessors of the IPBES database and the approach used in this study. Bacher *et al.* (2025) for example does not explicitly state if the used NCP definitions include their descriptions of the production mechanisms as has been done here.

Such a mismatch in definition might for example be the case for *Dreissena polymorpha*. Here, impacts on NCP 11 - Energy are recorded in the database, with the rationale that *D. polymorpha* affects the productivity of hydropower plants through blockage and damage to infrastructure leading to costs for repairs, modifications and inactivity (U.S. Congress Office of Technology Assessment, 1993; Pimentel *et al.*, 2000; Cusack, Harte and Chan, 2009; Strayer, 2009). The mismatch of recorded impacts and NCP definition also applies to *Pontederia crassipes*; here, too, the blocking and obstruction of hydropower plants was classified as a negative impact on NCP 11 (Bacher *et al.*, 2025). While these impacts do exist, they cannot be linked to NCP 11 - Energy when strictly following the definition and production mechanism that refer to the production of energy from biomass and do not include energy production from solar, wind and water (IPBES, 2019b). Also for NCP 6 - Regulation of freshwater quantity, the

recorded impacts in the database (Bacher *et al.*, 2025) do not match the NCP description of IPBES (IPBES, 2019b). According to GIDIAS (Bacher *et al.*, 2025), *Dreissena polymorpha* and *Pontederia crassipes* affect NCP 6 by blocking water pipes (Minchin, Lucy and Sullivan, 2002; Aloo *et al.*, 2013), whereas the NCP refers to the regulation of water quantity by ecosystems (IPBES, 2019b).

Looking at the relevance of freshwater quantity for the SDGs, in the first step of the analysis, NCP 6 – Regulation of freshwater quantity was linked to 31 targets, spread across 11 SDGs (Figure 2). Access to water is relevant for various economic sectors as well as the jobs and income that result from it. In agriculture, for example, water is needed to irrigate crops (IPBES, 2019b) and irrigation in the agricultural sector accounts for ~ 70% of freshwater withdrawals (FAO, 2022), but tourism, transport and hydropower (IPBES, 2019b; Redhu *et al.*, 2023) are also dependent on the availability of water. Blockage of water pipes used for irrigation by zebra mussels (Minchin, Lucy and Sullivan, 2002) therefore can impact SDG targets linked to agriculture, food security and health. Similarly to the zebra mussel the water-hyacinth is also linked to impact on NCP 6 through clogging of water pipes, however the species is also linked to altered flowrates, increased evapotranspiration and flood regimens (Gebregiorgis, 2017; Ali and El-Din Khedr, 2018; Shackleton *et al.*, 2018), impacts that are relevant for NCP 6 (IPBES, 2019b) and effect the associated SDG targets.

Furthermore, on several accounts references given in the IPBES database do not actually discuss the impacts supposed to be referenced, e.g. the database records an impact of *Dreissena polymorpha* on NCP 5 – Regulation of Ocean acidification, however the reference (Strayer, 2009) does not mention an impact relevant for NCP 5. Another issue is that the selection of literature in the IPBES database might include data gaps due to the method of literature collection (Bacher *et al.*, 2025) and thus possibly does not exhaustively document the impact of the six example species on the respective NCPs.

If one were to be very precise, one would have to calculate the impact of an NCP on the target using the NCP and SDG target indicators for each target and then analyze how the invasive species affects the NCP. For example, looking at the SDG target 8.1 *Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries* and the species *Rattus rattus* and *Dreissena polymorpha*, which both have economic impacts due to damages they cause. Rats cause \$19 billion of damages to stored crops in the U.S. each year alone (Pimentel *et al.*, 2000). While for the U.S. economy this impact might not decrease target achievement, for another nation this damage might impair progress toward the achievement of the target. In the case of *Dreissena polymorpha* impact on target 8.1 comes from costs for water treatment due to declining water quality (Colautti *et al.*, 2006), which represents an additional financial burden for poor communities.

Conclusion

More than half of the 169 SDG targets are dependent on nature and NCPs for their development (Butchart *et al.*, 2019; Hole *et al.*, 2022) and nevertheless nature and NCPs are under pressure from land and sea-use change, exploitation, climate change and invasive species (IPBES, 2019a). In particular, the pressure from land-use change combined with climate change is fueling the spread of IAS (IPBES, 2023).

Invasive species influence the SDGs and their targets beyond SDG 15 and target 15.8 (Lenzner *et al.*, 2024). And as shown in this study, changes in the NCPs caused by the 6 reference species affect 12 out of 17 SDG and they especially influence the development of SDGs 1, 2, 3, 6 and 8. With negative impact on all linked SDGs and positive impact on 11 SDGs. However, IAS and their impact on these SDGs are not recognized in the Agenda 2030 (United Nations, 2015; Lenzner *et al.*, 2024).

Linking IAS impacts on SDGs targets through NCP provides insight into how changes in NCPs affect the development of the SDGs and their targets. However, while linking IAS impacts on SDG targets through their impacts on NCPs was successful and it is interesting to see how IAS can impact SDGs through changes to nature and NCPs, the exclusive use of literature from the database has unnecessarily complicated the confirmation process for literature support. Therefore, missing literature evidence for links does not mean that these are false but that they have not yet been documented and might act as research frontiers.

Ultimately, invasive species have ecological, economic and social impacts, which are given too little consideration in the 2030 Agenda (Lenzner *et al.*, 2024). In order to gain further insights into the connection of NCP contributions to the development of the SDGs, a detailed analysis of NCP contributions to SDGs is necessary, e.g. through assessing regional NCP trends using the proposed indicators from the Chapter 2.3 supplementary material (IPBES, 2019b) and then linking them to the suggested SDG target indicators. Such an analysis could provide a deeper understanding of how NCPs influence SDG development of a region or nation. To subsequently gain deeper insights into how IAS impacts SDG development, detailed analysis on how species influence NCP trends are needed.

References:

- Adhikari, B. *et al.* (2022) 'Nature's contributions to people and the Sustainable Development Goals in Nepal', *Environ. Res. Lett.*, 17, p. 93007. Available at: <https://doi.org/10.1088/1748-9326/ac8e1e>.
- Adom, P.K. *et al.* (2021) 'Energy poverty, development outcomes, and transition to green energy', *Renewable Energy*, 178, pp. 1337–1352. Available at: <https://doi.org/10.1016/J.RENENE.2021.06.120>.
- Ali, Y.M. and El-Din Khedr, I.S. (2018) 'Estimation of water losses through evapotranspiration of aquatic weeds in the Nile River (Case study: Rosetta Branch)', *Water Science*, 32(2), pp. 259–275. Available at: <https://doi.org/10.1016/J.WSJ.2018.08.002>.
- Aloo, P. *et al.* (2013) 'A review of the impacts of invasive aquatic weeds on the bio-diversity of some tropical water bodies with special reference to Lake Victoria (Kenya)', *Biodiversity Journal*, 4(4), pp. 471–482.
- Alston, J.M. and Pardey, P.G. (2014) 'Agriculture in the Global Economy', *Journal of Economic Perspectives*, 28(1), pp. 121–146. Available at: <https://doi.org/10.1257/jep.28.1.121>.
- Anderson, C.B. *et al.* (2019) 'Determining nature's contributions to achieve the sustainable development goals', 14, pp. 543–547. Available at: <https://doi.org/10.1007/s11625-018-0643-5>.
- Ayanda, O.I., Ajayi, T. and Asuwaju, F.P. (2020) 'Eichhornia crassipes (Mart.) Solms: Uses, Challenges, Threats, and Prospects'. Available at: <https://doi.org/10.1155/2020/3452172>.
- Bacher, S. *et al.* (2023) *Chapter 4. Impacts of invasive alien species on nature, nature's contributions to people, and good quality of life 1*. Available at: <https://doi.org/10.5281/zenodo.7430731>.
- Bacher, S. *et al.* (2024) 'IPBES Invasive Alien Species Assessment, database for Chapter 4. Impact Evidence Database'. Zenodo. Available at: <https://doi.org/10.5281/zenodo.13997856>.
- Bacher, S. *et al.* (2025) 'Global Impacts Dataset of Invasive Alien Species (GIDIAS)', *Scientific Data*, 12(1), p. 832. Available at: <https://doi.org/10.1038/s41597-025-05184-5>.
- Ballester, J. *et al.* (2023) 'Heat-related mortality in Europe during the summer of 2022', *Nature Medicine*, 29(7), pp. 1857–1866. Available at: <https://doi.org/10.1038/s41591-023-02419-z>.
- Banday, A.H. *et al.* (2024) 'Exploring the potential of marine natural products in drug development: A comprehensive review', *Phytochemistry Letters*, 59, pp. 124–135. Available at: <https://doi.org/10.1016/J.PHYTOL.2024.01.001>.
- Barbier, E.B. and Burgess, J.C. (2019) 'Sustainable development goal indicators: Analyzing trade-offs and complementarities', *World Development*, 122, pp. 295–305. Available at: <https://doi.org/10.1016/j.worlddev.2019.05.026>.
- Basaula, R. *et al.* (2023) 'Effects of invasive water hyacinth on fish diversity and abundance in the Lake Cluster of Pokhara Valley, Nepal', *Global Ecology and Conservation*, 46, p. e02565. Available at: <https://doi.org/10.1016/J.GECCO.2023.E02565>.
- Bergman, D.L. (2000) *The economic impact of invasive species to Wildlife Services' cooperators*. Available at: <https://www.researchgate.net/publication/253524603>.
- Blackburn, T.M. *et al.* (2014) 'A Unified Classification of Alien Species Based on the Magnitude of their Environmental Impacts', *PLoS Biology*, 12(5), p. e1001850. Available at: <https://doi.org/10.1371/journal.pbio.1001850>.
- Blackburn, T.M., Bellard, C. and Ricciardi, A. (2019) 'Alien versus native species as drivers of recent extinctions', *Frontiers in Ecology and the Environment*, 17(4), pp. 203–207. Available at: <https://doi.org/10.1002/fee.2020>.

Booy, O. *et al.* (2017) 'Impact of Biological Invasions on Infrastructure', in *Impact of Biological Invasions on Ecosystem Services*. Cham: Springer International Publishing, pp. 235–247. Available at: https://doi.org/10.1007/978-3-319-45121-3_15.

Brauman, K.A. *et al.* (2019) 'Chapter 2.3. Status and Trends – Nature's Contributions to People (NCP). In: Global assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.', in E.S. Settele, J. D.S. N.H.T. (eds) Brondízio (ed.). Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), p. 1082.

Bukalasa, J.S. *et al.* (2018) 'Associations of residential exposure to agricultural pesticides with asthma prevalence in adolescence: The PIAMA birth cohort', *Environment International*, 121, pp. 435–442. Available at: <https://doi.org/10.1016/j.envint.2018.09.029>.

Butchart, S.H.M. *et al.* (2019) *Chapter 3. Assessing progress towards meeting major international objectives related to nature and nature's contributions to people., Global assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.*

Cameron, L., Chase, C. and Contreras Suarez, D. (2021) 'Relationship between water and sanitation and maternal health: Evidence from Indonesia', *World Development*, 147, p. 105637. Available at: <https://doi.org/10.1016/J.WORLDDEV.2021.105637>.

CBD (2014) 'Pathways of Introduction of invasive species, their prioritization and management', *Convention on Biological Diversity*, (June 2014), p. 18.

Cherwoo, L. *et al.* (2024) 'Water hyacinth biomass valorization: fostering biodiversity and sustainable development in the bioeconomy', *Biodiversity and Bioeconomy: Status Quo, Challenges, and Opportunities*, pp. 445–474. Available at: <https://doi.org/10.1016/B978-0-323-95482-2.00020-1>.

Chikowore, G. *et al.* (2021) 'Reduction of Grazing Capacity in High-Elevation Rangelands After Black Locust Invasion in South Africa', *Rangeland Ecology & Management*, 76, pp. 109–117. Available at: <https://doi.org/10.1016/j.rama.2021.02.006>.

Chikowore, G., Chidawanyika, F. and Martin, G.D. (2022) 'Contributions of black locust (*Robinia pseudoacacia* L.) to livelihoods of peri-urban dwellers in the Free State Province of South Africa', *GeoJournal*, 87(6), pp. 4565–4578. Available at: <https://doi.org/10.1007/s10708-021-10515-1>.

Coetzee, J.A., Jones, R.W. and Hill, M.P. (2014) 'Water hyacinth, *Eichhornia crassipes* (Pontederiaceae), reduces benthic macroinvertebrate diversity in a protected subtropical lake in South Africa', *Biodiversity and Conservation*, 23(5), pp. 1319–1330. Available at: <https://doi.org/10.1007/s10531-014-0667-9>.

Colautti, R.I. *et al.* (2006) 'Characterised and Projected Costs of Nonindigenous Species in Canada', *Biological Invasions*, 8(1), pp. 45–59. Available at: <https://doi.org/10.1007/s10530-005-0236-y>.

Compendium of WHO and other UN guidance in health and environment, 2024 update. Geneva: World Health Organization (2024) *Compendium of WHO and other UN guidance on health and environment 2024 update*.

Cusack, C., Harte, M. and Chan, S. (2009) 'The Economics Of Invasive Species'. Available at: http://www.hear.org/articles/cip_winter2001v2n1_guilty.pdf.

Davies, B., Hlela, M.B.K.M. and Rother, H.-A. (2023) 'Child and adolescent mortality associated with pesticide toxicity in Cape Town, South Africa, 2010–2019: a retrospective case review', *BMC Public Health*, 23(1), p. 792. Available at: <https://doi.org/10.1186/s12889-023-15652-5>.

Degaga, A.H. (2019) 'Water Hyacinth (*Eichhornia crassipes*) Biology and Its Impacts on Ecosystem, Biodiversity, Economy and Human Well-being', *Journal of Natural Sciences Research* [Preprint]. Available at: <https://doi.org/10.7176/JNSR/9-12-04>.

Dersseh, M.G. *et al.* (2019) 'Water hyacinth: Review of its impacts on hydrology and ecosystem services- Lessons for management of Lake Tana', *Extreme Hydrology and Climate Variability: Monitoring, Modelling, Adaptation and Mitigation*, pp. 237–251. Available at: <https://doi.org/10.1016/B978-0-12-815998-9.00019-1>.

Díaz, S. *et al.* (2018) 'Assessing nature's contributions to people: Recognizing culture, and diverse sources of knowledge, can improve assessments', *Science*, pp. 270–272. Available at: <https://doi.org/10.1126/science.aap8826>.

Dossou, H.-J. *et al.* (2020) 'Invasive rodents and damages to food stocks: a study in the Autonomous Harbor of Cotonou, Benin', *Agronomy, Society and Environment*, 2020(1), pp. 28–36. Available at: <https://doi.org/10.25518/1780-4507.18326i>.

Dueñas, M.A. *et al.* (2021) 'The threat of invasive species to IUCN-listed critically endangered species: A systematic review', *Global Ecology and Conservation*, 26, p. e01476. Available at: <https://doi.org/10.1016/J.GECCO.2021.E01476>.

EEA (2024) *Responding to climate change impacts on human health in Europe: focus on floods, droughts and water quality*. Luxembourg. Available at: <https://doi.org/10.2800/4810>.

Enyew, B.G., Assefa, W.W. and Gezie, A. (2020) 'Socioeconomic effects of water hyacinth (*Echhornia Crassipes*) in Lake Tana, North Western Ethiopia', *PLOS ONE*. Edited by A. Bajwa, 15(9), p. e0237668. Available at: <https://doi.org/10.1371/journal.pone.0237668>.

EPPO (2021) 'PM 9/8 (2) *Pontederia crassipes*', *EPPO Bulletin*, 51(3), pp. 610–615. Available at: <https://doi.org/10.1111/epp.12784>.

Ezama, D.O. (2019) 'The Maritime Commons : Digital Repository of the World Maritime Impact of water hyacinth infestation in Nigerian inland waters : utilization and management IMPACT OF WATER HYACINTH INFESTATION IN NIGERIA INLAND WATERS : UTILIZATION AND MANAGEMENT By'.

FAO (2022) *The State of the World's Land and Water Resources for Food and Agriculture 2021 – Systems at breaking point*. FAO. Available at: <https://doi.org/10.4060/cb9910en>.

GEA (2012) *Global Energy Assessment: toward a sustainable future - Chapter 5 - Energy Security, Global Energy Assessment*.

Gebregiorgis, F.Y. (2017) *Management of water hyacinth (Eichhornia crassipes [Mart.] Solms) using bioagents in the Rift Valley of Ethiopia*. Wageningen University. Available at: <https://doi.org/10.18174/401611>.

Global Invasive Species Database (2025a) *100 of the World's Worst Invasive Alien Species*. Available at: https://www.iucngisd.org/gisd/100_worst.php (Accessed: 29 April 2025).

Global Invasive Species Database (2025b) *Species profile: Aedes albopictus*. Available at: <http://www.iucngisd.org/gisd/species.php?sc=109> (Accessed: 28 April 2025).

Global Invasive Species Database (2025c) *Species profile: Dreissena polymorpha*. Available at: <https://www.iucngisd.org/gisd/species.php?sc=50> (Accessed: 28 April 2025).

Global Invasive Species Database (2025d) *Species profile: Felis catus*. Available at: <https://www.iucngisd.org/gisd/species.php?sc=24>.

Global Invasive Species Database (2025e) *Species profile: Rattus rattus*. Available at: <https://www.iucngisd.org/gisd/species.php?sc=19>.

Golden, C.D. *et al.* (2011) 'Benefits of wildlife consumption to child nutrition in a biodiversity hotspot', *Proceedings of the National Academy of Sciences of the United States of America*, 108(49), pp. 19653–19656. Available at: <https://doi.org/10.1073/PNAS.1112586108/-/DCSUPPLEMENTAL>.

- Herrera, H. W. *et al.* (2020) 'Distribution and habitat preferences of Galápagos ants (Hymenoptera: Formicidae)', *Belgian Journal of Entomology*, 93, pp. 1–60. Available at: www.srbe-kbve.be.
- Hidalgo González, I., Medarac, H. and Magagna, D. (2020) 'Projected freshwater needs of the energy sector in the European Union and the UK. Technical report in publication, Joint Research Centre (European Commission)', *Technical report in publication, Joint Research Centre (European Commission)* [Preprint]. Available at: <https://doi.org/10.2760/796885>.
- Hole, D.G. *et al.* (2022) 'Make nature's role visible to achieve the SDGs'. Available at: <https://doi.org/10.1017/sus.2022.5>.
- Hosen, M.E. *et al.* (2024) 'Biomass energy for sustainable development: evidence from Asian countries', 26, pp. 3617–3637. Available at: <https://doi.org/10.1007/s10668-022-02850-1>.
- Hulme, P.E. *et al.* (2014) 'Greater Focus Needed on Alien Plant Impacts in Protected Areas', *Conservation Letters*, 7(5), pp. 459–466. Available at: <https://doi.org/10.1111/conl.12061>.
- IPBES (2019a) *Global assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Debating Nature's Value*. Available at: <https://ipbes.net/global-assessment%0Ahttps://ipbes.net/global-assessment-report-biodiversity-ecosystem-services>.
- IPBES (2019b) 'IPBES Global assessment – Chapter 2.3 Supplementary materials', *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, p. 91.
- IPBES (2022) *Thematic Assessment Report on the Sustainable Use of Wild Species of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Edited by J.M.. E.M.R.. D.J.. D.M.C.. H.A.. and K.D. (eds.). Fromentin. Bonn, Germany: IPBES secretariat. Available at: <https://doi.org/10.5281/zenodo.6425599>.
- IPBES (2023) *Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Edited by H.E.. Roy et al. Bonn, Germany: IBPES secretariat. Available at: <https://doi.org/10.5281/zenodo.7430682>.
- Jones, B.A. (2019) 'Infant health impacts of freshwater algal blooms: Evidence from an invasive species natural experiment', *Journal of Environmental Economics and Management*, 96, pp. 36–59. Available at: <https://doi.org/10.1016/J.JEEM.2019.05.002>.
- Kateregga, E. and Sterner, T. (2009) 'Lake Victoria Fish Stocks and the Effects of Water Hyacinth', *The Journal of Environment & Development*, 18(1), pp. 62–78. Available at: <https://doi.org/10.1177/1070496508329467>.
- Kenfack Voukeng, S. *et al.* (2019) 'The attitudes of riparian communities to the presence of water hyacinth in the Wouri River Basin, Douala, Cameroon', *African Journal of Aquatic Science*, 44(1), pp. 7–13. Available at: <https://doi.org/10.2989/16085914.2018.1538868>.
- Lammertsma, D.R., Bruinderink, G.W. and Griffioen, a J. (2012) 'Risk assessment of Sika deer *Cervus nippon* in the Netherlands.', *Alterra-rapport - wageningen university and research centre* [Preprint].
- Lazzaro, L. *et al.* (2018) 'Invasive alien plant impacts on human health and well-being.', in *Invasive species and human health*. Wallingford: CABI, pp. 16–33. Available at: <https://doi.org/10.1079/9781786390981.0016>.
- Lenzner, B. *et al.* (2024) 'The neglected importance of managing biological invasions for sustainable development'. Available at: <https://doi.org/10.1002/pan3.10712>.
- Litsinger, J.A. *et al.* (2009) 'Comparison of insect pest complexes in different Philippine dryland rice environments: Population densities, yield loss, and management', *International Journal of Pest Management*, 55(2), pp. 129–149. Available at: <https://doi.org/10.1080/09670870802604054>.

- Makundi, R. and Oguge, N. (2014) *Rodent Pest Management in East Africa-An Ecological Approach*. Available at: <https://www.researchgate.net/publication/235347850>.
- Malve, H. (2016) 'Exploring the ocean for new drug developments: Marine pharmacology', *Journal of Pharmacy and Bioallied Sciences*, 8(2), pp. 83–91. Available at: <https://doi.org/10.4103/0975-7406.171700>.
- Marselle, M.R. *et al.* (2021) 'Pathways linking biodiversity to human health: A conceptual framework', *Environment International*, 150, p. 106420. Available at: <https://doi.org/10.1016/J.ENVINT.2021.106420>.
- Martínez, G.J. and Manzano-García, J. (2019) 'Perception and use of non-native and invasive flora from Sierras de Córdoba in central Argentina', *Acta Botanica Brasilica*, 33(2), pp. 241–253. Available at: <https://doi.org/10.1590/0102-33062018abb0316>.
- Masifwa, W.F., Twongo, T. and Denny, P. (2001) *The impact of water hyacinth, Eichhornia crassipes (Mart) Solms on the abundance and diversity of aquatic macroinvertebrates along the shores of northern Lake Victoria, Uganda, Hydrobiologia*.
- Midgley, J.M., Hill, M.P. and Villet, M.H. (2006) 'The effect of water hyacinth, Eichhornia crassipes (Martius) SolmsLaubach (Pontederiaceae), on benthic biodiversity in two impoundments on the New Year's River, South Africa', *African Journal of Aquatic Science*, 31(1), pp. 25–30. Available at: <https://doi.org/10.2989/16085910609503868>.
- Minchin, D., Lucy, F. and Sullivan, M. (2002) 'Zebra Mussel: Impacts and Spread', in *Invasive Aquatic Species of Europe. Distribution, Impacts and Management*. Dordrecht: Springer Netherlands, pp. 135–146. Available at: https://doi.org/10.1007/978-94-015-9956-6_15.
- Mironga, J. M., Mathooko, J. M. and Onywere, S.M. (2012) 'Effect of Water Hyacinth Infestation on the Physicochemical Characteristics of Lake Naivasha', *Research Journal of Environmental Science*, 2(7), pp. 103–113.
- Mironga, J.M., Mathooko, J.M. and Onywere, S.M. (2011) 'The Effect of Water Hyacinth (Eichhornia Crassipes) Infestation on Phytoplankton Productivity in Lake Naivasha and the Status of Control', *Journal of Environmental Science and Engineering*, 5, pp. 1252–1260.
- Moreira, M. *et al.* (2025) 'A systematic review of Nature's Contributions to People: impacts on science, policy, and sustainability', *Sustainability Science* [Preprint], (0123456789). Available at: <https://doi.org/10.1007/s11625-025-01694-8>.
- Motzke, I. *et al.* (2013) 'Ant seed predation, pesticide applications and farmers' income from tropical multi-cropping gardens', *Agricultural and Forest Entomology*, 15(3), pp. 245–254. Available at: <https://doi.org/10.1111/afe.12011>.
- Musinguzi, L. *et al.* (2022) 'Common water hyacinth (Pontederia crassipes) invades Lakes Edward, George, and Kazinga Channel: A call for immediate action', *Journal of Great Lakes Research*, 48(6), pp. 1723–1727. Available at: <https://doi.org/10.1016/J.JGLR.2022.09.008>.
- Näslund, J. *et al.* (2021) 'Emerging Mosquito-Borne Viruses Linked to Aedes aegypti and Aedes albopictus : Global Status and Preventive Strategies', *Vector-Borne and Zoonotic Diseases*, 21(10), pp. 731–746. Available at: <https://doi.org/10.1089/vbz.2020.2762>.
- Nega, D.T. *et al.* (2024) 'A comprehensive policy framework for unlocking the potential of water hyacinth in Ethiopia's circular bioeconomy', *Journal of Cleaner Production*, 435, p. 140509. Available at: <https://doi.org/10.1016/J.JCLEPRO.2023.140509>.
- Nilsson, M., Griggs, D. and Visbeck, M. (2016) 'Policy: Map the interactions between Sustainable Development Goals', *Nature*, pp. 320–322. Available at: <https://doi.org/10.1038/534320a>.

- Olson, L.J. (2006) 'The Economics of Terrestrial Invasive Species: A Review of the Literature', *Agricultural and Resource Economics Review*, 35(1), pp. 178–194. Available at: <https://doi.org/10.1017/S1068280500010145>.
- Paini, D.R. *et al.* (2016) 'Global threat to agriculture from invasive species', *Proceedings of the National Academy of Sciences*, 113(27), pp. 7575–7579. Available at: <https://doi.org/10.1073/pnas.1602205113>.
- Palazón, S. and Roy, S. (2014) 'Neovison vison (American mink)', *CABI Compendium* [Preprint]. Available at: <https://doi.org/10.1079/cabicompendium.74428>.
- Park, A.S. *et al.* (2020) 'Prenatal pesticide exposure and childhood leukemia – A California statewide case-control study', *International Journal of Hygiene and Environmental Health*, 226, p. 113486. Available at: <https://doi.org/10.1016/j.ijheh.2020.113486>.
- Pejchar, L. and Mooney, H.A. (2009) 'Invasive species, ecosystem services and human well-being', *Trends in Ecology & Evolution*, 24(9), pp. 497–504. Available at: <https://doi.org/10.1016/J.TREE.2009.03.016>.
- Pimentel, D. *et al.* (2000) 'Environmental and economic costs of nonindigenous species in the United States', *BioScience*, 50(1), pp. 53–65. Available at: [https://doi.org/10.1641/0006-3568\(2000\)050\[0053:EAECON\]2.3.CO;2](https://doi.org/10.1641/0006-3568(2000)050[0053:EAECON]2.3.CO;2).
- Pothen, F. and Welsch, H. (2019) 'Economic development and material use. Evidence from international panel data', *World Development*, 115, pp. 107–119. Available at: <https://doi.org/10.1016/J.WORLDDEV.2018.06.008>.
- Pradhan, P. *et al.* (2017) 'A Systematic Study of Sustainable Development Goal (SDG) Interactions', *Earth's Future*, 5(11), pp. 1169–1179. Available at: <https://doi.org/10.1002/2017EF000632>.
- Pyšek, P. *et al.* (2020) 'Scientists' warning on invasive alien species', *Biological Reviews*, 95(6), pp. 1511–1534. Available at: <https://doi.org/10.1111/brv.12627>.
- R Core Team (2024) 'R: A Language and Environment for Statistical Computing'. Vienna, Austria: R Foundation for Statistical Computing. Available at: <https://www.r-project.org>.
- Ramula, S. (2015) 'Lupinus polyphyllus (garden lupin)', *CABI Compendium* [Preprint]. Available at: <https://doi.org/10.1079/cabicompendium.31710>.
- Rédei, K. (1999) 'Black locust (*Robinia pseudoacacia* L.) energy plantations in Hungary', *Silva Gandavensis*, 64(1999). Available at: <https://doi.org/10.21825/sg.v64i0.827>.
- Redhu, Sonika *et al.* (2023) 'Unveiling the nexus between water scarcity and socioeconomic development in the water-scarce countries', 26, pp. 19557–19577. Available at: <https://doi.org/10.1007/s10668-023-03425-4>.
- Reid, H. and Shafiqul Alam, S. (2017) 'Ecosystem-based approaches to adaptation: evidence from two sites in Bangladesh', *Climate and Development*, 9(6), pp. 518–536. Available at: <https://doi.org/10.1080/17565529.2016.1167663>.
- Rentschler, J. and Leonova, N. (2023) 'Global air pollution exposure and poverty'. Available at: <https://doi.org/10.1038/s41467-023-39797-4>.
- Saleh, M. *et al.* (2017) 'Biological Pest Control for Sustainable Agriculture in Egypt', in, pp. 145–188. Available at: https://doi.org/10.1007/698_2017_162.
- Shackleton, R.T. *et al.* (2017) 'Distribution and socio-ecological impacts of the invasive alien cactus *Opuntia stricta* in eastern Africa', *Biological Invasions*, 19(8), pp. 2427–2441. Available at: <https://doi.org/10.1007/s10530-017-1453-x>.
- Shackleton, R.T. *et al.* (2018) 'Social-ecological drivers and impacts of invasion-related regime shifts: consequences for ecosystem services and human wellbeing', *Environmental Science & Policy*, 89, pp. 300–314.

Available at: <https://doi.org/10.1016/J.ENVSCI.2018.08.005>.

Shackleton, R.T., Shackleton, C.M. and Kull, C.A. (2015) 'The role of invasive alien species in shaping local livelihoods and human well-being: A review Keywords: Biological invasions Ecosystem services Impacts Management Policy Social-ecological systems Social Sustainable livelihoods Vulnerability'. Available at: <https://doi.org/10.1016/j.jenvman.2018.05.007>.

Simões, M. *et al.* (2022) 'Residential proximity to crops and agricultural pesticide use and cause-specific mortality: A prospective census-based cohort study in the Netherlands', *Science of The Total Environment*, 817, p. 152932. Available at: <https://doi.org/10.1016/j.scitotenv.2022.152932>.

Simothy, L., Mahomoodally, F. and Neetoo, H. (2018) 'A study on the potential of ants to act as vectors of foodborne pathogens', *AIMS Microbiology*, 4(2), pp. 319–333. Available at: <https://doi.org/10.3934/microbiol.2018.2.319>.

Smith, P. *et al.* (2021) 'Soil-derived Nature's Contributions to People and their contribution to the UN Sustainable Development Goals', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 376(1834), p. 20200185. Available at: <https://doi.org/10.1098/rstb.2020.0185>.

Steffen, W. *et al.* (2015) 'Planetary boundaries: Guiding human development on a changing planet', *Science*, 347(6223). Available at: <https://doi.org/10.1126/science.1259855>.

Stein, B.A. and Flack, S.R. (1996) 'America's Least Wanted: Alien Species Invasions of U.S. Ecosystems', *The Nature Conservancy*, pp. 1–31.

Strayer, D.L. (2009) 'Twenty years of zebra mussels: Lessons from the mollusk that made headlines', *Frontiers in Ecology and the Environment*, 7(3), pp. 135–141. Available at: <https://doi.org/10.1890/080020>.

Thi Nguyen, T.H. *et al.* (2015) 'Habitat suitability of the invasive water hyacinth and its relation to water quality and macroinvertebrate diversity in a tropical reservoir', *Limnologica*, 52, pp. 67–74. Available at: <https://doi.org/10.1016/j.limno.2015.03.006>.

Traveset, A. and Rodríguez-Pérez, J. (2008) 'Seed Dispersal', *Encyclopedia of Ecology, Five-Volume Set*, 1–5, pp. 3188–3194. Available at: <https://doi.org/10.1016/B978-008045405-4.00860-0>.

Turbelin, A.J. *et al.* (2022) 'Introduction pathways of economically costly invasive alien species', *Biological Invasions*, 24(7), pp. 2061–2079. Available at: <https://doi.org/10.1007/s10530-022-02796-5>.

Turbelin, Anna J *et al.* (2023) 'Biological invasions are as costly as natural hazards', *Perspectives in Ecology and Conservation*, 21, pp. 143–150. Available at: <https://doi.org/10.1016/j.pecon.2023.03.002>.

Twohig-Bennett, C. and Jones, A. (2018) 'The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes', *Environmental Research*, 166(June), pp. 628–637. Available at: <https://doi.org/10.1016/j.envres.2018.06.030>.

U.S. Congress Office of Technology Assessment (1993) *Harmful Non-Indigenous Species in the United States September 1993, Director*.

United Nations (2015) 'Transforming Our World: the 2030 Agenda for Sustainable Development United Nations United Nations Transforming Our World: the 2030 Agenda for Sustainable Development', *United Nations*, p. 41. Available at: <https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981>.

United Nations (2023) *The Sustainable Development Goals Report 2023: Special Edition, Towards a Rescue Plan for People and Planet, The Sustainable development Goals Report 2023: Special Edition*. Available at: <https://unstats.un.org/sdgs/report/2023/>.

United Nations (2024) *The United Nations World Water Development Report 2024: Water for Prosperity and Peace, Water for Prosperity and Development*. Available at: <https://www.unwater.org/publications/un-world-water-development-report-2024%0Ahttps://unesdoc.unesco.org/ark:/48223/pf0000388948>.

Vítková, M. *et al.* (2017) 'Black locust (*Robinia pseudoacacia*) beloved and despised: A story of an invasive tree in Central Europe', *Forest Ecology and Management*, 384, pp. 287–302. Available at: <https://doi.org/10.1016/j.foreco.2016.10.057>.

Wauters, N. *et al.* (2014) 'Distribution, behavioral dominance and potential impacts on endemic fauna of tropical fire ant *Solenopsis geminata* (Fabricius, 1804) (Hymenoptera: Formicidae: Myrmicinae) in the Galápagos archipelago', *Pan-Pacific Entomologist*, 90(4), pp. 205–220. Available at: <https://doi.org/10.3956/2014-90.4.205>.

White, M.P. *et al.* (2019) 'Spending at least 120 minutes a week in nature is associated with good health and wellbeing OPEN'. Available at: <https://doi.org/10.1038/s41598-019-44097-3>.

WHO (2021) 'Nature, biodiversity and health: an overview of interconnections', *World Health Organization: European Centre for Environment & Human Health*, pp. 1–32. Available at: <https://www.euro.who.int/en/health-topics/environment-and-health/urban-health/publications/2021/nature,-biodiversity-and-health-an-overview-of-interconnections-2021>.

WHO (2024) *Dengue and severe dengue*. Available at: <https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue> (Accessed: 26 April 2025).

WHO, UNICEF and World Bank (2022) *State of the World 's drinking water: an urgent call to action to accelerate progress on ensuring safe drinking water for all*. Available at: <http://apps.who.int/iris>.

Wickham, H. (2016) 'Elegant Graphics for Data Analysis'. Springer-Verlag New York. Available at: <https://ggplot2.tidyverse.org>.

Wickham, H. *et al.* (2019) 'Welcome to the Tidyverse Tidyverse package', 4, pp. 1–6. Available at: <https://doi.org/10.21105/joss.01686>.

Wijesundara, S. (2010) 'Invasive Alien Plants in Sri Lanka', *Biodiversity Secretariat of the Ministry of Environment*, (2010), pp. 27–38.

Witt, A., Beale, T. and van Wilgen, B.W. (2018) 'An assessment of the distribution and potential ecological impacts of invasive alien plant species in eastern Africa', *Transactions of the Royal Society of South Africa*, 73(3), pp. 217–236. Available at: <https://doi.org/10.1080/0035919X.2018.1529003>.

"The content of this publication has not been approved by the United Nations and does not reflect the views of the United Nations or its officials or Member States.
<https://www.un.org/sustainabledevelopment/>"

Supplementary materials

1. Supplementary Tables

S 1: Definitions of Nature's Contributions to People used for the linking process – the longer definition from Chapter 2.3 supplementary material (IPBES, 2019b) was used for the linking of NCP benefits to targets of the Sustainable Development Goals

Nature's Contribution to People	Definitions from Chapter 2.3. Status and Trends – Nature's Contributions to People (NCP). (Brauman <i>et al.</i>, 2019)	Definitions from Appendix 2 of IPBES Global assessment – Chapter 2.3 Supplementary materials (IPBES, 2019b)
1. Habitat creation and maintenance	The formation and continued production, by ecosystems, of ecological conditions necessary or favorable for living beings important to humans.	Same as short definition
2. Pollination and dispersal of seeds	Facilitation by animals of movement of pollen among flowers, and dispersal of seeds, larvae, or spores of organisms beneficial or harmful to humans	Same as short definition
3. Regulation of air quality	Regulation (by impediment or facilitation) by ecosystems of atmospheric gases; filtration, fixation, degradation, or storage of pollutants	Regulation (by impediment or facilitation) by ecosystems, of CO ₂ /O ₂ balance, O ₃ for UV-B absorption, levels of sulphur oxide, nitrogen oxides (NO _x), volatile organic compounds (VOC), particulates, aerosols. Filtration, fixation, degradation or storage of pollutants that directly affect human health or infrastructure
4. Regulation of climate	Climate regulation by ecosystems (including regulation of global warming) through effects on emissions of greenhouse gases, biophysical feedbacks, biogenic volatile organic compounds, and aerosols	Climate regulation by ecosystems through positive or negative effects on emissions of greenhouse gases, biophysical feedbacks from vegetation cover to atmosphere, direct and indirect processes involving biogenic volatile organic compounds (BVOC), moisture recycling, and regulation of aerosols and their precursors.
5. Regulation of ocean acidification	Regulation, by photosynthetic organisms, of atmospheric CO ₂ concentrations and so seawater pH	Regulation, by photosynthetic organisms (on land or in water), of atmospheric CO ₂ concentrations and so seawater pH, which affects associated calcification processes by many marine organisms important to humans (such as corals and shellfish).
6. Regulation of freshwater quantity	Regulation, by ecosystems, of the quantity, location and timing of the flow of surface and groundwater	Regulation, by ecosystems, of the quantity, location and timing of the flow of surface and groundwater used for drinking, irrigation, transport, hydropower, and as the support of non-material contributions (NCP 15, 16, 17) Regulation of flow to water-dependent natural habitats that in turn positively or negatively affect people downstream, including via flooding (wetlands including ponds, rivers, lakes, swamps) Modifying groundwater levels, which can ameliorate dryland salinization in unirrigated landscapes
7. Regulation of freshwater quality	Regulation, through filtration of particles, pathogens, excess nutrients, and other chemicals, by ecosystems of water quality	Regulation – through filtration of particles, pathogens, excess nutrients, and other chemicals – by ecosystems or particular organisms, of the quality of water used directly (e.g. drinking) or indirectly

		(e.g. aquatic foods, irrigated food and fibre crops, freshwater and coastal habitats of heritage value)
8. Formation and protection of soils	Formation and long-term maintenance of soils including sediment retention and erosion prevention, maintenance of soil fertility, and degradation or storage of pollutants	Sediment retention and erosion control, soil formation and maintenance of soil structure and processes (e.g. such as decomposition and nutrient cycling) that underlie the continued fertility of soils important to humans. Filtration, fixation, degradation or storage of chemical and biological pollutants (pathogens, toxics, excess nutrients) in soils and sediments that are important to humans.
9. Regulation of hazards	Amelioration, by ecosystems, of the impacts of hazards; reduction of hazards; change in hazard frequency	Amelioration, by ecosystems, of the impacts on humans or their infrastructure caused by e.g. floods, wind, storms, hurricanes, seawater intrusion, tidal waves, heat waves, tsunamis, high noise levels, fires Reduction, by ecosystems of hazards like landslides, avalanches Increase, by organism, of probability of hazards (e.g. beaver dams affecting floods)
10. Regulation of detrimental organisms	Regulation, by ecosystems or organisms, of pests, pathogens, predators, competitors, parasites, and potentially harmful organisms	Regulation, by ecosystems or organisms, of pests, pathogens, predators, competitors, etc. that affect humans, plants and animals, including e.g.: * Regulation by predators or parasites of the population size of non-harmful important animals (e.g. large herbivore populations by wolves or lions) * Regulation (by impediment or facilitation) of the abundance or distribution of potentially harmful organisms (e.g. venomous, toxic, allergenic, predators, parasites, competitors, disease vectors and reservoirs) over the landscape or seascape * Removal of animal carcasses and human corpses by scavengers (e.g. vultures in Zoroastrian and some Tibetan Buddhist traditions) * Regulation (by impediment or facilitation) of biological impairment and degradation of infrastructure (e.g. damage by pigeons, bats, termites, strangling figs to buildings)
11. Energy	Production of biomass-based fuels, such as biofuel crops, animal waste, fuelwood, and agricultural residue	Same as short definition
12. Food and Feed	Production of food from wild, managed, or domesticated organisms on land and in the ocean; production of feed	Production of food from wild, managed, or domesticated organisms, such as fish, bushmeat and edible invertebrates, beef, poultry, game, dairy products, edible crops, wild plants, mushrooms, honey Production of feed (forage and fodder) for domesticated animals (e.g. livestock, work and support animals, pets) or for aquaculture, from the same sources
13. Materials, companionship and labor	Production of materials derived from organisms in cultivated or wild ecosystems and direct use of living organisms for decoration, company, transport, and labour	Production of materials derived from organisms in cultivated or wild ecosystems, for construction, clothing, printing, ornamental purposes (e.g. wood, fibres, waxes, paper, resins, dyes, pearls, shells, coral branches). Direct use of living organisms for decoration (i.e.

		ornamental plants, birds, fish in households and public spaces), company (i.e. pets), transport, and labor (including herding, searching, guidance, guarding).
14. Medicinal, biochemical and genetic resources	Production of materials derived from organisms for medicinal purposes; production of genes and genetic information	14 a Production of materials derived from organisms (plants, animals, fungi, microbes) used for medicinal and veterinary purposes 14 b. Production of genes and genetic information used for plant and animal breeding and biotechnology
15. Learning and inspiration	Opportunities for developing capabilities to prosper through education, knowledge acquisition, and inspiration for art and technological design (e.g., biomimicry)	Learning and inspiration: provision, by landscapes, seascapes, habitats or organisms, of opportunities for the development of the capabilities that allow humans to prosper through education, acquisition of knowledge and development of skills for well-being, information, and inspiration for art and technological design (e.g. biomimicry)
16. Physical and psychological experiences	Opportunities for physically and psychologically beneficial activities, healing, relaxation, recreation, leisure, and aesthetic enjoyment based on close contact with nature	Provision, by landscapes, seascapes, habitats or organisms, of opportunities for physically and psychologically beneficial activities, healing, relaxation, recreation, leisure, tourism and aesthetic enjoyment based on the close contact with nature. E.g. hiking, recreational hunting and fishing, birdwatching, snorkeling, gardening
17. Supporting identities	The basis for religious, spiritual, and social-cohesion experiences; sense of place, purpose, belonging, rootedness or connectedness, associated with different entities of the living world; narratives and myths, rituals and celebrations; satisfaction derived from knowing that a particular landscape, seascape, habitat or species exist	Landscapes, seascapes, habitats or organisms being the basis for religious, spiritual, and social cohesion experiences Provisioning of opportunities by nature for people to develop a sense of place, purpose, belonging, rootedness or connectedness, associated with different entities of the living world (e.g. cultural, sacred and heritage landscapes, sounds, scents and sights associated with childhood experiences, iconic animals, trees or flowers) Basis for narratives and myths, rituals and celebrations provided by landscapes, seascapes, habitats, species or organisms Source of satisfaction derived from knowing that a particular landscape, seascape, habitat or species exist in the present
18. Maintenance of options	Capacity of ecosystems, habitats, species or genotypes to keep human options open in order to support a later good quality of life	Same as short definition

S2: Sustainable Development Goals and targets (from the UN Agenda 2030 (United Nations, 2015)) descriptions used for linking Nature's Contributions to Peoples benefit for SDG target development; the short name of the SDGs are taken from the 2023 Sustainable Development Goals Report (United Nations, 2023)

<i>SDG (short)</i> (United Nations, 2023)	<i>SDG (name long)</i> (United Nations, 2015)	SDG Targets (United Nations, 2015)
<i>SDG 1 - No Poverty</i>	<i>SDG 1 - No Poverty</i>	1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than \$1.25 a day 1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions 1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable 1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance 1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters 1.a Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions 1.b Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions
<i>SDG 2 - Zero Hunger</i>	<i>SDG 2 - Zero Hunger</i>	2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round 2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons 2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment 2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality 2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed 2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries 2.b Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round 2.c Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility
<i>SDG 3 - Good Health and Well Being</i>	<i>SDG 3 - Good Health and Well Being</i>	3.1 By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births 3.2 By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births 3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases 3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being

		3.5 Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol 3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents 3.7 By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes 3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all 3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination 3.a Strengthen the implementation of the World Health Organization Framework Convention on Tobacco Control in all countries, as appropriate 3.b Support the research and development of vaccines and medicines for the communicable and non-communicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, in accordance with the Doha Declaration on the TRIPS Agreement and Public Health, which affirms the right of developing countries to use to the full the provisions in the Agreement on Trade-Related Aspects of Intellectual Property Rights regarding flexibilities to protect public health, and, in particular, provide access to medicines for all 3.c Substantially increase health financing and the recruitment, development, training and retention of the health workforce in developing countries, especially in least developed countries and small island developing States 3.d Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks
SDG 4 – Quality education	<i>SDG 4 - Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all</i>	4.1 By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes 4.2 By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education 4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university 4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship 4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations 4.6 By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy 4.7 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development 4.a Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all 4.b By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries 4.c By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States
SDG 5 – Gender equality	<i>SDG 5 - Achieve gender equality and empower all women and girls</i>	5.1 End all forms of discrimination against all women and girls everywhere 5.2 Eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation 5.3 Eliminate all harmful practices, such as child, early and forced marriage and female genital mutilation 5.4 Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility within the household and the family as nationally appropriate 5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life 5.6 Ensure universal access to sexual and reproductive health and reproductive rights as agreed in accordance with the Programme of Action of the International Conference on Population and Development and the Beijing Platform for Action and the outcome documents of their review conferences 5.a Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial

		services, inheritance and natural resources, in accordance with national laws 5.b Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women 5.c Adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels
SDG 6 – Clean water and sanitation	<i>SDG 6 - Ensure availability and sustainable management of water and sanitation for all</i>	6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all 6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations 6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally 6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity 6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate 6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes 6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies 6.b Support and strengthen the participation of local communities in improving water and sanitation management
SDG 7 – Affordable and clean energy	<i>SDG 7 - Ensure access to affordable, reliable, sustainable and modern energy for all</i>	7.1 By 2030, ensure universal access to affordable, reliable and modern energy services 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix 7.3 By 2030, double the global rate of improvement in energy efficiency 7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology 7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support
SDG 8 – Decent work and economic growth	<i>SDG 8 - Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all</i>	8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries 8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labor-intensive sectors 8.3 Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services 8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead 8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value 8.6 By 2020, substantially reduce the proportion of youth not in employment, education or training 8.7 Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms 8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment 8.9 By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products 8.10 Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all 8.a Increase Aid for Trade support for developing countries, in particular least developed countries, including through the Enhanced Integrated Framework for Trade-Related Technical Assistance to Least Developed Countries

		8.b By 2020, develop and operationalize a global strategy for youth employment and implement the Global Jobs Pact of the International Labour Organization
SDG 9 – Industry, innovation and infrastructure	<i>SDG 9 - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation</i>	9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all 9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries 9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets 9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities 9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending 9.a Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States 9.b Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities 9.c Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020
SDG 10 – Reduced inequalities	<i>SDG 10 - Reduce inequality within and among countries</i>	10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average 10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status 10.3 Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard 10.4 Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality 10.5 Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations 10.6 Ensure enhanced representation and voice for developing countries in decision-making in global international economic and financial institutions in order to deliver more effective, credible, accountable and legitimate institutions 10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies 10.a Implement the principle of special and differential treatment for developing countries, in particular least developed countries, in accordance with World Trade Organization agreements 10.b Encourage official development assistance and financial flows, including foreign direct investment, to States where the need is greatest, in particular least developed countries, African countries, small island developing States and landlocked developing countries, in accordance with their national plans and programmes 10.c By 2030, reduce to less than 3 per cent the transaction costs of migrant remittances and eliminate remittance corridors with costs higher than 5 per cent
SDG 11 – Sustainable cities and communities	<i>SDG 11 - Make cities and human settlements inclusive, safe, resilient and sustainable</i>	11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums 11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons 11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries 11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage 11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

		11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management 11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities 11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning 11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels 11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials
SDG 12 – Responsible consumption and production	<i>SDG 12 - Ensure sustainable consumption and production patterns</i>	12. 1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries 12.2 By 2030, achieve the sustainable management and efficient use of natural resources 12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses 12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment 12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse 12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle 12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities 12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature 12.a Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production 12.b Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products 12.c Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities
SDG 13 – Climate action	<i>SDG 13 - Take urgent action to combat climate change and its impacts</i>	13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries 13.2 Integrate climate change measures into national policies, strategies and planning 13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning 13.a Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly \$100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible 13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities
SDG 14 – Life below water	<i>SDG 14 - Conserve and sustainably use the oceans, seas and marine resources for sustainable development</i>	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution 14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans 14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels 14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics 14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information 14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing

		that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation 14.7 By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism 14.a Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries 14.b Provide access for small-scale artisanal fishers to marine resources and markets 14.c Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of "The future we want"
SDG 15 – Life on Land	<i>SDG 15 - Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss</i>	15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements 15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally 15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world 15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development 15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species 15.6 Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed 15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products 15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species 15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts 15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems 15.b Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation 15.c Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities
SDG 16 – Peace, justice and strong institutions	<i>SDG 16 - Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels</i>	16.1 Significantly reduce all forms of violence and related death rates everywhere 16.2 End abuse, exploitation, trafficking and all forms of violence against and torture of children 16.3 Promote the rule of law at the national and international levels and ensure equal access to justice for all 16.4 By 2030, significantly reduce illicit financial and arms flows, strengthen the recovery and return of stolen assets and combat all forms of organized crime 16.5 Substantially reduce corruption and bribery in all their forms 16.6 Develop effective, accountable and transparent institutions at all levels 16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels 16.8 Broaden and strengthen the participation of developing countries in the institutions of global governance 16.9 By 2030, provide legal identity for all, including birth registration 16.10 Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements 16.a Strengthen relevant national institutions, including through international cooperation, for building capacity at all levels, in particular in developing countries, to prevent violence and combat terrorism and crime 16.b Promote and enforce non-discriminatory laws and policies for sustainable development

SDG 17 – Partnerships for the Goals	<i>SDG 17 - Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development</i>	17.1 Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection 17.2 Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of ODA/GNI to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries; ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries 17.3 Mobilize additional financial resources for developing countries from multiple sources 17.4 Assist developing countries in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring, as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress 17.5 Adopt and implement investment promotion regimes for least developed countries 17.6 Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism 17.7 Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed 17.8 Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology 17.9 Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the Sustainable Development Goals, including through North-South, South-South and triangular cooperation 17.10 Promote a universal, rules-based, open, non-discriminatory and equitable multilateral trading system under the World Trade Organization, including through the conclusion of negotiations under its Doha Development Agenda 17.11 Significantly increase the exports of developing countries, in particular with a view to doubling the least developed countries' share of global exports by 2020 17.12 Realize timely implementation of duty-free and quota-free market access on a lasting basis for all least developed countries, consistent with World Trade Organization decisions, including by ensuring that preferential rules of origin applicable to imports from least developed countries are transparent and simple, and contribute to facilitating market access 17.13 Enhance global macroeconomic stability, including through policy coordination and policy coherence 17.14 Enhance policy coherence for sustainable development 17.15 Respect each country's policy space and leadership to establish and implement policies for poverty eradication and sustainable development; 17.16 Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable Development Goals in all countries, in particular developing countries 17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships 17.18 By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts 17.19 By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries
---	---	---

S 3: This Table shows the number of linked NCPs per SDG

SDG	Number of			
	link		no link	
	n	%	n	%
SDG 1	16	88.9	2	11.1
SDG 2	15	83.3	3	16.7
SDG 3	18	100	0	0
SDG 4	3	16.7	15	83.3
SDG 5	3	16.7	15	83.3
SDG 6	10	55.6	8	44.4
SDG 7	5	27.8	13	72.2
SDG 8	15	83.3	3	16.7
SDG 9	6	33.3	12	66.7
SDG 10	2	11.1	16	88.9
SDG 11	10	55.6	8	44.4
SDG 12	9	50	9	50
SDG 13	10	55.6	8	44.4
SDG 14	12	66.7	6	33.3
SDG 15	14	77.8	4	22.2

S 4: Number of strong and weak links to NCPs per target

Link strength	Targets												
	SDG 1.1	SDG 1.2	SDG 1.3	SDG 1.4	SDG 1.5	SDG 1.a	SDG 1.b						
strong link	9	8	-	3	7	1	-						
weak link	6	5	-	7	5	-	-						
no link	3	5	18	8	6	17	18						
	SDG 2.1	SDG 2.2	SDG 2.3	SDG 2.4	SDG 2.5	SDG 2.a	SDG 2.b	SDG 2.c					
strong link	11	8	10	9	2	-	-	-					
weak link	4	7	2	3	4	2	-	-					
no link	3	3	6	6	12	16	18	18					
	SDG 3.1	SDG 3.2	SDG 3.3	SDG 3.4	SDG 3.5	SDG 3.6	SDG 3.7	SDG 3.8	SDG 3.9	SDG 3.a	SDG 3.b	SDG 3.c	SDG 3.d
strong link	3	10	8	11	-	-	-	2	5	-	-	-	-
weak link	5	4	4	7	-	1	1	1	3	-	2	-	1
no link	10	4	6	0	18	17	17	15	10	18	16	18	17
	SDG 4.1	SDG 4.2	SDG 4.3	SDG 4.4	SDG 4.5	SDG 4.6	SDG 4.7	SDG 4.a	SDG 4.b	SDG 4.c			
strong link	-	-	-	-	-	-	-	-	-	-			
weak link	3	2	1	2	1	-	1	1	-	1			
no link	15	16	17	16	17	18	17	17	18	17			
	SDG 5.1	SDG 5.2	SDG 5.3	SDG 5.4	SDG 5.5	SDG 5.6	SDG 5.a	SDG 5.b	SDG 5.c				
strong link	-	-	-	-	1	-	1	-	-				
weak link	-	-	-	-	-	-	1	-	-				
no link	18	18	18	18	17	18	16	18	18				
	SDG 6.1	SDG 6.2	SDG 6.3	SDG 6.4	SDG 6.5	SDG 6.6	SDG 6.a	SDG 6.b					
strong link	7	1	4	-	-	7	-	-					
weak link	1	2	3	4	-	1	-	-					
no link	10	15	11	14	18	10	18	18					
	SDG 7.1	SDG 7.2	SDG 7.3	SDG 7.a	SDG 7.b								
strong link	2	3	-	-	-								
weak link	3	2	1	1	-								
no link	13	13	17	17	18								
	SDG 8.1	SDG 8.1-	SDG 8.2	SDG 8.3	SDG 8.4	SDG 8.5	SDG 8.6	SDG 8.7	SDG 8.8	SDG 8.9	SDG 8.a	SDG 8.b	
strong link	3	-	-	-	-	-	-	-	-	2	-	-	

weak link	12	-	4	5	1	2	-	-	-	1	-	-
no link	3	18	14	13	17	16	18	18	18	15	18	18
	SDG 9.1	SDG 9.2	SDG 9.3	SDG 9.4	SDG 9.5	SDG 9.a	SDG 9.b	SDG 9.c				
strong link	1	1	-	-	1	-	1	-				
weak link	4	1	-	2	1	1	1	-				
no link	13	16	18	16	16	17	16	18				
	SDG 10.1	SDG 10.2	SDG 10.3	SDG 10.4	SDG 10.5	SDG 10.6	SDG 10.7	SDG 10.a	SDG 10.b	SDG 10.c		
strong link	2	-	-	-	-	-	-	-	-	-		
weak link	-	-	-	-	-	-	-	-	-	-		
no link	16	18	18	18	18	18	18	18	18	18		
	SDG 11.1	SDG 11.2	SDG 11.3	SDG 11.4	SDG 11.5	SDG 11.6	SDG 11.7	SDG 11.a	SDG 11.b	SDG 11.c		
strong link	-	-	-	2	5	2	-	-	2	-		
weak link	-	-	-	6	2	-	1	-	1	1		
no link	18	18	18	10	11	16	17	18	15	17		
	SDG 12.1	SDG 12.2	SDG 12.3	SDG 12.4	SDG 12.5	SDG 12.6	SDG 12.7	SDG 12.8	SDG 12.a	SDG 12.b	SDG 12.c	
strong link	-	2	-	3	1	-	-	-	-	-	-	
weak link	-	3	2	4	-	-	-	-	-	-	-	
no link	18	13	16	11	17	18	18	18	18	18	18	
	SDG 13.1	SDG 13.2	SDG 13.3	SDG 13.a	SDG 13.b							
strong link	4	-	-	-	-							
weak link	6	2	4	-	1							
no link	8	16	14	18	17							
	SDG 14.1	SDG 14.2	SDG 14.3	SDG 14.4	SDG 14.5	SDG 14.6	SDG 14.7	SDG 14.a	SDG 14.b	SDG 14.c		
strong link	1	4	3	2	3	-	1	-	1	-		
weak link	4	4	2	1	3	2	1	2	1	1		
no link	13	10	13	15	12	16	16	16	16	17		
	SDG 15.1	SDG 15.2	SDG 15.3	SDG 15.4	SDG 15.5	SDG 15.6	SDG 15.7	SDG 15.8	SDG 15.9	SDG 15.a	SDG 15.b	SDG 15.c
strong link	12	11	11	11	11	-	2	4	-	-	-	-
weak link	2	2	1	2	3	4	2	2	1	1	1	1
no link	4	5	6	5	4	14	14	12	17	17	17	17

S 4: Number of SDG targets linked to individual NCPs and number of strong and weak links per NCP

NCP	strong link		weak link		no link		Total number of links
	n	%	n	%	n	%	n
NCP 1	25	14.8	26	15.4	118	69.8	51
NCP 2	22	13	28	16.6	119	70.4	50
NCP 3	10	5.9	12	7.1	147	87	22
NCP 4	15	8.9	12	7.1	142	84	27
NCP 5	1	0.6	8	4.7	160	94.7	9
NCP 6	19	11.2	12	7.1	138	81.7	31
NCP 7	20	11.8	7	4.1	142	84	27
NCP 8	17	10.1	11	6.5	141	83.4	28
NCP 9	12	7.1	13	7.7	144	85.2	25
NCP 10	7	4.1	19	11.2	143	84.6	26
NCP 11	19	11.2	26	15.4	124	73.4	45
NCP 12	21	12.4	2	1.2	146	86.4	23
NCP 13	12	7.1	4	2.4	153	90.5	16
NCP 14	12	7.1	7	4.1	150	88.8	19
NCP 15	2	1.2	14	8.3	153	90.5	16
NCP 16	11	6.5	1	0.6	157	92.9	12
NCP 17	1	0.6	1	0.6	167	98.8	2
NCP 18	16	9.5	13	7.7	140	82.8	29
Total	242	8.0	216	7.1	2584	84.9	458

S 6: Table shows which NCP is impacted negatively or positively by the sample species

NCP	Species with negative or positive impacts on NCPs		
	total	negative impacts	positive impacts
NCP 1	3	<i>Solenopsis geminata</i> , <i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i>	
NCP 2	2	<i>Solenopsis geminata</i>	<i>Pontederia crassipes</i>
NCP 4	1		<i>Robinia pseudoacacia</i>
NCP 5	1	<i>Dreissena polymorpha</i>	
NCP 6	2	<i>Dreissena polymorpha</i> , <i>Pontederia crassipes</i>	
NCP 7	2	<i>Dreissena polymorpha</i> , <i>Pontederia crassipes</i>	<i>Pontederia crassipes</i>
NCP 8	1	<i>Robinia pseudoacacia</i>	<i>Robinia pseudoacacia</i>
NCP 9	1		<i>Pontederia crassipes</i>
NCP 10	4	<i>Solenopsis geminata</i> , <i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i>	<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i>
NCP 11	3	<i>Dreissena polymorpha</i> , <i>Pontederia crassipes</i>	<i>Robinia pseudoacacia</i> , <i>Pontederia crassipes</i>
NCP 12	5	<i>Solenopsis geminata</i> , <i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i> , <i>Rattus rattus</i>	<i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i>
NCP 13	4	<i>Dreissena polymorpha</i> , <i>Pontederia crassipes</i> , <i>Felis catus</i>	<i>Robinia pseudoacacia</i> , <i>Pontederia crassipes</i>
NCP 14	2	<i>Dreissena polymorpha</i>	<i>Pontederia crassipes</i>
NCP 16	4	<i>Solenopsis geminata</i> , <i>Pontederia crassipes</i> , <i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i>	<i>Dreissena polymorpha</i> , <i>Robinia pseudoacacia</i>
NCP 18	4	<i>Dreissena polymorpha</i> , <i>Pontederia crassipes</i> , <i>Felis catus</i> , <i>Rattus rattus</i>	

S7: Number of IAS-NCP-SDG target links assessed for literature support per NCP, with number of Literature support yes/no per NCP

NCP	no	yes	total
NCP 1	140 91.5%	13 85.0%	153
NCP 2	95 93.1%	7 6.9%	102
NCP 4	26 96.3%	1 3.7%	27
NCP 5	9 100%	0 0%	9
NCP 6	30 48.4%	32 51.6%	62
NCP 7	16 19.7%	65 80.3%	81
NCP 8	44 83.0%	9 17.0%	53
NCP 9	16 64.0%	9 36.0%	25
NCP 10	147 80.8%	35 19.2%	182
NCP 11	153 85.5%	26 14.5%	179
NCP 12	111 60.3%	73 39.7%	184
NCP 13	59 73.7%	21 26.3%	80
NCP 14	38 100%	0 0%	38
NCP 16	59 81.9%	13 18.1%	72
NCP 18	95 81.9%	21 18.1%	116
Total	1038	325	1363

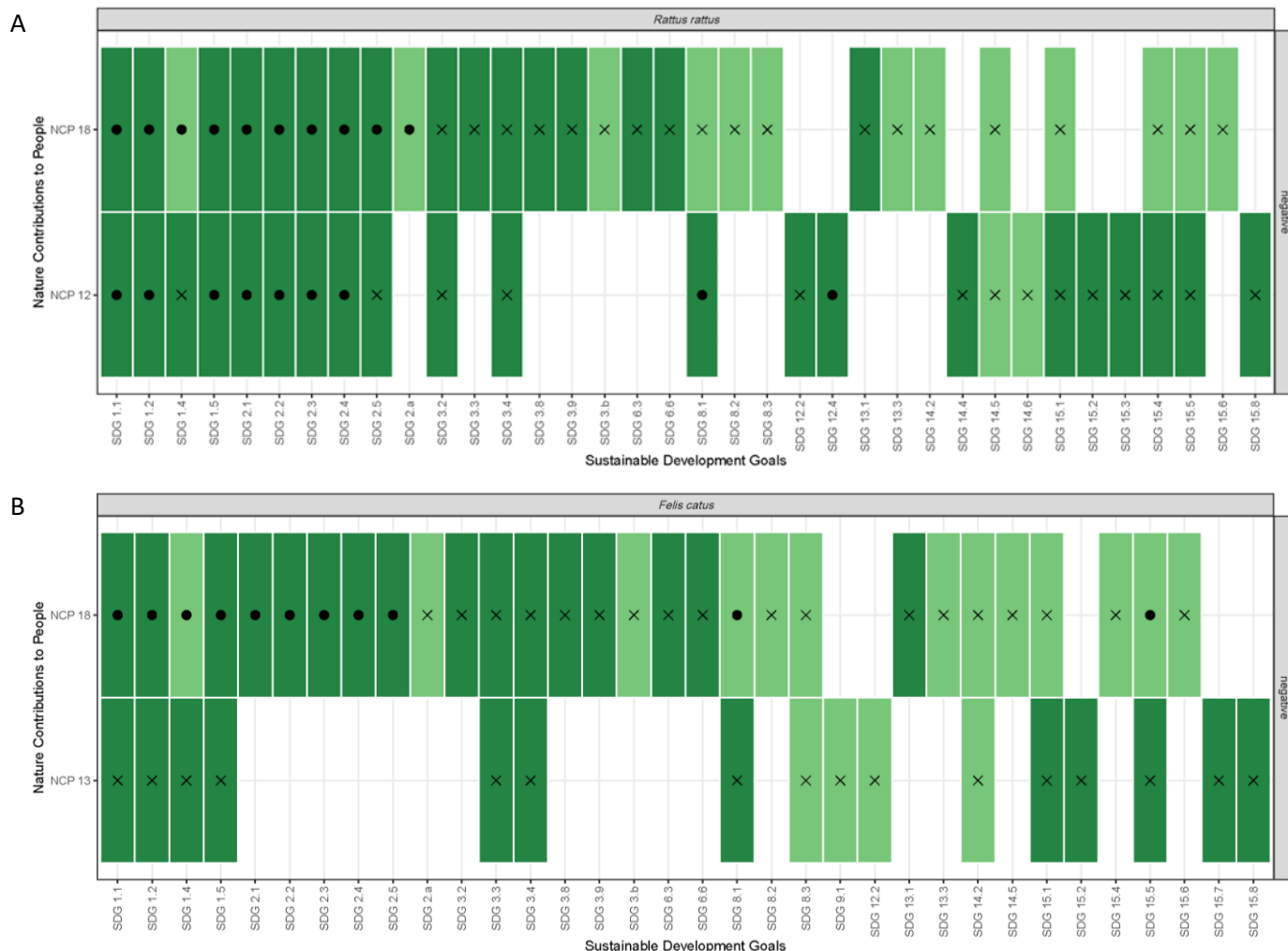
S8: Table showing the number of targets with literature support for the IAS-NCP-SDG target links

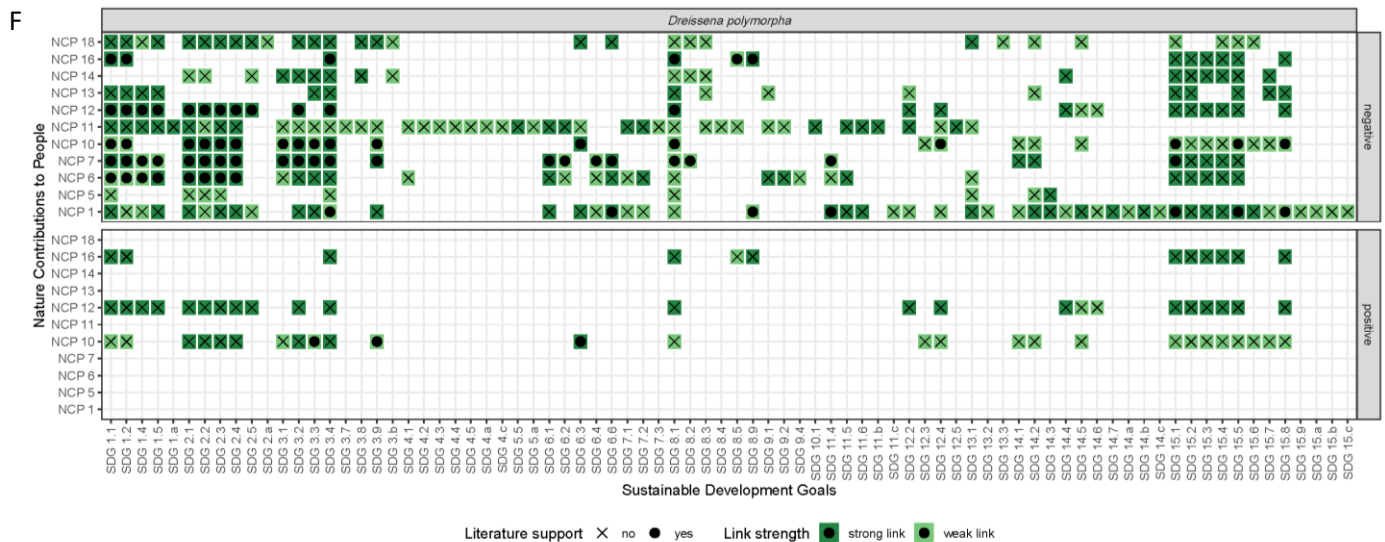
SDG			SDG			SDG			SDG		
Target	no	yes	Target	no	yes	Target	no	yes	Target	no	yes
SDG 1.1	26	23	SDG 4.2	4	0	SDG 8.9	7	4	SDG 14.1	15	0
SDG 1.2	25	23	SDG 4.3	4	0	SDG 9.1	11	4	SDG 14.2	26	0
SDG 1.4	16	17	SDG 4.4	4	0	SDG 9.2	5	1	SDG 14.3	7	0
SDG 1.5	16	19	SDG 4.5	4	0	SDG 9.4	3	1	SDG 14.4	15	0
SDG 1.a	3	1	SDG 4.a	4	0	SDG 9.5	2	0	SDG 14.5	25	0
SDG 2.1	21	19	SDG 4.c	4	0	SDG 9.a	2	0	SDG 14.6	11	0
SDG 2.2	22	18	SDG 5.5	4	0	SDG 9.b	2	0	SDG 14.7	5	0
SDG 2.3	20	17	SDG 5.a	6	0	SDG 10.1	6	0	SDG 14.a	5	0
SDG 2.4	20	17	SDG 6.1	12	6	SDG 11.4	6	7	SDG 14.b	5	0
SDG 2.5	16	5	SDG 6.2	6	3	SDG 11.5	13	2	SDG 14.c	3	0
SDG 2.a	5	1	SDG 6.3	20	3	SDG 11.6	7	0	SDG 15.1	36	10
SDG 3.1	13	4	SDG 6.4	7	3	SDG 11.7	2	0	SDG 15.2	41	1
SDG 3.1	1	1	SDG 6.6	10	8	SDG 11.b	6	1	SDG 15.3	34	2
SDG 3.2	28	11	SDG 7.1	9	4	SDG 11.c	3	0	SDG 15.4	40	0
SDG 3.3	26	8	SDG 7.2	10	3	SDG 12.2	21	1	SDG 15.5	33	12
SDG 3.4	34	17	SDG 7.3	2	2	SDG 12.3	7	0	SDG 15.6	16	0
SDG 3.6	1	0	SDG 7.a	2	0	SDG 12.4	24	3	SDG 15.7	17	0
SDG 3.7	4	0	SDG 8.1	28	21	SDG 12.5	4	0	SDG 15.8	28	3
SDG 3.8	10	0	SDG 8.2	6	3	SDG 13.1	15	2	SDG 15.9	3	0
SDG 3.9	16	8	SDG 8.3	14	3	SDG 13.2	3	0	SDG 15.a	3	0
SDG 3.b	6	0	SDG 8.4	4	0	SDG 13.3	7	0	SDG 15.b	3	0
SDG 4.1	5	1	SDG 8.5	8	2	SDG 13.b	2	0	SDG 15.c	3	0

2. Linking IAS impact on NCPs to impact on SDGs

Linking *Rattus rattus* impact on NCPs to Sustainable Development Goals

GIDIAS (Bacher *et al.*, 2025) lists *R. rattus* with negative impact to NCP 12 – Food and Feed and NCP 18 – Maintenance of Options. NCP 12 and 18 show a total of 52 links to SDG targets, for 19 (35.5%) (Table 6, Supplementary Figure 1 A) of these links there is literature support for the negative impact of *Rattus rattus*. With the references in the IPBES database, literature support for SDGs 1 and 2 could be determined relatively well, but no link could be confirmed for SDG 3. Furthermore, it is surprising that *Rattus* is not linked to NCP 10 - Regulation of Detrimental Organisms in the IPBES database, as *R. rattus* is a known transmitter of diseases to humans (Global Invasive Species Database, 2025e). Recorded impacts in the database are damages to food production, harvests and agriculture (Bergman, 2000; Pimentel *et al.*, 2000; Makundi and Ogue, 2014; Dossou *et al.*, 2020), resulting in loss of income and economic damages (Pimentel *et al.*, 2000; Dossou *et al.*, 2020) as well as reduced availability of food (Olson, 2006; Makundi and Ogue, 2014; Dossou *et al.*, 2020).





Supplementary Figure 1: This figure shows individual heatmaps for the sample six species (*Rattus rattus*, *Solenopsis geminata*, *Felis catus*, *Pontederia crassipes*, *Robinia pseudoacacia* and *Dreissena polymorpha*) in combination with their recorded negative and positive impacts on Nature's Contributions to People (NCP) and the targets of the Sustainable Development Goals linked to the individual NCPs. The green fields indicate a target dependent on a NCP, the two different greens indicate the link strength. The x or dot within a green field indicates, if there is literature support for an IAS impact on a SDG target through its impact (positive or negative) on a NCP.

Linking *Solenopsis geminata* impact on NCPs to Sustainable Development Goals

S. geminata is associated with negative impact on 5 NCPs (Bacher *et al.*, 2025). Out of 165 links analyzed, literature support was found for 16 (9.7%) (Table 6, Supplementary Figure 1 C). The impact of *Solenopsis* on NCP 1 and NCP 2 could only be confirmed for SDG 15.5, since reference (Wauters *et al.*, 2014) mentions that the species harvests seeds and preys on certain butterfly eggs - however, the extent to which this affects NCP 2 is not discussed. According to Wauters *et al.* (2014) *S. geminata* negatively impacts ecological balances of ecosystems, through preying on invertebrates and vertebrates alike and altering their population (especially in tropical island ecosystems). The species is further known to be a vector for pathogenic and toxic microorganisms through food to humans (Simothy, Mahomoodally and Neetoo, 2018), impacting food safety (SDG 2 and 3).

Literature support could be found for the links from NCP 12 to targets of SDG 1, 2, 8 and 12. *S. geminata* is associated with negative impacts on agriculture through seed predation and destruction of crops (e.g. rice) (Litsinger *et al.*, 2009; Herrera, H. W. *et al.*, 2020). These impacts on agriculture have a negative impact on the subsistence and income of smallholder farms and poor communities (Motzke *et al.*, 2013).

Linking *Felis catus* impact on NCPs to Sustainable Development Goals

GIDIAS (Bacher *et al.*, 2025) lists *Felis catus* with negative impact on NCP 13 – Materials,

companionship and labor and NCP 18 – Maintenance of options. While none of the NCP 13 and SDG target links show literature support, 11 links for NCP 18 do (Supplementary Figure 1 B). Negative impacts of cats to SDGs through NCP 18, are mostly due to the reduction of bird and small mammal diversity, leading to economic damages or decrease in options for hunting (Bergman, 2000).

Linking *Pontederia crassipes* impact on NCPs to Sustainable Development Goals

The water hyacinth is linked to 12 NCPs, with negative impact on 9 and positive impact on 8 NCPs according to GIDIAS (Bacher *et al.*, 2025). For 494 analyzed NCP-SDG target links, literature support was identified for 32.6% (Table 6, Supplementary Figure 1 D).

Based on the given reference literature (Wijesundara, 2010), the negative impact of water hyacinth on NCP 1 could only be confirmed for a few links associated with freshwater ecosystems.

Wijesundara (2010) indicates negative impacts on habitats for native fish and bird species in Sri Lanka, but the given literature does not give further information on the species impacts on the relevancy of the fish species for fishery. However, the species is listed as one of the IUCN 100 Worst Invaders (Global Invasive Species Database, 2025a) for its impact on ecosystems (EPPO, 2021) and other studies indicate negative impacts on fishery and livelihoods (Musinguzi *et al.*, 2022; Basaula *et al.*, 2023), which has in turn negative impacts on reduction of poverty, hunger and malnutrition.

The reference literature for the impact of *P. crassipes* on NCP 6, suggests that the species has a negative impact on freshwater quantity by blocking water pipes, restriction of water flow and access to water (Aloo *et al.*, 2013; Gebregiorgis, 2017). However, the NCP refers to the regulation of water quantity by ecosystems, e.g. through precipitation or evapotranspiration (IPBES, 2019b). Therefore, while the water-hyacinth blocking water pipes is not relevant for NCP 6, its impacts on altered flow rates, increased evapotranspiration and flood regiments (Gebregiorgis, 2017; Ali and El-Din Khedr, 2018; Shackleton *et al.*, 2018) are relevant for NCP 6 and associated SDG targets. Changes in water availability impacts water dependent industries, e.g. agriculture and food security (IPBES, 2019b; FAO, 2022; Redhu *et al.*, 2023) and subsequently impacts the development of poverty reduction, hunger, health, sanitation and more.

However, the species influences not only the water quantity but also water quality (NCP 7). The impact of *Pontederia* on the NCP is both positive and negative. While the presence of *Pontederia* is associated with altered oxygen concentrations in water bodies (Mironga *et al.*, 2011; 2012; Coetzee *et al.*, 2014), anoxia (Masifwa *et al.*, 2001) and altered macroinvertebrate diversity (Midgley *et al.*, 2006), it also leads to a reduction in water pollution (Reid and Shafiqul Alam, 2017) and increased water clarity (Thi Nguyen *et al.*, 2015).

NCP 11 is also negatively and positively influenced by *Pontederia*, e.g. dried water hyacinth is used as

cooking fuel by poor people in some regions (Reid and Shafiqul Alam, 2017). The recorded negative impact on NCP 11 is the blockage of hydropower infrastructure (Witt, Beale and van Wilgen, 2018; Ezama, 2019). Yet, the negative impact, recorded in the IPBES database, does not actually negatively impact the production of NCP 11, since hydropower is not mentioned within the NCP description (IPBES, 2019b). Nonetheless, the blocking of hydropower is detrimental to the SDG targets depending on the availability of energy.

NCP 12, as well as NCP 7 and 11, has recorded negative and positive impacts, e.g. water-hyacinth can be used as fodder for cattle (Reid and Shafiqul Alam, 2017), while it also impacts food production. Through reduced catchability of fish (Kateregga and Sterner, 2009; Kenfack Voukeng *et al.*, 2019; Enyew, Assefa and Gezie, 2020), damages to crops, increased costs for producers (e.g. decreased lifespan of fishing equipment)(Enyew, Assefa and Gezie, 2020), *Pontederia crassipes* threatens food security, income and revenue from fishing and farming.

Linking *Robinia pseudoacacia* impact on NCPs to Sustainable Development Goals

Black locust is associated with impact on 8 NCPs, some of which are both negatively and positively influenced by the species (Bacher *et al.*, 2025). For Robinia, 262 NCP-SDG targets links were examined, for 16.8% (Table 6, Supplementary Figure 1 E) of the links there is literature support. Most of the confirmed links are links of targets associated with NCP 12 – Food and feed, due the species' impairment of livestock grazing capacities (Chikowore *et al.*, 2021) indicating a negative impact on income and food from livestock production. Positive impacts are associated with production of honey (Vítková *et al.*, 2017). Furthermore, black locust can be used as construction material (NCP 13)(Vítková *et al.*, 2017; Martínez and Manzano-García, 2019).

Other confirmed links are to NCP 11 – Energy, since black locust is used for energy production or as cooking fuel (Rédei, 1999; Vítková *et al.*, 2017) according to the reference literature of the IPBES database, however other literature does not indicate a significant contribution to peoples livelihoods (Chikowore, Chidawanyika and Martin, 2022). A positive impact on 3.4 & 3.9 results from the switch from fossil based cooking fuels to biofuels, reducing deaths from indoor air pollution (GEA, 2012), however I could not find further literature to support this link.

Linking *Dreissena polymorpha* impact on NCPs to Sustainable Development Goals

GIDIAS (Bacher *et al.*, 2025) links the zebra mussel to 11 NCPs, while the species is associated with negative impact to all 11 NCPs, it is also linked to positive impact on 3 NCPs (NCP 10, 12 & 16). For 74 of 351 links analyzed literature support could be identified (Table 6, Supplementary Figure 1 F).

Dreissena is known for its impacts on ecosystems through changes to benthic communities, nutrients

regimes, predation etc. (Global Invasive Species Database, 2025c). Negative impacts of the species on poverty reduction result from reduced water availability due to clogged water pipes (Minchin, Lucy and Sullivan, 2002) (even if this impact does not result directly from negative impact on NCP 6, it is still relevant for SDG 1) as well as declining water quality and costs for water treatment (Colautti *et al.*, 2006), which represents an additional financial burden for poor communities. Decrease in water quality due to *D. polymorpha* invasion leads to less water available for irrigation in agriculture, reduced yield of edible fish due to accumulation of heavy metals (Stein and Flack, 1996; Pejchar and Mooney, 2009), which has negative implications for SDG 2 and 3. Adverse effects to health also result from algal blooms due to mass die-off of zebra mussels, releasing toxins into lakes (Jones, 2019).

While not relevant for NCP 11, the species does impact energy production from hydropower through clogging of and damage to infrastructure (U.S. Congress Office of Technology Assessment, 1993; Pimentel *et al.*, 2000; Colautti *et al.*, 2006; Cusack, Harte and Chan, 2009; Strayer, 2009) and therefore negatively influences SDG targets associated with reduced energy production capacities.