JNCC Report 741

Supplementing the Database of Nature Based Solution (NbS) case studies to include pollution threats

(Research & Review Report)

Rhodes, K. & Rendle, E.

July 2023

ISSN 0963 8091

JNCC's report series serves as a record of the work undertaken or commissioned by JNCC. The series also helps us to share, and promote the use of, our work and to develop future collaborations.

For further information on JNCC's report series please contact:
Joint Nature Conservation Committee
Quay House
2 East Station Road
Fletton Quays
Peterborough
PE2 8YY

https://jncc.gov.uk/
Communications@jncc.gov.uk

This report was produced for JNCC under an external contract, by Rhodes, K. & Rendle, E. at Resilient Coasts Ltd for/under F21-0708-1581 (15).

This report should be cited as:
Rhodes, K.[1] & Rendle, E.[1] 2023. Supplementing the Database of Nature Based Solution (NbS) case studies to include pollution threats. *JNCC Report No. 741 (Research & Review Report)*, JNCC, Peterborough, ISSN 0963-8091.
https://hub.jncc.gov.uk/assets/b7f9b180-fd59-49f9-bfd4-d10b80d8922f

Author affiliation:
[1] Resilient Coasts Ltd, North Quay House, Sutton Harbour, Plymouth PL4 0RA.

Evidence Quality Assurance:
This report is compliant with JNCC's Evidence Quality Assurance Policy
https://jncc.gov.uk/about-jncc/corporate-information/evidence-quality-assurance/

The views and recommendations presented in this report do not necessarily reflect the views and policies of JNCC.

Summary

JNCC has contracted Resilient Coasts Ltd to expand the International Climate Finance (ICF) database (Library of Projects), originally developed by JNCC, to include information on pollution threats. The assignment supports the new JNCC-Defra project “Reducing Pollution Through Partnership”; a one-year project to scope and help design a wider pollution programme to enhance the ability of low and middle-income countries to manage chemicals and to reduce air, chemical, and waste pollution. Overall, the main aim of the programme is to reverse biodiversity loss and climate change, build ecological resilience and improve human social and physical well-being.

In 2020, JNCC screened 34 environmental databases for Nature-based Solutions (NbS) projects. From these 34 environmental databases, 2,934 projects were identified where NbS were implemented; this formed the Library of Projects. JNCC then selected 378 projects from the Library of Projects that met both the definition of a NbS and passed the JNCC selection criteria (i.e. aiming to achieve the ‘triple win’ of biodiversity enhancement, climate change mitigation and adaptation, and poverty reduction) to form the Database of Nbs Case Studies. Although not originally identified, this subset of the Library of Projects contains some case studies that are focussed on pollution.

This assignment aims to interrogate the Database of NbS case studies to identify case studies in low and middle-income countries that aim to tackle pollution. This process identified a short list of case studies alongside an updated database that can be used to inform pollution management and control related works. Case studies were identified where NbS mitigation actions were implemented successfully to tackle pollution and where measures were implemented but were unsuccessful. Also, case studies where the implementation of NbS projects were hindered by pollution were highlighted.

Following the review of the NbS database, 39 case studies were found to aim to implement NbS actions to tackle pollution. This subset contained completed, ongoing and planned case studies. Of these case studies, five projects were identified as the most valuable with potential to expand the knowledge of implementing NbS to tackle pollution. These are completed projects where the success of the pollution mitigation is clearly reported in post-project evaluation and guidance for replication is available.

The revised Pollution Supplemented NbS database and summary of pollution related findings, including detailed case study reviews, will be used as a key source of information by JNCC and Defra, essentially functioning as the detailed guidance for how NbS can be used globally to contribute to decreasing pollution and to help facilitate communication with recipient countries.

Contents

1 Approach

1.1 Methodology

The initial scope of this project was to assess case studies where research was carried out in Official Development Assistance (ODA) eligible countries. The Database of NbS case studies provided by JNCC was filtered by whether the location is ODA eligible (case studies taking place in non-ODA eligible countries were still included in the database but were hidden as they were not interrogated for pollution as part of this project). The resulting filtered database contained 283 case studies located in low and middle-income countries to be assessed as a priority. Non-ODA eligible case studies were still included but were not interrogated for pollution as part of this project.

Additional spreadsheet category headings provided by JNCC to include pollution-related information were added to the revised database (Appendix 1). Each case study was accessed via the hyperlink provided and the existing information included in the database for each case study was reviewed (Appendix 2). If the hyperlink had expired or required a log in to access the case study, a web search of the case study title was conducted to find the project information at an alternative website. If applicable, the new location of the case study was added to the note's column. The case study website was navigated to find a summary of the project and any related documents such as project proposal, annual reports, and final reports.

Project information was screened for keywords pertaining to pollution. The keywords used for screening case studies for relevance to pollution adapted from the IUCN Red List Threat Classification Scheme (Version 3.2)

- Pollution
- Pollutant(s)
- Wastewater / wastewater
- Sewage
- Run-off / runoff / run-off
- Effluent(s)
- Oil spill(s)
- Seepage
- Nutrient load(s)
- Soil erosion
- Sedimentation
- Herbicide(s)
- Pesticide(s)
- Garbage
- Waste
- Acid rain
- Smog
- Ozone

- Excess energy

For each case study, the summary homepage of the project website was reviewed for the presence of keywords. If additional project documents were available, these were also screened. Some case studies have published multiple documents relating to a single project such as annual progress reports, final report, funding proposals, CEO endorsement letters, and risk assessments. To achieve the project objectives and determine if a case study is related to pollution, it was not always necessary to screen every available project-related document. In addition to screening the project homepage, the following documents were prioritised for screening (dependant on availability):

- For completed projects: Final project report and project proposal.
- For ongoing projects: Annual reports and project proposal.
- For projects not yet started: Project proposal.

Where keywords were found, these were listed in the database, and the case study was reviewed in further detail to determine if it was related to pollution and if so, in what capacity.

Following initial screening, all case studies were assigned a number based on how they related to pollution:

- 0 = Not related to pollution
- 1 = Study clearly evidences levels of success or failure utilising NbS to tackle pollution.

This categorisation seemed too simplistic as a range of projects provided pollution co-benefits and may or may not have evidenced these benefits. Therefore, two further categories were added to provide more details about the project.

- 2 = Study is pollution related but the success of measures implemented is not evidenced. For example, a study that aims to tackle pollution through mangrove restoration and quantifies the number of mangrove propagules planted but does not measure baseline contaminant levels prior-implementation or monitor this benefit post-implementation. Additionally, any uncompleted/planned project that intends to evidence pollution change, but success of measures is not yet determined.
- 3 = Pollution related in some capacity, but it is not a main aim of the study to tackle pollution through NbS. No details are provided on if or how pollution was measured, or lessons learnt relating to pollution mitigation.

If the study was determined to have aimed to implement NbS to tackle pollution and was therefore categorised as 1 or 2 as per above, the additional spreadsheet categories were populated with case study information.

Definitions for all pollution mitigation/adaptation measures added to the database were collated (Appendix 3).

2 Results

The Pollution Supplemented NbS database contains 378 original database case studies, of which 283 are ODA-eligible. The latter was screened as per the described methodology. The resulting database is presented filtered to ODA-eligible locations as these were the case studies interrogated for pollution as part of this project. Following the database review, 39 case studies were found to implement NbS actions to tackle pollution directly, whereas those that did not numbered 244.

Of the 39 shortlisted, five were identified as Category 1 as per the categorisation described in the methodology; completed projects where the implemented NbS quantified pollution control and management successfully from a measured baseline. These case studies have published project evaluations evidencing levels of success in mitigating pollution through a variety of NbS strategies and have published lessons learnt valuable for any organisation attempting to duplicate the pollution mitigation measures. In depth reviews of these case studies can be found in the case studies section of this report.

In total, 34 case studies were identified as Category 2, thereby determined to either be ongoing or planned projects which aim to tackle pollution through NbS however the success is currently unknown or completed projects that did not clearly and directly evidence the success of pollution abatement measures. A brief review of a select number of Category 2 projects is provided in the following case studies section. These ongoing and/or planned projects have the potential to hold valuable information and therefore should not be dismissed but revisited to learn the success and lessons outcome once completed. Results of monitoring activities to date could also be requested from these highlighted projects prior to project completion, an effort which would require painstaking work to identify, contact and interview key staff.

A further 49 case studies were found to mention pollution control or management in a very minor capacity, and therefore identified as Category 3, with no evidence of the pollution mitigation success described in the project information available or reports found online. Furthermore, 195 case studies were found to be unrelated to pollution with the NbS implemented to tackle other issues, category 0.

The 39 Category 1 or 2 case studies identified as aiming to mitigate pollution through NbS actions tackled a variety of pollution sources, including all categories from the IUCN Red List Threat Classification Scheme (Version 3.2) which are as follows (some tackled more than one source):

- 9.1 Domestic & urban wastewater = 14 case studies
- 9.2 Industrial & military effluents = 8 case studies
- 9.3 Agricultural & forestry effluents = 24 case studies
- 9.4 Garbage & solid waste = 16 case studies
- 9.5 Air-borne pollutants = 6 case studies
- 9.6 Excess energy = 1 case studies

In addition to the above pollution categories, one case study (**Bioremediation in the Cordillera Blanca Peasant Community, Peru,** database number 327) was identified that tackled an issue of natural contamination, rather than pollution from an anthropogenic source included in the IUCN Red List Threat Classification Scheme.

Of the Category 1 or 2 case studies, 21 aimed to tackle a single type of pollution source and 18 case studies tackled multiple sources of pollution. The projects tackling multiple pollution sources typically run over a longer timescale, cover a larger geographical area, and have secured a large amount of funding. For example, the case study **R2R Implementing a Ridge to Reef Approach to Protect Biodiversity and Ecosystem Functions** (database number 195) implemented Ecosystem-based Management (EbM) in Tuvalu to tackle multiple sources of pollution: 9.1 Domestic & urban wastewater, 9.3 Agricultural & forestry effluents and 9.4 Garbage & solid waste.

On review of the database, 21 categories of NbS were identified which provided pollution mitigation and/or adaptation measures. A full list of these NbS measures, alongside definitions, is summarised in Appendix 3. The most common NbS actioned were Ecosystem-based Management (EbM) and wetland restoration, each implemented by seven of the case studies to mitigate pollution. Climate smart or resilient agriculture, reforestation, Integrated Water Resource Management (IWRM), and Sustainable urban Drainage Systems (SuDS) were each implemented by four separate case studies. All other NbS identified to mitigate pollution were implemented by three or fewer projects.

Those which implemented a single primary NbS pollution mitigation/adaptation measure numbered 26 case studies. There were also 13 case studies which implemented multiple NbS to tackle pollution issues or events. For example, the ongoing project **Ethiopian Urban Nationally Appropriate Mitigation Action (NAMA): Creating Opportunities for Municipalities to Produce and Operationalise Solid Waste Transformation (COMPOST)** (database number 96) aimed to tackle issues of solid waste pollution and air-borne pollutants via three NbS: urban parks, recycling of organic waste (composting) and reforestation.

In determining whether the success of a project implementing NbS to tackle pollution were hindered by forms of pollution, the database literature was reviewed mindful of this requirement. Of the 39 projects categorised 1 and 2, it was noted that 37 projects made no reference to any failure of measures due to pollution events. One case study, **Araucárias Square: rain garden and pocket forest, Brazil** (database number 288) concluded that the ongoing success of the project is hampered by pollution in the form of solid waste. Another ongoing case study, **Implementing Ecosystem-based Management in Ecologically Critical Areas in Bangladesh** (database number 120) noted that urban waste, agro-chemical pollutants, and untreated industrial waste may pose a health and safety risk to staff implementing the project. It will be valuable to review this project again on completion (due in 2024) to determine if the risk was managed effectively or if pollution significantly hindered the success of the NbS.

3 Case Studies

3.1 Primary case studies of interest

Following assessment of the Pollution Supplemented NbS database, five case studies are reported below in Tables 1 to 5. These projects showcase a variety of NbS measures undertaken to mitigate pollution in ODA-eligible countries. The five case studies are:

1. **Araucárias Square: rain garden and pocket forest, Brazil** (database number 288). This small-scale project in Sao Paulo transformed a decommissioned fuel station into a public rain garden. The area functions as a SuDS filtering runoff contaminated with sewage and pollutants from urban sources. This case study provides quantified data of pollution mitigation and flood prevention in an urban landscape. Although the success of the NbS relies on private funding and is impeded by ongoing pollution in the form of solid waste, the rain garden contributes to biodiversity enhancement and poverty reduction.
2. **Bioremediation in the Cordillera Blanca Peasant Community, Peru** (database number 327). This project demonstrates the use of a NbS to tackle a natural source of pollution affecting water quality for a farming community. The study quantified the output of decontaminated water from the bioremediation system and established ongoing post-project monitoring of the NbS.
3. **Establishing Sustainable Management of the Lake Sofia Catchment Madagascar** (database number 15). Sustainable agricultural techniques and wetland restoration under the umbrella of EbM were implemented to tackle pesticide pollution. Prior to implementation of the NbS strategy, baseline data was collected concerning levels of pesticide contamination in the sediment of the study area. Data regarding the contaminant levels post-study is not presented, however, the project claims success in working towards improving the issue of poor water quality through major decreases in agricultural chemical inputs.
4. **Building with Nature Indonesia** (database number 371). Ecoshape Foundation applied a Building with Nature approach to protect the coastline of Demak. Local stakeholders who converted from traditional aquaculture techniques to sustainable Associated Mangrove Aquaculture (AMA) have found their income increased. This is attributed partly to the reduction in use of chemical inputs and the ability of naturally recruited mangroves to filter out industrial effluents polluting waterways. Further details of the NbS implemented are published in a technical guideline (Bosma et al., 2020) and uptake of techniques has been noted across Indonesia.
5. **Blue Forests Initiative** (database number 38). This ongoing project aims to monetise the value of ecosystem services, including pollution abatement, provided by protected mangroves. Due for completion in 2024, the project is on target to reach goals for mangrove propagules planted, area of mangrove forest protected and subsequent economic benefits.

3.1.1 Case study 1: Araucárias Square: rain garden and pocket forest, Brazil

Table 1. Summary of case study 1: Araucárias Square: rain garden and pocket forest, Brazil.

Category	Description
Database number	288
Name of case study	Araucárias Square: rain garden and pocket forest (Reis *et al*. 2017)
Country	Brazil
Project date (start-end, status)	2017 - Completed
ODA or non-ODA	ODA
Funding source (budget)	Private funding by a resident, amount undisclosed
Ecosystem or biome	City
Intervention type	Sustainable drainage systems (SuDS)
Benefits and triple win notes	Climate change: Quantified Biodiversity loss: Qualified Poverty reduction: Qualified
Pollution category	9.1 Domestic & urban wastewater 9.4 Garbage & solid waste
Primary mitigation or adaptation measure	Sustainable Drainage Systems (SuDS)
Secondary mitigation or adaptation measure	Not applicable
Pollution appraisal (either monetised, quantified, qualified, unspecified).	Quantified
Description of appraisal	Sao Paulo is vulnerable to recurrent severe floods due to urban growth and consequent landscape change. Land-cover change has led to the disappearance of 3,000 km of watercourses and subsequent storm water run-off is contaminated by sewage discharge and diffuse pollution. Araucárias Square in Sao Paulo was a 650 m² abandoned fenced lot used as a local rubbish dump. The project aimed to transform the site to provide an urban public space, manage storm water and recover ecological functions and native biodiversity. Ten truckloads of waste and five underground decommissioned petrol tanks were removed. All the old fencing was removed, and the area was decontaminated, uncovering fertile ground from the Pinheiros river floodplain. The area was developed into a public rain garden with small patches of three different ecosystems: forest, cerrado (Brazilian Savannah) and wetlands. The planting included species native to the area prior to urbanisation, rare species of trees and edible and herbaceous plants. The rain garden acts as a SuDS that collects and filters polluted land run-off, thereby preventing contaminated water infiltrating the river and groundwater, as well as mitigating flood risk.

Category	Description
Success indicators	• During a storm in 2018, the rain garden collected 100% of the run-off of 900 m² that would otherwise go to the drainage system that previously flooded lower areas with polluted water. Within four hours, storm water and run-off infiltrated to the underground water table that flows to the Green River. The garden thrives, even in the dry season, and vegetation benefits from nutrients in the run-off. • The rain garden has dispersed the previous rat problem.
Lessons learnt	• The confluence of active citizens' activities enabled the transformation of the urban landscape. • Success is attributed to the funding from a resident, involvement of local activists, ability to hire an engineer and public engagement or participation. • Volunteers were motivated to participate in the efforts to plant the pocket forest through social media. • Transformation from a rubbish site to public garden has lifted the area and benefited residents and business owners. • The area is also benefiting from the proximity to metro stations and new development; the shops have been renovated and an empty building now houses a medical clinic.
Hinderance by pollution or other issues (failure mechanisms discussed)	• Rubbish being brought to the area is the most relevant ongoing problem. • A limiting factor to note is that the continued success of the project relies on the personal investment and ongoing commitment of a resident to maintain the area that now belongs to the public.

Figure 1. Araucárias Square before intervention (left) and after transformation with planting of native species (right). (Images sourced from Oppla Case Study (Guiherme Castagna Nik Sabey, Ricardo Cardim, Sergio Reis)).

3.1.2 Case study 2: Bioremediation in the Cordillera Blanca Peasant Community, Peru

Table 2. Summary of case study 2: Bioremediation in the Cordillera Blanca Peasant Community, Peru.

Category	Description
Database number	327
Name of case study	Bioremediation in the Cordillera Blanca Peasant Community, Peru (Chavez 2020)
Country	Peru
Project date (start-end, status)	2010 to 2020 - Completed
ODA or non-ODA	ODA
Funding source (budget)	Source and budget unknown
Ecosystem or biome	Streams and rivers
Intervention type	Bioremediation
Benefits and triple win notes	Climate change: Unspecified Biodiversity loss: Unspecified Poverty reduction: Qualified
Pollution category	Natural contamination
Primary mitigation or adaptation measure	Bioremediation
Secondary mitigation or adaptation measure	Not applicable
Pollution appraisal (either monetised, quantified, qualified, unspecified).	Quantified
Description of appraisal	In the Negro River sub-basin, glacial retreat has exposed geological formations rich in minerals that oxidize and release metal particles into the water which generates acidification and discolours the water. The reduced water quality posed a health risk to the local community as well as impacting livelihoods of farmers who rely on pastures for grazing cattle. The Mountain Institute and Local Agricultural Research Committee implemented Participatory Action Research to design a bioremediation technique integrating engineering, ecosystem management and social components. The water from the Chonta canal now passes through a series of sedimentation traps and ponds, containing native hydrophilic plants such as reeds and cattails. The root system filters out pollutants, and laboratory-grown bacteria reduce the acidity before returning the water to the canal. The intervention has successfully solved the issue of water pollution and acidification. Although this study showcases the use of bioremediation to tackle natural sources of contamination, this technique can also be effective against limited sources of anthropogenic pollution including agricultural pesticides, chemical manufacture, and landfill contaminants (Vidali 2001).

Category	Description
Success indicators	• The canal now provides 120 litres of purified water per second. The bioremediation technique has improved the quality of water for human consumption, domestic use and irrigation. • The availability and condition of pastures for grazing cattle is improved and livestock health improved. The financial output of agricultural practices has increased, benefiting the local community.
Lessons learnt	• To implement a solution, interaction between the committee, local researchers, project facilitators and local government was maintained. A collaboration of local and academic knowledge ensured community support, adaptation to issues as they arose and project success. • There must be the measures and training in place for maintenance, continuous monitoring of the system and subsequent interpretation of data to ensure proper functioning including annual cleaning of the sediment ponds and water quality monitoring twice a year. • For the bioremediation system, it is necessary to plan the supply of microorganisms required to remove the contaminants. In this case, it was not possible to acquire bacteria from wastewater treatment plants and bacteria were instead grown in a laboratory and released in the wetland.
Hinderance by pollution or other issues (failure mechanisms discussed)	• No hinderance by pollution reported. • The committee formed to tackle the issue of pollution took longer to institutionalize than expected. Members found the position to be time-consuming and some had to leave for this reason.

Figure 2. Cleaning of sedimentation ponds (Image sourced from Panorama case study (Doris Chavez), © Mountain Institute).

3.1.3 Case study 3: Establishing Sustainable Management of the Lake Sofia Catchment, Madagascar

Table 3. Summary of case study 3: Establishing Sustainable Management of the Lake Sofia Catchment Madagascar.

Category	Description
Database number	15
Name of case study	Establishing Sustainable Management of the Lake Sofia Catchment Madagascar (Avent & Bamford 2018)
Country	Madagascar
Project date (start-end, status)	2015 to 2018 - Completed
ODA or non-ODA	ODA
Funding source (budget)	Darwin Initiative grant funded by the Department for International Development (now the Foreign, Commonwealth & Development Office) (GBP 276,527)
Ecosystem or biome	Wetlands
Intervention type	Wetland restoration
Benefits and triple win notes	Climate change: Unspecified Biodiversity loss: Quantified Poverty reduction: Monetised
Pollution category	9.3 Agricultural & forestry effluents
Primary mitigation or adaptation measure	Ecosystem-based Management (EbM)
Secondary mitigation or adaptation measure	Sustainable agriculture & wetland restoration
Pollution appraisal (either monetised, quantified, qualified, unspecified).	Qualified
Description of appraisal	Over 60% of Madagascar's wetlands have either been lost or severely degraded due to conversion, sedimentation, invasive species, and over-harvesting. This habitat loss has led to a dramatic decline in wetland biodiversity and community well-being has suffered because of loss of ecosystem services. The Wildfowl and Wetlands Trust aimed to implement EbM in the Lake Sofia catchment to avoid the loss of native wetlands and biodiversity, support sustainable farming and improve conditions for local communities enabling them to move beyond a subsistence only economy. The project restored 8.75 hectares of aquatic and marginal habitat and post-restoration monitoring was implemented. Fully representative community management structures surrounding Lake Sofia were re-established and strengthened. An assessment of pesticides (Cypermethrin) in the sediment of Lake Sofia showed average concentrations of 0.23 mg/kg, up to 20 times the concentrations potentially lethal to amphipod species. To tackle the issue of pesticide pollution, a pilot study was carried out to transition 468 farmers to sustainable rice production involving the application of targeted natural pesticides. Chemical pesticide usage decreased from a baseline of 83% to 12.5% and production averaged 4.7 T/ha compared to control sites producing 1.5 T/ha. Farmers also used no herbicides to prepare the fields, instead manually weeding.

Category	Description
Description (continued)	A further 1,459 farmers received training on the use of environmentally sensitive fertilizers and pesticides. Of these additional participants, pesticide use decreased from 76% at the start of project to 55% in 2017. It should be noted that although chemical pesticide use is quantified, data regarding the concentrations of Cypermethrin in the sediment post-study is not included in the project evaluation.
Success indicators	• Major decreases in agricultural chemical inputs and the preservation and restoration of marsh habitat works towards improved access to clean water as approximately 1,450 people within the area (predominantly from poor and marginalised groups) rely on natural watercourses as their primary source of drinking water. • Nine community structures were established to manage and protect the natural resources of Lake Sofia. Due to interventions by this project, 41% of households have an improved understanding of wetland management and conservation value compared to only 16% of control households. The wetlands restored and preserved by these communities is important in tackling pollution. In the 2015 water quality monitoring program, relatively high levels of nitrate were detected in the inflow (around 5 mg/l), indicating organic pollution. These pollution levels are not present in the lake itself highlighting the importance of the marsh habitats in filtering and cleaning water that flows into the lakes. The study concludes that the protection and restoration of these wetlands contributes to the Convention on Biological Diversity Aichi Target 8: Bringing pollution, including from excess nutrients, down to levels that are not detrimental to ecosystem function and biodiversity.
Lessons learnt	• The structure of project partnerships worked well due to strong project management and good coordination of partnerships. It is recommended that other complex multi-stakeholder partnerships should agree clear monitoring and evaluation, and reporting systems which are flexible and adaptive throughout project. • Relationships in Madagascar take a long time to develop due to feeling of mistrust and individuals' concerns over conflict of interest between conservation and livelihoods. Strong and honest environmental education and awareness plus delivery of early tangible livelihood benefits alleviated concerns. This effort was aided by the worthwhile investment of a specialist poverty alleviation partner.
Hinderance by pollution or other issues (failure mechanisms discussed)	• No hinderance by pollution reported. • The creation of management transfer agreements took longer than planned which in-turn led to delays with other project activities such as planned reforestation efforts. • There were issues monitoring and evaluating ecological indicators due to lack of identification of reliable comparison sites.

Figure 3. 450+ farmers are now involved in sustainable rice schemes (Image sourced from Darwin Initiative (Robert Shore), © Wildfowl & Wetlands Trust Limited).

3.1.4 Case study 4: Building with Nature Indonesia

Table 4. Summary of case study 4: Building with Nature Indonesia.

Category	Description
Database number	371
Name of case study	Building with Nature Indonesia (Tonneijck *et al*. 2022)
Country	Indonesia
Project date (start-end, status)	2015 to 2020 - Completed
ODA or non-ODA	ODA
Funding source (budget)	EcoShape Foundation (EUR 8,000,000)
Ecosystem or biome	Mangrove
Intervention type	Mangrove restoration
Benefits and triple win notes	Climate change: Qualified Biodiversity loss: Qualified Poverty reduction: Qualified
Pollution category	9.2 Industrial & military effluents
Primary mitigation or adaptation measure	Associated Mangrove Aquaculture (AMA)
Secondary mitigation or adaptation measure	Mangrove restoration
Pollution appraisal (either monetised, quantified, qualified, unspecified).	Qualified

Category	Description
Description of appraisal	Demak is a coastal district in Central Java province threatened by severe erosion and flooding caused by the removal of a protective belt of mangroves and their replacement by aquaculture ponds. Sediment and water flows that previously maintained shorelines are disrupted by ineffective hard infrastructure. The livelihoods of the communities who depend on aquaculture are threatened by pollution. Wetland International, the Indonesian government and EcoShape Foundation intervened in 2015 to protect the coastline with a Building with Nature approach. 119 ha were dedicated to mangrove restoration and an additional 60 ha protected to provide coastal protection. The mangrove roots absorb heavy metals and filter sea-borne toxins such as industrial waste. Village communities were introduced to a system for environmentally friendly aquaculture practices while simultaneously regenerating mangroves. Coastal field schools taught techniques optimising the use of locally available natural resources and inputs such as organic fertiliser, solid and liquid compost, and fermented waste. This approach reduces or eliminates the use of external inputs such as synthetic chemicals which pollute the ecosystem. By the end of the project, 464 ha of ponds were converted to using sustainable aquaculture practices. Associated Mangrove Aquaculture (AMA) is a technique by which part of the aquaculture pond situated along inland waterways is given up making space for riverine mangroves. A double line of bunds is created along the river with sluice gates operated to encourage natural sedimentation. Mangroves naturally recruit in the newly sedimented areas. As an intermediary between open water and the aquaculture ponds, the mangrove greenbelt purifies incoming water of chemical pollution, such as discharge from factories in Semarang. Following training, 100 farmers chose to try AMA introducing the system to 167 ha of ponds. Typically, farmers converted 10% of their pond to mangrove habitat. In most locations, natural mangrove seedlings regrew within one year with a recovery success rate of 75%. As a result of this project and lessons learnt, a technical guideline has been published so that AMA techniques can be replicated (Bosma *et al*. 2020).
Success indicators	• Sustainable aquaculture practices have boosted productivity and increased income threefold. Farmers use modern measuring devices daily and have found improvements in the water quality. • AMA offers a more sustainable alternative to silvofishery systems (where mangroves are grown inside the ponds or on the pond bunds) which do not contribute to coastal protection and may have negative effects on aquaculture, hampering pond maintenance and reducing productivity by creating litter and shade. • Fish and bird populations and diversity have increased upon mangrove recovery. Mangrove restoration has also enhanced fisheries and increased wild catch. • The NbS used inspired public uptake across Indonesia.

Category	Description
Lessons learnt	• Stakeholder engagement, a financial incentive program (bio-rights) and improvement of production in new ponds led to high uptake of sustainable techniques. • Best aquaculture practices proved popular as they required less investment and boosted aquaculture productivity and income. As a result of successful aquaculture revitalisation, farmers were willing to give up land to create a riverine greenbelt. • The coastal field schools were a worthwhile investment proving critical to both mangrove restoration and increasing production from sustainable aquaculture. The trained villagers passed on their insights in other villages, giving a multiplier effect. • Directly addressing rapid land subsidence caused by groundwater pumping in and around Semarang was beyond the scope of the project. Ensuring long term benefits requires support from the government, notably in securing alternative water supplies for industry.
Hinderance by pollution or other issues (failure mechanisms discussed)	• No hinderance by pollution reported. • 2020 tidal floods and local subsidence (caused by excessive groundwater extraction) led to the flooding of some ponds and failure of the associated mangroves. The continued success of the project is not guaranteed as there has been growing pressure to zone land in severely eroded areas of Demak for industrial development.

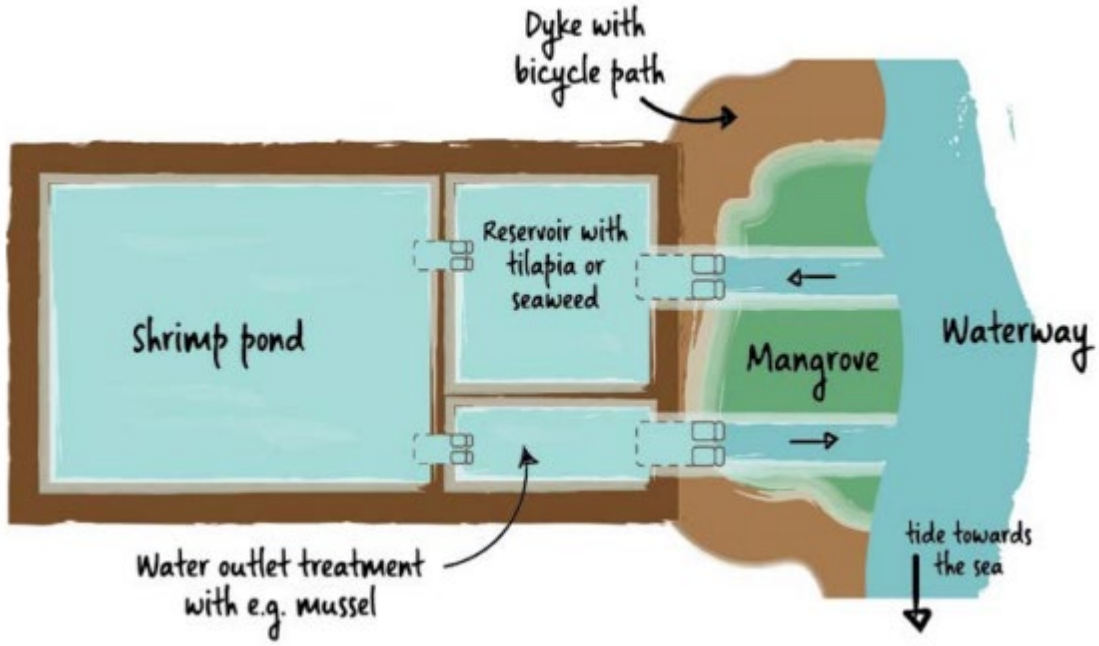

Figure 4. A complex associated mangrove aquaculture system for better water management (Image sourced from Wetlands International case study (Tonneijck *et al.* 2022) © Roel Bosma 2020).

3.1.4 Case study 5: Blue Forests Initiative

Table 5. Summary of case study 5: Blue Forests Initiative.

Category	Description
Database number	38
Name of case study	Blue Forests Initiative (DEFRA 2021)
Country	Madagascar & Indonesia
Project date (start-end, status)	2016 to 2024 - Ongoing
ODA or non-ODA	ODA
Funding source (budget)	Department for Environment, Food, and Rural Affairs (GBP 10,145,972)
Ecosystem or biome	Mangrove
Intervention type	Mangrove management
Benefits and triple win notes	Climate change: Monetised Biodiversity loss: Quantified Poverty reduction: Monetised
Pollution category	9.3 Agricultural & forestry effluents
Primary mitigation or adaptation measure	Mangrove management
Secondary mitigation or adaptation measure	Mangrove restoration
Pollution appraisal (either monetised, quantified, qualified, unspecified).	Monetised
Description of appraisal	Blue Ventures is leading an 8-year project at multiple sites across Madagascar and Indonesia to protect and restore mangrove forests and ecosystem services, preventing carbon emissions and supporting security of livelihoods in coastal communities. Mangroves in these areas are being quickly deforested, despite coastal communities relying on these habitats for their day-to-day livelihoods. The ecosystem services they provide, such as coastal protection, pollution abatement and erosion control are being impacted. This project aims to significantly reduce mangrove deforestation by helping local people to set up the appropriate institutional structures to instigate community-led mangrove management plans. Although this project is currently ongoing, the framework aims to achieve this through the protection of mangrove habitats, avoiding deforestation, and conservation reforestation efforts. The ecosystem services which mangroves provide are currently valued by the market at zero. The project aims to monetise ecosystem services provided by mangroves which are listed as shoreline protection, pollution abatement and protection from sedimentation. Blue Ventures also aims work with the coastal communities to provide viable alternative livelihoods to help reduce reliance on destructive mangrove logging and aquaculture practices.

Category	Description
Success indicators	• Aims for 179,678 ha of mangrove forest protected from deforestation or under sustainable local management by 2023. In 2019, reported 6229 ha are now protected. A further 5199 ha are ratified management plans, and 1100 ha are secured under Marine Protected Area control. By 2020, the project had planted 1,005,865 mangrove propagules, contributing significantly to mangrove restoration. • Ecosystem services benefits: Economic benefit from increased shoreline protection, pollution abatement and protection from sedimentation is expected to equate to USD 524,259 over 8 years. As of December 2020, Blue Ventures reports progress towards this impact indicator is on target at USD 281,680. • Transformational change is a key indicator of project success. As models prove to be successful and benefits are realised, neighbouring communities recognise the benefits of adopting the same livelihoods, fisheries, and sustainable mangrove management models. By the establishment of Blue Ventures' models in five sites, it is expected that an additional 99 sites will benefit from the natural proliferation of communities realising benefits and adopting the same models.
Lessons learnt	Although this project is incomplete, some lessons have been published in the annual reviews: • It is important to account for potential legal obstacles, and associated resource implications, when developing work plans. • Despite close relationships with local authorities, legal issues have caused significant delays. • A holistic approach to community programmes which includes health work is key building relationships, gaining trust and therefore ultimately achieving outcomes to increasing the climate resilience of communities.
Hinderance by pollution or other issues (failure mechanisms discussed)	• No hinderance by pollution reported. • The COVID-19 pandemic has resulted in delays to project delivery as social distancing rules and restrictions against travel have prevented project activities from taking place. As a result, the program has been extended by one to December 2024. • Some efforts to provide alternative sources of income to unsustainable mangrove aquaculture have been suspended by the Government of Madagascar due to a conflict of interest with their own plans for aquaculture in the area.

Figure 5. Mangrove monitoring (Image sourced from Blue Ventures case study (Ismaël Ratefinjanahary), © Blue Ventures).

3.2 Secondary case studies of interest

The case studies reported above are not an exhaustive list of projects found in the Pollution Supplemented NbS database aiming to utilising NbS to tackle pollution. We have shortlisted additional case studies of interest below which have not been reported in full within this scope of work.

A case study of interest in the Oppla database like the **Araucárias Square: rain garden and pocket forest** project (database number 288) has been identified. **EcoPark Natura: filtration gardens** (database number 297) is another example of a small-scale project successfully tackling pollution in Brazil through SuDS. Filtration gardens implemented in 2013 successfully treat 132 m³ of industrial and sanitary effluents from a cosmetics factory daily. The case study reports no hinderance by pollution and has published lessons learnt regarding results achieved compared to traditional waste-water treatment plants, maintenance and potential for replication.

Additional completed case studies have been identified that tackle pollution to some extent through NbS:

- **Empowering Ivorian communities to conserve biodiversity and improve their livelihoods** (database number 26) had a role in supporting a Landscape Management Plan that tackled pesticide pollution through climate-smart farm management practices.
- **R2R Implementing a Ridge to Reef Approach to Protect Biodiversity and Ecosystem Functions** (database number 195) aims to tackle a variety of pollution sources through EbM. However, a final report is not yet available online, so a full appraisal of the project's success is not currently possible.
- **Coastal Partners: Haiti** (database number 345) applied ecosystem-based disaster risk reduction to tackle contaminated runoff, sewage and sedimentation pollution through sustainable agriculture and reforestation. The study concludes that NbS applied have contributed to a reduction in sedimentation run-off which degrades coastal and marine ecosystems.

- **River Partners: Democratic Republic of the Congo** (database number 348) is a small-scale pilot study utilising IWRM and revegetation to tackle water quality issues caused by heavy sedimentation. The study does not aim to provide evidence of reduced sedimentation pollution, which would require a larger study area and longer time period but does demonstrate that IWRM provides an effective framework for promoting ecosystem-based disaster risk reduction.

3.3 Incomplete projects to revisit

The database also contains uncompleted case studies that aim to tackle pollution through NbS. The success of these cannot be fully assessed as the projects are either partially complete or are currently in the planning stages. The list below summarises uncompleted case studies of interest:

- **Increasing the resilience of biodiversity and livelihoods in Colombo's wetlands** (database number 18) is a 3-year project due to be completed in 2023. Sustainable wetland management is being put in place to improve water quality. The study aims to quantify a significant reduction in biochemical oxygen demand, nitrogen, and phosphorous pollution.
- **Implementing a "Ridge to Reef" Approach to Preserve Ecosystem Services, Sequester Carbon, Improve Climate Resilience and Sustain Livelihoods in Fiji** (database number 79) is a Global Environment Facility funded project aiming to tackle pollution from agricultural and forestry effluents. Through Integrated Coastal Management, IWRM and reforestation, the project aims to reduce, and where possible eliminate, the flow of sediments, excess nutrients, pesticides, heavy metals, and solid wastes being delivered from the land to the ocean.
- **Ethiopian Urban NAMA: Creating Opportunities for Municipalities to Produce and Operationalise Solid Waste Transformation** (COMPOST) (database number 96) is an ongoing project currently estimated to end June 2022. This case study links integrated solid waste management with urban green infrastructure to mitigate pollution caused by household waste and to improve air quality.
- **Implementing Ecosystem-based Management in Ecologically Critical Areas in Bangladesh** (database number 120) is utilising a hydrological baseline to quantify changes in pollution on a large-scale following EbM intervention.
- **A resilient and resilience enhancing danggit farming in Catbalogan City, Philippines** (database number 179) is a project to establish developmental aquaculture, moving communities away from damaging aquaculture practices and traditional fishing of depleted stocks. The sustainable aquaculture practices reduce pollution by growing marine flora and fauna around fish farms to remove pollution-causing fish manure, food waste and other organic/inorganic debris generated by fish farms. The proposal report available does not state a project start date and it is unclear whether this project has been completed.

3.4 Next steps and recommendations

Many of the case studies originally due to end in 2020 and 2021 are still ongoing due to global pandemic-related delays associated with Covid-19. We recommend that this task should be revisited in 2 to 3 years times to review the case studies currently in progress which are shortly due for completion. In addition to this, it may be valuable to contact project managers for select ongoing case studies in the interim to request additional pollution information and any findings to date. Revisiting this task later will also allow the opportunity to screen for any new post-project evaluations for completed projects. This will be especially relevant for assessing long-term success of case studies and for determining if pollution caused any hinderance to the ongoing success of NbS.

To further build on the knowledge gained from this report, it will be highly valuable to also review the case studies from non-ODA eligible countries. These case studies have been filtered out of the presented database but can be unhidden for further review in the future. Although the Reducing Pollution Through Partnership project seeks to assist low and middle-income countries, there will be valuable methods and lesson learnt from NbS applied in high-income countries who are more likely to have the resources to innovate in this field.

References

Avent, T.& Bamford, A. 2018. Establishing Sustainable Management of the Lake Sofia Catchment, Madagascar. *Darwin Initiative: Final Report*, UK.

Bosma, R.H, Debrot, D., Rejeki, S., Tonneijck, F., Yuniati, A.W. & Sihombing, W. 2020. Associated Mangrove Aquaculture Farms; Building with Nature to restore eroding tropical muddy coasts. *Ecoshape technical report,* Dordrecht.

Chariar, V.M. & Sakthivel, S.R. 2011. *Ecological Sanitation: Practitioner's Handbook*. Government of India and UNICEF.

Chavez, D. 2020. Biorremediación en la Comunidad Campesina Cordillera Blanca, Perú. [online]. Available from: https://panorama.solutions/en/solution/biorremediacion-en-la-comunidad-campesina-cordillera-blanca-peru [Accessed 05 May 2022].

Department for Environment, Food, and Rural Affairs (Defra). 2021. Blue Forests Initiative [online]. Available from: https://devtracker.fcdo.gov.uk/projects/GB-GOV-7-ICF-P0001-BV/summary [Accessed 05 May 2022].

Farrington, D.W., Lunt, J., Davies, S. & Blackburn R.S. 2005. *Biodegradable and Sustainable Fibres*. Woodhead Publishing, Sawston.

Food and Agriculture Organization of the United Nations (FAO). 2013. *Climate-Smart Agriculture Sourcebook*. Rome, Italy.

Global Water Partnership (GWP). 2000. Integrated Water Resources Management. *Technical Advisory Committee Background Papers No. 4,* Stockholm.

IUCN Glossary of Definitions. 2022 [online]. Available from: https://www.iucn.org/sites/dev/files/iucn_glossary_of_definitions_en_2022.04.pdf [Accessed 26 April 2022].

Konijnendijk, C.C., Annerstedt, M., Busse Nielsen, A. & Maruthaveeran, S. 2013. Benefits of Urban Parks: A Systematic Review. *A Report for IFPRA*, Copenhagen & Alnarp.

McLeod, K.L., Lubchenco, J., Palumbi, S.R. & Rosenberg, A.A. 2005. *Scientific Consensus Statement on Marine Ecosystem-Based Management*. COMPASS, Oregon.

Reis, S., Cardim, R., Sabey, N. & Castagna, G. 2017. Araucárias Square: rain garden and pocket forest. *Brazilian Case Studies*, Brazil.

Secretariat of the Convention on Biological Diversity (CBD). 2009. Connecting Biodiversity and Climate Change Mitigation and Adaptation*: Key messages from the Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change under the Convention on Biological Diversity,* Montreal.

Tonneijck, F., Van der Goot, F. & Pearce, F. 2022. Building with Nature in Indonesia: Restoring an eroding coastline and inspiring action at scale. *Wetlands International and Ecoshape Foundation*, Dordrecht.

United Nations Environment Program. 2021. A Beginner's Guide to Sustainable Farming [online]. Available from: https://www.unep.org/news-and-stories/story/beginners-guide-sustainable-farming [Accessed 26 April 2022].

United States Environmental Protection Agency (EPA). 2020. *Recycling Economic Information Report,* Washington, DC.

Vidali, M. 2001. Bioremediation. An Overview. *Pure and Applied Chemistry*, **73**, 1163-1172.

Woods Ballard, B., Wilson, S., Udale-Clarke, H., Illman, S., Scott, T., Ashley, R. & Kellagher, R. 2015. The SuDS Manual. *CIRIA Report C753*, London.

Weblinks

Table 6. URLs for descriptive text within the report:

Descriptive text	URL
Database of NbS case studies	https://hub.jncc.gov.uk/assets/376d989f-0563-4e7f-b034-c79108f63758#database-of-nbs-case-studies.xlsx
Threat Classification Scheme (Version 3.2)	https://www.iucnredlist.org/resources/threat-classification-scheme
Revised database	https://hub.jncc.gov.uk/assets/376d989f-0563-4e7f-b034-c79108f63758#database-of-nbs-case-studies.xlsx
Oppla Case Study	https://oppla.eu/sites/default/files/uploads/eu-brazil-nbs-dialogue-araucarias.pdf
Panorama case study	https://panorama.solutions/en/building-block/la-biorremediacion
Darwin Initiative	https://www.darwininitiative.org.uk/project/DAR22007/
Wetlands International case study	https://www.wetlands.org/download/23482/
Blue Ventures case study (Ismaël Ratefinjanahary)	https://blog.blueventures.org/en/guardians-of-blue-carbon/

Appendix 1

Table 7. Descriptions of additional spreadsheet categories relating to pollution.

Column header	Description of the information provided
Pollution related?	Does the case study aim to tackle pollution via NbS? Accepted Values: Yes; No.
Pollution categorisation	Categorisation defining how project relates to pollution (refer to Methodology for further information). Accepted Values: 0; 1; 2; 3.
Keywords found	Keywords present in case study documentation. Accepted Values: None; Pollution; Pollutant(s); Wastewater / wastewater; Sewage; Run-off / runoff / run off; Effluent(s); Oil spill(s); Seepage; Nutrient load(s); Soil erosion; Sedimentation; Herbicide(s); Pesticide(s); Garbage; Waste; Acid rain; Smog; Ozone; Excess energy.
Notes	Notes relating to project aims, methodology, pollution mitigation success/failure. Free text.
Date accessed (ODA Pollution)	Date which the project information was accessed and recorded by the Resilient Coasts team. DD/MM/YYYY format.
Budget	Total project budget in currency referenced in project documentation. Numerical value followed by currency.
Pollution category	Pollution categories from the IUCN Red List Threat Classification Scheme (Version 3.2). Accepted Values: 9.1 Domestic & urban wastewater; 9.2 Industrial & military effluents; 9.3 Agricultural & forestry effluents; 9.4 Garbage & solid waste; 9.5 Air-borne pollutants; 9.6 Excess energy.
Pollution sub-category (if available)	Pollution sub-categories from the IUCN Red List Threat Classification Scheme (Version 3.2). Accepted Values: 9.1.1 Sewage; 9.1.2 Run-off; 9.1.3 Type Unknown/Unrecorded; 9.2.1 Oil spills; 9.2.2 Seepage from mining; 9.2.3 Type Unknown/Unrecorded; 9.3.1 Nutrient loads; 9.3.2 Soil erosion, sedimentation; 9.3.3 Herbicides & pesticides; 9.3.4 Type Unknown/Unrecorded; 9.5.1 Acid rain; 9.5.2 Smog; 9.5.3 Ozone; 9.5.4 Type Unknown/Unrecorded; 9.6.1 Light pollution; 9.6.2 Thermal pollution; 9.6.3 Noise pollution; 9.6.4 Type Unknown/Unrecorded.
Primary pollution mitigation/ adaptation measure	Primary NbS intervention type of the case study which addresses pollution. The terminology in the project documentation is used, or a similar such term to those already collected. Definitions of the intervention types were collected (Appendix 4). Free text box to allow for listing of interventions.
Secondary pollution mitigation/ adaptation measure(s)	Secondary NbS intervention type(s) of the case study which addresses pollution. The terminology in the project documentation is used, or a similar such term to those already collected. Definitions of the intervention types were collected (Appendix 4). Free text box to allow for listing of any other interventions of relevance.
Lessons learnt	Summary of any lessons learnt as outlined in project documentation. Free text.

Column header	Description of the information provided
Project status (ODA Pollution)	An updated status of the project at the time of 'Date accessed'. Accepted Values: Completed; Ongoing; Planned; Unknown.
If completed, has a project evaluation been published?	Whether a project evaluation is available from the stage where the project finished. Accepted Values: Yes; No; Project uncompleted.
If completed, has a post-project evaluation been published?	Whether a project evaluation is available from > 1 year after the project finished. Accepted Values: Yes; No; Project uncompleted.
Project hindered by pollution?	Whether the project documentation notes any NbS measures that were hindered as a consequence of pollution. Accepted Values: Yes; No.

Appendix 2

Table 8. Spreadsheet categories already present in the JNCC Database of NbS Case Studies.

Column header	Description of the information provided and/or data validation
Name of case study	The project name provided on the database
Name of database	Name of the database hosting the case study
Link	Hyperlink to the case study
Date accessed	Date which the project information was accessed and recorded by the JNCC Project team. DD/MM/YYYY format.
Focal area	Focal area of the case study. Accepted Values: Marine; Terrestrial; Urban.
Geographic region	UN sub-region which the project is implemented in. Breakdown of countries into regions can be accessed here: https://unstats.un.org/unsd/methodology/m49/
Country (if relevant)	Country/countries which benefit from the project. 'Regional' is provided if the project documentation only states the relevant UN sub-region.
Is the location ODA-eligible?	Whether the country (or countries) which benefit from the project are included in the 'DAC List of ODA Recipients: Effective Reporting on 2020 Flows' (https://www.oecd.org/dac/financing-sustainable-development/development-finance-standards/DAC-List-of-ODA-Recipients-for-reporting-2020-flows.pdf). 'Partly' is provided when not all the countries benefiting from the project are ODA-eligible. Accepted Values: Yes; No; Partly.
Ecosystem or biome	Primary ecosystem or biome for which the project is implemented in. The categorisation scheme is based on that of the Chausson et al. (2020) paper entitled 'Mapping the effectiveness of nature-based solutions for climate change adaptation'. More information in this scheme can be found in the paper's supplementary materials: https://onlinelibrary.wiley.com/action/downloadSupplement?doi=10.1111%2Fgcb.15310&file=gcb15310-sup-0001-Appendix.docx. Accepted Values: Arctic & Subarctic/Subantarctic tundra; Aquatic production/artificial landscapes; Boreal forests and taiga; Coastal (includes shoreline, beaches, and dunes, but not mangroves, deltas/estuaries, or saltmarsh); Coral reefs; Created forest (plantations); Created grass (artificial grasslands, grass strips); Created other; Deserts and xeric shrublands; Estuaries & Wetlands (tidal, semi-submerged) - Multiple; Informal settlements; Kelp Forest; Large Marine Ecosystems - Multiple (includes surface waters, deep-sea, MPAs, and integrated coastal to open ocean but not benthic); Mangrove; Mediterranean shrublands and forests; Montane/alpine (forests, grasslands, steppe, shrublands); Mudflats; Multiple; Oyster reefs; Polar seas; Ponds and lakes (inland); Temperate forests (broad leaf, mixed, coniferous); Terrestrial production/artificial landscapes; Temperate grasslands (including savanna, shrubland); Tropical and subtropical grasslands (including savanna, shrublands); Towns and cities; Tropical and subtropical forests (dry forest, moist/rainforest, coniferous); Wetlands (inland, i.e. swamp marsh bogs fens, except inland peatlands); Peatland; Reef Ecosystem - Other (rocky, etc); Saltmarshes; Sea floor (benthic) – includes hydrothermal vents, seamounts, trenches; Seagrass meadows; Streams and rivers; Submerged Aquatic Vegetation - Other; Watershed.
Year of start date	Accepted Values: *Year*; Not stated.
Year of end date	Accepted Values: *Year*; Not stated; Ongoing.

Column header	Description of the information provided and/or data validation
Project status	The status of the project at the time of 'Date accessed'. Accepted Values: Completed; Ongoing; Planned; Unknown.
Primary intervention type	Primary NbS intervention of the case study. The terminology in the project documentation was largely used or a similar such term to those already collected. Definitions of the NbS intervention types are provided in the 'Interventions Definitions' tab in the 'Database of NbS Case Studies'.
Does the intervention provide benefits for the following? [Climate change; Biodiversity loss; Poverty reduction]	Whether the project reported or suggested benefits for each of the three outcomes in the 'triple win'. Based on project documentation, this was either 'unspecified' if they did not specify a benefit for that outcome, 'qualified' if the project specified a benefit without any quantification, 'quantified' if the benefit had a numerical value or 'monetised' if the project financially valued the benefit. For climate change, both benefits for mitigation and adaptation were included. For biodiversity, area-based proxies were accepted for 'quantified' biodiversity benefits. Accepted Values (for each climate change, biodiversity loss and poverty reduction): Unspecified; Qualified; Quantified; Monetised.
Does the intervention aim to provide benefits for biodiversity loss, climate change and poverty (triple win)?	Whether the benefits for (i) climate change; (ii) biodiversity loss; and (iii) poverty reduction are all at least specified (i.e. 'qualitised', 'quantified' or 'monetised' in Columns O - Q). Accepted Values: Yes; No.
Is information on the funding mechanism provided?	Whether the funding information for the project is available. Accepted Values: Yes; No.
Was the project performance monitored?	Whether the project performance was monitored in some capacity (i.e. Annual Report). Accepted Values: Yes; No.
Is the post-project evaluation available?	Whether a post-project evaluation was available. Accepted Values: Yes; No.

Appendix 3

Table 9. NbS identified which provided pollution mitigation and/or adaptation measures.

Pollution mitigation/ adaptation measure	Definition
Agroforestry	An ecologically based natural resource management system in which trees are integrated in farmland and rangeland (IUCN 2022).
Associated Mangrove Aquaculture (AMA)	A concept for associating aquaculture with forestry by means of a greenbelt of mangrove along shorelines of waterways in the estuaries (Bosma *et al.* 2020).
Bioremediation	The use of living organisms, primarily microorganisms, to degrade environmental contaminants into less toxic forms. It uses naturally occurring bacteria and fungi or plants to degrade or detoxify substances hazardous to human health and/or the environment (Vidali 2001).
Climate smart/resilient agriculture	An approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change (FAO 2013).
Ecological Sanitation Systems	A 'sanitize-and-recycle' closed-loop approach to sanitation. Urine and faeces are stored and processed until they are free of disease organisms. The nutrients contained in the excreta are then recycled by using them in agriculture (Chariar & Sakthivel 2011).
Ecosystem-based Adaptation (EbA)	Ecosystem-based adaptation uses biodiversity and ecosystem services in an overall adaptation strategy. It includes the sustainable management, conservation, and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change (CBD 2009).
Ecosystem-based Management (EbM)	A process that integrates biological, social, and economic factors into a comprehensive strategy aimed at protecting and enhancing sustainability, diversity, and productivity of natural resources. EBM emphasises the protection of ecosystem structure, functioning and key processes; is place-based in focusing on a specific ecosystem and the range of activities affecting it; explicitly accounts for the interconnectedness among systems, such as between air, land and sea; and integrates ecological, social, economic and institutional perspectives, recognizing their strong interdependences (McLeod *et al*. 2005).
Habitat management (of mangroves / wetland)	Management activities involving vegetation, soil and other physiographic elements or characteristics in specific areas, with specific conservation, maintenance, improvement, or restoration goals (IUCN 2022).
Integrated aquaculture	An aquaculture system sharing resources such as water, feeds, and management, with other activities; commonly agricultural, agro-industrial, infrastructural (wastewaters, power stations, etc.) (IUCN 2022).
Integrated Coastal Management (ICM)	A broad and dynamic process that requires the active and sustained involvement of the interested public and many stakeholders with interests in how coastal resources are allocated and conflicts are mediated. ICM is multi-purpose oriented, it analyses and addresses implications of development, conflicting uses and interrelationships between physical processes and human activities, and it promotes linkages and harmonisation among sectoral coastal and ocean activities (IUCN 2022).

Pollution mitigation/ adaptation measure	Definition
Integrated Water Resource Management (IWRM)	The coordinated development and management of water, land, and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP 2000).
Recycling of organic waste (composting)	Composting is a method of waste disposal that allows organic materials to be recycled into a product that can be used as a valuable soil amendment (Farrington *et al*. 2005).
Recycling solid waste	Recycling is the process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new products (EPA 2020).
Reforestation	Direct human-induced conversion of non-forested land back to forested land. In the context of the Kyoto Protocol to the UNFCCC, reforestation can take place on land that was historically forested but as of December 31, 1989, was subject to another land-use (IUCN 2022).
Restoration (of mangroves / wetland)	All the key ecological processes and functions are re-established, and all the original biodiversity is re-established; Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human wellbeing and biodiversity benefits (IUCN 2022).
Revegetation	Re-establishment of non-forest vegetation and restoration of degraded non-forested lands, such as overgrazed native grasslands or cultivated wetlands (IUCN 2022).
Sustainable agriculture	Farming that meets the needs of existing and future generations, while also ensuring profitability, environmental health, and social and economic equity. It favours techniques that emulate nature–to preserve soil fertility, prevent water pollution and protect biodiversity (UNEP 2021).
Sustainable Drainage Systems (SuDS)	Drainage systems that are environmentally beneficial, causing minimal or no long-term detrimental impact (Woods Ballard *et al*. 2015).
Urban Parks	Delineated open space areas, mostly dominated by vegetation and water, and generally reserved for public use. Urban parks are mostly larger but can also have the shape of smaller ‘pocket parks’. Urban parks are usually locally defined (by authorities) as ‘parks’ (Konijnendijk *et al*. 2013).

Acronyms and Abbreviations

AMA:	Associated Mangrove Aquaculture
EbM:	Ecosystem-based Management
GBP:	Great British Pound
ICF:	International Climate Finance
IWRM:	Integrated Water Resource Management
NAMA:	Nationally Appropriate Mitigation Action
NbS:	Nature-based Solution
ODA:	Official Development Assistance
SuDS:	Sustainable Drainage Systems
USD:	United States Dollar