A Guide for Integrated Conservation & Sanitation Programs & Approaches

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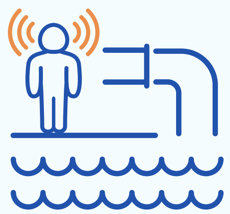
Purpose of the document

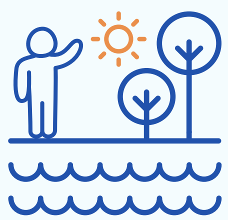
Human and ecosystem health are inextricably linked, yet strategies to improve both are addressed in siloed ways (Wakwella et al., 2023). For instance, the water, sanitation, and hygiene (WASH) sector focuses on the provision of services for safe drinking water, sanitation, and hygiene to improve human health and wellbeing. However, although there is substantial evidence to show that unsafely managed sanitation degrades ecosystems and makes them more vulnerable to climate change (Wear et al., 2023), and that ecosystem loss and degradation negatively impacts human health (Herrera et al., 2017; Wakwella et al., 2023), the sanitation and conservation sectors rarely work in a coordinated and strategic way to achieve their interconnected goals.

The Science for Nature and People Partnership (SNAPP) Improving Coastal Health working group formed in 2020 to develop resources to help marine conservation and sanitation practitioners work together on integrated conservation and sanitation programs. Informed by the outcomes of a needs assessment launched in 2021 to better understand the challenges and opportunities related to integrated programs, we created this document as a first step towards providing advice on implementing integrated conservation and sanitation programs.

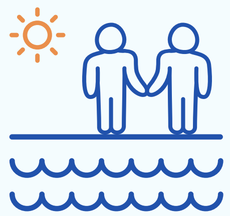
The purpose of this guide is:



Create awareness among stakeholders about the impacts of poor sanitation and wastewater pollution on ocean health and the importance of more integrated solutions.



Outline the benefits of an integrated approach for achieving human and ecosystem health goals and simultaneously improving climate resilience.



Provide guidance to the conservation and sanitation sectors on how to work in partnership.

The information contained in this guide is primarily aimed at actors who could participate in the sanitation-conservation interface, including practitioners from both sectors, investors, governments, research scientists, and private businesses. We focus on domestic wastewater pollution impacts on tropical coastal marine ecosystems, including mangroves, seagrass, and coral reefs, although we reference other coastal systems when relevant. This resource is also flexible enough for the guidance to be adapted for other coastal and marine environments. Freshwater ecosystems are considered in this guide in their role as transportation of diffuse pollution, but the specific impacts of wastewater pollution on freshwater aquatic life are not included. Other land-based sources of pollution, including from agriculture and development (e.g., agrochemicals, chemical contaminants, sediments) are also outside the scope of this guide, as there are already several resources on addressing these sources of pollution.

We hope this is the first of many resources to help guide collaboration and coordination across sectors to achieve human and ecosystem health goals.

Glossary

- **Biodiversity conservation:** To ensure the protection and sustainable management and use of biodiversity, so as to maintain threshold levels that allow diverse organisms to thrive in the future through natural processes, such as natural selection and evolution (Jaisankar et al., 2018).
- **Blackwater:** A waste stream from toilets that is the mixture of urine, feces, flush water, and cleansing materials (e.g. toilet paper) (**Fig. 1**). Blackwater contains pathogens (mainly from feces) and nutrients that are diluted in the flush water (Tilley et al., 2014).
- **Coastal and marine ecosystems:** Ecosystems located in the land-sea interface (Ayyam et al., 2019). The present guide focuses primarily on tropical ecosystems such as mangroves, seagrass, and coral reefs, but refers to other coastal ecosystems where relevant.
- **Contaminants vs. Pollutants:** Contaminants are considered chemical elements or compounds that are present at concentrations above background or that should not be present. A pollutant is a contaminant that is found at concentrations that cause adverse biological effects in living beings (Chapman, 2007).
- **Ecosystem health:** The state or ability of ecosystems to maintain their organization, structure, and functions needed to deliver ecosystem services, and manage external stress through time (Costanza, 1992).
- **Ecosystem services:** The ecological functions or processes that directly or indirectly contribute to sustainable human wellbeing (Costanza, 2020).
- **Excreta:** Urine and feces combined with any flushing water (SuSanA, 2018).
- **Fecal sludge:** Excreta collected via non-sewered sanitation systems, such as pit latrines, leach pits, and septic tanks (SuSanA, 2018).
- **Greywater:** Water generated from washing food, clothes, and dishware, as well as from bathing, but not from toilets. It may contain traces of excreta (e.g., from washing diapers) and pathogens (Tilley et al., 2014).
- **Latrine back-end:** The containment facility where fecal waste is stored, treated, or disposed (Tilley et al., 2014).
- **Natural resources:** Materials or substances occurring in nature which can be exploited for economic gain. This term differs from ecosystem services in that ecosystem services are the benefits provided to humans through the transformation of resources (or environmental assets, including land, water, vegetation and atmosphere) into a flow of essential goods and services e.g. clean air, water, and food. As an example, an ecosystem service provided by coastal marine ecosystems is the support and maintenance of fish populations, which can then be extracted as a natural resource.
- **Nature-based solutions:** For this guide, it refers to the planned and deliberate use of ecosystems and ecosystem services to improve water quality or quantity, and to increase resilience to climate change (UNEP-DHI et al., 2018).
- **Non-sewered sanitation systems:** All on-site sanitation systems that are not sewered. This typically includes leach tanks, septic tanks, aerated treatment units, cesspools, and pit latrines. In the sanitation sector, all excreta that is collected in on-site systems is called fecal sludge, but for septic tanks an additional term of septage is sometimes used. Fecal sludge can be removed/ transported and treated in fecal sludge treatment plants or other treatment facilities, such as sludge drying beds. The term wastewater is used in this guide to describe excreta from on-site systems. In the case of septic tanks, any treated septage discharged via drainage fields is termed treated wastewater in this guide (**Fig. 1**).
- **Pharmaceutical and personal care products:** These include numerous groups of chemicals used to treat or prevent animal and human disease, or chemicals contained in personal care products such as shampoos and deodorants (Boxall et al., 2012). They are consistently associated with sewage and wastewater (Meyer et al., 2019) and are classed as Contaminants of Emerging Concern (Hoyet, 2018).
- **Receiving environment:** the natural environment that receives any discharge of waste, including from leaching, runoff, and discharge of treated and untreated wastewater.

- **Resilience:** The capacity of individuals, communities, institutions, businesses, and systems to survive, adapt and thrive no matter what kinds of chronic stresses and acute shocks they experience.

- **Safely managed sanitation:** The term that applies to improved sanitation facilities that are not shared with other households and where excreta are safely disposed of in situ or treated off site. Improved sanitation facilities include: flush/pour flush toilets to piped sewer systems; septic tanks or pit latrines that are safely contained and do not leach into the environment; pit latrines with slabs (including ventilated pit latrines), and composting toilets (WHO, n.d.). To be classified as safely managed sanitation, treatment for waste coming from sewer systems must consist of "at least secondary treatment, or primary treatment with a long ocean outfall" (WHO, n.d.). See **Box 15** For more details

- **Shocks:** An acute natural or human-made event or phenomenon threatening major loss of life, damage to assets and a community's ability to function and provide basic services, particularly for poor or vulnerable populations. For the purpose of this guide, an example of an acute sanitation shock might be a storm induced sewage release due to combined sewer overflow (CSO), creating a cascading effects threat to human and natural systems and species. The chronic infrastructure issue related to this intersects as a stress (see definition below).

- **Sustainable sanitation:** To qualify as sustainable sanitation, a sanitation system has to be economically viable, socially acceptable, technically and institutionally appropriate, and protect human health, the environment, and natural resources (SuSanA, n.d.).

- **Sanitation services chain:** A term that refers to fecal waste flow through: capture; storage; emptying; transport; treatment; and end use or final disposal (**Fig. 1**). Emptying is an additional step for on-site sanitation systems compared to off-site ones (SuSanA, n.d.).

- **Sewered sanitation systems:** Systems that transport blackwater and greywater as sewage via piped networks to wastewater treatment plants for treatment, resulting in discharge of effluent (liquids) and sludge or biosolids (solids). The effluent from sewered sanitation systems is referred to as sewage. The term sewerage or sewage system refers to the infrastructure used to convey sewage. For this guide, all sanitation waste streams, including discharge, are termed wastewater (**Fig. 1**).

- **Stresses:** Chronic events, whether natural or human-made, weaken community and ecosystem functioning, especially for vulnerable populations. An example is outdated infrastructure causing untreated wastewater release, harming both humans and nature. These chronic stresses combine with sudden shocks like storms, floods, and sewage releases. Wastewater harms coastal ecosystems chronically, while cyclones, floods, and heatwaves are acute stressors. Experiencing chronic stress reduces resilience to acute events (Gove et al., 2023).

- **Wastewater:** The term typically includes sewage captured from both residential and industrial sources. In this guide, fecal sludge is also included as a wastestream in this definition to simplify the wording. However, it is acknowledged that fecal sludge and sewage are two different types of sanitation waste streams and, where appropriate, that distinction is made in any technical text. Throughout the document, we differentiate between treated and untreated wastewater where relevant.

- **Wastewater treatment processing stages:**
  - Primary wastewater treatment is the physical removal of solids from sewage via screening and settling.
  - Secondary treatment is the partial breakdown of the organic parts of sewage via biological processes like activated sludge.
  - Advanced wastewater treatment is any process which reduces the level of impurities in a wastewater below that attainable through conventional secondary or biological treatment. Includes the removal of nutrients such as phosphorus and nitrogen and a high percentage of suspended solids.
  - Tertiary treatment further removes contaminants in the wastestream via filtration and other techniques.

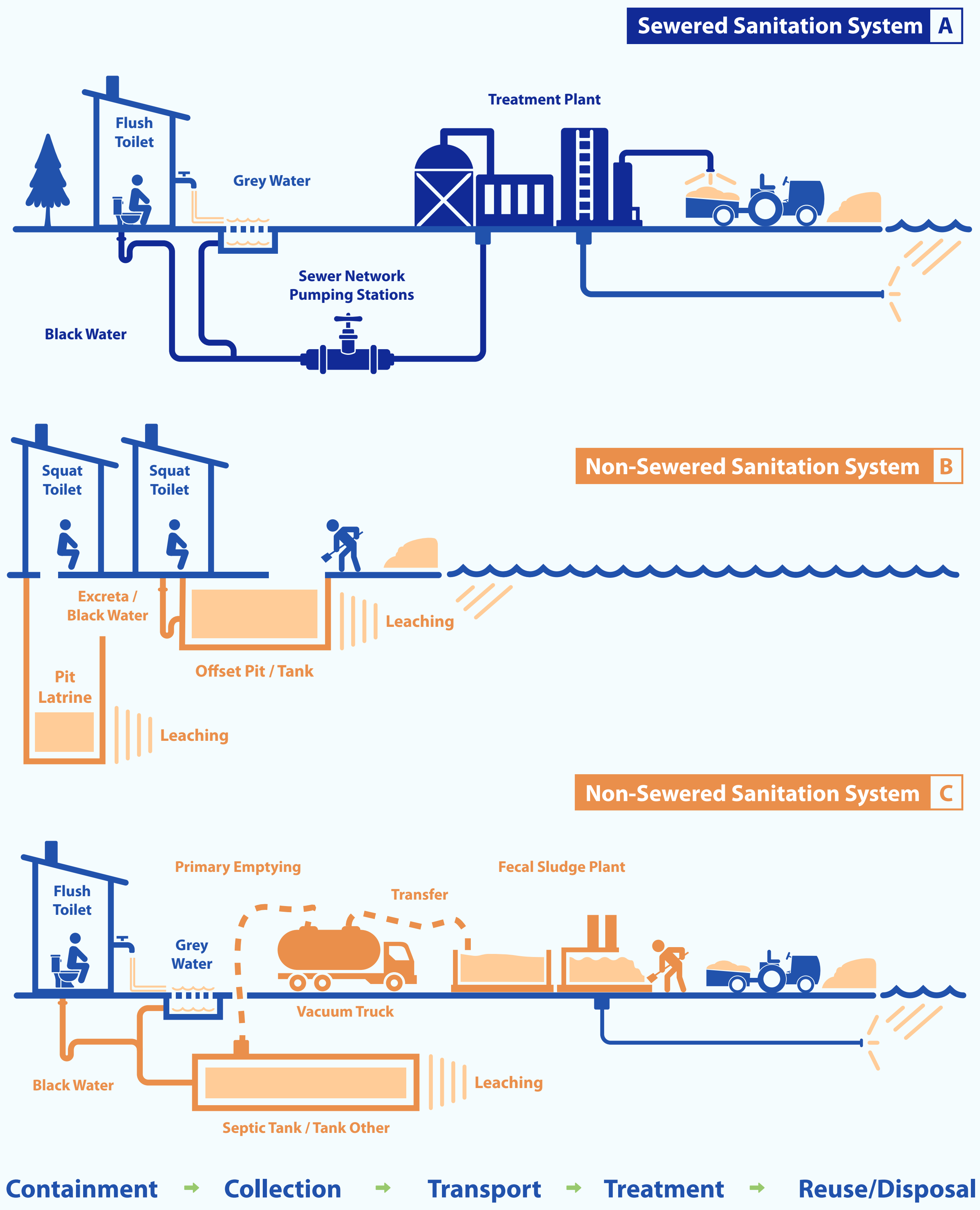


*Fig.1: Sanitation services chains. **Scenario A:** Sewered sanitation systems with a conventional wastewater treatment plant. Occurs in both more and less developed countries. However, in less developed countries there is a higher likelihood that the plant will have a lower level of treatment and operational challenges. **Scenario B:** Non-sewered sanitation systems where there is no fecal sludge treatment plant and only hand emptying. The most common scenario in both rural and urban areas in less developed countries. **Scenario C:** Non-sewered sanitation system where there is a fecal sludge treatment plant and commercial emptying services. Generally, this occurs in rural areas in more developed countries*

1. Overview

Over 40% of the world's population (**3.46 billion people**) lack access to safely managed sanitation services (UNICEF & WHO, 2023), and over **1,000 children** die each day due to preventable water and sanitation-related diseases (UNICEF, 2023). The economic consequences of unsafely managed sanitation is significant, costing an estimated **US$223 billion** each year due to health care expenses and lost productivity (Wee, 2018). By 2050, over two-thirds of the world's population will live in urban areas, posing interconnected risks like ecosystem degradation, climate change, inequality, and pandemics. These risks are amplified by rapid urbanization, poor infrastructure, and limited resources (RCN, 2019), including sanitation. Climate migration will exacerbate these challenges, particularly in coastal zones.

Concerns around access to sanitation services primarily focus on the human health implications of exposure to unsafely managed human waste. However, all over the world, in developing and developed countries, **oceans are polluted from unsafely managed sanitation and are used to dispose of wastewater** (both treated and untreated) (OSA, 2021).

Wastewater pollution is generated across the sanitation services chain and enters the environment in multiple ways (Fig. 2):

- Open defecation or on-site systems piped directly to water bodies where untreated excreta and wastewater enters the environment (e.g., defecating in oceans or rivers and hanging toilets).
- Surface run-off from open defecation zones and overflowing pit latrines (Amin et al., 2020).
- Leaching from pit latrines, leach pits, and over-full septic tanks, plus injection wells for wastewater disposal that reaches groundwater (Graham & Polizzotto, 2013; Orner et al., 2018).
- Direct discharge of raw wastewater from wastewater treatment plants during bypass events (e.g., after heavy rainfall treatment plants do not have the capacity to treat all the incoming wastewater) (Xie et al., 2022) or fecal sludge from emptying trucks.
- Discharge of treated or partially treated waste from wastewater treatment plants (Hamdhani et al., 2020).

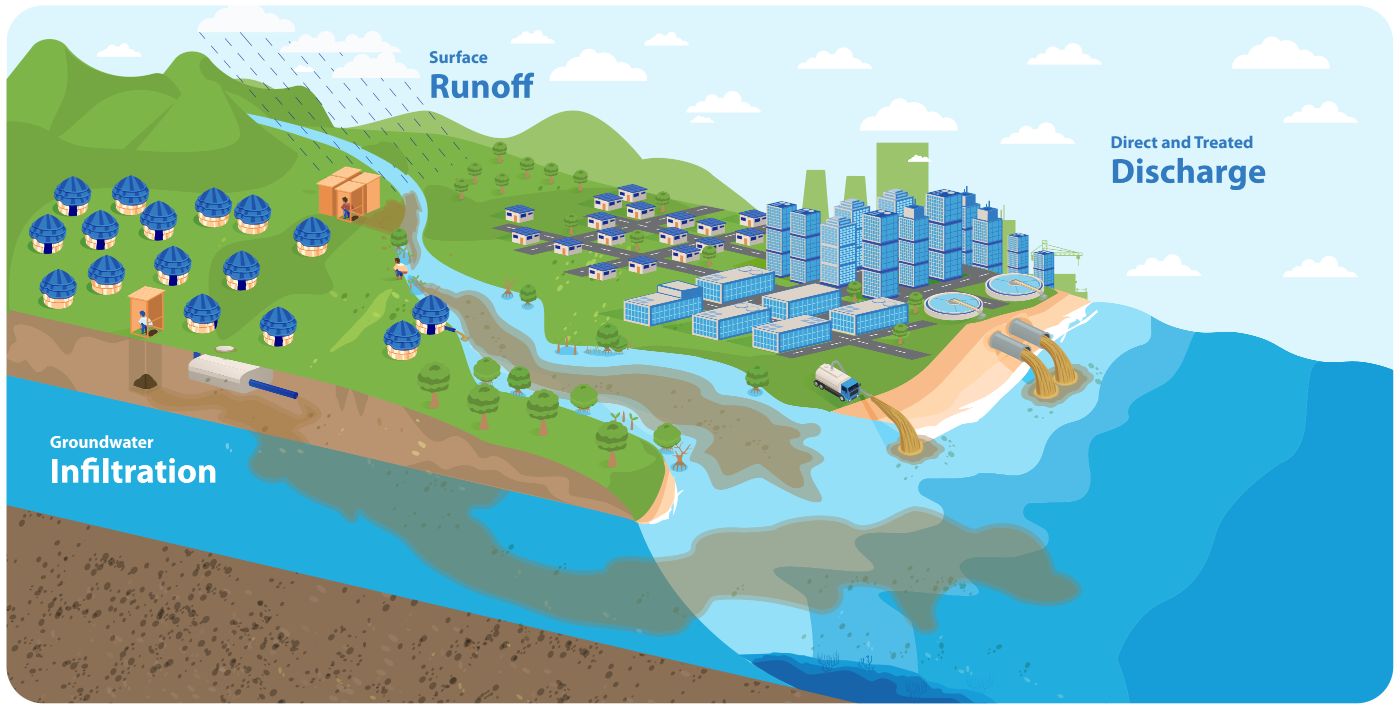


***Fig. 2:** Pathways for wastewater pollution to enter coastal marine environments*

In recent years, it has become clear that wastewater discharge into the environment is resulting in contamination of coastal marine ecosystems and is a global threat occurring in most areas with human populations (Tuholske et al., 2021; Wear et al., 2023; Wear & Vega Thurber 2015).

80%

300-400 Million Tons

~80% of the world's industrial and municipal wastewater is discharged without treatment to surface waters, equaling about **300–400 million tons*** of pollution each year (IPBES, 2019; UNESCO, 2021). This proportion is even higher in developing countries due to a lack of infrastructure.

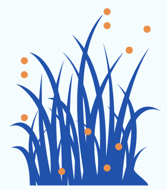
55%

Coral Reefs

55% of coral reefs are exposed to wastewater pollution (Tuholske et al., 2021), and ~15% of coral reefs are exposed to only wastewater pollution and no agricultural or sediment pollution (Andrello et al., 2022; Tuholske et al., 2021).

7 $2s^2 2p^3$
N
Nitrogen
14.007

An estimated **4.3-7.1 million tons of nitrogen** from wastewater enter coastal environments every year, from both unsafely and safely managed sanitation (Wear et al., 2023).



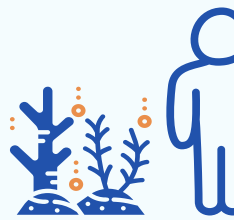
88%

Seagrass Ecosystems

An estimated **88% of all seagrass ecosystems** (both tropical and temperate) are exposed to wastewater pollution (Tuholske et al., 2021).

An estimated **1.5 million tons of phosphorus** from wastewater enter surface waters every year (Van Puijenbroek et al., 2019).

15 $3s^2 2p$
P
Phosphorus
30.974



104 / 108

Wastewater pollution has been documented in **104 out of 108** coral reef regions with human populations present (Wear & Vega Thurber, 2015).

Globally, **26 classes of pharmaceutical drugs** have been recorded in the marine environment of **34 countries**, with several instances of bioaccumulation in a wide range of species, which is likely a vast underestimation of their prevalence (Dehm et al., 2021; Fabbri & Franzellitti, 2015; Greene, 2022; Madikizela et al., 2020; Madikizela & Ncube, 2022).

** all references of tons is metric.*

Wastewater pollution in coastal marine environments has several documented impacts on ecosystems and species (Appendix 1).

- Pathogens present in wastewater cause **coral disease** (Lamb et al. 2017).
- Nutrient pollution negatively impacts **coral growth, larval and adult coral survival, coral disease prevalence, bioerosion processes, and fertilization** (Nalley et al., 2023; Prouty et al., 2017; Yoshioka et al., 2016; Zhao et al., 2021).
- Wastewater pollution has caused **large scale fish mortality events** (Wear et al., 2023).
- Wastewater pollution has resulted in **significant loss of seagrass meadows** (Bryars & Neverauskas, 2004).
- Pharmaceuticals **significantly alter fish behavior** (Brodin et al., 2014).

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Wastewater pollution in the ocean makes coastal marine ecosystems and coastal human populations more vulnerable to climate change.

- Wastewater pollution increase the **prevalence and severity of coral diseases and bleaching** (Claar et al., 2020; Gove et al., 2023; Wang et al., 2018), while warmer ocean temperatures increase the virulence of pathogens and susceptibility of organisms to disease outbreaks (Bruno et al., 2007; Groner et al., 2021).
- Wastewater pollution inhibits the **recovery of coral reefs** following bleaching events (Gove et al., 2023).
- Nutrient enrichment makes mangroves more vulnerable to erosion (Naidoo, 2009), while sea level rise and storm surges increase erosion rates (Oppenheimer et al., 2019).
- Nutrient enrichment makes mangroves more **likely to die from climate-related drought** (Lovelock et al., 2009).
- Marine heat waves **amplify eutrophication and deoxygenation** caused by wastewater pollution (Brauko et al., 2020), which can increase the severity of fish kills (Wear et al., 2023).
- Nutrients from wastewater reduce the ability of mangroves to store carbon, **leading to increased emissions** and undermining blue carbon initiatives (Santos-Andrade et al., 2021).

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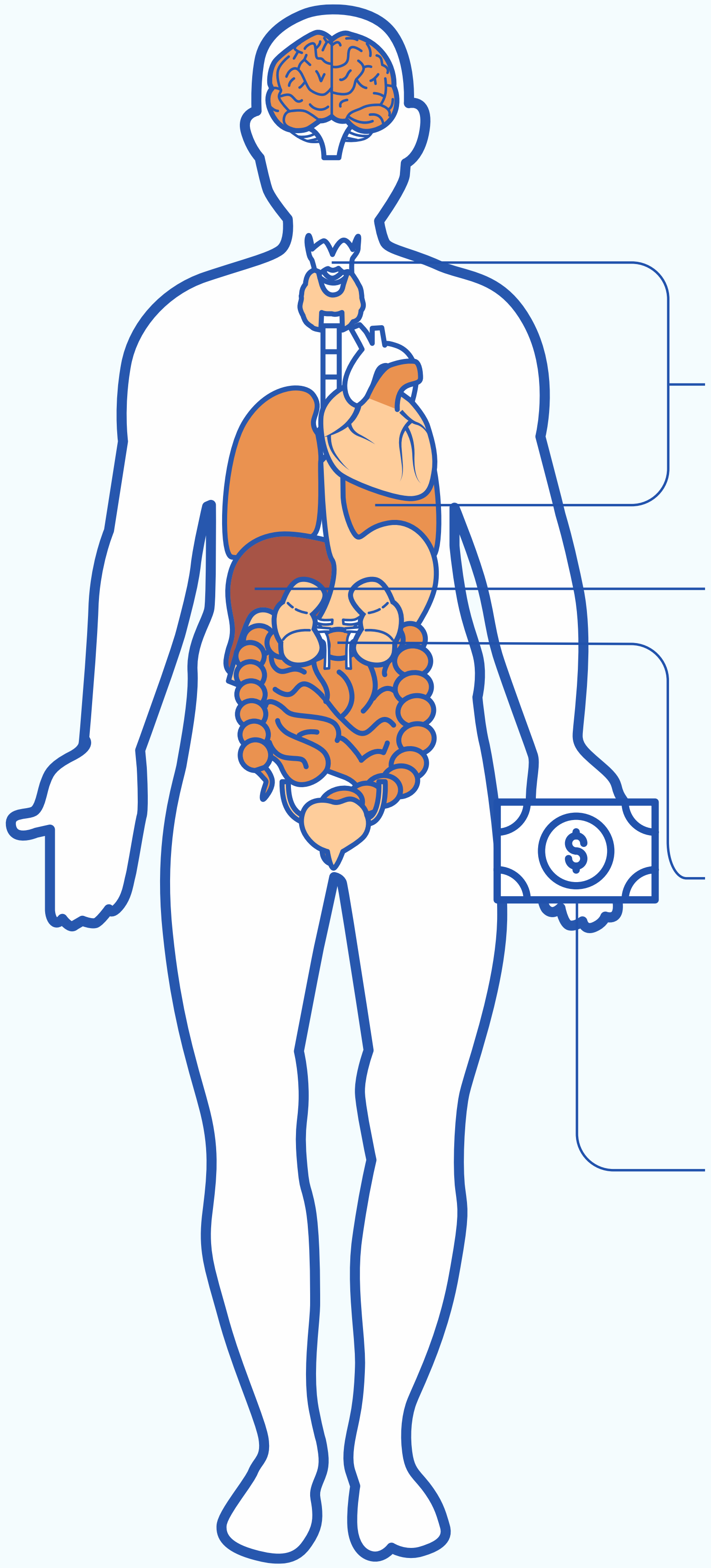
BOX 1

Coastal and marine ecosystems provide significant economic benefits to countries

Mangrove forests, seagrass meadows, and coral reefs are remarkable coastal ecosystems that offer an array of indispensable ecosystem services crucial to the wellbeing of both marine life and coastal communities. Mangroves and seagrass meadows play a pivotal role in carbon sequestration and oxygen production, with mangroves storing up to five times as much organic carbon as tropical upland forests (Donato et al., 2011). Both filter water and help to maintain water clarity, making them an important component of nature-based solutions to wastewater management (Lamb et al., 2017). Recently, the filtration service of seagrass was conservatively estimated to prevent 8 million cases of gastroenteritis globally each year (Ascioti et al., 2022). The loss of mangroves and seagrass meadows can lead to more saltwater intrusion into groundwater, which can undermine water security initiatives (Barbier, 2016; Hilmi et al., 2017). Mangroves and seagrass meadows act as natural nurseries, providing essential habitat for numerous marine species, while also serving as a buffer against coastal erosion and storm surges (Ayyam et al., 2019; Barbier et al., 2011; Mehvar et al., 2018). Coral reefs offer unparalleled biodiversity and account for at least 35% of all marine species globally (Fisher et al., 2015). They deliver critical services like shoreline protection, providing homes for marine life, supporting hundreds of millions of people around the world, and attracting tourists, thus bolstering economies and coastal livelihoods (Kawarazuka & Béné, 2010; Spalding et al., 2017; Teh et al., 2013). Structurally complex coral reefs not only support more fish species, they are critical for coastal protection, especially in the face of sea-level rise (Darling et al., 2017; Harris et al., 2018) (Fig. 3). **Importantly, coral reefs less exposed to wastewater pollution were able to recover following a coral bleaching event** (Gove et al., 2023).

Based on provisioning, regulating, habitat, and cultural services provided by ecosystems, the total estimated economic values (US$/ha/yr, converted to 2023 values) for coral reefs is **$516,945**, followed by wetlands (i.e., tidal marshes, mangroves and salt water wetlands) at **$284,478**, and coastal systems (i.e., estuaries, continental shelf area, and seagrass) at **$42,437** (de Groot et al., 2012), with the global estimated total value being **US$41 trillion/year** (Costanza et al., 2014). The economic value of coastal marine ecosystem services dwarfs the value of terrestrial ecosystem services, which have been valued at **$7,725** for tropical forests, **$4,421** for temperate forests, **$2,330** for woodlands, and **$4,213** for grasslands (de Groot et al., 2012). The economic benefits these ecosystems provide to countries, along with the political influence that ocean industries have, makes their protection a powerful argument for action on wastewater pollution.

Fig. 3: Ecosystem services provided by coastal and marine ecosystems



Wastewater pollution in the ocean also has significant public health consequences:

An estimated **180 million** cases of upper respiratory disease and gastroenteritis occur each year as a result of bathing in polluted ocean waters or ingesting contaminated seafood (Shuval, 2003).

~4 million cases (and 40 thousand deaths) of infectious hepatitis A and E (HAV/HEV) occur annually from contaminated seafood from polluted coastal waters (Shuval, 2003).

Dozens of outbreaks of norovirus, which causes an estimated **685 million cases** of acute gastroenteritis and an economic burden of **US$60 Billion annually**, have been linked to consumption of contaminated bi-valve mollusks, which accumulate norovirus from exposure to wastewater pollution (Campos et al., 2017; CDC, 2023; Laio et al., 2021; Razafimahefa et al., 2019).

The public health consequences of wastewater pollution in coastal marine environments results in an estimated **$19.8 billion** a year in economic losses (Shuval, 2003, converted to 2023 values).

BOX 2

Public health effects and costs associated to contaminated coastal waters in California

According to epidemiological research, exposure to coastal waters can result in different types of illness such as gastroenteritis and acute respiratory disease, as well as eye, skin, and ear infections. These illnesses are caused by pathogenic microorganisms derived from fecal contamination, particularly from wastewater discharge. It is estimated that California beaches attract between **150-400 million** visitors every year (Given et al., 2006). However, California beaches are impacted by a large amount of treated wastewater runoff that is released to coastal marine waters through outfalls adjacent to many beaches, negatively impacting coastal water quality (Dwight et al., 2002; Li & Zhang, 2019; Noble et al., 2000).

The human health consequences of exposure to wastewater pollution at California beaches have been documented in several studies:

Dwight et al. (2005) estimated the economic burden from illnesses associated with exposure to polluted marine waters in two popular beaches (Newport & Huntington) in Orange County, California:

- Gastrointestinal illnesses per year amounted to **$1.3 million** in health costs, acute respiratory disease cost **$951,378**, ear ailments cost **$767,221**, and eye ailment cost **$304,335**, resulting in a cumulative annual health burden of **$3.3 million**.

Given et al. (2006) estimated the number of gastrointestinal illnesses by swimming in contaminated coastal waters at **28 beaches comprising160 km of coastline** in Los Angeles and Orange Counties:

- The annual visitation estimate was close to **80 million** during the year 2000.
- Between **627,800** and **1,479,200** gastrointestinal illnesses are estimated to occur as a result of recreation at these beaches.
- Such estimates correspond to an economic loss per year of more than **$20 million** (in year 2000 dollars).

Li & Zhang (2019) studied the loss in productivity, measured in sick leave, caused by contact with fecal-contaminated water along the coast of California: When the geometric mean of **35 cfu/100 mL** of enterococci bacteria is surpassed, there is a **0.6%** increase in sick leave, which represents an additional **3.56 million** sick leave days annually in California alone.

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2. The challenge

Marine conservation practitioners are confronted with several challenges in protecting coastal marine ecosystems from wastewater pollution:

1. Ineffectiveness of traditional conservation strategies

Marine protected areas (MPAs) and traditional conservation approaches are proving inadequate to address pollution in coastal areas, posing a threat to marine ecosystems and biodiversity (Bégin et al., 2016; Lamb et al., 2016; Suchley & Alvarez-Filip, 2018; Wenger et al., 2016). Furthermore, MPA design and implementation seldom considers pollution impacts or activities on land (Loiseau et al., 2021; Williams et al., 2023).

2. Funding gaps and expectations

Management of wastewater pollution has traditionally received much less investment compared to other marine conservation interventions, despite its recognized impact (Wear, 2016). Furthermore, the time frames and funding required to achieve success may not match the expectations of programs and policy targets that seek short-term results (Wakwella et al., 2023).

3. Lack of jurisdiction and appropriate policies

Many countries lack wastewater discharge standards or marine water quality guidelines and marine environmental managers do not have the authority or mandate to manage wastewater pollution. In addition, there are different sectoral mandates and priorities, which makes coordination of activities difficult. There are also often challenges in engaging upstream stakeholders, who may or may not experience the impacts of wastewater pollution in coastal marine environments (Álvarez-Romero et al., 2015; Kerr et al., 2014; Lymer et al., 2017; Wakwella et al., 2023).

4. Data gaps and uncertainty

There are gaps in our understanding about how wastewater pollution affects coastal marine ecosystems, including what level of exposure is detrimental, how the different pollutants within wastewater interact, how wastewater pollution interacts with other stressors that coastal marine ecosystems are facing, and how changes in ecosystem condition will influence ecosystem service provision. This makes it very difficult to predict the exact changes that will occur as a result of exposure to wastewater pollution and to communicate the need for action.

5. Persistent pollutants in treated wastewater

Even after treatment, wastewater can contain harmful concentrations of pollutants, including nutrients, pharmaceutical and personal care products, and microplastics. Conventional wastewater treatment methods often fail to adequately remove these substances (Hidayaturrahman & Lee, 2019; Kayode-Afolayan et al., 2022; Tahir et al., 2023; Watkinson et al., 2007), leaving coastal marine ecosystems exposed to a chronic source of pollution.

6. Urgency to build climate change resilience

There is a synergistic relationship between wastewater pollution and climate change: climate change exacerbates wastewater pollution impacts on coastal marine ecosystems, which in turn makes them more vulnerable to climate change impacts (see Section 1). The loss of coastal marine ecosystems also makes coastal populations more vulnerable to climate change impacts. These same coastal populations are on the frontline for broader and intersecting shocks and stresses, as well as the aforementioned pressures of massive urbanization and climate migration.

The sanitation sector faces a multitude of challenges that pose significant barriers to achieving universal access to safe and sustainable sanitation. These challenges include:

1. Shortage of technical capacity and skilled contractors

Building and maintaining sanitation systems to international standards requires technical expertise, skilled contractors, and resource supply chains. Unfortunately, many places struggle with a lack of technical capacity, and challenges associated with sourcing parts and equipment to build and maintain systems (IWA, 2014; Thomas, 2014).

2. Lack of political will, insufficient policies, and lack of compliance and enforcement

There is a deficiency of political will and inadequate policies to ensure the establishment of safe sanitation systems (Wateraid, 2018). This includes the regulation of effluent discharge quality and the creation of an enabling environment that supports sustainable sanitation practices (Tsetse et al., 2016). The lack of regulatory capacity further complicates the situation. Even when policies are in place, lack of compliance and enforcement means policy goals are not being realized.

3. Limited financial resources, revenue models, and targeted finance products

The scarcity of financial resources, combined with the significant capacity needed to source and manage funds, impedes the implementation and continued operation and maintenance of sanitation infrastructure and services, especially in low-income areas. Sanitation sector service providers in most developing countries often struggle to meet the conditions required for commercial finance investments (Pories et al., 2019). This deficiency hampers the development of inclusive and comprehensive sanitation systems, leaving many communities without access to safe sanitation (Fonseca et al., 2020).

4. Imbalance in resource allocation

Sanitation initiatives often receive less attention and funding compared to drinking water interventions. This skewed resource allocation slows down progress in sanitation efforts and exacerbates the challenges faced by the sector (The World Bank & UNICEF, 2017).

5. Sanitation technology gap

Sustainable sanitation options that capture nutrients and/or energy from excreta are not widely available due to lengthy research and development pipelines, as well as policy and regulatory constraints. The slow uptake of new sanitation technologies and inadequate infrastructure to accommodate population growth, particularly in urban areas, contributes to the prevalence of unsafe sanitation practices.

6. Environmental challenges

Many places have tough physical environments that hinder the implementation of sanitation systems. These include factors such as being prone to flooding, having high groundwater tables, being more rural or remote, and communities living on islands and more isolated coastal areas (Perez et al., 2012; Tillet and Jones, 2021). In some cases, challenges around delivery of sanitation services have persisted for decades (Tillet & Jones, 2021). Solutions for implementing sanitation systems in these environments have primarily been technological, however, there are limited examples of these technological solutions being integrated within wider financing solutions and service delivery models (Tillet & Jones, 2021)

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3. Confronting the challenge through partnerships

Both sectors recognize the importance of sanitation for improving public health, protecting the environment, and delivering economic benefits. Commitments and targets stated in international agreements addressing sanitation, conservation, and climate resilience are not only interconnected but are intrinsically interdependent on one another:

- Reducing nutrient pollution into the marine environment (**SDG 14.1**, Target 7 - **Kunming-Montreal Global Biodiversity Framework [GBF]**) requires participation of local communities in improving water and sanitation management (SDG 6.B), reducing pollution from wastewater, and substantially increasing recycling and safe reuse globally (SDG 6.3), while promoting related technologies (Art. 10 - **Paris Agreement, SDG 6.A**).

- In the **Universal Declaration of Human Rights**, the right to a standard of living adequate for health and wellbeing (Art. 25) involves the right to water and sanitation (A/RES/64/292, **SDG 6.2**) and the right to a clean, healthy, and sustainable environment (A/76/L.75).

- Part of strengthening resilience to climate change (Art. 7 - **Paris Agreement, SDG 13.1 and 13.2**), involves conserving and enhancing sinks and reservoirs of greenhouse gasses (Art. 5 - Paris Agreement), such as coastal marine ecosystems (**SDG 14.2**). Likewise, adaptation to climate change (Art. 7 - **Paris Agreement**) requires taking into consideration vulnerable groups, communities, and ecosystems (Goal A and B - **Kunming-Montreal GBF**; Art. 3 and 5 - **The Ramsar Convention on Wetlands**).

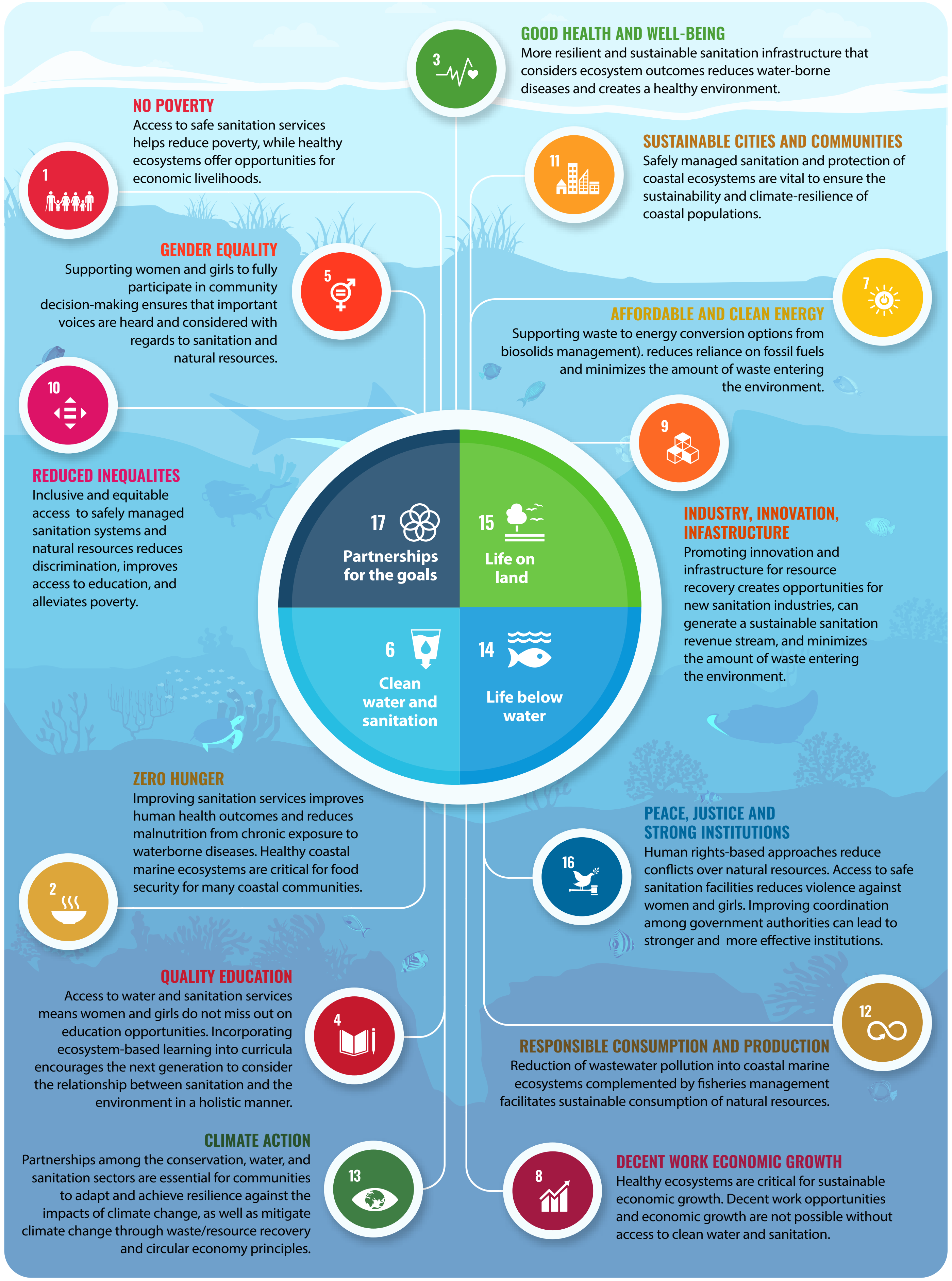

***Fig. 4:** Shared Sustainable Development Goals from Agenda 2030 between sanitation and conservation sectors*

It is clear that to achieve these ambitious outcomes, the challenges faced by both sectors need to be overcome. **Given the overlapping goals of the conservation and sanitation sectors, there is a strategic opportunity to work together and bring about positive change.**

- Partnership approaches between conservation and sanitation practitioners have the potential to **achieve multiple shared goals encompassing the environment, society, and the economy (Fig. 4)**. Partnerships can foster shared knowledge and resources, leading to a more integrated and holistic approach to environmental and public health challenges.
- The marine conservation sector can **bring new voices to the table** by brokering engagement from the aquaculture, fisheries, and tourism sectors, who have an economic incentive to care about coastal marine ecosystem health, and have more clout to affect political will to take action.
- By fostering collaboration between the two sectors, **more strategic resource allocation** becomes possible, enabling both sectors to access **a broader suite of funding sources** to meet their objectives.
- The global emphasis on the Blue Economy creates new incentives for countries to invest in ocean health (OECD, 2020) and the marine conservation sector can work to **drive investment into sanitation programs**.
- Protecting the natural environment also **enhances resilience to climate change**, reducing flood risks and erosion, improving water security, and fostering natural resources for sustainable livelihoods (see **Section 1**).

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4. Working together in partnership

4.1 How to partner

Partnerships come in many forms and by definition involve organizations and individuals that have agreed to work together on a specific project or to achieve a particular, mutually beneficial goal (Margoluis *et al.*, 2000). The nature of partnership among upstream community actors with sanitation challenges and downstream communities is complex and layered with threats and risks throughout the watershed to coast.

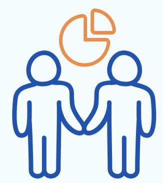
For multisectoral projects and approaches suggested in this guide, a good partnership relies on the following principles and values:

Establish a collective vision

Not just from one sector but with many voices and views coming together to ensure equitable representation and to understand each other and the strengths and weaknesses of each sector. Identifying common objectives, such as preserving marine ecosystems, enhancing public health, promoting sustainable development, and boosting climate-resilience, can create a unified purpose that guides collaboration.

Use shared language and terms

It is important to make sure that partners understand the key terms used by other sectors in order to develop a common way of messaging to stakeholders about all of the aspects of the project and recognize the equal value of each sector's approach and expertise.



Ensure mutual respect and equity

Recognizing the expertise and importance of each sector and respecting differing opinions and perspectives will foster an environment where collaboration can thrive. Equitable partnerships recognize the value of multiple knowledge systems, facilitate opportunities for effective engagement of all stakeholders, and ensure that the costs and benefits of any project or program are spread fairly.

Promote transparency and open communication

Clear and honest communication builds trust. All parties involved should feel free to express their concerns, ideas, and needs without fear of judgment or repercussion. Transparency is achieved through dialogue, with an emphasis on early consultations and sharing of information and data to build trust, and open discussions on project challenges.

Establish a collective vision

Not just from one sector but with many voices and views coming together to ensure equitable representation and to understand each other and the strengths and weaknesses of each sector. Identifying common objectives, such as preserving marine ecosystems, enhancing public health, promoting sustainable development, and boosting climate-resilience, can create a unified purpose that guides collaboration.

Support coordination and cooperation

Coordination and communication mechanisms need adequate attention and resourcing, as well as buy-in by all sectoral teams or partners. Coordination is often best achieved when there is a coordination body with a mandate to integrate across sectors (Jupiter et al., 2017). Encouraging cooperative efforts where each sector complements the other's strengths and weaknesses creates a synergistic relationship that is more productive and fulfilling.

Maximize efficiency

Cost and resource sharing can raise the impact and lower costs associated with programs that combine interrelated objectives across WASH and conservation sectors (Bonnardeaux, 2012). This includes initiating joint planning rather than undertaking parallel and independent activities.

Operate with Integrity

Upholding ethical principles and conducting all activities with integrity fosters a positive reputation and ensures that all actions are aligned with the shared values of the partnership.

Focus on monitoring and learning

As part of developing a collective vision, partners should consider joint learning questions for monitoring and evaluation and use evidence-based science to guide the development of adaptive solutions that drive systems-change at multiple levels (Aquaya & Hilton Foundation , 2022).

Foster accountability and responsibility

Both sectors must be accountable for their commitments and responsible for contributing to the shared goals. Each partner has an ethical obligation to each other to accomplish goals with integrity and in a relevant and appropriate way. This includes adhering to agreed-upon guidelines, timelines, and quality standards.

Be inclusive

Planning should adopt contextually appropriate best practices for gender equity and social inclusion, particularly given the critical role of women and girls in water management, the challenges they face with poor sanitation systems, and their vulnerability to biodiversity loss and climate change (Godden et al., 2023; GWTF, 2006, UN WomenWatch, 2009; Unilever Domestos & WSSCC, 2017).

Encourage adaptability, flexibility, empathy, and understanding

Recognizing that changes may occur and being willing to adapt to new circumstances, information, or challenges will keep the partnership resilient and focused on long-term success. Taking the time to understand the specific challenges, limitations, and concerns of each sector builds empathy and leads to more compassionate and effective collaboration.

Acknowledge uncertainty

Because of the challenges associated with fully tracking pollution flows and impacts (Brown et al., 2018), partnerships working to manage pollution should adopt precautionary principles.

Emphasize sustainability and long-term thinking

Both sectors should aim for solutions that are not only effective in the short term but also sustainable in the long run. This involves considering the environmental, social, and economic impact of decisions and actions.

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BOX 3

WASH in Watersheds

The Water, sanitation, and hygiene (WASH) in Watersheds (WiW) is a framework for bringing together health, development, and conservation organizations to advance common goals on improved water conservation and human and animal health and wellbeing, through more holistic, integrated approaches.

Summary of project

Conservation International (CI) and Conservation South Africa (CSA) worked in the Eastern Cape province of South Africa for almost a decade to implement a WiW project, in close collaboration with the Alfred Nzo District Municipality (ANDM), and communities in this water scarce area. The ANDM has the mandate for water service provision within the district (Edmond et al., 2022). Funded by the United States Agency for International Development's (USAID) Africa Biodiversity Collaborative Group,[1] CSA engaged villages in watersheds to create access to potable water by partnering with local governments and communities. The combined effort of NGOs, public sectors, and local community partners was essential in achieving water access. CSA community engagement staff provided technical knowledge related to sustainable and sanitary water retrieval, while the communities were the drivers for change with their specific and nuanced understanding of the problems they faced.

Despite the project's conservation-focused goal on land and water resource management, human wellbeing was the first step in its actualization. The work involved an integrated approach between water collection for local people with unmet WASH needs and environmental efforts to protect biodiversity and natural lands. Local government partners and leaders played a huge role in the facilitation of these projects by engaging with non-government organizations (NGOs) and imploring their communities to do the same. The collaborative and interdisciplinary nature of WiW gave partners in local communities not only potable water, but the opportunity to see the value of conservation of ecosystems as a source of water and biodiversity. Increased access to clean water also served as an opportunity to raise awareness for local communities on improved sanitation and hygiene behaviors.

Local government as partner

- **Leveraging a watershed-wide conservation platform**, the close working between CSA and ANDM relationship fostered the accomplishments of several results including:
- **Restoration and protection** of nine natural springs.
- **Training of water monitors** on water quality monitoring, collection of water quality data, and continued maintenance of infrastructure to protect natural springs, and sponsoring them to complete accredited water resource management training programs.
- **Reaching hundreds of households** through peer-to-peer sanitation best practices awareness campaigns, led by community members, in partnership with ANDM.
- **Completing participatory stream and river health assessments** with villages to raise awareness of their importance and the need to restore degraded wetlands for water security.
- **Engaging policy makers** through a Climate Change and WASH Summit at the ANDM offices to build on program results through municipal actions.
- **Advocating for ANDM's** financial and social support for sustainable nature-based methods of water provision to communities.

[1] The collaborative is composed of the African Wildlife Foundation, Conservation International (CI), the Jane Goodall Institute, The Nature Conservancy, Wildlife Conservation Society, World Resources Institute and World Wildlife Fund - US.

Lessons learned and best practices

In line with CI's rights-based approach to conservation, there is special consideration to the importance of working in partnership with diverse organizations and communities. Although there is an investment required in terms of time, patience, and learning, CI's outcomes and activities are strengthened when reaching out beyond the usual audiences and stakeholders.

Key lessons include:

- Partnering with complementary associations and NGOs in the target area can strengthen gaps in community-voiced needs, such as some of the poverty alleviation and job creation ideas expressed during the needs assessment.
- Continued investment of time and energy into relationships with government officials and community leadership is essential. The evolution of community engagements in this setting from formal meetings to more of a collaborative team approach has been a critical part of the success so far.
- Several key factors that contribute to fair and effective partnerships include: mutual respect and trust; equitable collaboration in project/program design and implementation; transparency and accountability; validation and respect for experiences and non-monetary contributions; clearly defined goals and objectives.
- Creating buy-in within the leadership, and working with empowered individuals involved in the partnership process to make decisions directly can advance mutually beneficial relationships and goals, whereby each organization gains capacity and learns from one another.
- Throughout the project planning and implementation cycle, it is imperative to provide dedicated funding and ample time to bring together our respective staff in a holistic, transparent manner to build trust, accountability, and a collaborative partnership.

Although the project was more focused on water, the lessons learned through cross-sectoral collaboration across multiple stakeholder groups provides key insights into structuring and implementing integrated conservation and sanitation programs.

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4.2 Who should be involved?

There are multiple types of stakeholders that should be involved when implementing an integrated approach to conservation and sanitation, each with their own drivers, roles, and responsibilities (Fig. 5):

This level of collaboration is high-value and high-demand. The most productive working groups have: adequate resources; agreed upon leadership; and a shared understanding for decision making, goal setting, and desired project outputs. Once formed, the project has access to experts in policy, technology, finance, governance, and local needs and perceptions to secure the enabling conditions for implementation and ongoing operations of integrated projects

Each stakeholder group brings something different to the table (Table 1).

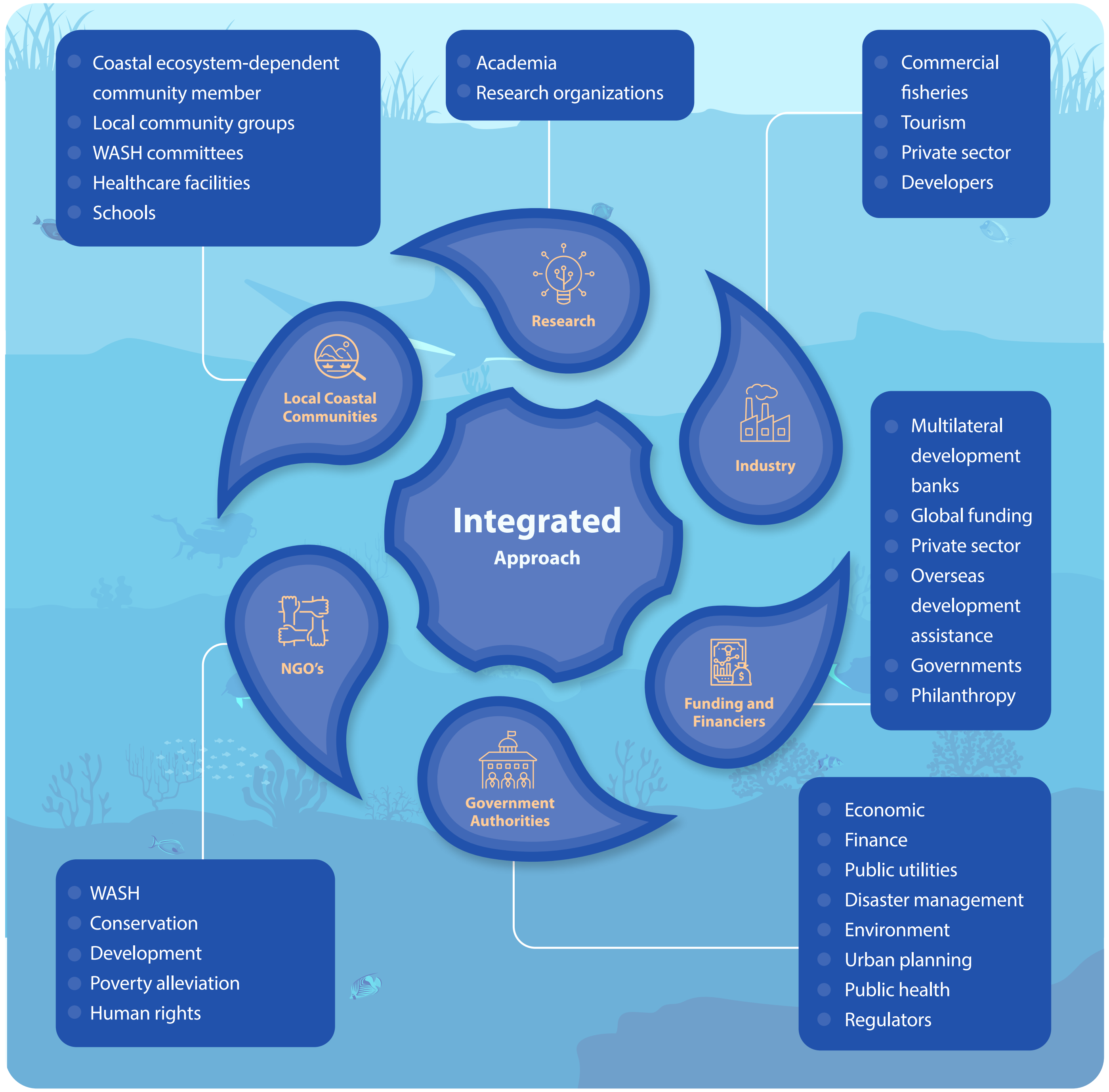

Fig. 5: The different stakeholder groups that could be involved when implementing integrated conservation and sanitation programs

Table 1: Co-benefits of multi-sector collaboration and their individual drivers outlined by stakeholder user group

Stakeholder	Drivers/Interests	Assets and Resources Contributed	Benefits Received from an Integrated Approach
Funding and Financiers	- Mission-drive - Philanthropy - Development of finance obligations - Indicators of success and "return on resilience value" - Geographically focused - Insurability and risk transfer (insurance and reinsurance financing mechanisms)	- Grants, program related investments, and other funding and financing (debt/equity/bonds/ guarantees) - Standards or program requirements that encourage integrated approaches - Gap-filling during unanticipated shocks in the system (see Box 16)	- Accomplish multiple objectives - More efficient use of investments - Potential for return on investments
Governments Authorities	- Duty bearers with legal and ethical responsibilities - Legislative mandate - Environmental, economic, and social obligations - Obligations to international treaties and agreements	- Official development assistance - Ability to create laws and regulations and related capital planning from national to local level - Alignment of funding and investments from a variety of financial and funding institutions - Development policies - Monitoring, compliance, and enforcement - Community awareness, outreach, and education	- Better coordination of policies - Avoiding duplicate or conflicting policies - Cost-savings - Achievement of multiple government priorities - Achievement of targets for international agreements - Increased efficiency - Knowledge sharing - Formation of strategic partnerships that can be leveraged for other purposes - Risk

Stakeholder	Drivers/Interests	Assets and Resources Contributed	Benefits Received from an Integrated Approach
Industry	Livelihoods and employment Economic growth Profit Increasing justice, equity, inclusion, and diversity Training Promotion of products and approaches Corporate social responsibility	o Streamlining processes for regulation/compliance o Protect buyers and sellers o Innovation o Strong ability to influence political will o Ability to make decisions and adapt to changes more quickly o Innovative technologies and options for sanitation in different contexts o Operations, maintenance, and ownership of private infrastructure o Important champions	o Opportunities to showcase corporate social responsibility o Protection of assets o Risk minimization o Economic benefits o Livelihood security o Access
Local Coastal communities	o Health and wellbeing o Improved conditions and ecosystem health o Access o Cultural practice o Poverty alleviation o Justice, equity, diversity and inclusion o Livelihood security o Food security o Access o Cultural practice o Project accountability	o Deep understanding of local context o Traditional knowledge o Ability to influence change o Important champions for projects o Ability to influence political will	o Economic benefits o Health and wellbeing o Livelihood security o Food security o Access o Cultural practice

Stakeholder	Drivers/Interests	Assets and Resources Contributed	Benefits Received from an Integrated Approach
NGOs	o Mission-driven o Broker of communication, knowledge, and relationships among different actors o Capacity strengthening and support of empowerment o Decolonizing development o Increasing justice, equity, inclusion, and diversity	o Partnerships o Activity support, especially with workshops, landscape assessments, and monitoring and evaluation o Linking practitioners to science o Planning o Advocacy o Education and awareness o Funding	o Achievement of project goals o Co-benefits that can be showcased to donors, governments, and communities o Learned lessons that can inform work in other locations
Research	o Evidence-based science o Knowledge generation o Publishing results o Motivated to engage in applied science	o Data o Analytical skills o Freedom of expression o Innovative technologies and options for sanitation in different contexts o Monitoring and evaluation	o Novel scientific findings o Opportunities to showcase outputs to funders and employers o Ability to attract funding and students

BOX 4 

Wastewater treatment in West End, Roatán, Honduras Part 1: Partnership in action

Prepared by Tanya Amaya and Pamela Ortega from the Coral Reef Alliance

The wastewater treatment plant in West End, Roatán has become a role model for community based sanitation solutions. What once was a small and traditional activated sludge plant with significant room for improvement, is now becoming a state-of-the-art facility that continually improves the environmental conditions that lead to a healthy reef and the quality of life for the local community. There initially were two water associations in West End that were merged into Polo's Water Association in response to the community's need for a stronger and more reliable community organization to manage both water and sanitation. After a process to solidify the board, it was legally registered around 2009, gaining full recognition as a water and sanitation service provider by the Central Government.

For a decade, partners worked on alliance building and investment in infrastructure repairs, maintenance, operation costs, and most importantly, the creation of a sustainable management model implemented by Polo's Water Association. Now, the plant effectively treats over **110 million liters** of raw sewage each year. The improvements achieved in West End go hand in hand with establishing a network of diverse WASH and conservation stakeholders to promote cross-sectoral collaboration. To advance the mission of the West End wastewater treatment plant, both Polo's Water Association and the Coral Reef Alliance (CORAL) have been building strong partnerships with the following:

- **Donors/funders**
  CORAL, MARfund, Seacology, The Summit Foundation, anonymous donors, Overseas Development Assistance (ODA) organizations, such as the Inter American Development Bank (IDB) who provided the funds to build the plant and is now an advocate for the project.
- **Policymakers**
  Government institutions including the Water and Sanitation Services Regulation Entity (ERSAPS), Administrative Commission for the Bay Islands Tourism Free Zone (ZOLITUR), Forestry Conservation Institute (ICF), Ministry of Health, Ministry of Tourism, National Water and Sanitation Council (CONASA)/National Autonomous Water and Sanitation Service (SANAA), and the Municipality of Roatán through its Community Development, Environment, Tourism, Urbanism, and Water/ Sanitation Units.
- **NGOs**
  Marine Protected Area (MPA) comanagers, The Bay Islands Conservation Association (BICA), The Roatán Marine (Park RMP), Azure[2] and Agua para el Pueblo - Honduras, Reef Resilience, and platforms such as SNAPP, Ocean Sewage Alliance, and PANORAMA Solutions/ GIZ.
- **Local community groups and rights-based organizations**
  West End community association (Patronato in Spanish), Aguas de Puerto Cortes, Municipal water division of Tela (DIMATELA), Jesus de Otoro water and sanitation association (JAPOE), Aguas de Siguatepeque, and Aguas Sierra de Montecillos.
- **Industry**
  The Bay Islands Tourism Bureau.

Together and throughout their involvement in the history of the West End wastewater treatment plant, each stakeholder has played a role in providing technical assistance, funding for infrastructure, soft funding for effective management, securing compliance with standards, and the creation of a safer environment for the local community (see **Boxes 14 & 16**). This innovative approach to wastewater management is setting a precedent for other communities facing similar challenges. It is a success story of community-based, sustainable development that can inspire neighboring communities in the Western Caribbean and beyond to invest in similar projects.

[2] A Catholic Relief Services and IDB Lab initiative that integrates support and funding from multiple sources.

5. Taking action

5.1 Planning for integrated conservation and sanitation approaches

There are many types of planning frameworks used by both sanitation and conservation practitioners in their respective sectors to respond to a challenge. However, while there are some commonalities between conservation and sanitation planning frameworks, there are also key differences that need to be reconciled so that these two sectors can work together more easily.

In both sanitation and marine conservation, planning is a systematic process to guide decision making, to allocate efforts and resources effectively, and to incorporate the feedback of stakeholders (Álvarez-Romero et al., 2011; WHO, 2022). Both planning processes usually operate on a regional or local level, but often with different government authorities managing different parts of each system. However, sanitation and marine planning systems are different in their operation regimes, mandates, political jurisdictions, timelines, funding sources, spatial jurisdictions, stakeholders, and control over their systems so they need different planning approaches.

Conservation planning focuses on the spatial allocation of conservation areas and management efforts based on distribution of conservation values (Pressey & Bottrill, 2009). One of the challenges and limitations of coastal marine conservation planning is that marine resource managers commonly do not have the mandate to manage land-based sources of pollution like wastewater, making it difficult to implement management interventions to address pollution (Álvarez-Romero et al., 2011; Kerr et al., 2014).

Sanitation planning focuses on providing guidance and resources to develop appropriate and affordable sanitation solutions considering sanitation facilities and technologies, hygiene, community practices, community management, institutional and management arrangements, and stakeholders' needs (Parkinson et al., 2014; WHO, 1996). However, although the impacts of wastewater pollution on freshwater and coastal marine ecosystems are well documented, existing sanitation planning tools do not provide sufficient information or advice on how to incorporate environmental protection when improving sanitation systems, including where to dispose of wastewater pollution or solid waste to minimize harm to coastal marine ecosystems (**Appendix 5**).

To develop a more integrated approach to planning, experts in sanitation and marine conservation from the SNAPP working group conducted an initial joint analysis between two commonly used frameworks:

- **Sanitation sector** - Countywide Inclusive Sanitation Planning (Government of Kenya, 2019)
- **Conservation sector** - Framework for Systematic Conservation Planning (Cowling & Pressey, 2003)

During the analysis of the two frameworks, several common steps and objectives were identified. These commonalities were brought together to create a ten-step integrated planning framework that uses language that is common to a diverse range of stakeholders. A summary of the ten-step framework is provided (**Table 2**). A full description of the ten-step framework, along with descriptive notes, guidance, and links to external resources is located in **Appendix 2**.

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Table 2: Ten-step joint planning framework developed specifically for pollution of coastal marine ecosystems

Integrated Planning Step	Activity Details	Sections and Resources with Additional Information
Step 1. **Initial problem framing; making a case for action**	1 Determine if coastal marine ecosystems are vulnerable to wastewater pollution.	Section 5.2: Evaluating the risk to coastal marine ecosystems from wastewater pollution Appendix 4: Risk screening to assess whether coastal ecosystems and resources are vulnerable to wastewater pollution
Step 2. **Engage key stakeholders**	2.1 Conduct a detailed stakeholder analysis and identify the key stakeholders associated with sanitation, wastewater pollution, and conservation. This includes those contributing to and affected by the polluting sources, including users of the receiving environments, as well as relevant government agencies, and private enterprises. 2.2 Approach key stakeholders individually and share the problem statement and invite them to participate. Ensure you have considered gender, equity and social inclusion (GESI) factors in your stakeholder selection.	Section 4.2: Who should be involved?
Step 3. **Form a multi-sector working group**	3.1 Based on stakeholder engagement, create a multi-sector working group and invite stakeholders. It is critical that government partners are included. 3.2 In the first working group meeting, decide on a clear vision and objectives to articulate how you will work together (e.g., guiding principles). 3.3 Assess the information you have available and map out what additional information may be needed.	Section 4.1: How to partner Section 4.2: Who should be involved?
Step 4. **Conduct a detailed pollution risk assessment**	4.1 Design a data collection methodology based on the list of data you identified in the previous step and your available resources. 4.2 Complete a detailed risk assessment of the pollution sources and receiving marine ecosystems. Include future risk projections as populations and climate change.	Table 4: Examples of sources of information that can be used to conduct an in-depth risk assessment. Appendix 5: A risk assessment of wastewater pollution in Australia
Step 5. **Assess the implementation environment**	5.1 Complete an assessment of the enabling environment to understand the conditions in place and weaknesses in the system that could hinder implementation and long-term sustainability of interventions.	Section 5.2: Evaluating the risk to coastal marine ecosystems from wastewater pollution Section 5.3: Aligning and coordinating efforts to better achieve integrated outcomes.

Integrated Planning Step	Activity Details	Sections and Resources with Additional Information
Step 6. **Design interventions to reduce the risks and impacts**	**6.1** Agree on desired project outcomes and identify potential interventions to achieve them, considering a range and mix of suitable interventions appropriate for the specific context, including those focused on strengthening the enabling environment, behavior change approaches, technology options, and nature-based solutions. **6.2** Use a structured decision-making framework to identify and prioritize interventions by using methods such as multi-criteria decision analysis, return of investment or cost-benefit analysis. **6.3** Develop a costed implementation plan. **6.4** Develop a plan for operation and maintenance of infrastructure, including options for funding and a hand-over plan, if relevant. **6.5** Conduct an assessment of the project team, partners, and local expertise to ensure all necessary skills are covered. For instance, if no sanitation contractors are available, then capacity building and training will be required. This also includes someone who can analyze and report on the monitoring data and project progress. **6.6** Communicate and review the implementation plan with stakeholders for feedback and approval.	**Section 5.4:** Setting pollution reduction targets **Box 5:** Community-based WASH planning and management in Papua New Guinea **Box 6:** Integration of conservation and sanitation through nature-based solutions **Box 7:** Evaluating the ecosystem and health benefits of investment in improved wastewater treatment in pilot sites in Panama and Trinidad and Tobago **Box 8:** Failure to implement project funded sanitation infrastructure – reflections from Fiji
Step 7. **Identify funding options and secure financing***	**7.1** Identify and secure resources for prioritized interventions, including monitoring and evaluation. Explore conservation and blue economy finance mechanisms. **7.2** Plan for the long-term financial sustainability of the implementation activities. Consider key questions: What entity will own and operate the infrastructure long term? Is revenue sufficient or will additional funding be needed? If so, how will resourcing of on-going implementation be financed? Is there an opportunity for revenue generating resource recovery?	**Section 9:** Leveraging Blue Carbon to Fund Sanitation Projects **Box 10:** Resource recovery from wastewater and fecal sludge: an Example from Kenya

Integrated Planning Step	Activity Details	Sections and Resources with Additional Information
Step 8. **Design monitoring and evaluation framework**	**8.1** Develop social and ecological indicators of progress and success for agreed upon outcomes. **8.2** Identify monitoring approaches to collect data on indicators, including mid-project evaluations. Diverse forms of knowledge, including anecdotal evidence, storytelling, and the experience of community leaders can be used for understanding environmental patterns, impacts of sanitation practices and climate, and traditional practices within the community. **8.3** Develop a communication plan for how to communicate progress of the project to key stakeholders.	See **Appendix 2**
Step 9. **Implement activities**	**9.1** Once interventions have sufficient resources secured then commence implementation **9.2** Ensure activities, responsibilities, timeframes, methods, or approaches are well-defined among the involved parties before beginning. **9.3** Ensure required resources are in place, e.g., equipment, personnel, facilities, approvals, etc.	
Step 10. **Monitor, evaluate, and adapt management interventions as needed**	**10.1** Assess if the interventions implemented have achieved the project outcomes using indicators of success. It may take several years before any ecosystem benefits are achieved. Ecosystem recovery might not be apparent where multiple coastal ecosystem stressors are present. In these cases, reducing wastewater pollution should be one part of a holistic conservation strategy to address local stressors. **10.2** Community engagement and awareness-building are important for monitoring efforts, particularly in areas with insufficient governmental resources. Simple and accessible monitoring programs supported by local NGOs can help bridge connections between communities, governments, and the private sector.	**Box 11:** Holistic water pollution management in action: Tampa Bay

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BOX 5

Community-based WASH planning and management in Papua New Guinea

WaterAid has been working with communities in Papua New Guinea (PNG) since 2004 to implement sustainable water and sanitation interventions. Over this time, the approach to community based water resource management (CBWRM), sanitation and hygiene promotion has evolved based on experience, learnings, and research. Broadly, the approach aims to elicit effective, sustainable, and scalable strategies to improve sanitation, hygiene and water resource management, through behavior change. This includes undertaking community awareness, training, and outreach to support communities to change their behavior and in turn improve health outcomes. Participation needs to be inclusive and representative of the different groups in the community.

First, Wateraid works with communities to conduct a community assessment in order to understand the geographic, socioeconomic, and environmental conditions in the community. The assessment includes mapping of village features (through a participatory rural approach), and the exploration of norms, attitudes, and practices around WASH. The community identifies any barriers that different groups in the community face, including community WASH management structures, women, and people living with disability and reflect on the overall results and their implications in WASH interventions. Climate change impacts on the community and people are also identified. These assessments allow for the participatory design of interventions that fulfill the community's vision of a healthy village.

Once the initial assessments have been completed, they work to support the communities to end open defecation through the use of the Community-Led Total Sanitation (CLTS) behavior change approach and facilitation of the Healthy Islands Approach (a Government of PNG endorsed approach for healthy communities).

From there, training encourages the community to identify the positive aspects in the community to build on, the ideal vision of the community in five years, and how recent efforts in water and sanitation have changed their lives. This is complemented by reflection on their experiences managing water resources and the capability of the community to drive positive change. Then, through a series of group discussions, good and bad attitudes that can influence the failure or success of projects in the community are identified. Through reflections, participants explore how the community can take ownership in solving the community challenges by identifying the available resources to support addressing community challenges. The community then creates a list of actions to be undertaken to end open defecation, lists of households committed to building toilets, and nominates coordinators and leaders that will follow-up with their neighbors, communicate accessibility barriers in WASH and provide support to people who are vulnerable or marginalized.

The training aims to **support individuals and communities** to take action toward healthy lives, communities, and environments through Community Based Water Resource Management (CBWRM) and the provision of safe WASH services, which includes identifying champions to support community mapping of water sources and practices that can negatively impact them. The training paves the way for setting up a Village Health Development Committee, which acts on behalf of the community to make plans, design programs, implement, monitor, supervise and evaluate the activities carried out in a community, foster better cooperation and participation, and lead activities to improve community health such as food, water, housing, and environment.

In reflecting on the training, Wateraid has recognized that while the training focuses on freshwater ecosystems within discussions on how open defecation puts important water sources at risk, the primary aim of the training is to improve human health based outcomes. Human impacts to coastal marine natural resources are not discussed and could be considered under the framework of "healthy environment, healthy people." Coastal communities in PNG are often very reliant on fisheries for food and livelihood security, and coastal marine ecosystems for coastal protection. Explicit inclusion of these considerations and the individuals reliant on these resources would strengthen the holistic approach that underpins all of the work. This recognition has motivated Wateraid to strengthen relationships with conservation groups in order to adapt community awareness materials in coastal contexts.

BOX 6

Integration of conservation and sanitation through nature-based solutions

There is an increasing interest from the sanitation sector in implementing nature-based solutions (NBS) to both replace and complement gray infrastructure (van Hullebusch et al., 2021). The term "nature-based solutions" in the sanitation sector often refers to engineered solutions that filter wastewater with plants, such as constructed wetlands (Arias et al. 2021). However, the protection and restoration of ecosystems as an NBS can also be a powerful tool for delivering sanitation and conservation outcomes.

Watershed protection and management, **especially the protection and restoration of forests, riparian vegetation, wetlands, mangroves, and seagrass meadows**, can complement sanitation interventions by filtering pollutants and pathogens, slowing groundwater infiltration, and delivering important human health outcomes (Brauman et al., 2007; Herrera et al., 2017; Jenkins et al., 2018; Lamb et al., 2017; Pattanayak et al., 2007). Recent estimates suggest that ecosystems treat nearly 42 million tons of human waste per year worldwide, with this ecosystem service estimated to have an annual economic value of at least US $4.4 billion (Willcock et al., 2021). NBS benefits for sanitation and biodiversity go beyond pollution reduction (UNESCO, 2018). They also include conserving or restoring ecosystem integrity and connectivity (IUCN, 2020) by connecting rivers to floodplains (UNEP-DHI et al., 2018) or terrestrial and marine ecosystems (Hilmi et al., 2021).

Nonetheless, there are a series of challenges for NBS implementation. Government instruments such as policies, regulations, and building codes favor gray infrastructure (Cassin & Matthews, 2021; Shiao et al., 2020; UNESCO, 2018). Consequently, this also influences the preferences of policy makers and the general public for gray infrastructure, reinforcing the use of built infrastructure over NBS (Shiao et al., 2020; UNESCO, 2018). Adding to this, lack of knowledge and understanding about NBS cost-effectiveness, thresholds after which further investment in NBS do not render more benefits, time frame for delivery of benefits, and guidance from design to assessment are important barriers for their adoption (UNESCO, 2018).

NBS benefits are highly context-dependent, being influenced by local physical and biological characteristics of the site of interest, the type of NBS and management, the scale of implementation, and period of time to observe expected outcomes (Vigerstol et al., 2021). All these factors, in combination with others, lead to the perception of NBS to be less efficient or riskier (UNESCO, 2018), and in practice, NBS are seriously underfunded compared to gray infrastructure (UNESCO, 2018).

To address such challenges, there are a couple of pathways for their adoption. As the current enabling environment for most countries was developed for gray infrastructure (UNESCO, 2018), incorporation of NBS into existing institutional, policy, legal, and regulatory frameworks is a pathway for its adoption by the public and private sector (Timboe & Pharr, 2021; UNESCO, 2018). Such incorporation can also allow countries to respond to commitments in several international environmental agreements (UNESCO, 2018).

Assessing co-benefits through a more comprehensive cost-benefit analysis can address knowledge gaps and uncertainty about return on investment, facilitating more efficient investments and harnessing financial resources from diverse sectors (UNESCO, 2018). Decision-making around the implementation of NBS needs to consider other stressors on the environment and their interactions with NBS, as they can affect their performance and viability over time (Cassin & Matthews, 2021).

The implementation of NBS for sanitation requires higher collaboration across sectors to ensure success than gray-infrastructure approaches since they will involve multiple sectors, such as the government authorities in charge of conservation and sanitation, as well as private sector actors. Therefore, an enabling environment that responds to such multidisciplinarity and challenges, and promotes cooperation, needs to be created (Timboe & Pharr, 2021; UNESCO, 2018). Current policy frameworks are fragmented in many countries and NBS can help to break sectoral silos by bringing sectors together to work on a common agenda and adding coherence between policy and institutional frameworks (UNESCO, 2018).

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BOX 7

Evaluating the ecosystem and health benefits of investment in improved wastewater treatment in pilot sites in Panama, and Trinidad and Tobago

Investing in wastewater management improvements can be costly, particularly in resource-constrained regions like the Caribbean, where **80% of untreated domestic wastewater enters the sea**, leading to water pollution and diminished ecosystem services (Gray et al., 2015). Emphasizing the economic benefits of environmental protection through wastewater management can significantly boost political will for such investments. Conducting thorough cost-benefit analyses becomes crucial in this context, as it showcases tangible advantages that can be derived from these environmental protection measures (Gray et al., 2015).

By quantifying the positive impact on the economy, decision-makers can understand the potential monetary gains from protecting and restoring valuable ecosystems such as rivers, mangroves, seagrass beds, and coral reefs. Furthermore, highlighting the potential health benefits and reduced healthcare costs resulting from improved wastewater management can sway policymakers towards supporting these initiatives (Gray et al., 2015).

A qualitative economic valuation approach using Multi-Criteria Decision Analysis (MCDA) was conducted in Trinidad & Tobago and Panama to compare the ecosystem and human health benefits to the cost of investing in improved domestic wastewater management (Gray et al., 2015). MCDA follows a structured set of steps, including identifying decision-making criteria for evaluating wastewater treatment options, defining study site boundaries, assessing the current wastewater situation, proposing management scenarios, and collecting data on all relevant criteria. This approach relies on the best available data and expert input to assess trade-offs effectively. It involves weighting benefits and costs based on a set of key criteria defined by stakeholders. It is a commonly used tool by governments to make informed decisions regarding ecosystem and human health impacts from their investments (Gray et al., 2015).

Each location was concerned about the impacts of wastewater pollution on the ecosystem services and natural resources provided by their coastal ecosystems. They were all reliant on their coastal ecosystems for tourism, fisheries, coastal protection, and carbon sequestration, and Trinidad was additionally focused on their role in flood attenuation, natural filtration, and species protection. In each location, there were concerns about the state of their sanitation systems. In Trinidad & Tobago, there was limited connection to the wastewater treatment plant, with the majority of the population using septic tanks and pit latrines. In Panama, although there was a much higher rate of connected households, wastewater was often discharged directly into the environment during storm overflow events. All locations had infrastructure that was past its lifetime or operational capacity.

To conduct the MCDA, each location provided a weighting to a range of criteria that were identified as important, including the current state of the sanitation systems in place, the operation and maintenance costs, and the ecosystem and human impacts from wastewater pollution. Participants then provided a score for the current state and two different wastewater management scenarios. Overall, in the preliminary results for the three pilot sites, forecasted benefits from reducing wastewater pollution outranked the cost of investing in wastewater management.

Although the results from the MCDA are qualitative, they provide a structured way of understanding connections between sanitation systems and coastal marine environments, based on best available data and expert input, and allows those interested to weigh the benefit and cost trade-offs based on a key set of criteria deemed important for decision-making. They can be used to determine overall preferences among different intervention options that can achieve the desired future state that stakeholders have agreed upon. In the case of Trinidad & Tobago and Panama, although there was limited quantitative information available to conduct the analysis, the results clearly highlighted that the importance of coastal and marine ecosystems and natural resources for communities and the economy justified investment into reducing wastewater pollution.

BOX 8 

Obstacles to implementing project funded sanitation infrastructure – reflections from Fiji

In Fiji, unsafe sanitation has been identified as a key risk factor for typhoid fever (Jenkins et al., 2019; Prasad *et al*., 2018,) and poor freshwater and coastal marine ecosystem health (Wakwella et al., 2023). The Watershed Interventions for Systems Health in Fiji (WISH Fiji) project aims to address these overlapping problems through a collaborative effort between government, academic, and NGO partners. In doing so, the WISH Fiji project aims to transform both environmental and public health action from reactive to preventative, and improve the overall health of the system.

In the initial design of the WISH Fiji project, improving non-sewered sanitation was identified as a key intervention needed for rural communities. The Water Safety and Sanitation Planning (WSSP) process led by WISH Fiji between **2020 and 2021 revealed that across the 29 communities, that only 11- 21% of the sanitation could be assessed as safely managed** (Nasim *et al*., 2023). During the WSSP process, 13 very-high-risk latrines were identified that were either; very close to surface water bodies (<30 m from a river, creek or drain), directly piped into surface water, or that were reported to be overflowing or leaking (especially post rainfall). The project had funding to address these issues and put out a call for sanitation contractors to build new septic tanks in these communities (valued at ~ US$100,000).

After testing the market with half-a-dozen open tendering calls for septic tanks contractors, the WISH Fiji project found that there was only one contractor who wanted to implement the sanitation work. But unfortunately, the end of project deadlines were a barrier and no funded non-sewered sanitation interventions were implemented.

An analysis of this scenario revealed that the scope of work was too small for larger professional engineering firms (who are often led by qualified expatriate engineers), who primarily focus on building commercial sanitation systems for hotels and businesses. But the sanitation work and requirements were assessed as too complex (e.g. building to the Fiji National code and working with an international project team in English) for smaller sanitation companies (e.g. private plumbers) who felt they could not comply. There was also a skills shortage in Fiji at this time, as many qualified trades people had left to participate in regional labor schemes in Australia and New Zealand. Further, the cost of building materials had increased due to supply chain disruptions post Covid-19. This meant that there was high demand for tradespeople and materials, which contributed to the challenge. Fiji is one of the more economically developed countries in the Pacific region and hence it is anticipated there would be an even greater shortage of sanitation capacity in other Pacific Island Countries. This experience in Fiji is not unique and similar sanitation capacity gaps have been identified in developing countries around the world (International Water Association, 2014).

Recommendations from this experience for sanitation implementation

- Anticipate that there might not yet be local sanitation companies who have the skills (nor willingness) to engage in sanitation projects that have international requirements (e.g. built to standard code, formal contracting, upfront costs carried by the contractor & communication in English with the project management team).
- Having the right timelines and in-house project management/construction skills are critical factors for success. Long time frames (> 12 months) are needed for sanitation tendering, contracting, construction, and sign-off. Frequently, the NGO space works on short grant extensions (< 6 months), long contracting times, and a lack of in-house construction skills or skills to oversee construction projects (especially for non-WaSH NGOs). Projects need to ensure they have all the relevant expertise they need on the project team, and critically evaluate if the project timelines and enabling environment conditions on the ground are conducive for sanitation infrastructure interventions.
- If there are a limited number of sanitation companies or contractors with the right experience, then projects should invest in training programs to strengthen local capacity. The cost and time commitments needed for such a training program may be significant. However, it would ensure that quality infrastructure is built and that the technical capacity to service the technology is in place.

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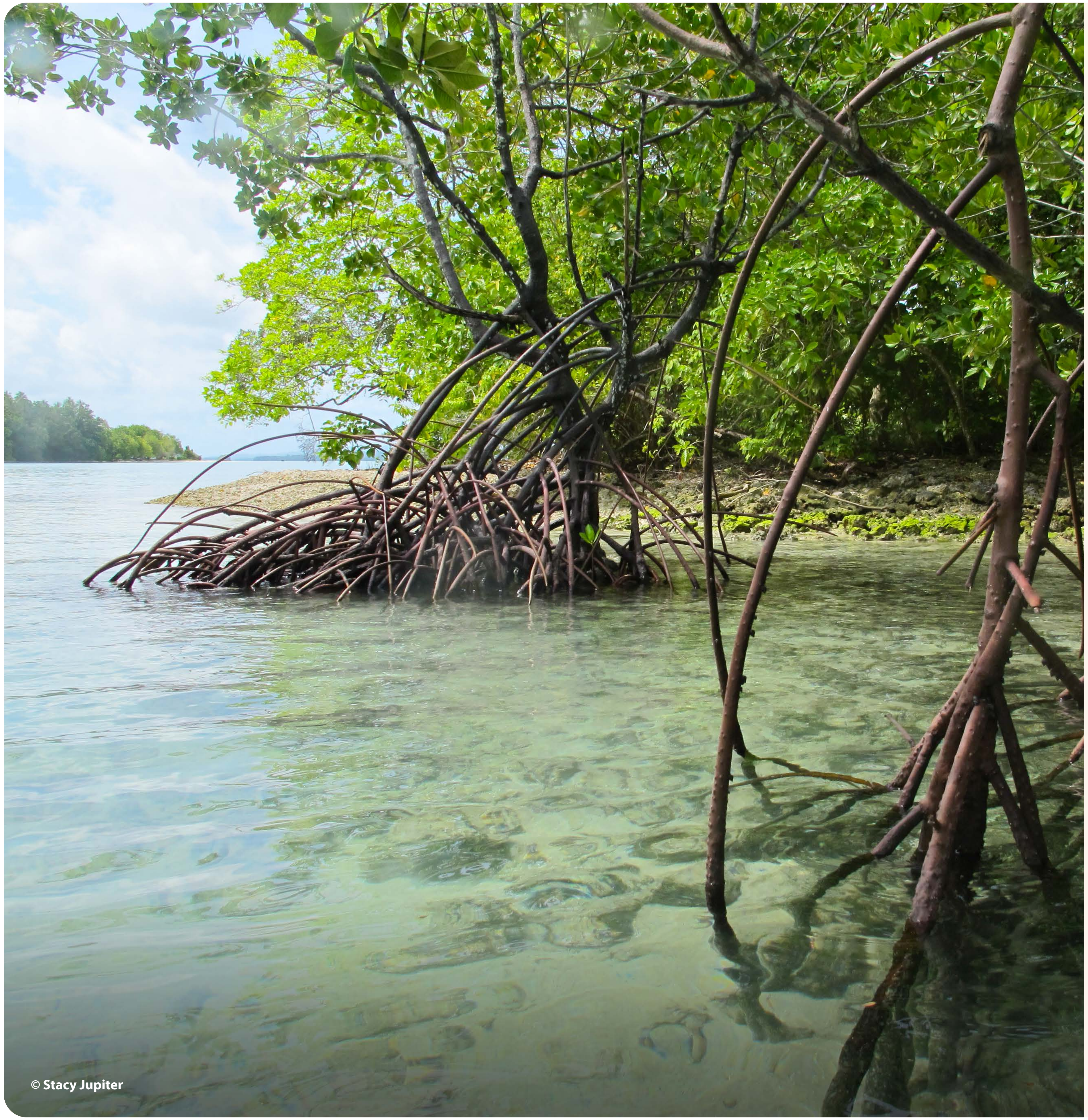

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BOX 9

Leveraging Blue Carbon to Fund Sanitation Projects

Carbon markets are a mechanism that allow carbon emitters (organizations, companies and individuals) who need or want to offset greenhouse gas emissions, to purchase carbon credits generated from approved activities that capture or sequester carbon (Enríquez-Salamanca, 2017). Recently, the demand for blue carbon has significantly increased in recent years with the increased recognition of the carbon sequestration capacity of coastal ecosystems such as mangroves, tidal salt marshes, and seagrass meadows (Howard et al., 2014; Schindler Murray & Milligan, 2023).

One of the main programs offering blue carbon credits is the Verified Carbon Standard (VCS) Program. Importantly for the sanitation sector, **one of the approved project activities that generate carbon credits is nutrient load reductions** as a means to improve water quality and restore degraded tidal wetlands (e.g., tidal marshes, mangroves, and seagrass meadows). Accessing blue carbon credits for improving wastewater pollution not only creates a new revenue source, it may create additional political will for action on sanitation.

In order to develop a blue carbon project for sanitation, standardized and reliable frameworks and metrics are needed to spatially assess and link wastewater impacts on coastal ecosystems. The OECD (2022) recommends a "**spatially targeted risk approach**" to better understand nitrogen pollution pathways from sources to impacts. The risk screening approach described in **Section 5.2** can be used to develop a spatially targeted risk approach.

Although blue carbon represents an exciting opportunity, there are still several challenges that need to be overcome. There are scientific uncertainties around the estimation of carbon capture (belowground and in fauna marina) (Claes et al., 2022; Howart et al,. 2014); high costs of implementation (Claes et al., 2022; Schindler Murray & Milligan, 2023), which can compromise project development; limited capacity for measurement, reporting and verification; uncertainty around land tenure and blue carbon rights; and perceived risks due to few operational projects and past failures, slow scaling up of projects due to lack of clarification from governments about rules, and market uncertainties (Schindler Murray & Milligan, 2023).

As the blue economy is continuously evolving (e.g. financial mechanisms, accounting standards, etc.), there are opportunities for governments to provide regulatory and financial incentives that promote and facilitate the implementation of blue carbon projects; fund research to address knowledge gaps; build regional and global partnerships to access and exchange technical expertise and best practices; and build community awareness to create social license of projects (Schindler Murray & Milligan, 2023).

BOX 10

Resource recovery from wastewater and fecal sludge: an example from Kenya

Overview

A shift is underway towards viewing human waste as a source of value-added goods (Faragò et al., 2021; Smol, 2023). This transition to a circular economy in sanitation offers several benefits: increased nutrient recycling, higher water reuse rates, and energy generation to achieve CO2 neutrality while reducing the extraction of natural resources (Faragò et al., 2021; Smol, 2023; UNEP, 2023). Circular practices also enhance cost-effectiveness and energy efficiency of operations(Renfrew et al., 2022). This shift can transform the sanitation sector from a costly, heavily subsidized service into a more sustainable one, with benefits extending beyond revenue generation (Rodriguez et al., 2020). For example, wastewater nitrogen recovery methods can fulfill about 30% of the global demand for nitrogen fertilizer (Kehrein et al., 2020).

Crucially, resource recovery benefits terrestrial, coastal, and marine ecosystems. The traditional linear water management model extracts water used in sanitation, often treats it for use, then contaminates it before releasing it into receiving environments, putting pressure on water resources and ecosystems (Rodriguez et al., 2020; Vu et al., 2021). Treating wastewater as an asset alleviates pressure on ecosystems (UNEP, 2023; Vu et al., 2021).

Despite its potential, there are barriers to resource recovery that need to be addressed to facilitate a move towards a more circular economy:

1. **Enabling Environment:** There need to be clear policies, regulations, institutional capacity, intersectoral coordination, positive private sector incentives, and community awareness (Rodriguez et al., 2020; UNEP, 2023).
2. **Quality Control:** The quality of recovered resources can vary due to different processes and technologies and can contain several contaminants. Regulations must ensure resources meet human and ecosystem health standards (Kehrein et al., 2020; Buta et al., 2021). This includes policies related to agricultural runoff to ensure that recovered waste does not become an agricultural pollution problem for coastal ecosystems.
3. **Cost and Market Considerations:** Price competitiveness between raw products and circular-derived ones needs to be addressed. This can be supported through the development of attractive markets for recovered products, with a focus on temporal and geographical supply-demand balance (Kehrein et al., 2020).

Resource recovery in action

Sanivation, a Kenyan sanitation company, partners with local governments to convert fecal sludge into solid fuel "superlogs" using a circular economy approach (Sanivation, 2020, 2023). This model provides employment, increases safe waste management, reduces fecal-related diseases, and replaces firewood, offsetting carbon emissions. Superlogs offer advantages over traditional firewood, making them suitable for various industries, including tea farms and factories (Sanivation, 2020). Revenue from superlog sales covers operational costs, ensuring infrastructure sustainability.

In Malindi, a coastal Kenyan town reliant on tourism, a City-Wide Inclusive Sanitation Plan was developed and the county is partnering with Sanivation. There is no sewerage coverage or wastewater treatment plant, so nearly all inhabitants rely on on-site sanitation systems and only 25% of fecal waste is safely treated (Akinyi, et al., n.d.). Collected sludge is illegally dumped in unregulated areas like municipal dumps, agricultural fields, rivers, and stormwater drains.

Malindi's partnership with Sanivation for a waste-to-resource fecal sludge treatment plant fits within a much broader approach to delivering sustainable sanitation services. The plan emphasizes service delivery, including pit emptier associations, transfer stations, performance-based contracts, and sewers (Akinyi, et al., n.d.). The plan aims to make the county clean, healthy, and productive, and regain the distinction as Kenya's "cleanest coastal town".

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BOX 11

Holistic water pollution management in action: Tampa Bay

Tampa Bay is an estuary located in Florida, USA. It experienced severe eutrophication between 1940 and 1980, a period characterized by fast growing population (quadrupled in this period) and urbanization in the watershed. Pollution in Tampa Bay watershed originated from a range of sources, including urban, residential, and agricultural stormwater runoff, discharges of treated municipal sewage effluent, malfunctioning or improperly sighted septic systems, fertilizer industrial discharges, as well as other sources of atmospheric nitrogen deposition (Morrison et al., 2011).

In recognition of this problem and as a result of citizen action, In 1980, a state statute went into place that required all wastewater treatment plants (WWTP) to meet advanced wastewater treatment standards, which allowed maximum concentrations of 3 mg L^{-1} total nitrogen, 1 mg L^{-1} total phosphorus, and 5 mg L^{-1} of biochemical oxygen demand. When all WWTPs met this requirement, there was a **90% reduction** in annual total nitrogen loads from WWTPs. Furthermore, in 1991, the Tampa Bay National Estuary Program (TBNEP), a partnership between the public and private sector, was established to provide support in developing and implementing a plan to improve the management of other sources of water pollution entering the bay.

The TBNEP brought together several government agencies from the local, state, and federal levels, non-governmental organizations, private-sector organizations, and universities who all participated in the design of ecological objectives, management interventions, and monitoring programs (Morrison et al., 2011).

The main roles included (Morrison et al., 2011):

- bringing together the region's scientist and managers to develop goals for the management of natural resources in the bay;
- identifying information required to define and prioritize management options that helped to achieve set goals;
- assisting partners in the implementation of management actions and programs;
- monitoring and reporting the progress towards the achievement of goals;
- identification of alternative management actions when those implemented did not result in progress toward goals;
- foster public stewardship of the bay's natural resources through education;
- work as a scientific and technical broker for technical assessments and evaluation, as well as for the development of local and regional policy in terms of management.

Additional nutrient control measures were adopted regarding the use of fertilizers, shipping operations, and power plants. Cumulatively, such interventions resulted in a **60% reduction in annual total nitrogen load** in relation to the worst case in the 1970s. As a consequence, environmental parameters, such as water clarity, chlorophyll a, and seagrass cover, improved across the years (Morrison et al., 2011; Thompson Saud & Wenger, 2022).

Such outcomes were the result of (Morrison et al., 2011):

- citizen action that called government attention to act;
- Science-based water quality targets and a seagrass restoration goals to achieve coverage observed in 1950;
- a multidisciplinary and multi-entity collaboration of more than 40 organizations that implemented more than 250 projects to reduce nutrient pollution with a total **nitrogen load reduction of over 5000 tons** from 1978 to 2003, driven largely by improved wastewater treatment;
- implementation of regulations by the state and federal governments to require compliance with advanced wastewater treatment standards and the cooperative development of a nitrogen management strategy.

However, the bay faces new challenges. Data recorded from 2020 shows a decrease in seagrass coverage by **11,518 acres** since 2016 when it reached its maximum value and exceeded the goal of 40,000 acres. Currently, research and development plans are being undertaken to better understand this trend (Beck et al., 2023).

5.2 Evaluating the risk to coastal marine ecosystems from wastewater pollution

One of the first questions both sanitation and marine conservation practitioners might ask is, **how do I know if there are wastewater pollution impacts on coastal marine ecosystems in my area?**

In many places, wastewater pollution impacts have already been documented. Therefore, **the first step in evaluating potential risk is to see if there is existing information in your area on wastewater pollution impacts in coastal marine environments**.

If there have not been recorded impacts but there is interest or concern about potential impacts, there are several important factors to consider in order to evaluate whether these ecosystems are at risk:

1. The state of sanitation systems;
2. Where in the watershed the wastewater pollution is generated;
3. The watershed characteristics related to pollution transport;
4. The coastal conditions that drive pollution transport within the marine environment;
5. The location and type of coastal marine ecosystems, the ecosystem services they provide, and natural resources that are exposed to wastewater pollution. This includes places where activities or interests that are dependent on healthy ecosystems occur, such as fisheries, aquaculture, tourism, or coastal protection; and places that are significant from a biodiversity conservation perspective, such as fish spawning aggregations, marine protected areas, or restoration sites.

One of the key differences for assessing the potential risks to coastal marine ecosystems from wastewater pollution compared to traditional sanitation tools such as excreta flow diagrams is that the information **must be spatially-explicit** to assess potential exposure. Because watershed and coastal pollution transport processes and the downstream coastal marine environments are all variable across a landscape, the risk of impact to ecosystems and natural resources should be analyzed spatially. This will not only enable the proper assessment of risk, **it will also help with prioritizing interventions and directing conservation funding sources towards areas within the sanitation system that are having the greatest impact**.

In addition to on-the-ground conditions that influence whether coastal marine ecosystems are at risk from wastewater, there will be factors related to the sanitation and conservation enabling environments that will influence risk. The main components of the sanitation enabling environment (Jiménez et al., 2016; Tsetse et al., 2016; SWA, n.d.) relate to:

- Policy and Strategy
- Institutional arrangements
- Financing
- Planning, monitoring, and review
- Capacity development

While not referred to specifically as an enabling environment, similar themes are embedded in the new Global Biodiversity Framework, especially around tools and solutions for implementing and mainstreaming biodiversity conservation.

Sanitation, pollution, and marine conservation experts from the SNAPP working group have developed **a preliminary risk screening tool** to offer guidance on whether coastal marine ecosystems and resources could be vulnerable to wastewater pollution based on on-the-ground conditions (**Fig. 6**) and the state of the enabling environment in both sectors. The tool outlines a series of questions about your system to help you identify if coastal marine ecosystems are at risk to wastewater pollution (**Appendix 4**). The information generated can serve as the evidence for the need for further investigation into the problem.

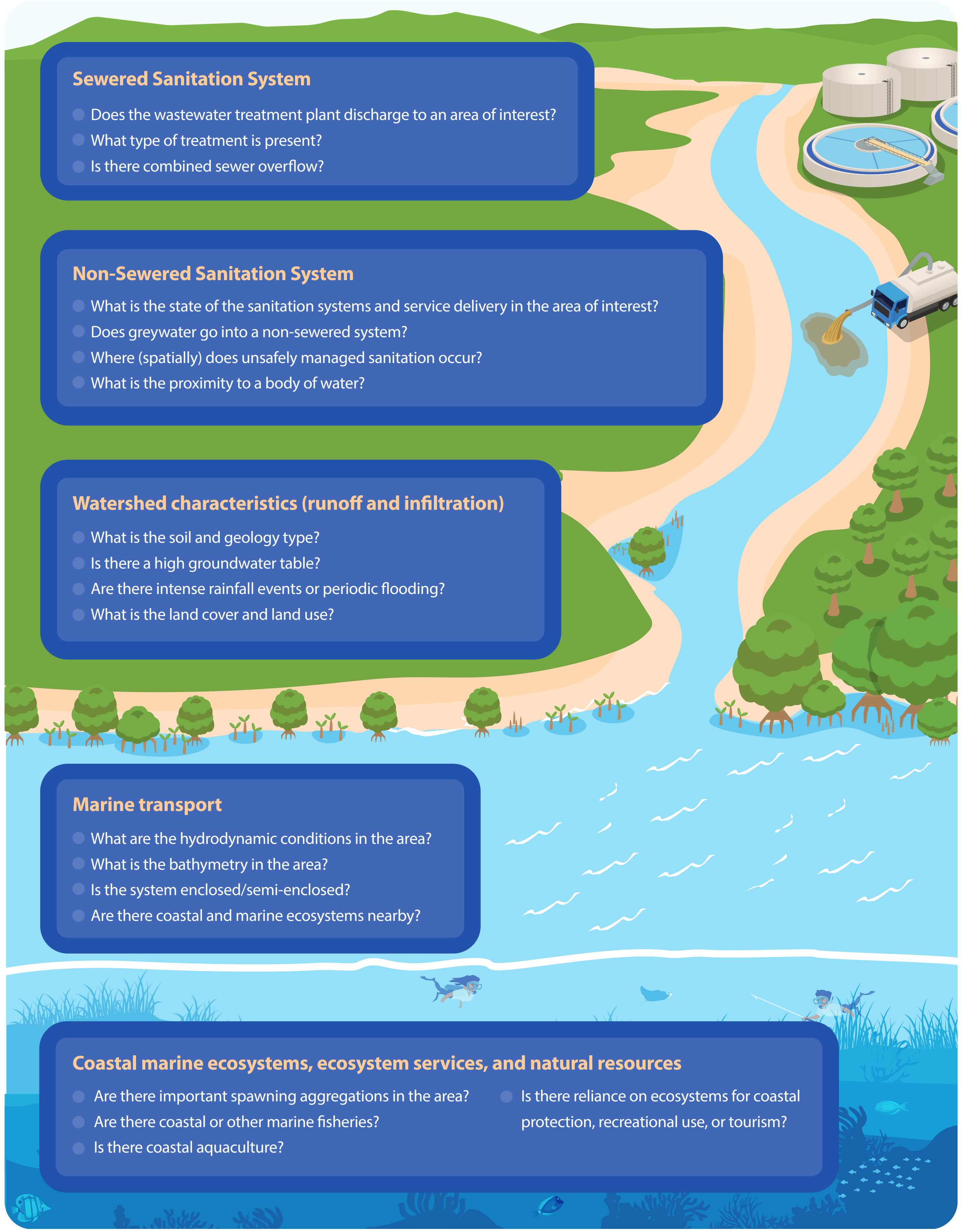

Fig. 6: *Factors to consider when assessing whether coastal marine ecosystems and ecosystem services are at risk from wastewater pollution*

BOX 12

Assessing the potential for wastewater pollution on an island reliant on tourism

Marine conservation practitioners working on an island in the Philippines with fringing coral reefs, seagrass, and mangroves are working with local government partners and communities to protect and conserve coral reefs. The island is reliant on tourism and wants to sustainably develop the tourism sector, with an emphasis on ecotourism. Many of the existing tourist accommodations are on or very close to the beach in a flat and low-lying part of the island. A review of government reports on tourism development indicated that many septic tanks at tourist accommodations and facilities were broken or overflowing. Some of the larger hotels have their waste transported off the island by barge. Further conversations with key informants indicated that there are no septic tank emptying services on the island and no fecal sludge treatment facilities. Furthermore, many people were unaware that septic tanks needed to be emptied. Based on this information, there was concern that wastewater pollution could be entering the ocean.


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A visual assessment of the ocean on the part of the island with most of the tourism highlighted that there was minimal wave activity and the ocean was generally calm. There were women gleaning for oysters in the intertidal areas and there were fishers close to shore. When conducting a visual assessment of the ecosystems in this area on snorkel, there was a strong thermocline and halocline, indicating limited mixing of the water and a source of freshwater, likely groundwater, in the coastal area. The seagrass was covered with epiphytes and there was high macroalgal cover and limited coral cover, suggesting ecosystem exposure to excess nutrients.

Based on the preliminary assessment of the state of sanitation systems and services, the hydrodynamics, the state of the ecosystems, and the presence of fishing activities, the marine conservation practitioners are now planning a more in-depth assessment and looking at developing partnerships with the government entities involved in sanitation and tourism.


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If the answers to the risk screening questions highlight a potential risk, we advise that a more comprehensive risk assessment be conducted. Comprehensive risk assessments require in-depth consideration of factors that are going to be specific to the conditions in a given location. As such, the development of a comprehensive risk assessment is outside the scope of this guide, but we provide an example of how one was conducted for Queensland, Australia (**Appendix 5**). We also highlight potential sources of information for more in-depth considerations of risk (**Table 3**).

Table 3: Examples of sources of information that can be used to conduct an in-depth risk assessment

Factors for Consideration	Potential Sources of Information
Sanitation system	○ Similar information and sources as collected for the generation of a comprehensive excreta flow diagram (see Annexes 2-4 in SFD manual) ○ Available effluent discharge values
Watershed characteristics	○ GIS layers ○ Hydraulic models ○ Local land-use maps, published and gray literature, and government documents ○ Water quality data
Marine transport	○ Open-access remote sensing ○ Pollution transport models ○ Pollution assessment and monitoring approaches (see the Pollution Assessment and Monitoring Manual)
Coastal ecosystems and natural resources	○ GIS layers (Allen Coral Atlas - https://allencoralatlas.org/, Mangrove Watch - http://mangrovewatch.org.au/, Seagrass Watch - https://www.seagrasswatch.org/, World Database on Protected Areas - https://www.protectedplanet.net/en/thematic-areas/wdpa) ○ Ecological monitoring to identify marine assets or impacts from pollution (see pollution assessment and monitoring manual) ○ Key informant interview
Enabling environment	○ Institutional and Coordination Mechanisms ○ Self Assessment - Organization for Economic Co-operation and Development ○ Strengthening Enabling Environment for Water, Sanitation and Hygiene (WASH)

5.3 Aligning and coordinating efforts to better achieve integrated outcomes

To support an integrated approach, strong institutional structures and coordination mechanisms are crucial. When government agencies coordinate and communicate with each other based on ad hoc or temporary arrangements and individual initiative to address different aspects of policies, problems arise (Gudgin et al., 1982; UNDP, 2017). Problems include (Jordan & Lenschow, 2010; UNDP, 2017; Victorian Auditor-General's Office, 2018):

- a lack of clarity around roles and responsibilities;
- overlapping mandates;
- a weakened policy implementation process,
- the ability to collect reliable and quality data to assess the progress and performance of implemented policies;
- an overly complex, duplicative, or inadequate regulatory frameworks;
- lack of ownership of the problem.

While aligning approaches taken by each sector can be strategic, coordinated programming is required to deliver a more streamlined and integrated approach. Coordination is important to identify sectoral and conflicting interests or priorities to promote and align targeted actions across institutions, sectors, and government levels under a long-term vision and direction (OECD, 2019a). Coordination can optimize joint planning for a more streamlined delivery of programs. Built upon the OECD (2019) recommendations for policy coordination and coherence for sustainable development, the following is suggested for an integrated approach:

1. Establish clear mandates and responsibilities for agencies in charge of sanitation services provision, environmental protection, and coordination with other institutions or the private sector (OECD, 2016).
2. Develop capacities within public service to lead, formulate, implement, monitor, and evaluate coherent policies across sectors (OECD, 2016).
3. Mobilize sufficient resources for the required work based on specific contexts and needs.
4. Utilize high-level coordinating mechanisms such as councils or committees within the center of government or a government authority with policy coherence leadership.
5. Encourage formal governance arrangements and informal mechanisms that facilitate communication and collaboration between government authorities and other governmental and non-governmental institutions.

A body of literature highlights the need for policy coordination, integration,and coherence to achieve greater synergies across sectors and government levels and strategic use of policy planning mechanisms and tools (Al-Zu'bi, 2016; Ferry, 2021; Fopa Tchinda & Talbot, 2023; Jordan & Lenschow, 2010; Peters, 2018; UNDP, 2017; von Lüpke et al., 2023). This is particularly important in sanitation and marine conservation where their jurisdictional boundaries, legal mandates, or remits do not cover the other sector's domain (see **sections 2 & 5.1**).

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A mechanism for coordination, such as a coordination body, can play a vital role in examining issues, providing policy advice, and ensuring strategies can succeed. In places where there have been documented **water quality improvements in coastal areas from sewage and runoff, a coordination body has played a key role in integrating sectors to implement management actions cohesively** (Thompson-Saud & Wenger, 2022). Existing coordination bodies, such as national and sub-national bodies developed to coordinate activities around sustainable development or climate change, which are present in many countries (UNDP, 2017; von Lüpke et al., 2023), can be leveraged for the implementation of integrated approaches due to their multi-sectoral nature. Coordination bodies do not have to be within government and in many cases, organizations are well placed to take on this role, however the legal mandate to operate is a key factor in their success (Wakwella et al., 2023).

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BOX 13

Challenges in Managing the Environmental Impacts of Domestic On-Site Sanitation Systems in Melbourne, Australia

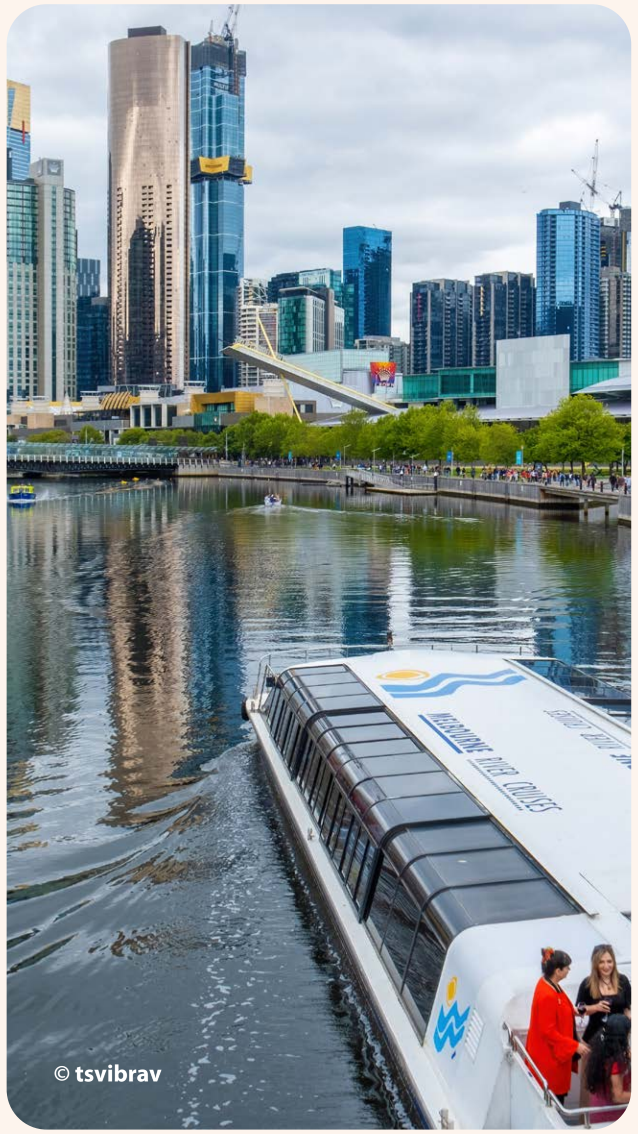
In the 1950s, Melbourne's metropolitan area grew rapidly, but sewage infrastructure development lagged. To accommodate growth, councils permitted the use of onsite sanitation systems. These properties were included in backlog programs for eventual sewer connection. Many such properties were in Mornington Peninsula Shire Council (MPSC) and Yarra Ranges Council (YRC) Mornington Peninsula and Yarra Ranges, with South East Water Ltd. (SEW) and Yarra Valley Water Ltd. (YVW) managing the respective backlog programs.

The Department of Environment, Land, Water and Planning Victoria (DELWP) is in charge of setting the environmental regulatory framework that Councils and Water Authorities implement. Environment Protection Authority Victoria (EPA) dictates what onsite sanitation systems can be used and is in charge of ensuring compliance with the regulatory framework set out by DELWP. Councils oversee system installation, use, and management, and verify that property owners are installing approved systems. Property owners are responsible for servicing and maintaining systems to contain wastewater on their property. Councils develop domestic wastewater management plans (DWMPs) identifying high-risk townships. High-risk properties are referred to water authorities for sewer connection or alternative treatment. Water authorities are also responsible for determining the most cost-effective wastewater treatment option, be it sewer connection or an alternative onsite sanitation system suitable for high risk areas.

In response to a 2006 audit revealing inadequate environmental protection from low-performance onsite systems, the Victorian Government conducted a new audit in 2018. This audit assesses agencies' effectiveness in managing domestic wastewater from poorly performing onsite systems to protect the environment and public health.

The audit found that **individual and cumulative environmental and public health risks and impacts** are not adequately managed despite some efforts made since the last audit. This is partially due to **poor leadership and limited collaboration** between DELWP, the EPA, Councils, and the water authorities, resulting in the following issues:

- An overly complex, onerous and **duplicative regulatory framework**.
- A continued **lack of clarity around roles and responsibilities**.
- Regulatory tools that do **not adequately drive property owners**' compliance with planning permits and legislation.
- Councils not being held to account for their role in domestic wastewater management."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Additionally, there are underpinning issues and some of them are as follow:

Data Collection Challenges: Reliable and consistent data collection by councils is lacking for assessing individual and cumulative risks associated with onsite sanitation systems. This makes it difficult to prioritize unsewered areas for sewer installation. Additionally, the limited use of water quality data poses a significant constraint.

Inefficient Risk Management: Both councils have inadequately assessed their risk management controls for poorly performing onsite systems. This has led to incorrect definitions of wastewater management options for properties or townships, resulting in duplicated efforts and increased costs for water authorities and customers.

Limited Water Quality Programs: Yarra Ranges Council had a short-term water quality program with limited results, making it difficult to assess the impact of sanitation systems on the environment and public health.

Reactive Collaboration: The collaborations between the EPA, DELWP, the councils, and water authorities are largely reactive. Improvements are needed, particularly in enhancing cooperation between Yarra Valley Water and the Yarra Ranges Council.

Approval Redundancy: Property owners are burdened with multiple approvals for the use and management of onsite systems. This results in councils investing more effort in approvals rather than monitoring system performance.

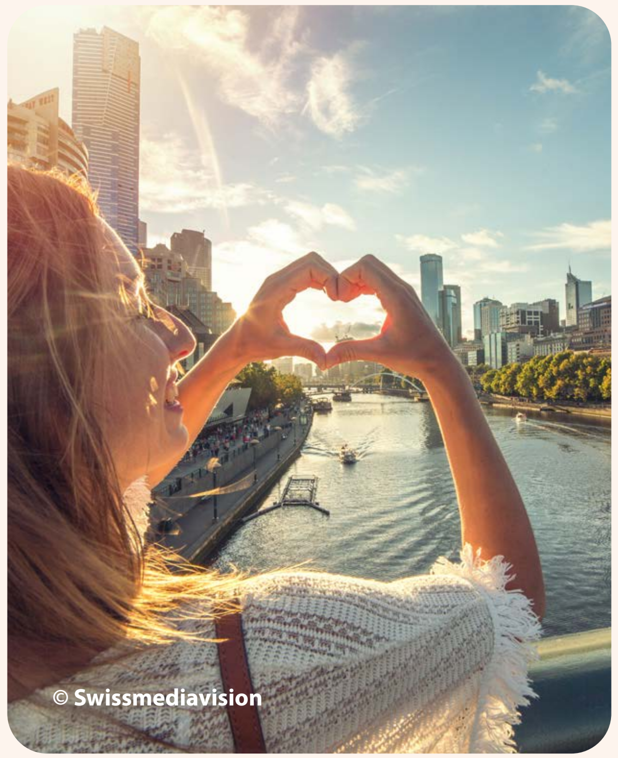
Since the findings of the audit, there have been efforts from the audited agencies to address the issued recommendations, such as implementing innovative projects and actions to improve cost, effectiveness, and timeliness to connect high-risk townships to sewer, exploration by the water authorities on alternative service options for properties in high risks areas, use of more comprehensive risk-assessment measures to prioritize properties for sewering, improvement of their water quality programs, and improvement of the compliance inspection program. However there are still several opportunity areas to improve outstanding regulatory, policy, communication, collaboration, and technical gaps to fully address recommendations to prevent impacts on ecosystems and public health.

Compliance Oversight: Compliance inspections and audits are not comprehensive in terms of coverage and frequency. Additionally, both councils lack sufficient resources to effectively oversee the compliance of onsite systems.

Lack of Public Knowledge: Property owners often lack knowledge about proper system maintenance, the life cycle costs of onsite systems, and ongoing maintenance requirements. There is a need for a comprehensive community information and education strategy, as well as a formal evaluation mechanism for both councils.

Data Deficiency: Both councils lack accurate data on properties connected to sewer systems as this data is not shared by the water authorities. This data gap affects their ability to assess the number of properties that should be included in their backlog programs.

Evaluation Framework Missing: YVW's Community Sewerage Program, designed to deliver environmental and public health benefits more efficiently, lacks an evaluation framework to assess its success, hindering the assessment of its impact.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Coordination bodies can take on many roles (OECD, 2019a; UNDP, 2017):

- Work as an advisory body to government
- Examine coordination issues and provide advice for strategy and policy success.
- Ensure that sectoral policies are aligned and complementary
- Managing sectoral and conflicting interests or priorities to promote and align targeted actions across institutions, sectors, and government levels under a long-term vision and direction.
- It can help influence political will and move action forward in a priority area
- Develop or coordinate policy implementation strategies
- Engage with stakeholders
- Develop a monitoring framework and indicators of success
- Follow up and review goals and targets
- Recommend financing strategies and options for policy implementation
- Promote vertical coherence by coordinating policy and activities across government levels

The body's location, legal support, and responsibilities are important considerations (OECD, 2019a; UNDP, 2017):

- It should be placed within a structure with the necessary political will and influence to impact decisions effectively. **A powerful coordinating body responsible for coordinating across sectors is more likely to overcome sectoral interests and lead the policy process successfully** (OECD, 2019a; UNDP, 2017; Von Lüpke et al., 2023). Conversely, a voluntary body without sufficient resources and mandate will have limited influence (UNDP, 2017).
- **Environmental institutions often face challenges in intragovernmental negotiations compared to key economic sectors** (Von Lüpke et al., 2023). Thus, establishing or strengthening alliances with influential ministries will lead to more traction on environmental issues (Al-Zu'bi, 2016; Jordan & Lenschow, 2010).

For instance, when monitoring the implementation of the Sustainable Development Goals or climate change, **placing the coordinating body under the office of the president/prime minister has improved coordination** compared to placing it within a ministry (UNDP, 2017). This addresses the perception that certain issues such as climate change, fall solely under the jurisdiction of a particular government authority, rather than requiring collaboration across sectors (UNDP, 2017).

The composition of the coordinating body should be diverse and inclusive to represent different perspectives and build on the expertise of its members to yield more informed analysis, decisions and recommendations. In addition to government bodies, representatives from civil society, the private sector, business, philanthropy, and academia are strongly encouraged to foster a stronger sense of ownership (UNDP, 2017). Their involvement is particularly important in shaping the orientation of policy design, particularly when the technical and analytical capacity of the government staff is low (von Lüpke et al., 2023). Ultimately, the mechanisms or arrangements will be highly influenced by the government system and consequently will face different coordination challenges (Ferry, 2021). Based on reviewed literature about coordination mechanisms, particularly from the OECD (2019a) and the UNDP (2017), Table 4 aims to provide a set of questions and guidance for a general assessment of the status of the coordination mechanisms in any jurisdiction.


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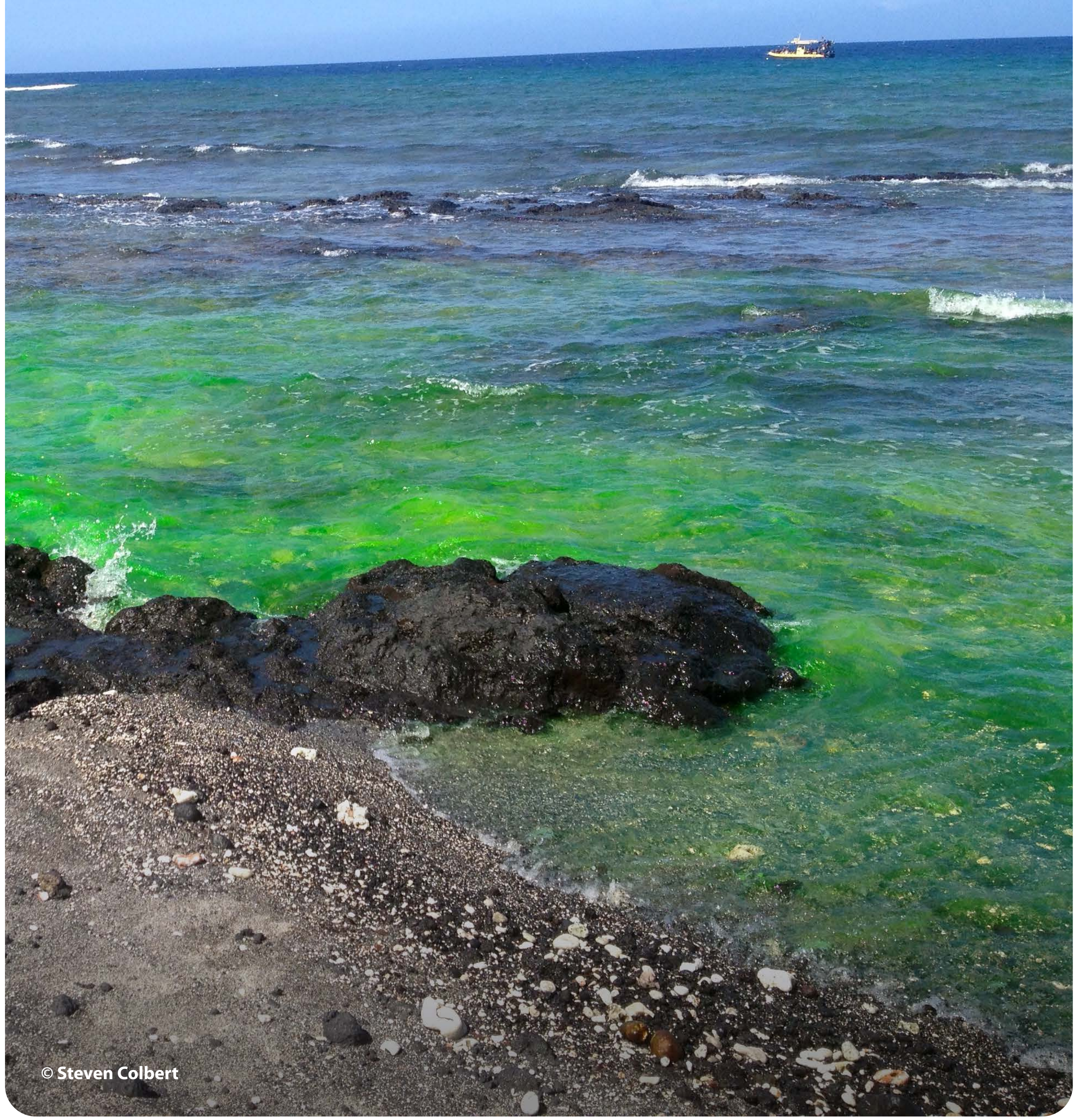
Table 4: Questionnaire to determine course of action to improve effectiveness of coordination between marine conservation and sanitation sectors

Diagnostic Question	Guidance Based on Answer	
	Yes	**No**
Is there a key institution or body designated to coordinate work between sectors? (UNDP, 2017)	Ensure coordination between sanitation and the environmental sector occurs in an integrated and collaborative way.	Advocate for a formal mechanism with legal mandate and sufficient resources under a high-level of the government structure (office of the president or prime minister) (UNDP, 2017; OECD, 2019a).
Is the coordination body under a government institution with sufficient authority, legitimacy and capacity to have influence over the involved sectors? (OECD, 2019a; UNDP, 2017)	Ensure it has a clear roadmap or strategy in place to guide work, with clearly defined roles and targets (UNDP, 2017).	Work to strengthen the authority and legitimacy of the coordinating body or identify pathways to move the coordination body to a government institution with such capabilities.
Does the institution or coordination body have mechanisms in place to coordinate work across multiple sectors (horizontal) and government levels (vertical) (UNDP, 2017)	Ensure there are incentives in place for each sector and government level participation, as well as inclusive representation, and clear roles and responsibilities (UNDP, 2017)	Identify formal and informal mechanisms at both dimensions to support effective communication within and outside government (OECD, 2019a).
Are there mechanisms in place to ensure diverse participation from the private sector, academia, philanthropy, civil society and vulnerable or disadvantaged groups? (UNDP, 2017)	Ensure their perspectives are included throughout the policy planning and implementation process (UNDP, 2017).	Identify barriers and develop strategies to address them to ensure effective engagement.
Are there mechanisms to allow better arbitration between conflicting views and interests? (UNDP, 2017)	Ensure they are effective by implementing routine evaluations and incorporating results into processes.	Develop formal and agreed arbitration processes that are fair and equitable.

5.4 Setting pollution reduction targets

One of the main intersections between the conservation and sanitation sectors is through the intentional discharge of treated wastewater pollution into coastal marine environments. In recognition of the environmental impacts of wastewater pollution, countries have implemented regulations that mandate pollution reduction (Thompson-Saud & Wenger, 2022). There are three ways to think about setting pollution reduction targets, which we detail below. A strengthened policy and regulatory environment can support the implementation of better standards, requirements for developments, and can drive private sector innovation and improvement.



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1. Wastewater discharge standards

Wastewater discharge standards are one of the most common approaches to regulating and reducing wastewater pollution. They set concentrations that specific pollutants must not exceed.

The best practice and preferred method for developing ecosystem threshold values is to have chronic ecotoxicity data that determines the no-effect concentration of a pollutant for at least 15 species belonging to at least four taxonomic groups (Warne et al., 2018). Generating this level of data is a massive undertaking, especially considering the range of pollutants that occur in wastewater (Wear & Vega Thurber, 2015). Previous studies have focused on developing pollutant thresholds for specific groups of marine species, especially reef-building corals (Connell et al., 2017; Erftemeijer & Lewis 2006; Nalley et al., 2021, 2023; Thomsen et al., 2020; Tuttle & Donahue, 2022; Wenger et al., 2017), but there has been no synthesis of existing studies across a range of species and taxonomic groups to enable the development of an ecosystem-level threshold.

Despite the creation of wastewater discharge standards being such a common and sought-after approach, **there is limited ecotoxicology evidence** supporting threshold values in policies. **The lack of appropriate ecotoxicology data for coastal marine ecosystems is a significant data gap** and undermines our ability to regulate wastewater discharge through discharge standards. **Further, it makes it very difficult to assess whether existing policies are stringent enough to protect coastal marine ecosystems.** Additionally, coastal and marine species are often more sensitive to pollutants than humans (e.g., human health threshold for copper vs. reef-building coral threshold (Nalley et al., 2021), therefore standards that have been established to protect human health will not necessarily be sufficient to protect coastal and marine ecosystem health.

The ecotoxicology data gap also hinders our ability to meet global goals. For instance, SDG target 6.3 sets out to: '**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.' To track progress towards this target, SDG indicator 6.3.2 monitors the proportion of bodies of water (**freshwater only**) with good ambient water quality, **as per national and/or subnational water quality standards**. However, if there is limited scientific evidence supporting water quality standards then there is the potential to **meet our goals without sufficiently improving ecosystem conditions**.

Even when pollutant thresholds exist for species, translating those thresholds into discharge standards is complex and influenced by multiple factors, including the hydrodynamic conditions at the discharge location, the ecosystems present and their distance from the discharge point, the suite of pollutants that are being discharged, the total volume of wastewater being discharged, the consistency of exposure, and any other polluting activities occurring in the area. In many cases, countries have set different wastewater discharge standards for different receiving water bodies, primarily based on the environmental, recreational, or industrial attributes present in those waters, but seldom incorporate hydrological considerations that inform risk (see **section 5.2** and **Appendix 4**). **Wastewater discharge policies should include requirements for outfall position and designated areas for safe disposal of waste that consider sensitivity and vulnerability of ecosystems within receiving water bodies**. These factors should be incorporated into sanitation planning frameworks to guide decision-making around treatment plant site selection and wastewater and solid waste disposal.

A major challenge with wastewater discharge standards is that countries are failing to meet their existing ones, so setting more conservative standards could make it more difficult to achieve the goals. A strong regulatory environment, where government authorities have the mandate and resources to enforce compliance is necessary to meet standards. Additionally, to support governments in meeting wastewater discharge standards, the Compendium of Sanitation Systems and Technologies, a commonly used tool by sanitation practitioners for identifying technology options, should be updated to include more information on which pollutants are removed by different treatment technologies, including pollutants such as microplastics and pharmaceutical and personal care products, which have known impacts to coastal marine ecosystems and are not currently mentioned in the Compendium.

BOX 14

Wastewater treatment in West End, Roatán, Honduras Part 2

Prepared by Tanya Amaya, Pamela Ortega from the Coral Reef Alliance, Dr. Antonella Rivera (CORAL)

The wastewater treatment plant uses an activated sludge system with extended aeration, meaning there is primary and secondary processing, with a denitrification tank under construction. In the primary process, there is a double grid channel where all the coarse solids are retained, and then it goes through the grit channel where sand is removed, then to a grease trap. The secondary treatment receives the effluent to a pumping well (with submersible pumps) that sends the water to the anoxic contactor and passes to the reactor, commonly called an aeration tank. Residual water is passed through a clarification process where plates in parallel allow sedimentation and where the remaining solids pass to the bottom. They are then sent to a sludge digester (currently a sun-drying process but soon this step will be executed through a dehydrator). The clear water goes to a chlorine doser and then the treated water goes through a flow meter (treated water reading) and is sent to the receiving body, the beach in West End, Roatán.

Since its construction in 2011, the plant has had additional investments of USD$791,347 from different donors and from revenue streams generated by the treatment plant including the installation of 98 solar panels that reduce daytime energy consumption, resulting in a 50% reduction in monthly electricity costs, and a new aeration system consisting of fine bubble diffusers and a denitrification tank (currently under construction) a new generator, and mechanical dewatering for improved sludge management, which will be built later this year;ll of this is done in a 660-m2 operating area. These improvements to the treatment process have proven highly efficient in removing pollutants and ensuring the water discharged back into the sea meets quality standards.

The outcomes achieved in the ocean are incredibly promising

- **There is compliance with Honduran wastewater discharge regulations**[3] and stricter regulations such as the Cartagena Convention aimed to prevent marine pollution.
- Following the construction of the plant, coral disease levels dropped 25% from 2011 and reached 0% in 2016 and 2018.
- Starting in 2019, the public beach in West End was declared a Blue Flag swimming beach, an international standard for safe swimming. A milestone for one of the most populated beaches in Honduras. This recognition is also an indicator of the importance of the marine water quality monitoring implemented by the Bay Islands Conservation Association and CORAL, since the information generated has been one of the most effective tools to advocate for policy enforcement, fundraising, and investing in sanitation. Importantly, the Blue Flag accreditation has been modified for the context, to acknowledge that the beach is not just for tourism, which is often the case for beaches accredited under the Blue Flag program, but that it is a community asset that needs to support the wellbeing of local communities.

[3] https://www.fao.org/faolex/results/details/es/c/LEX-FAOC175670/

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2. Treatment level targets

One approach to reducing the level of wastewater pollution entering the environment is to mandate a treatment level that wastewater treatment plants should achieve, rather than specific discharge standards for different pollutants. Typically, treatment levels refers to primary, secondary, advanced nutrient removal, or tertiary, which results in a reduction of pollutant concentrations in specific parameters that are targeted during each treatment stage. In both the United States (US) and the European Union (EU), secondary treatment standards have been set as the minimum treatment level for wastewater treatment plants (European Commission, n.d.; US EPA, 2022a). Additionally, within the EU, more advanced treatment is required for urban areas of more than 10,000 people in watersheds with sensitive waters. In Australia, minimum recommended treatment levels are set based on the location of the discharge (ARMCANZ & ANZECC, 1997). Mandating treatment levels that differ by population size or by the type of ecosystems or natural resources in the receiving environment could reduce costs associated with setting a national treatment level target. The different designations applied to different water bodies that guide wastewater discharge standards (**Appendix 6**) could similarly be applied to treatment levels.

The use of the risk screening tool in section 5.2 can help to identify areas where higher treatment levels or more stringent discharge standards should be required.

The treatment standards set by the US and the EU have been focused on reduction of organic matter, suspended solids, pathogens, and nutrients (in the EU context). However, in 2022, the EU updated the Urban Wastewater Treatment Directive in recognition of the need to regulate the treatment of microplastics and micro-pollutants, such as pharmaceuticals and personal care products (European Commission, 2022).


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BOX 15

Is safely managed sanitation safe enough?

Safely managed sanitation for all is one of the primary goals of the sanitation sector. It is defined by the World Health Organization as:

"The population using an improved sanitation facility that is not shared with other households and where excreta are safely disposed of in situ or treated off site"[1].

Improved sanitation facilities capture the front-end infrastructure, which must have a washable floor and a superstructure, with the intent of separating people from feces. Considerations of safely managed sanitation look at the latrine back-end receiving infrastructure, where the wastewater needs to be safely contained and treated or removed/transported and treated off-site[1].

The World Health Organization considers populations using sewer connections that are not shared and deliver excreta to treatment plants where they receive treatment (**at least secondary treatment, or primary treatment with a long ocean outfall**[1]) as "safely managed sanitation".

Primary treatment is the first stage where solids and organic matter are removed predominantly through sedimentation or flotation (Tilley et al., 2014). The definition and description of secondary treatment is the removal of biodegradable organic matter and suspended solids, and typically disinfection, through chemical and biological processes. Although secondary treatment does lead to some reduction in nutrients, separating nitrogen from effluent requires more advanced treatment processes (Tilley et al., 2014), and there is substantial evidence that coastal and marine ecosystems are sensitive to nutrient pollution (**Appendix 1**). Furthermore, secondary treatment does not remove pharmaceutical and personal care products and other micropollutants of concern (Pistocchi et al., 2022).

Assessing whether safely managed sanitation as it is currently defined is sufficient to protect coastal marine ecosystems is hindered by a lack of data. For instance, a review of 97 peer-reviewed on the impacts of wastewater pollution on coral reefs conducted as part of this project found that the vast majority of studies showing impacts either 1) did not report the type or state of sanitation systems, 2) the sanitation systems in place did not meet the definition of "safely managed sanitation", or 3) there were multiple sources of pollution, making it impossible to disentangle the impacts of wastewater specifically. Out of the 97 studies, only 4 had sufficient details to link wastewater pollution from "safely managed sanitation" to coral reef health, with all finding a negative impact (**Appendix 8**), indicating that conventional secondary treatment may not be sufficient to protect coral reef ecosystems. However, as described in **Box 14**, secondary treatment was sufficient to reduce coral disease levels in Roatán, although it is unclear whether there were additional ecosystem benefits. To better quantify how coastal marine ecosystems respond to wastewater pollution and management, ecosystem studies need to do a much better job reporting on the sanitation systems in place. **This can be achieved through stronger partnerships and joint research programming between the conservation and sanitation sectors.**


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[1] ***World Health Organization:*** *https://www.who.int/data/gho/indicator-metadata-registry/imr-details/4820*

3. Pollutant load reduction targets

One of the Principles of Partnership outlined in **Section 4.1** is acknowledging the uncertainty associated with managing wastewater pollution and acting **under the guidance of the precautionary principle**. In most cases where coastal marine ecosystems are impacted by wastewater pollution, there will be limited information as to the exact pollution-load reduction needed to bring about recovery, even when it is clear that some level of pollution reduction needs to occur. In these instances, setting a target pollutant load within the context of an adaptive management framework will allow for pollution reduction efforts to move forward, supported by monitoring to assess how coastal marine ecosystems are responding.

As an example, The Kunming-Montreal Global Biodiversity Framework (2022) sets out ambitious targets for achieving biodiversity conservation goals in 2023. Among those is Target 7, a pollution reduction target, which states:

Reduce pollution risks and the negative impact of pollution from all sources, by 2030, to ***levels that are not harmful to biodiversity and ecosystem functions and services,*** *considering cumulative effects, including:* ***reducing excess nutrients lost to the environment by at least half*** *including through more efficient nutrient cycling and use; reducing* ***the overall risk from pesticides and highly hazardous chemicals by at least half*** *including through integrated pest management, based on science, taking into account food security and livelihoods; and also preventing, reducing, and working towards eliminating plastic pollution.*

The target of at least a 50% reduction in excess nutrients and other chemicals is not based on the sensitivity of any ecosystem in particular, but rather an acknowledgement of the current impact of pollution on the environment and the need to ambitiously reduce levels of pollution. However, there are good examples of development of ecologically-relevant pollutant load reduction targets (Brodie et al., 2017). Pollutant load reduction targets may be especially appropriate in situations where there are a range of polluting activities present that are both point and nonpoint source and the goal is to reduce total pollution loads (as opposed to pollution loads from wastewater specifically). The use of total daily maximum loads (TDML) in the USA operates under this principle, wherein the TDML is used to determine the loading capacity of the waterbody and to allocate that load among different pollutant sources, so that the appropriate control actions can be taken, and water quality standards achieved (US EPA, 2022). Importantly, TDML serve as the link between water quality standards and the range of policy instruments that can be implemented to incentivise or mandate pollution reduction across various sources of pollution (Taylor et al., 2012; US EPA, 2022; Xepapadeas 2011). Working in a holistic manner to meet overarching pollution reduction targets will require a cross-sectoral and integrated approach, and the guidance provided here on partnership in **Section 4** will also be applicable to other multi-sector approaches.

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6. Funding and financing integrated approaches

There has been a shift in the last 10+ years in the realm of funding and financing - grants, debt, equity, and beyond - including implementation and investment in multi-sectoral projects, that has expanded the size, type, and intersection of investors and grant makers that surround potential project implementation at all scales.

As communities respond and prepare for more devastating collisions of shocks and stresses around the globe, including the chronic nature of climate change-induced cascading effects, the demand for "aligned," "braided," and "blended" finance is increasing, especially for the most vulnerable populations. The intersection of conservation and sanitation is no different. Long term success of integrated conservation and sanitation approaches requires diverse investment products, platforms and partners.

BOX 16

The Investment Protocol for Coastal Resilience: Unlocking financial flows for coastal resilience solutions for cities, communities and regions

Prepared by Stewart Sarkozy-Banoczy, Ocean Sewage Alliance

Led by a diverse group of organizations - United Nations Climate Champions (Oceans), the Ocean and Climate Platform, ICLEI, Precovery Labs, Resilient Cities Network - the Investment Protocol for Coastal Resilience (in Africa) - IPCRA was launched at the UN Ocean Conference in 2022 with the intention of creating new pathways and partnerships to align funding and financing for coastal communities, starting in African mainland and island locations, specifically designed to create co-benefits and a "return on resilience value" that brought radical collaboration and the scaling up of action. At COP27 in Egypt, the partner organizations released a "Blue-Tinted White Paper" that laid out a snapshot of the present funding and financing marketplace and the intended elements of the Investment Protocol.

In order to tackle the dual challenges of setting up innovative, scalable, and bankable adaptation and resilience projects in coastal communities, while securing private and public capital at a variety of stages and vehicles, the Investment Protocol was intended to help address structural barriers (e.g., capacity, resources, feasibility studies, risks aversion, etc.) and provide an avenue for collaboration among key private and public financial institutions, relevant blue economy industries and coastal communities.

The "blue paper" acts as a first pillar for the Protocol and is a summary of funding and financing options and mechanisms, as well as a mapping of the key stakeholders. The paper highlights main gaps and puts forward recommendations to unlock financial flows at the scale needed. The second pillar will create a framework for investments in coastal cities (including objectives, criteria for success, operating principles/standards for investment). The third pillar, focusing on implementation, is a funding platform to encourage holistic collaboration for investment in coastal cities' adaptation and building resilience. The paper intended to inform the key stakeholders involved in funding and financing coastal cities adaptation and building resilience. These include: private banks, asset managers, pension funds, private equity firms, insurance and credit rating agencies; multilateral banks, international development aid; philanthropic and impact investment sectors, relevant blue economy/blue tech industries such as coastal tourism, real estate, water/sanitation, shipping, ports, fisheries and aquaculture, offshore renewable energy, as well as innovators at a variety of scales; and coastal cities leaders, practitioners and related funding and financing institutions.

A key aspect of the Investment Protocol was the definition of seven mixed, holistic levers within which to combine and account for co-benefits (return on resilience value), including three levers of added importance to this guide and the deeper integration of conservation and sanitation - 1. Waste Management: plastics, marine debris, sewage reduction; 2. Nature based solutions, habitat restoration, biodiversity; 3. Tourism, fisheries and frontline communities intersections - combined with 4. Port and marina operations and facilities; 5. Economic resilience to cascading shocks and stresses; 6. Shipping and marine pollution reduction and energy transition; and 7. Equitable workforce development, job and industry creation.

These levers were combined with "tips" for investors that are meant to increase the viability of the enabling environment:

1. **Precovery rather than recovery:** For coastal adaptation and resilience investments, capital expenditures tend to be lower than business value generated and are substantially lower than the cost of inaction/delayed action. Therefore, it is paramount to invest in adaptation and resilience building actions and to better integrate adaptation "cascading benefits" and a precovery framework into financial decision making at large, avoiding or reducing the constant cycle of recovery.
2. **Explore the different financial mechanisms:** A large set of financial options are available and investors should partner with other stakeholders to set up bankable projects and reach the level of investment required.
3. **Leverage ocean-based industries:** The growing blue economy sectors offer opportunities for coastal cities to attract new sources of capital, which should be directed, in part, to building and implementing adaptation solutions. Adaptation measures should be integrated into blue investments, such as port energy transition, tourism infrastructure and offshore wind development.
4. **Invest in nature:** Estimating the value of Nature-based Solutions for adaptation and factoring other benefits (e.g. carbon sequestration, biodiversity gain, tourism) into existing frameworks, such as cost-benefit analysis, help make the business case and increase the willingness to invest in coastal adaptation infrastructure. Capturing cost-savings can be facilitated by the insurance sector while financial institutions can shape the market to manage risks associated with nature-based solutions (by increasing premiums for projects including nature-based solutions for instance).
5. **Build local capacity:** In low-income countries in particular, investments must seek to enhance the capacities of local institutions in order to improve understanding of climate risks and uncertainties, as well as to move away from reliance only on donor funding, which is based on a project-based logic that is contrary to long-term planning.
6. **Engage with local communities:** Coastal adaptation must be planned on a large spatial scale, which allows the participation of all stakeholders concerned and local challenges and governance structure.

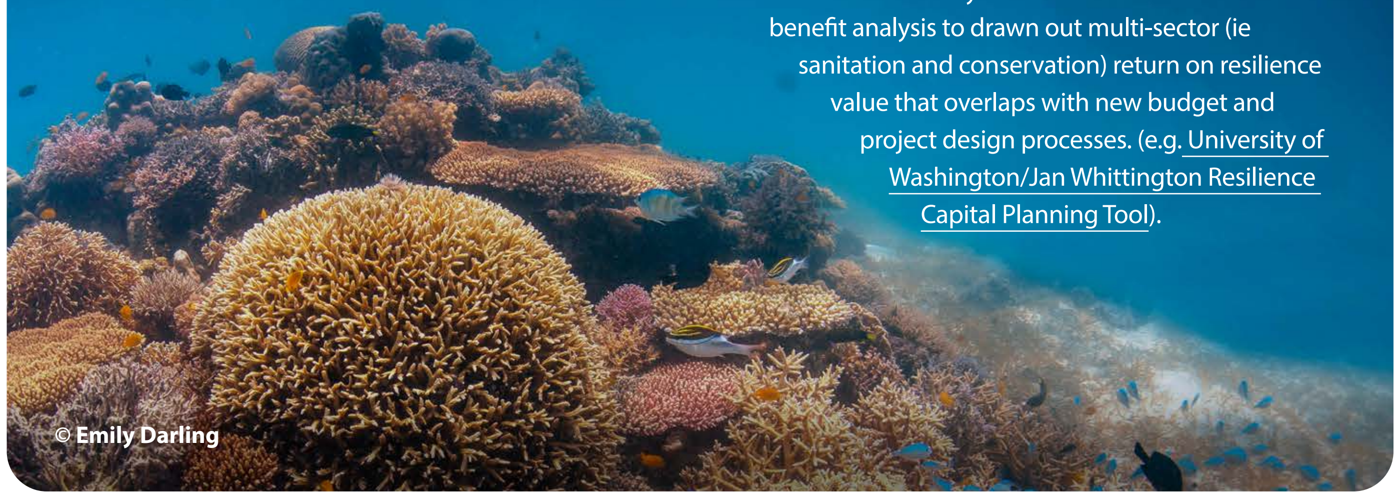

©Stewart Sarkozy-Banoczy

While not exclusively the intersection of conservation and sanitation sectors, this partnership and the Protocol are examples of the planning, project design, financing and implementation that the sectors require for best practice and success in successful blending of investment sources of all types in projects that are meant to benefit both conservation and sanitation.

https://climatechampions.unfccc.int/wp-content/uploads/2022/09/Investment-Protocol-for-Coastal-Cities-Adaptation-and-Resilience.pdf

However, as mentioned in Section 2, both sectors (and their overlapping sectors) struggle to secure project planning funding, let alone the large-scale capital investments needed for sanitation infrastructure or the ongoing investments into environmental management. A lot has been written about sustainable financing for each sector (ADBI, 2022; Cabrera et al., 2021; Emerton et al., 2006; OECD, 2019b; UNICEF, 2022). Integrated conservation and sanitation programs create additional complexity that will influence how projects are funded. Based on the experiences of members of the SNAPP working group, we outline several recommendations related to funding integrated programs:

1. **Leverage Conservation Funding but Acknowledge some Barriers:**
   - Recognize the potential for conservation funds to be invested in sanitation programs, especially in light of the harmful effects of wastewater pollution on coastal marine ecosystems.
   - Acknowledge the need for additional evidence of wastewater impacts to coastal marine environments to get funding that might otherwise not be needed for sanitation-only focused projects.
   - Appreciate the fact that conservation funders may lack experience in gray infrastructure investments. Therefore, further time investment for enhanced communication and knowledge sharing will be needed between sectors.
   - Acknowledge the absence of clear policies in some conservation organizations and government agencies regarding infrastructure investments.
   - Recognize that integrated sanitation and conservation programs may not always align with specific conservation funding themes and may only partially fund projects.
   - Reinforce linkages related to newer sectoral funding mechanisms for adjacent funding pools to allow for the inclusion of sanitation. (e.g. Urban Water Resilience Initiative - African Cities Water Adaptation Fund (ACWA Fund).
2. **Allocate Additional Resources for Integrated Programs:**
   - Understand that integrated conservation and sanitation initiatives typically demand more resources during planning, design, and monitoring compared to single-sector projects.
   - Longer term funding commitments up to 10+ years are needed to support the relationship building, policy and enabling environment strengthening, and business model development to ensure long-term success of projects.
3. **Navigate Government Budget Challenges:**
   - Acknowledge that government agencies often have allocated budgets for priority projects or areas. Multi-sector projects with a broader range of actors could either have an advantage in funding approval if efficiencies are articulated or could struggle by not clearly fitting into one sector's agenda.
   - Recognize that the prioritized locations for sanitation and conservation projects may not always align. Hence, it is crucial to understand, based on evidence, pollution dispersal pathways that link source and impact areas in different locations.
   - Adopt emerging holistic government capital planning and project design tools to integrate existing or proposed funding at a variety of scales, instigating a "multi-criteria analysis" rather than standard cost-benefit analysis to drawn out multi-sector (ie sanitation and conservation) return on resilience value that overlaps with new budget and project design processes. (e.g. University of Washington/Jan Whittington Resilience Capital Planning Tool).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4. Strategic Identification of Priority Locations:

- During project scoping, identify investment priority locations for each sector. The development of integrated projects in priority locations for both sectors could lead to early wins that create political will and improve confidence in funders for investing in integrated programs.
- Align project planning stages with the funding priorities of both conservation and sanitation sectors to leverage funding from both sectors.

5. Formation of Funding Consortiums and Investment Platforms: Consider creating funding consortiums and investment platforms (see example, Box 16) dedicated to integrated programs to streamline the project preparation and funding acquisition process.

- Limited and short term grants are often stitched together inefficiently to ensure project planning activities can continue and require a major time investment to acquire. More dedicated and longer-term funding sources for early planning stages would improve efficiency and allow more projects to move forward.
- Identifying and implementing sustainable revenue-generating models to support ongoing operations and maintenance of sanitation systems and programs is a major challenge for ensuring long term viability of solutions. Support from finance experts in designing a menu of solutions could assist practitioners in identifying an appropriate solution for their local need while considering ocean health.
- Development of a suite of one-stop shop finance products that meet the needs of the full project cycle from science and relationship-building to long term operations could speed up the pace and scale of achieving improved sanitation and ecosystem health outcomes.

6. Address Related Challenges:

- Establish a strong enabling -environment for the development of more robust water quality / wastewater discharge standards and their enforcement.
- Develop ownership and revenue-generation models to support ongoing operation and maintenance of sanitation systems and programs. Such business models can consider the conservation sector as a funding contributor as long as there are ecological benefits. (e.g. Washington DC Stormwater Retention Credit Trading Program)
- Update instruments of the enabling environment that not only promote policy integration, coordination, and cooperation between sectors but also that allows for the adoption of innovative and non-conventional solutions (e.g., nature-based solutions, water sensitive urban design, resource recovery, including training-related activity and project certifications like the Waterfront Edge Design Guidelines (WEDG))

7. Explore Payment Integration Models: Assess the feasibility of combining payments for wastewater management with water or energy provision where applicable.

8. Diversification of funding sources: Explore innovative financial instruments including those around blue economy (e.g., ODA, blue carbon market, payments for ecosystem services, debt-for-nature swaps, payment for watershed services, blue/green bonds).

- In regions where payment integration is not feasible, explore innovative public-private partnership models.
- Build an enabling policy environment for the adoption of a variety of financial mechanisms that can help practitioners build business models and finance solutions for the broader life cycle of these projects, including non sanitation and non conservations origin sources that hold the responsibility for taking major infrastructure steps (e.g. government/municipality entities beyond sanitation and environment).
- Use the integration of global agreements (e.g. SDGs) with the creation of expanding types of investment products (e.g. resilience taxonomy and quantifications for nature based solutions for climate/blue/green bonds from the Climate Bonds Initiative).

9. Integrate nature-based solutions and blue economy instruments into Laws and Regulations: Ensure that nature-based solutions and its co-benefits are integrated into laws and regulations as a preferred type intervention when appropriate and leverage their economic benefits through the use of blue economy instruments.

10. Align Financing, Building Codes, Zoning, Insurance, and other instruments of the enabling environment: Align building codes, zoning regulations, insurance policies, and financing mechanisms to enable municipal budgets to be adjusted and prioritized for critical sanitation and conservation projects. (e.g. the International Code Council-Alliance for National and Community Resilience "Community Resilience Benchmarks")

11. Policy coherence for human and ecosystem health: Foster coherent institutional, policy and regulatory frameworks for financing that equally promote human and ecosystem health across government levels and sectors.

12. Learn from other Places: Creating and sharing examples and case studies of financing solutions for sanitation projects that account for ecosystem health and leverage its benefits, will help practitioners to identify the best fit and supporting policy needed to advance these efforts, particularly in remote areas and challenging environments. (e.g. Cities Climate Finance Leadership Alliance, Ocean Sewage Alliance, Water Finance Coalition)

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BOX 17

Wastewater treatment in West End, Roatán, Honduras Part 3

Prepared by Tanya Amaya and Pamela Ortega from the Coral Reef Alliance (CORAL)

Operation of the wastewater treatment plant in West End is expensive due to high energy consumption. Other resources were needed to fund the wastewater treatment plant in West End in addition to a 10 to 12-year investment in governance, infrastructure and capacity building. The strategy to address such needs involved investing in fundraising with donors and foundations to ensure that what was achieved could continue progressing in the future. The government supported interventions but did not have the technical and financial resources to contribute to existing efforts. **Investment in solar panels, nonetheless, resulted in 50% savings in electricity costs**.

One of the challenges in finding capital, operation, and maintenance funds was the need to secure funding from multiple sources, which required a huge time commitment in identifying and applying for different. There were barriers to obtaining funds, one of them was limited access to private banking with considerable interest rates (20-30%). Additionally, at the beginning of the project, it was harder to secure conservation funds. However, with the success of the project, it is more clear to conservation donors the value of investing in wastewater treatment for coral reef conservation. Building a strong network of partners was key to help Polo's Water Association to get support from the public and private sector such as donors and conservation NGOs. This helped to promote collaborative problem-solving, planning and fundraising as a result of coordination of several organizations that decided support, advocate and investment.

One of the ongoing challenges in wastewater treatment is the need for sustainable and reliable financing. There were two approaches that were implemented in order to address this challenge and build a community-based management model. The first was to improve access to water as the basis of the service. Since Polo's is a community association this was a clear priority that later opened the possibility to begin working on sanitation improvement and wastewater treatment. The way it works is that households are connected to the treatment plant and have to pay a fee for this service. However, in return, households receive potable water on a daily and consistent basis. This water quality is also periodically audited by a third party laboratory that Polo's pays for. Initially, users paid a flat fee, however, now households have individual meters that monitor water consumption and users pay based on how much they consume. This allows for the treatment plant to better understand who is using their service. Connection was voluntary at the start, but is now enforced through a municipal ordinance.

At first there was strong resistance to being connected to the treatment plant and having to pay a fee. However, with several community awareness measures combined with success in the treatment plant, community support has risen substantially. **In 2023, fee collection was at 85%.** However, COVID-19 and its impact on tourism brought fee collection down to **25% in 2020 until most of 2022**, highlighting the challenges that external shocks have on revenue streams and the need to have diversified revenue streams. Creating this revenue stream has allowed Polo's to invest in improvements in the plant in collaboration with partners. However, fee collection needs to be higher to enable continued investments, as well as identifying other sources of revenue that build financial resilience into the system. Polo's success at operations and revenue generation has meant that they are in a stronger position to meet the conditions required for commercial finance investments. Polo's is now engaging in peer to peer exchanges with other service providers in the country to talk about their success, facilitated by CORAL, demonstrating the important role that conservation organizations can play in this space.

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7. Conclusions

There is significant opportunity for conservation and sanitation to work together to achieve multiple local, national, and international goals for both sectors. However, there are still several barriers that need to be overcome to improve collaboration and coordination. We leave you here with our reflections and recommendations for next steps.

1. **Cross-sector collaboration is hard but necessary.**
   It requires learning about how a new sector operates and interacting with an entirely new cohort of professionals. Inevitably, when learning about a new field, you will make unintentional mistakes about how that field operates. These mistakes should be addressed without judgment and be treated as a learning and teaching opportunity. Working towards a shared vision means committing and re-committing yourself to helping the other sector learn about how your sector works, and to learning about how their sector works.

2. **There needs to be more opportunities for dialogue.**
   Conservation and sanitation conferences and professional events should prioritize inviting members of the other sector to give keynote addresses and organize sessions or workshops. It is only through sustained interactions will collaborations between conservation and sanitation at all levels become the norm.

3. **Reducing wastewater pollution needs to be at the forefront of climate-resilient strategies for coastal and marine ecosystems and coastal communities.**
   There is abundant evidence that wastewater pollution makes them more vulnerable to climate change impacts, which in turn makes communities reliant on coastal and marine ecosystems more vulnerable to climate change.

4. **Many countries lack the policy framework or coordination mechanisms that will enable integrated projects.**
   This is not only a challenge for collaboration between conservation and sanitation, but also for other development challenges where multiple sectors must work together. If we are to be successful in achieving the international goals we have agreed to, integrated policies,programWWand approaches must be implemented. This starts through building the awareness and the capacity of different stakeholders (see section 4.2) on why collaboration is required.

5. **There are significant data gaps that hinder our ability to effectively manage wastewater pollution.**
   As a priority, we need more research to support the development of wastewater discharge standards. In addition, ecological monitoring programs must record information about the sanitation systems in place, to allow us to better understand the sanitation conditions that both degrade coastal marine ecosystems and have limited impacts. This will allow us to prioritize and steer conservation investment into sanitation projects.

6. **Funding and financing entities require additional blending in investment products and project design**.
   In coordination with government planning and budgets (coordinated with good policy enforcement), the integration of sanitation and conservation, as with other thematic funding and financing pillars, will encourage more robust change and intersections from a variety of scales and contexts globally.

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APPENDIX 1.

Impacts of wastewater pollution on coastal marine ecosystems

Table A1: Impacts of wastewater pollution on tropical coastal marine ecosystems, and marine species. We have included both observations that have been observed through exposure to wastewater pollution in the environment, as well as impacts from specific pollutant groups assessed in laboratory

Pollutant	Impact on Mangroves	Impact on Seagrass	Impact on Corals and Coral Reefs	Impact on Marine Fish or Other Species
Wastewater	o Physiological alterations and decreased abundance of key mangrove engineer species (Theuerkauff et al., 2020). o Reduction of the symbiotic relationship between mycorrhizal fungi and mangrove roots (Wang et al., 2014).	o Significant reduction of seagrass cover (Bryars and Neverauskas, 2004). o Decrease in leaf length, surface area and biomass; changes in epiphyte community composition on leaves and rhizomes (Mabrouk et al., 2013).	o Coral disease (Lamb et al., 2017). o Coral growth anomalies and algal overgrowth (Aguiar et al., 2023). o Increased bioerosion (Prouty et al., 2017) o Degradation of reefs, death of coral, phase shifts in community composition, and reduced resilience (Lachs et al., 2019).	o Residual concentrations of antibiotics in benthic marine ecosystems contribute to an increased selection of antibiotic resistant genes in the microbial community (González-Gaya et al., 2022). o Juvenile fish exposed to contaminated estuaries decreased nearly half the survival rate compared to non-impacted fish (Meador, 2014). o Organs pathologies observed in fish, particularly in gills and liver, whose severity is directly related to proximity to a wastewater outfall (Corbett et al., 2015). o Hemorrhages in fins, abdomen, and around the mouth, and severe infection of the spleen in dead fish from a massive fish kill linked to wastewater pollution (Al-Marzouk et al., 2005).
Heavy Metals	o Accumulation in plant tissues, particularly the root system (Lewis et al., 2011). o Heavy metals are transferred to species that consume mangrove or their products (Sandilyan and Kathiresan, 2014). o Release of heavy metals under stress conditions (Sandilyan and Kathiresan, 2014). o Reduced plant growth and biomass (Yim & Tam, 1999)	o Metals accumulation in tissues, resulting in decreased biomass (Martin et al., 2022) and impaired photosynthetic efficiency (Li et al. 2023). o Sublethal effects at high concentrations: leaf necrosis, reduced shoot growth and recruitment (Li et al., 2023).	o Bioaccumulation, reduced fertilization (Reichelt-Brushett & Harrison, 2005), reproductive success, settlement, and survival of coral larvae (Goh, 1991). Population and growth alterations in endosymbiotic algae (Kayser 1976; Harland & Brown, 1989), o Increased tissue bleaching and death (Sabdono, 2009).	o Accumulation of heavy metals in arthropods and mollusks, cnidarians, and large fish, with greater levels in bottom-dwelling species (Fu et al., 2014). o Accumulation of heavy metals in fish organs such as kidney, liver, gills, skin and muscles (Afzaal et al., 2022). o Increased spinal deformities (Foley et al., 2022). o Reduced fecundity and fertilization success (Taslima et al., 2022). o Increased shape abnormality in reproductive organs, low embryo and larval survival and growth rate, growth retardation, skeletal deformities, premature and delayed hatching, increased rates of edema and visceral hemorrhage, decreased feeding rate, eye absence or abnormalities (Taslima et al., 2022).

Pollutant	Impact on Mangroves	Impact on Seagrass	Impact on Corals and Coral Reefs	Impact on Marine Fish or Other Species
Nutrients	o Nutrient enrichment causes a shift from belowground to aboveground productivity), leading to increased canopy height and rate of growth (Weaver & Armitage, 2018) but destabilization of root systems (Lovelock et al., 2009). o Nitrogen enrichment decreases resilience during drought by increasing tree mortality (Lovelock et al., 2009).	o Decline in shoot density, increased biomass, increased leaf and internode length (Cabaço et al., 2008). o Increased eutrophication and shift to a community dominated by macroalgae, epiphytes, (Cabaço et al., 2008), and phytoplankton (Gómez et al, 2022). o Necrosis in plants after exposure at specific ammonium concentrations, decrease of biomass, leaf, and internode length caused by high ammonium concentrations (Cabaço et al., 2008). o Anoxia and death (OSA, 2021; Wear et al., 2022). o Reduction in light availability, decreased photosynthesis and respiration rates, stress on physiology and growth (Jiménez-Casero et al., 2023).	o Nitrate: Increase in zooxanthellae density, chlorophyll-a concentration, photosynthetic rate and decreased growth and survival (Nalley et al., 2023). o Phosphate: increase in zooxanthellae density, reduction in photosynthetic efficiency, increased coral growth rate (Nalley et al., 2023). o Excess phosphorus in combination with other pollutants impairs calcareous skeleton formation, making coral structures fragile (Dunn et al., 2012). o Reduction on fertilization and coral larvae production (Loya et al., 2004), slow skeletal growth rate (Stambler et al., 1991). o Decreased growth of symbiotic microalgae (Muscatine, 1990) and subsequent limits carbon availability for coral growth and calcification, impacting skeletal densities and homeostasis (Fabricius, 2005; Holcomb et al., 2010; Langdon and Atkinson, 2005; Loya et al., 2004; Stambler et al., 1991). o Shift in community composition from slow-growing coralline algae to fast-growing algae, leading to reduced larval recruitment, coral growth and survival (Häder et al., 2020). o Increased vulnerability to bleaching (Donovan et al., 2020) and disease (Voss and Richardson, 2006; Bruno et al., 2003). o Reduced skeletal density due to increase of bioeroding organisms (Edinger et al., 2000).	o Driver of observed fish kills (Wear et al., 2023). o Changes in resource fish biomass across years with important reductions (Foo et al., 2021). o Eutrophication alters the gut microbiome diversity in fish, with potential implications in loss of functions (Degregori et al., 2021).
Sediments	o Mangrove death due to root smothering by excess sediment deposition (Ellison, 1999; Nardin et al., 2021).	o Significant decrease in survival rates at high burial depth (Benham et al., 2019). o Decreased shoot density and reduced growth rates as sediment burial increases(Benham et al., 2019). o Decreased photosynthetic activity and efficiency, reduced O2 exchange between leaf tissue and surrounding water at night, reduced internal aeration, and reduced below-ground tissue oxidation capacity (Brodersen et al., 2017).	o Reduced photosynthesis, growth rate, and fertilization success, limited larval settlement, local coral bleaching, partial mortality and death of adult colonies, death of larvae and juveniles (Tuttle & Donahue, 2022). o Reduced recruitment (Szmant, 2002). o Coral disease (Pollock et al. 2014)	o High proportion of sediments in fish stomachs (Britton et al., 2019), gill clogging (Bruton, 1985), and hypertrophy resulting in decreased growth rate (Sutherland & Meyer, 2007). o Sublethal and lethal impacts in fish at different life stages with greater effects when sediment is contaminated (Wenger et al., 2016). o Grazing impaired in herbivores, leading to algal overgrowth and replacement of corals as the dominant cover (McField et al., 2020; McField et al., 2022).

Pollutant	Impact on Mangroves	Impact on Seagrass	Impact on Corals and Coral Reefs	Impact on Marine Fish or Other Species
Pharmaceutical and personal care products	o High levels of antibiotics in shrimps with potential harmful effects on ecosystems (Le & Munekage, 2004).	o Accumulations of sunscreen UV filters and a type of paraben conservative on rhizomes (Agawin et al., 2022).	o Caffeine is accumulated in coral reefs and their inhabitants (Vieira et al., 2022). It induces oxidative stress, neurotoxicity, and negative effects on reproduction and development (Vieira et al., 2022). o Photoinhibition and bleaching in cnidarians exposed to UV filters through induction of viral infection on symbiotic microalgae (Danovaro et al., 2008). Polyp retraction as response to UV filters (Conway et al., 2021). o Native microbial community was dramatically reduced by antibiotics, which favored opportunistic organisms (Sweet et al., 2011). o Reduced invertebrate reproductive capacity by affecting gametes and fertilization success and altering motility and swimming velocity (Mohd Zanuri et al., 2017).	o Anti-inflammatory, psychiatric, and cardiovascular drugs can cause oxidative stress, activation of immune responses, genotoxic damage, DNA fragmentation or damage, impairment of reproductive capacity and endocrine system, and a decrease in resources for growth and reproduction on mussels, oysters, crab, clam, and cuttlefish (Mezzelani et al., 2018). o Antidepressants, psychiatric drugs and other pharmaceuticals induce behavior alteration such as decreased territorial aggression in coral reef fish, increased boldness, changes in locomotion and sociality, reduced feeding rate and activity, and increased male dominance (Brodin et al., 2014). o Chronic exposure to low levels of estrogen, induces feminization of male fish (Hamilton et al., 2022). o Antidepressants can be accumulated in fish liver, plasma, brain and muscle. Higher temperatures increase its uptake in brain and elimination in liver is impaired by acidification and warming conditions (Maulvault et al., 2018).
Pathogens	o No information available	o Seagrass provides conditions for fecal indicator bacteria to grow (Ferguson et al., 2016).	o Severe bleaching, tissue necrosis and death (Ben-Haim & Rosenberg, 2002). o Coral disease and massive die-off events (Sutherland et al., 2011).	o Ingestion of human fecal bacteria resistant to antibiotics (Al-Bahry et al., 2009). o Bacteria penetration and colonization of fish tissues such as muscles, skin and digestive tract (Niewolak and Tucholski, 2000). o Lesions in the epithelium of the skin and gills of fish caused by human fecal bacteria (Da Silva Souza et al., 2020) as well as in kidney (Topić Popović et al., 2019). o Contamination of fish gills with yeasts and molds from sugar beet effluent (Topić Popović et al., 2019).

Pollutant	Impact on Mangroves	Impact on Seagrass	Impact on Corals and Coral Reefs	Impact on Marine Fish or Other Species
Microplastics	o Mangrove microplastics work as reservoirs for pathogenic species to develop antibiotic resistance and spread (Tan et al., 2022; Sun et al., 2022). o Accumulation of microplastics among mangrove roots (Shelciya et al., 2023). o Microplastic ingestion by mangrove resident species (Fang et al., 2023).	o Seagrass meadows act as sink for microplastics which can be attached or embedded in seagrass blades and then ingested by herbivores (Walther & Bergmann, 2022). o Seagrass dwellers exposed to microplastics (Walther & Bergmann, 2022). o Microplastics present in seagrass can be transferred to other organisms such as fish, through herbivory (Goss et al., 2018). o Reduced number of leaves per shoot, root degeneration, impaired photosynthesis, increased oxidative damage and stress (Menicagli et al., 2022).	o Coral bleaching and tissue necrosis (Reichert et al., 2018; Syakti et al., 2019). o Impaired prey capture (Mouchi et al., 2019) and reduced growth under chronic exposure (Mouchi et al., 2019; Reichert et al., 2019). o Disrupt host-symbiont signaling, photophysiological stress, metabolic alterations, increased mucus production (Lanctôt et al., 2020) o Increased oxidative stress, apoptosis and ion transport in symbiont algae. Decreased detoxification activity, nutrient uptake, photosynthesis, and altered gene expression (Su et al., 2020). o Impair coral feeding efficiency by reducing food intake (Savinelli et al., 2020) o Reduced calcification and skeletal growth rates (Chapron et al., 2018).	o PVC modifies the composition of marine microbial assemblages (Focardi et al 2022) and impairs reproduction in zooplankton (Zimmermann et al., 2020). o Microplastic accumulation in fish tissues (John et al., 2022). o Ingestion, accumulation of microplastics with subsequent obstruction of the fish digestive system (Lusher et al., 2013). o Exacerbated the impacts of endocrine disrupting chemicals, leading to growth inhibition and retardation, reduced weight, damage of reproductive organs (Wang et al., 2022). o When ingested microplastics substitute food, there are detrimental effects on growth, physiology and body condition (Critchell and Hoogenboom, 2018). o Persistent organic pollutants contained in microplastics are able to transfer to fish and prolonged exposure increase bioaccumulation (Wardrop et al., 2016). o Pollutants contained in microplastics can induce physiological alterations such as endocrine disruption (Rochman et al., 2014).

APPENDIX 2.

Full integrated planning framework from a first analysis in the SNAPP working group to identify how work from both sectors can be integrated

Step #	Description	Activity Details	Products (Outputs)	Completed by who	Sections and Resources with Additional Information
1	**Initial problem framing; making a case for action**	Determine if coastal marine ecosystems are vulnerable to wastewater pollution. **Notes:** o If public data is available then that can be collated. o If no public data is available then the initial assessment can be completed by observations and talking to people who know of the situation.	**1.a** Risk screening matrix with results. **1.b** Develop a short report/presentation outlining the findings for action around the problem, and the need for stakeholders to engage. Link to known targets from frameworks such as the Sustainable Development Goals **Notes:** o Consider translating the short report/ communication into local language as appropriate	Concerned stakeholders - could be a single organization or individual	**Section 5.2:** Evaluating the risk to coastal marine ecosystems from wastewater pollution **Appendix 4:** Risk screening to assess whether coastal ecosystems and resources are vulnerable to wastewater pollution.
2	**Engage key stakeholders**	**2.1** Conduct a detailed stakeholder analysis and identify the key stakeholders associated with sanitation, wastewater pollution, and conservation. This includes those contributing to and affected by the polluting sources, including users of the receiving environments, as well as relevant government agencies, and private enterprises. **2.2** Approach key stakeholders individually and share the problem statement and invite them to participate. Ensure you have considered gender, equity and social inclusion (GESI) factors in your stakeholder selection.	**2.a** A detailed stakeholder map that includes key contacts and their role/motivation behind **2.b** Collated stakeholder feedback on the engagement and their willingness to engage **2.c** Meeting details from an open stakeholder consultation, including any new stakeholders to engage with.	If existing, a coordination body can be tasked with these activities. If not, this is a good opportunity for its creation, when appropriate. If there is no coordination body, activities could be conducted by the same concerned stakeholder from Step 1 or similarly minded stakeholders at this stage.	**Section 4.2:** Who should be involved?

Step #	Description	Activity Details	Products (Outputs)	Completed by who	Sections and Resources with Additional Information
3	**Form a multi-sector working group**	3.1 Based on stakeholder engagement, create a multi-sector working group and invite stakeholders. It is critical that government partners are included. 3.2 In the first working group meeting, decide on a clear vision and objectives to articulate how you will work together (e.g., guiding principles). 3.3 Assess the information you have available and map out what additional information may be needed. o have a plan as to how to engage with key stakeholders who chose not to be part of the multi-sector working. One option is to keep them passively informed of actions from the group via reports or emails. o it may not be possible to decide on a vision and objectives at this stage due to lack of information. This can wait until after the next step	3.a Working group structure and list of stakeholders (including contact details). Choose a lead or chair position. 3.b Drafted joint working groups vision (joint objectives if possible), decision making processes, communication plans, information needs and broad timeframes. 3.c List of information needs and how they can be filled (for example spatial maps and water quality data)	A coordination body and/or willing working group members	Section 4.1: How to partner Section 4.2: Who should be involved?
4	**Conduct a detailed pollution risk assessment**	4.1 Design a data collection methodology based on the list of data you identified in the previous step and your available resources. 4.2 Complete a detailed risk assessment of the pollution sources and receiving marine ecosystems. Include future risk projections as populations and climate change. Notes: o If you do not have financial or other resources to collect data then you can proceed with using logical estimates in your risk assessment o Revisit your scope and vision for the working group after the completion of this step	4.a A report that analyzes the data sets on the pollution types, locations and loads along with the data sets on the health and impacts on the receiving ecosystems. 4.b A completed risk assessment that identifies both the current and future impacts of pollution on the receiving coastal and marine ecosystems.	Assigned tasks to key working group members. If financial resources are present, a technical consultant could be engaged also.	Table 4: Examples of sources of information that can be used to conduct an in-depth risk assessment. Appendix 5: A risk assessment of wastewater pollution in Australia

Step #	Description	Activity Details	Products (Outputs)	Completed by who	Sections and Resources with Additional Information
5	**Assess the implementation environment**	5.1 Complete an assessment of the enabling environment where the project will be implemented to understand the conditions in place and weaknesses in the system that could hinder implementation and long-term sustainability of interventions. 5.2 Conduct policy mapping to understand how the current policy environment interacts with both the problem and opportunities for interventions.	5.a An assessment of the opportunities and threats present – strengths, weaknesses, opportunities or threats (SWOT) or other appropriate tool. 5.b A report on the alignment and any gaps in policies with respect to laws and accompanying regulation as well as with other elements of the enabling environment Note: o Often the law and regulations can be in-place but the enforcement piece is missing	Working group members, coordination body, or work conducted by a consultant if financial resources are present	Section 5.2: Evaluating the risk to coastal marine ecosystems from wastewater pollution Section 5.3: Aligning and coordinating efforts to better achieve integrated outcomes. Institutional and Coordination Mechanisms Self Assessment - Organisation for Economic Co-operation and Development Strengthening Enabling Environment for Water, Sanitation and Hygiene (WASH)
6	**Design interventions to reduce the risks and impacts**	6.1 Agree on desired project outcomes and identify potential interventions to achieve them, considering a range and mix of suitable interventions appropriate for the specific context, including those focused on strengthening the enabling environment, behavior change approaches, technology options, and nature-based solutions. 6.2 Use a structured decision-making framework to identify and prioritize interventions by using methods such as multi-criteria decision analysis, return of investment or cost-benefit analysis. 6.3 Develop a costed implementation plan. 6.4 Develop a plan operation and maintenance of infrastructure, including options for funding and a hand-over plan, if relevant. 6.5 Conduct an assessment of the project team, partners, and local expertise to ensure all necessary skills are covered. For instance, if no sanitation contractors are available, then capacity building and training will be required. This also includes someone who can analyze and report on the monitoring data and project progress. 6.6 Communicate and review the implementation plan with stakeholders for feedback and approval.	6.a An implementation plan that includes the shortlisted options from a range of interventions of different costs that can be implemented by different stakeholders 6.b Report with the results of the skill assessment showing those in place, missing and options for full coverage Note: o Government commitments to finance work (especially pollution source fixes) can be gained but require a planned strategy of how to link into their objectives and funding cycles.	Working group members or conducted by a consultant if financial resources are present	Section 5.4: Setting pollution reduction targets Box 5: Community-based WASH planning and management in Papua New Guinea Box 6: Integration of conservation and sanitation through nature-based solutions Box 7: Evaluating the ecosystem and health benefits of investment in improved wastewater treatment in pilot sites in Panama and Trinidad and Tobago Box 8: Failure to implement project funded sanitation infrastructure – reflections from Fiji Valuing the Costs and Benefits of Improved Wastewater Management: An Economic Valuation Resource Guide for the Wider Caribbean Region What Does It Take to Scale Up Rural Sanitation? Rural Sanitation Programming in Challenging Contexts: A desk based review Compendium of Sanitation Systems and Technologies Compendium of Sanitation Systems and Technologies for the Wider Caribbean Region Guide to Sanitation Resource Recovery Products & Technologies Nature-Based Solutions for Wastewater Treatment: A Series of Fact sheets and Case Studies Wastewater? From Waste to Resource

Step #	Description	Activity Details	Products (Outputs)	Completed by who	Sections and Resources with Additional Information
7	**Identify funding options and secure financing*** **In practice, funding will be needed to complete Steps 1-6 and options for this are discussed in **Section 6***	7.1 Identify and secure resources for prioritized interventions, including monitoring and evaluation. 7.2 Plan for the long-term financial sustainability of the implementation activities. Consider key questions: What entity will own and operate the infrastructure long term? Is revenue sufficient or will additional funding be needed? If so, how will resourcing of on-going implementation be financed?	7.a Grant applications and concept notes to solicit funding or confirmation of budget assignation from existing sources **Note:** ○ Government commitments to finance work (especially pollution source fixes) can be gained but require a planned strategy of how to link into their objectives and funding cycles.	Lead implementing organizations and/or the coordination body	**Section 6:** Financing integrated approaches Sustainable Ocean for All : Harnessing the Benefits of Sustainable Ocean Economies for Developing Countries Blue Carbon Handbook Developing Water, Sanitation and Hygiene (WASH) Finance Strategies A Guide | UNICEF Making Blended Finance Work for Water and Sanitation Securing Sustainable Financing for Conservation Areas
8	**Design a monitoring and evaluation framework**	8.1 Develop social and ecological indicators of progress and success for agreed upon outcomes. 8.2 Identify monitoring and evaluation approaches to collect data on indicators, including mid-project evaluations. Diverse forms of knowledge, including anecdotal evidence, storytelling, and the experience of community leaders can be used for understanding environmental patterns, impacts of sanitation practices and climate, and traditional practices within the community. 8.3 Develop a communication plan for how to communicate progress of the project to key stakeholders. **Notes:** ○ Be prepared that any intervention could take time to result in pollution reduction and positive impacts on the receiving ecosystem.	8.a Monitoring and evaluation framework 8.b Data analysis and communication plan.	Lead implementing organizations and/or the coordination body	Organizing Framework for Functional National WASH Monitoring and Evaluation Systems - Sanitation Learning Hub Global Seagrass Monitoring | Seagrass Data Collection Manual for mangrove monitoring in the Pacific Islands region Methods for Ecological Monitoring of Coral Reefs

Step #	Description	Activity Details	Products (Outputs)	Completed by who	Sections and Resources with Additional Information
9	**Implement activities**	**9.1** Once interventions have sufficient resources secured then commence implementation **9.2** Ensure activities, responsibilities, timeframes, methods, or approaches are well-defined among the involved parties before beginning. **9.3** Ensure required resources are in place, e.g., equipment, personnel, facilities, approvals, etc. **Note:** o If there are multiple interventions being implemented on different timeframes then this step will be repeated along with the monitoring and evaluation	**9a** Implementation plans, contracting, project management by the lead organizations as appropriate **9.b** Develop communication plans and material as appropriate	Lead implementing organizations and/or coordination body.	
10	**Monitor, evaluate, and adapt management interventions as needed**	**10.1** Assess if the interventions implemented have achieved the project outcomes using indicators of success. It may take several years before any ecosystem benefits are achieved. Ecosystem recovery might not be apparent where multiple coastal ecosystem stressors are present. In these cases, reducing wastewater pollution should be one part of a holistic conservation strategy to address local stressors. **10.2** Community engagement and awareness-building are important for monitoring efforts, particularly in areas with insufficient governmental resources. Simple and accessible monitoring programs supported by local NGOs can help bridge connections between communities, governments, and the private sector. **Note:** o If there was insufficient resourcing or lack of effective implementation of interventions it is possible that the working group will have to be disbanded without having met the original objectives.	**10.a** A report capturing the findings from the monitoring and evaluation, lessons learned, and progress towards outcomes. **Note:** o It is possible that the original vision and objectives might have been too ambitious. Capturing this will be useful for future implementation projects.	Organization assigned for monitoring and evaluation (best to be independent of the implementing organization, such as the coordination body)	**Box 11:** Holistic water pollution management in action: Tampa Bay

APPENDIX 3.

Questions to guide funding and financing discussions to address sanitation projects

Ownership Models for Infrastructure Solutions
Who will build the utility?
Who will own the utility into the future?
How will the ownership model directly impact the source of funds?

Ownership Models for Infrastructure Solutions
Where does the money for infrastructure come from (source)?
What collateral is needed?
Who needs to receive the funds?
How do the funds get to the appropriate entity?
Where does funding for initial studies and engineering feasibility (communication, community willingness, design, environmental impact assessment)?
Are there funds available for community scale solutions?

Funding for sustainable infrastructure
How do you mandate connection to community scale solutions to make it more affordable (Increasing used base will decrease cost to those connected.
Who conducts the operation and maintenance (O&M) of the utility?
How does ongoing O&M of infrastructure happen over the life of the infrastructure?

APPENDIX 4.

Risk screening to assess whether coastal ecosystems and resources are vulnerable to wastewater pollution

Factors for Consideration	What it Means
Sanitation System	
Sewered	
Does the wastewater treatment plant discharge to an area of interest?	If yes, this would indicate that there is a higher risk of pollution impacts in the environment.
Is there primary treatment only?	If yes, the discharged wastewater may contain a high load of pollutants because primary treatment only removes sediments that can settle (Allaoui et al., 2015; WHO, 2016).
Is there secondary treatment only?	If yes, the discharged wastewater may contain a moderate amount of pollutants because secondary treatment removes remaining organic matter and suspended particles from the primary effluent (Tahir et al., 2023).
Is there advanced nutrient removal?	Advanced nutrient removal is required to significantly reduce the amount of nitrogen and phosphorus that is discharged, which can cause significant ecosystem degradation (**Appendix 1**).
Is disinfection included in the treatment of waste?	If there is no disinfection, there could be a higher possibility of human disease incidence and exposure of coastal marine ecosystems to pathogens.
Is there tertiary treatment?	If yes, the discharged wastewater likely contributes minimally to pollution because tertiary treatment removes around 99% of pollutants (Allaoui et al., 2015), however it is important to confirm that advanced nutrient removal has also occurred (Paulo Bassin et al., 2021).
Is there combined sewer overflow?	Combined sewer overflows can lead to periodic discharge of untreated waste, especially during intense rainfall events (Dias, 2021).

Factors for Consideration	What it Means
Non-Sewered	
Is there a fecal sludge treatment facility?	If a fecal sludge treatment plant is present, assess for safe operation (e.g. where are treated products disposed of?) and whether waste is making it to the facility, and the level of treatment in place. If there is not a fecal sludge treatment plant then there is a higher likelihood that any emptied fecal sludge may be illegally disposed of on land or water bodies, which would indicate that there is a high risk of pollution impacts in the environment.
Are there collection or emptying services?	If yes, it means there is a system in place to remove waste from decentralized sanitation systems, which reduces the risk of the systems overflowing or malfunctioning. However, it is also important to assess if households are using the services and whether there is a treatment facility that the waste can be taken to.
Is fecal sludge transported to a treatment facility?	If there are emptying and transport services, it is important to assess whether the waste being safely transported to a treatment facility or whether it is being illegally directly discharged into the environment, which would indicate that there is a high risk of pollution impacts in the environment.
Is waste safely treated on-site (see Box 15)?	If there is a high coverage of septic tank systems that are appropriately sited and are treating waste appropriately, then there is less risk, although this is still dependent on the underlying geology (Wiegner et al., 2021). If there are fewer septic tanks and more pit-latrines and other tank type back-ends then there is more risk of fecal sludge leaching/pollution.
Are any latrine back-ends directly discharging into water bodies, including groundwater?	If yes, there are likely direct pollution impacts in the environment.
Does greywater go into a non-sewered system?	If yes, there is an additional volume of wastewater entering back-end systems, which likely has additional pollutant classes, such as detergents, oil, and grease.
Are there visibly polluted drains connected to water bodies?	If yes, direct pollution impacts are likely in the environment.
Proximity to a river or coast	Steeper environments (Wenger et al., 2018), however there is limited information on distance-based risk for pollution impacts. A previous study on nutrient transport from agriculture into water bodies indicates that pollutants can travel distances of over 400 m (Cao et al., 2018).

Factors for Consideration	What it Means
Watershed Characteristics (Runoff and Infiltration)	
Is there sandy soil?	Waste can be easily dispersed, because sandy soils are highly permeable and have high infiltration rates (Earle, 2023).
Is there volcanic or limestone geology?	Waste discharged into these systems is easily transported vertically, because the porosity of volcanic and limestone rocks makes them highly permeable (Wiegner et al., 2021; Earle, 2023).
Is there a high groundwater table?	The likelihood of groundwater contamination is greater if waste from on-site sanitation systems is not well contained compared to areas with deeper water tables (Graham & Polizzotto, 2013; Wiegener et al., 2021).
Is there a sloping landscape?	Precipitation in this landscape type will cause more rapid runoff (Earle, 2023), with the potential of pollution transport to downstream coastal marine ecosystems (Wenger et al., 2018). However, waterways with higher erosion rates may also reduce the risk of waterborne human diseases (Jenkins et al., 2016).
Is there periodic flooding?	Areas prone to flooding present the highest risk of contamination due to the proximity between the base of pit latrines and the saturated zone (Graham & Polizzotto, 2013). Additionally, pit latrines can overflow during flooding events (Tilley et al., 2014), leading to surface runoff of wastewater pollution.
Are there intense rainfall events?	Pollutants are more likely to be transported from pit latrines and leach fields to groundwater because water tables can rise above the bottoms of the pits (Graham & Polizzotto, 2013). Additionally, pit latrines can overflow during rainfall events (Tilley et al., 2014), leading to surface runoff of wastewater pollution.
Is the landscape predominantly modified?	In modified landscapes, there is a greater risk of surface runoff (Rogger et al., 2017).
Are there riparian buffers along waterways?	Riparian buffers play an important role in trapping pollutants before they enter waterways (Cao et al., 2018). Previous studies have identified riparian buffer fragmentation as a key driver in waterborne disease incidence (Jenkins et al., 2016).
Is the area likely to be inundated during a king tide or sea level rise event?	Rising sea levels may mean that some back-end systems that were once above the water table are now periodically submerged, which can affect their performance (Cooper et al., 2016).

Factors for Consideration	What it Means
Marine Transport	
Is there low wind speed?	Wastewater pollution will have a longer residence time if wind-driven flushing is limited, thereby exposing coastal marine ecosystems to pollution for longer periods of time (Geyer, 1997).
Is there low wave energy?	There will be longer residence times for wastewater pollution, thereby increasing exposure risk (Blacka et al., 2021). However, larger waves offshore from a coral reef can increase the likelihood of re-entrainment of pollution as it is pushed back into the reef system (Winter et al., 2020).
Is there limited tidal flushing?	The residence time of pollutants is increased (Alkhalidi et al., 2022; Ganoulis et al., 1988), prolonging the exposure risk.
Is the depth shallow?	The residence time of pollutants is increased (Alkhalidi et al., 2022; Ganoulis et al., 1988), prolonging the exposure risk.
Is the current speed low?	Mixing and dilution of pollutants will be limited (Ganoulis et al., 1988), increasing exposure risk.
Is the system enclosed/ semi-enclosed?	The system's flushing time will be reduced, thereby increasing the pollutant's residence time (Alkhalidi et al., 2022).
Are there coastal marine ecosystems nearby?	The likelihood of negative impacts on species and ecosystems will be greater (Carlson et al., 2021; Hamdhani et al., 2020).

Factors for Consideration	What it Means
Coastal Marine Ecosystems, Ecosystem Services, and Natural Resources	
Are there important spawning aggregations in the area?	There are potentially greater consequences if productivity hotspots for fisheries that have high ecological value are exposed to pollutants (Erisman et al., 2017).
Are there coastal or other marine fisheries?	Wastewater may impact fisheries productivity, with potential impacts on human health (Wear et al., 2023; Wenger et al., 2015).
Is there coastal aquaculture?	Wastewater may impact aquaculture species, with potential impacts on human health and economic gains (Eng et al., 1989; Lai et al., 2018; Razafimahefa et al., 2019). Aquaculture wastewater can also be an additional source of pollution to the system.
Is there reliance on ecosystems for coastal protection, recreational use, or tourism?	Protecting coastal marine ecosystems from different threats, particularly wastewater pollution, is crucial to maintain provided ecosystem services (Carlson et al., 2021) and to reduce human health impacts (Shuval et al., 2003).

Factors for Consideration	What it Means
The Enabling Environment	
Do the key government authorities working on sanitation and environmental/marine protection have clear mandates, roles, and responsibilities (OECD, 2019a; Tsetse et al., 2016; UNDP, 2017)?	Unclear or duplicated mandates, roles and responsibilities have been demonstrated to hinder policy coordination between agencies, particularly when each of them lack sufficient authority and influence to coordinate (Gudgin et al., 1982). It also can lead to duplication, overlap, and contradictions of policy (Peters, 2018; Fopa Tchinda & Talbot, 2023).
Are mandates translated into policy instruments and concrete actions measured with key performance indicators?	For mandates to be actionable, key actions and responsibilities need to be incorporated in relevant planning, regulatory and policy instruments to have an impact through on-ground implementation.
Are there legislated discharge standards or treatment levels in place for wastewater discharge into coastal and marine environments (e.g., wastewater discharge, fecal sludge management, marine water quality)?	Absence of legislated discharge standards or treatment levels represent a direct threat to human and coastal health as there are no legal pollution control measures for government oversight.
Is any government authority responsible for assessing and enforcing compliance with discharge standards?	Lack of an entity in charge of oversight and enforcement of discharge standards leaves ecosystems vulnerable to non-compliant or unregulated discharges.

Factors for Consideration	What it Means
Is there a budget for enforcement of standards?	Insufficient budget will lead to poor/limited enforcement and implementation of regulations (Islam & Islam, 2021) due to lack of resources to perform required activities. This can result in negative impacts to ecosystems by non-compliant discharges.
Are there penalties or fines derived from non-compliance with wastewater discharge or marine water quality regulations?	Absence of action against non-compliant entities promotes the perception that laws and regulations are not taken seriously and that enforcement is not a priority for authorities.
Is there a data system for tracking reliable and timely monitoring data, e.g., wastewater discharged, fecal sludge treatment and disposal, etc. (Tsetse et al., 2016)?	The capacity for collection and analysis of reliable water quality monitoring data is important to guide investment priorities, to assess the condition of aquatic ecosystems and their needs for protection and restoration (Islam & Islam, 2021).
Are there specific discharge or treatment requirements pertaining to sensitive coastal and marine environments?	Due to the range of ecosystem types and hydrodynamic conditions, it is not appropriate to develop a universal set of guidelines or standards that apply equally to all, as optimum water quality characteristics differ between regions (ANZECC & ARMCANZ, 2000). Guidelines should be defined for each individual site based on the local conditions, which can be done by using local reference data and risk-based decision frameworks (ANZECC & ARMCANZ, 2000).
Are sanitation and environmental policies consistent across different planning and regulatory instruments, e.g., permits, building codes, development plans, integrated coastal zone management plans, marine spatial plans?	Policy coherence is necessary to promote synergies and reduce contradictions across policies across different government and policies domains. Policy incoherence is likely to generate practice gaps during implementation and lead to mixed results (Fopa Tchinda & Talbot, 2023).

Factors for Consideration	What it Means
Do policies and regulations respond to future projections and scenarios? E.g., population growth, urban sprawl, climate trends, etc.	The development and implementation of policies should use tools such as strategic foresight and scenario development that enable identification, mitigation, or prevention of potential negative impacts on sanitation systems or coastal marine environments from future states (OECD, 2019a).
Are regular assessments of implemented actions a common practice to understand their effect? (OECD, 2019a)	Regular assessments can work as responsive and adaptive tools to identify, assess, anticipate, and address positive or negative impacts derived from policies. Adoption of ex-ante and ex-post impact assessments are important as well (OECD, 2019a).
What is the state of institutional support and capacity for the institutions regulating wastewater management and environmental protection? e.g., unfilled roles, training needs, etc. (Tsetse et al., 2016)	Institutional capacity is a prerequisite for effective planning and implementation of activities in the sanitation sector, such as service provision (Parkinson et al., 2014). Likewise, it is important for implementation and enforcement of water and environmental laws (Islam & Islam, 2021).
Are the downstream communities or populations of interest well represented and part of the decision-making process in relation to sanitation and ecological interventions/regulations (Tsetse et al., 2016)?	Community engagement is an important element for an effective water resource planning and management (Shahady & Boniface, 2018). Therefore, representation of the broader community is important in decision-making processes in this matter as (Dean et al., 2016a) as community actions have an impact on water demand, water quality, initiatives and policies promoted by the government (Dean et al., 2016b).
Are there long-term water quality and ecological monitoring programs and if so, do the ecological monitoring programs incorporate bioindicators of water pollution into their programs or map and monitor water pollution sources in their area?	Ecological monitoring is an important tool for assessing the state of coastal marine ecosystems. There are a suite of bioindicators for water pollution that should be measured as early warning indicators of water pollution stress occurring in coastal marine ecosystems. In addition, water quality and ecological monitoring should incorporate information about land-use and sanitation systems to improve decision-making about how to improve water pollution impacts.

APPENDIX 5.

A Risk Assessment of Wastewater Pollution in Australia

Prepared by Bianca Eagles

Overview

Queensland, Australia currently has 49 estuarine and coastal outfalls which release their treated wastewater effluent directly off Queensland's coastline. This risks the health of humans in the region due to the presence of over 750 swimming beaches and nearly 100 notable coastal recreational fishing sites. Additionally, Queensland is home to a vast array of coastal ecosystems including salt marshes, mangroves, seagrass beds, and coral reefs that are at risk of being impacted by the effluent.

Our research aimed to prioritize upgrades to wastewater treatment plants (WWTP) in Queensland to sustainably service a growing population and protect human and coastal ecosystem health. The prioritization list was created using a multi criteria decision analysis table with weighted scores to determine which WWTP should be upgraded first. The National Outfall Database was the main source of initial data gathering regarding all the outfalls in Queensland including their location and treatment type. Data on the maximum capacity, average dry weather flow, and equivalent population serviced for each WWTP was obtained by contacting the managing authorities of the WWTP directly and requesting the information. Population growth trends for each suburb were then obtained by the Queensland Governments' population growth reports. This data allowed us to determine whether the WWTP are currently running within their advised operational capacity and, with the expected population increase, whether they will still be within their operational capacity by the year 2041. Data was also obtained from open access websites for all fishing and swimming locations in Queensland, as well as the location of salt marshes, mangroves, seagrass beds and coral reefs. The distance from each wastewater outfall to the nearest fishing, swimming, and coastal ecosystem location was calculated using R Studio. Finally, all water quality data for the last 10 years from each outfall was obtained directly from the Queensland Department of Environment and Science's Water Tracking and Electronic Reporting System (WaTERS). This data included total nitrogen, total phosphorus, dissolved oxygen, enterococci, and fecal coliforms released by each outfall between 2013-2022. We combined all the aforementioned data into a decision analysis table and prioritized the upgrades to WWTP.

Table A2: The data and scoring used to undertake a multi-criteria decision analysis.

		Score				
ID	**Description**	**1**	**2**	**3**	**4**	**5**
1	Treatment type	None	Primary	Secondary	Tertiary	Biological Nutrient Removal
2	Operational Capacity	Currently over operational capacity and will be over in 2041.		Currently under operational capacity but will be over in 2041.		Currently under operational capacity and will remain under in 2041.
3	Average Dry Weather Flow	>8% of all dry weather flow in Queensland is released from this outfall.	>6%-<8% of all dry weather flow in Queensland is released from this outfall.	>4%-<6% of all dry weather flow in Queensland is released from this outfall.	>2%-<4% of all dry weather flow in Queensland is released from this outfall.	<2% of all dry weather flow in Queensland is released from this outfall.
4	Distance to nearest swimming location	Discharge directly into a swimming location.	Discharge >0-<100m to nearest swimming location which aligns with NSW close proximity for swimming beaches guidelines and 100m mixing zone.		Discharge >100m-<700m to the nearest swimming location so it is outside of the mixing zone and close proximity to a beach but still less than maritime vessel requirement.	Discharge >700m using maritime vessel guidelines for discharging treated sewage into the ocean near swimming locations.
5	Distance to nearest recreational fishing location	Discharge directly into a recreational fishing area.	Discharge >0-<100m to account for an acceptable mixing zone (Wastewater Release to QLD Technical Guidelines)		Discharge >100m-<700m to the nearest fishing location so its outside the mixing zone but still under GBRMPA maritime vessel guidelines.	Discharge >700m using maritime vessel guidelines for discharging treated sewage into the ocean near fishing locations.
6	Distance to nearest sensitive coastal ecosystem (salt marsh, mangroves, seagrass or coral reef)	Discharge directly into a sensitive coastal ecosystem.	Discharge >0-<100m to account for an acceptable mixing zone (Wastewater Release to QLD Technical Guidelines).		Discharge >100m-<700m to the nearest sensitive coastal ecosystem so its outside the mixing zone but still under GBRMPA maritime vessel guidelines.	Discharge >700m using maritime vessel guidelines for discharging treated sewage into the ocean near coastal ecosystems.

		Score				
ID	**Description**	**1**	**2**	**3**	**4**	**5**
7	Enterococci	Does not report data	Microbial water quality rank of D (WHO), and over one or more of blue flags swimming limit, primary contact safe swimming limits ANZECC & ARMCANZ (2000), and secondary contact fishing limits ANZECC & ARMCANZ (2000).	Microbial water quality rank of C, under blue flags swimming limits, under primary contact safe swimming limits ANZECC & ARMCANZ (2000), and under secondary contact safe fishing limits ANZECC & ARMCANZ (2000).	Microbial water quality rank of B, under blue flags swimming limits, under primary contact safe swimming limits ANZECC & ARMCANZ (2000), and under secondary contact safe fishing limits ANZECC & ARMCANZ (2000).	Microbial water quality rank of A, under blue flags swimming limits, under primary contact safe swimming limits ANZECC & ARMCANZ (2000), and under secondary contact safe fishing limits ANZECC & ARMCANZ (2000).
8	Nitrogen under slightly disturbed ecosystem limits – estuarine ANZECC & ARMCANZ (2000)	No				Yes.
9	Phosphorus under slightly disturbed ecosystem limits – estuarine ANZECC & ARMCANZ (2000)	No				Yes.

		Score				
ID	**Description**	**1**	**2**	**3**	**4**	**5**
10	pH ANZECC & ARMCANZ (2000)	pH lower and upper limit is outside both marine guidelines and safe swimming guidelines.		pH lower and upper limit is within either the marine guidelines or safe swimming guidelines, but not both.		pH lower and upper limit is within both marine guidelines and safe swimming guidelines
11	Fecal coliforms	Fecal coliform levels are over blue flag swimming limits, primary contact swimming limits ANZECC & ARMCANZ (2000), and secondary contact fishing limits ANZECC & ARMCANZ (2000).		Fecal coliform levels are under one of either the blue flag swimming limits, primary contact swimming limits ANZECC & ARMCANZ (2000), or secondary contact swimming limits ANZECC & ARMCANZ (2000) , but over the other two.		Fecal coliform levels are under blue flag swimming limits, primary contact swimming limits ANZECC & ARMCANZ (2000), and secondary contact fishing limits ANZECC & ARMCANZ (2000).
12	Dissolved Oxygen	Dissolved oxygen <2 mg/L (NSW hypoxia guidelines).		Dissolved oxygen >2-<4 mg/L (NSW hypoxia guidelines).		Dissolved oxygen >4 mg/L (NSW hypoxia guidelines).

APPENDIX 6.

Sanitation Planning Frameworks

Framework	Description	Link to Resource
Citywide Inclusive Sanitation	Emphasizes the provision of sanitation services for everyone while ensuring a safe management of waste along the whole sanitation service chain. It focuses on the enabling environment and considers a variety of solutions rather than just building infrastructure.	https://www.worldbank.org/en/topic/sanitation/brief/citywide-inclusive-sanitation#1
Sanitation 21	Focuses on the assessment of the existing sanitation situation to understand people's needs and demands as well as to provide realistic solutions. It considers social aspects particularly related to low and middle-income communities such as poverty, inequity, land ownership, environmental and economic context, rather than to infrastructure.	https://iwa-network.org/publications/sanitation-21-a-planning-framework-for-improving-city-wide-sanitation-services/
Community-Led Urban Environmental Sanitation (CLUES)	Provides the principles and steps for the implementation of sanitation infrastructure and services in disenfranchised urban and peri-urban communities. This multi-sector and multi-actor approach also accounts for water supply, solid waste management and storm drainage.	https://www.susana.org/en/knowledge-hub/resources-and-publications/library/details/1300#

Framework	Description	Link to Resource
Sanitation Safety Planning	A step-by step framework to assess health risks associated with sanitation systems and integrates considerations about climate change and climate variability.	https://www.who.int/publications/i/item/9789240062887
Compendium for Sanitation Technologies	A guidance document for engineers and planners in low- and middle-income countries, primarily intended to be used for communicative planning processes involving local communities. It is also intended for persons/experts who have detailed knowledge about conventional high-end technologies and require information on infrastructure and different system configurations. It is not intended as a stand-alone document for engineers, making decisions for the community, e.g., expert-driven decision-making.	https://www.iwa-network.org/wp-content/uploads/2016/06/Compendium-Sanitation-Systems-and-Technologies.pdf
Fecal Sludge and Septage Treatment: a guide for low and middle income countries	It provides guidance on the options for fecal sludge treatment and the choices between those options. It discusses the urban contexts that influence treatment requirements and overall septage treatment processes. It is intended for those working on the planning and design of septage treatment plants.	https://practicalactionpublishing.com/book/693/faecal-sludge-and-septage-treatment

APPENDIX 7.

Examples of waterbody classifications from wastewater discharge standard policies

Location	Water Body Classification	Description
Marshall Islands	Class AA	The uses to be protected in this class of water are oceanographic research, the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, compatible recreation and other aesthetic enjoyment; This class of waters shall remain in as nearly their natural, pristine state as possible with an absolute minimum of pollution from any source. to the extent possible, the wilderness character of such areas shall be protected; No point source discharge or zone of mixing shall be permitted in these waters.
Marshall Islands	Class A	The uses to be protected in this class of waters are recreational, including swimming, bathing, and other water contact sports, aesthetic enjoyment, and the support and propagation of aquatic life; The use of this class of waters for recreational purposes and aesthetic enjoyment shall not be limited in any way. Such waters shall be kept clean of any trash, solid materials or oil, and shall not act as receiving waters for any effluent which has not received the best degree of treatment or control practicable under existing technological and economic conditions and compatible with the standards established for this class; Class A waters are nearshore waters.
Marshall Islands	Class B	The uses to be protected in this class of waters are small boat harbors, commercial and industrial shipping, bait fishing, compatible recreation, the support and propagation of aquatic life, and aesthetic enjoyment; The discharge of any pollutant shall be controlled to the maximum degree possible. Sewage and industrial effluent shall receive the best degree of treatment practicable under existing technological and economic conditions. Treatment shall be compatible with the standards established for this class; The discharge of any pollutant shall be controlled to the maximum degree possible. Sewage and industrial effluent shall receive the best degree of treatment practicable under existing technological and economic conditions. Treatment shall be compatible with the standards established for this class; This designation shall apply only to a limited area next to sewage outfalls and boat docking facilities. The rest of the water area surrounding outfalls and docks shall be Class A unless given some other specific designation; Class B waters are nearshore waters.

Location	Water Body Classification	Description
Northern Mariana Islands	Class AA	The objective of this class that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-related source or actions. To the extent practicable, the wilderness character of such areas shall be protected. Mixing zones for any other discharge shall not be permitted; Siting of any source of human or animal wastewater or sewage discharge within 50 feet of any waterbody, or within 25 ft of the top of any cliff/steep embankment (greater than 20 ft vertical drop or having greater than 50% slope) above any waterbody is prohibited. This setback is a minimum setback and any additional setbacks listed in CNMI Wastewater Treatment and Disposal Rules and Regulations (NMIAC Title 65, Chapter 120) shall apply; The uses to be protected in this class of waters are the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, oceanographic research, and aesthetic enjoyment and compatible recreation with risk of water ingestion by either children or adults.
Northern Mariana Islands	Class A	The objective of this class of waters that their use for recreational purposes and aesthetic enjoyment be protected; Any other use shall be allowed as long as it is compatible with the protection and propagation of fish, shellfish, and wildlife, and with compatible recreation with risk of water ingestion by either children or adults. Such waters shall be kept clean of solid waste, oil and grease, and shall not act as receiving waters for any effluent which has not received the best degree of treatment of control practicable under existing technology and economic conditions and compatible with standards established for this class. A mixing zone is approvable in such waters; Siting of any source of human or animal wastewater or sewage discharge within 50 feet of any waterbody, or within 25 ft of the top of any cliff/steep embankment (greater than 20 ft vertical drop or having greater than 50% slope) above any waterbody is prohibited.

Location	Water Body Classification	Description
Philippines	Class SA: Protected Waters; Fishery Water Class I	Waters designed as national or local marine parks, reserves, sanctuaries, and other areas established by law, and/or declared as such by appropriate government agency, etc.; Waters suitable for shellfish harvesting for direct human consumption
Philippines	Class SB: Fishery Water Class II; Tourism Zones; Recreational Waters Class I	Waters suitable for commercial propagation of shellfish and intended as spawning areas for milkfish and similar species; For ecotourism and recreational activities; Intended for primary contact recreation (bathing, swimming, skin diving, etc.)
Philippines	Class SC: Fishery Water Class III; Recreational Waters Class II	For the propagation and growth of fish and other aquatic resources and intended for commercial and sustenance fishing; For boating, fishing, or similar activities; Marshy and/or mangrove areas declared as fish and wildlife sanctuaries
Philippines	Class SD	Navigable waters
Wider Caribbean Region	Class I	Waters in the Convention area that, due to inherent or unique environmental characteristics or fragile biological or ecological characteristics or human use, are particularly sensitive to the impacts of domestic wastewater. Class I waters include, but are not limited to: waters containing coral reefs, seagrass beds, or mangroves; critical breeding, nursery or forage areas for aquatic and terrestrial life; areas that provide habitat for species protected under the Protocol Concerning Specially Protected Areas and Wildlife to the Convention (the SPAW Protocol); protected areas listed in the SPAW Protocol; and waters used for recreation.
Wider Caribbean Region	Class II	Waters in the Convention area, other than Class I waters, that due to oceanographic, hydrologic, climatic or other factors are less sensitive to the impacts of domestic wastewater and where humans or living resources that are likely to be adversely affected by the discharges are not exposed to such discharges.

APPENDIX 8.

Negative impacts on coral reefs from safely managed sanitation

Table A8: Studies that have documented a negative impact from sanitation systems that meet the definition of safely managed sanitation

Location	Treatment Information	Observed Impacts	References
Thailand	Sewage is secondary treated and discharged around 500 m offshore	Elevated dissolved nutrient concentrations and lower dissolved oxygen, increased coral mortality, increased macroalgae cover, reduced fish abundance compared to sites without sewage pollution	Reopanichkul et al., 2009
Tobago	Secondary treated sewage enters Buccoo Bay and the Bon Accord Lagoon via several sewage treatment plants	Higher macroalgae cover, lower coral cover, elevated macroalgae N15 stable isotope values (a bioindicator for sewage pollution)	Lapointe et al., 2003
Hawai'i	The treated wastewater is disinfected and discharged into one of four injection wells. Wastewater is injected into vertical pipes that reach 180 to 385 feet into the earth where it mixes with groundwater before flowing into the ocean. Although the wastewater is treated for viral and bacterial pathogens that are harmful to human health, it is not treated for other nutrients or contaminants.	Increased bioerosion rates and percent volume erosion at the coral site closest to groundwater seep	Prouty et al., 2017
Guam	Both plants provide primary treatment of sewage (thus no treatment for nutrients), discharging effluent through newly constructed outfall pipes into the Philippine Sea approximately 640 m offshore at a depths of 45 m	Elevated macroalgae N15 stable isotope values and greater prevalence of coral disease compared to sites with less exposure to wastewater	Redding et al., 2013