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# Assessing strategies for remote island beach cleanups: Lessons from the Pacific and Alaska<sup>☆</sup>

Hanna Dijkstra<sup>a,b,\*</sup>, Kristina Tirman<sup>c,d</sup>

<sup>a</sup> Institute for Environmental Studies, VU Amsterdam, De Boelelaan 1105, 1081HV Amsterdam, the Netherlands

<sup>b</sup> Howell Conservation Fund, 1201 W Peachtree St NW Ste 2625 PMB, Atlanta, GA 23298, USA

<sup>c</sup> Ocean Conservancy, 1300 19th Street NW, 8th Floor, Washington, D.C. 20036, USA

<sup>d</sup> Sitka Sound Science Center, 834 Lincoln St, Sitka, AK 99835, USA

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## ABSTRACT

Plastic pollution is a pervasive environmental challenge, with significant ecological, economic, and social implications. While upstream solutions are essential, downstream cleanup efforts play a role in addressing existing and legacy pollution. This study assesses strategies for remote island beach cleanups through two case studies: Henderson Island in the South Pacific and Kruzof Island in Southeast Alaska. These regions, characterized by their isolation and heavy plastic pollution, highlight unique logistical, ecological, and social challenges in cleanup operations. Drawing on firsthand observations, this research identifies key strategies for effective cleanups in remote locations. The findings emphasize the importance of careful planning, local engagement and innovative technologies to balance the benefits of cleanup with the potential costs. The study describes cases using a six-step cleanup framework and evaluates cleanup strategies based on feasibility, cost-effectiveness, potential harms, and co-benefits. This research contributes to literature on innovative approaches to marine debris management.

## 1. Introduction

Plastic pollution is a global environmental issue, reaching from mountain peaks to deep ocean trenches. Its persistence leads to accumulation in nearly every ecosystem (Jambeck et al., 2015; Worm et al., 2017). Addressing this pollution effectively demands a combination of upstream and downstream strategies. Upstream solutions, such as regulation, waste management, and product redesign, aim to reduce plastic production and use, thereby cutting pollution at its source (Cordier and Uehara, 2019; Morasae et al., 2024). However, downstream cleanup can prevent plastic that is already in the environment from accumulating further, threatening marine life and ecosystem health (Browne et al., 2015). Within the negotiations for an international treaty on plastic pollution, an article on removal of existing and legacy plastic pollution is proposed. If included, environmental cleanups

and remediation may be embedded in national legislative frameworks, increasing in scale and scope. Importantly, scientists have advocated for cleanups to be environmentally sound, cost-effective, transparent, well-documented and socially just (Scientists' Coalition for an Effective Plastics Treaty, 2024).

Beach cleanup campaigns occur on a variety of scales. On an individual level, citizens can participate in 'plogging' or pledge to 'take three for the sea'<sup>1</sup> while in nature (Martínez-Mirambell et al., 2023). Cleanups can also be internationally organized campaigns spanning hundreds of countries and leading to a large amount of data, for example Ocean Conservancy's Clean Swell<sup>2</sup> app and the NOAA Marine Debris Tracker<sup>3</sup> app each have millions of collection events logged (Jorgensen et al., 2021).

While upstream measures are often more cost-effective, the world's oceans and coasts still accumulate vast amounts of plastic, much of

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\* Corresponding author at: Institute for Environmental Studies, VU Amsterdam, De Boelelaan 1105, 1081HV Amsterdam, the Netherlands.

E-mail address: [hanna.dijkstra@vu.nl](mailto:hanna.dijkstra@vu.nl) (H. Dijkstra).

<sup>1</sup> Plogging is the colloquial name for the activity of jogging and picking up trash. 'Take 3 for the sea' is a campaign that encourages individuals to pick up three pieces of litter when visiting the beach or natural areas.

<sup>2</sup> <https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/clean-swell-app/>

<sup>3</sup> <https://debristracker.org/>

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which originates from distant sources. Marine debris converges in remote, uninhabited locations where it poses risks to biodiversity and reduces ecological functioning. These “plastic sinks,” such as Henderson Island in the South Pacific and the rugged coastlines of Alaska, demonstrate how plastic pollution can accumulate in areas that have limited or no human presence, sometimes transported by ocean currents from thousands of miles away (Lavers and Bond, 2017; Ryan, 2023).

Though cleaning up litter from isolated locations presents a set of unique challenges, it can also generate benefits for the environment, raise awareness and gather data that can be used in advocacy efforts (Baxter et al., 2022; Burt et al., 2020; Jorgensen et al., 2021; Wyles et al., 2017). Accessing remote areas is often hindered by geographic barriers, high costs, and the logistical complexities of waste removal. Additionally, such operations can carry potential risks to fragile ecosystems, underscoring the need for careful planning and strategic approach (Battisti et al., 2020; Falk-Andersson et al., 2023). The particular demands of remote locations, therefore, call for innovative cleanup methods designed to address local environmental conditions and operational constraints.

Studies and assessments of marine and environmental plastic cleanup technologies and advanced monitoring methods have grown (Schmaltz et al., 2020; Sugianto et al., 2023; Veettil et al., 2022). These studies demonstrate the technological strides made towards advanced litter management, but cleanups can be conducted by a variety of stakeholders such as NGOs and volunteers, municipalities and governments organizations or private companies such as resorts. Given the diversity, there are few studies providing evidence into how to conduct effective cleanups, minimize harms and maximize benefits (Burt et al., 2020; Falk-Andersson et al., 2023; Haarr et al., 2024).

In this paper, we examine and assess strategies for performing cleanups in challenging, remote contexts, drawing on lessons from two case studies: Henderson Island, an uninhabited island in the South Pacific, and Kruzof Island, located in the Alexander Archipelago in Southeast Alaska. This study aims to answer the following key questions: (1) What are effective strategies for conducting beach cleanups in remote locations? (2) What trade-offs exist when selecting different remote cleanup strategies?. The paper offers insights that practitioners and researchers can apply to future remote cleanup initiatives. By exploring both the successes and limitations of these efforts, this paper provides a framework for planning and executing remote cleanups. Thus contributing to the growing body of research on effective strategies for addressing marine plastic pollution in the most difficult-to-reach environments.

## 2. Literature and background

### 2.1. Marine plastic cleanups

Academic articles as well as organizational toolkits provide guidelines for successful cleanups and monitoring studies: how to prepare materials, volunteers and data gathering. These practical guides recognize that each individual environmental, political and social context will be different and require different strategies. For example, Battisti et al. (2020) outline how project management tools can be used to best prepare for beach litter cleanups. They propose the main steps for cleanups as 1) context analysis, 2) input and planning, 3) operational process, 4) monitoring (outputs and outcomes) and 5) communication and documentation (Battisti et al., 2020). Ocean Conservancy has developed toolkits for conducting cleanups that can be used by individuals or for planning large-scale events, with specialized guides for Arctic locations (Ocean Conservancy, 2023). Currently, no guides specify how to conduct cleanups on remote islands, and much of the knowledge is retained by practitioners and volunteers with personal experience.

One element of planning a beach cleanup is balancing the economic and ecological costs and benefits (Brouwer et al., 2023). Potential ecological harms include disturbing native species and removing

biological materials or animals alongside anthropogenic litter (Falk-Andersson et al., 2023; Griffin et al., 2024). In Spain, municipal beach cleaning costs 1.34 €/kg, covering salaries, transport, and disposal (Cruz et al., 2020). In contrast, a small-island Seychelles cleanup cost 8.10 €/kg due to high transport expenses, despite relying on volunteers (Burt et al., 2020). Thus, economic costs of cleanups can be high and vary widely based on the geographic conditions, amount of litter, disposal and transport options and goals of the project. However, Falk-Andersson et al. (2023) conclude that cleaning litter should be done ‘when the plastic load is high, the risk of harming ecosystems is low, and the benefit of preventing plastics from reaching vulnerable ecosystems is high’ (p. 13306).

On the other hand, research has found political and public support for the benefits of beach cleaning. Governments have dedicated resources to marine litter management through national and regional initiatives, such as the EU Marine Strategy Framework Directive and regional seas conventions (Frantzi et al., 2021). Additionally, in 2024 all 175 UN member states signed an agreement to develop a legally binding instrument to end plastic pollution, with a focus on environmental and marine litter (Arora et al., 2024). Public support can be seen in the large numbers of volunteers who participate in campaigns (Jorgensen et al., 2021), such as the International Coastal Cleanup, or submit data to the many citizen science monitoring apps. Further, valuation studies show citizens are willing to contribute money towards the reduction of marine plastic pollution. A study in Norway suggests households would pay over 650 USD per year for such initiatives (Abate et al., 2020). A study across eight EU countries found 90 % of individuals willing to pay to mitigate marine pollution, preferring solutions that adopted a European approach (Khedr et al., 2023). In Ecuador, mainland residents were found to be willing to pay for reductions in litter on the Galapagos Islands (Zambrano-Monserrate and Ruano, 2020). These finding suggests citizens are willing to support environmental plastic mitigation, even in remote or distant locations.

Cleanups are a tool to reduce environmental pollution, and can be manual, relying on volunteers or paid collectors, or utilize technologies. A range of conventional and innovative cleanup technologies have been developed to manage marine plastic, such as static barriers, filtration and interception devices (Dijkstra et al., 2021; Griffin et al.). Technologies can support cleanups: drones, satellites or aerial imagery can identify litter hotspots, and devices used to filter or capture litter, such as the Hoola One<sup>4</sup> device can filter microplastics from sand (Schmaltz et al., 2020). Other technologies focus on recycling for recovered marine plastic, which is often degraded and challenging to process (Peña-Rodriguez et al., 2021; Ronkay et al., 2021). Recovered plastic can be used in artistic projects, used in construction materials and in some cases can be recycled into new products, especially if the collected plastic is relatively clean or homogenous, like fishing nets (Dijkstra et al., 2021; Jones et al., 2023).

### 2.2. Remote island cleanups

Academic studies discussing remote island cleanups are rare, with most publications about marine and beach litter focusing on monitoring results. A notable exception is a paper by Burt et al. (2020) which describes in detail the cost of conducting a comprehensive cleanup on Aldabra Atoll, part of the Republic of the Seychelles in the Southwest Indian Ocean (Burt et al., 2020). The cleanup took place over 3 weeks, comprised of 12 volunteers and removed 513 tons of debris from the atoll, with an estimated cost of \$8900 per ton of litter removed and 35.7 labor hours. This study demonstrates the labor intensiveness of remote island cleanups, the high costs, and operational challenges of managing a large team, transporting equipment, people, food, supplies and waste.

Other monitoring studies have demonstrated the potential to use

<sup>4</sup> For more details see the Hoola One website: <https://hoolaone.com/>

innovative monitoring strategies, such as boat-based photography (Papachristopoulou et al., 2020), drones (Deidun et al., 2018; Manzolli and Portz, 2024) or satellite imagery (Biermann et al., 2020) to map litter accumulation, technologies which could have useful applications for remote beaches. This type of data can be useful to optimize beach cleaning, however the direct link between innovative monitoring and practical cleanup strategizing is currently missing.

### 3. Case studies and study methodology

This study draws on lessons learned from field expeditions to two remote locations severely impacted by plastic pollution: Henderson Island in the South Pacific and Kruzof Island in Southeast Alaska, shown in Fig. 1.

#### 3.1. Study sites

##### 3.1.1. Henderson island: Case study

Henderson Island, an uninhabited UNESCO World Heritage site in the South Pacific, faces severe plastic pollution. Its East Beach is among the most contaminated worldwide. Shown in Fig. 2, comprehensive studies were conducted on East Beach in 2015 and 2019 (Lavers and Bond, 2017; Nichols et al., 2021). It has been hypothesized East Beach is an effective accumulation zone, with waste coming from distant sources, potentially discarded from ocean vessels (Kenyon, 2017; Ryan, 2023; Ryan and Schofield, 2020). The island has no permanent human population and is rarely visited by scientists, Pitcairn islanders or tourists. Henderson Island is home to many unique, endemic and endangered species including four endemic landbirds and numerous seabirds and sea turtles use the island for nesting (Brooke et al., 2004). Studies into ecological effects have found plastic in the bellies of birds in the Pitcairn islands, as well as evidence that plastic pollution is killing land crabs (Lavers et al., 2020; Lavers and Bond, 2024).

An expedition conducted in February 2024 to Henderson Island was used to test various cleanup approaches in a location with unique logistical constraints, including limited access and the need for low-impact operations. The goal of this expedition was to remove all waste from the polluted East Beach, monitor the litter density on the beach and

valorize waste by recycling. The expedition was a collaboration between Plastic Odyssey and Howell Conservation Fund and involved camping on Henderson Island for eight days.<sup>5</sup> The team conducted systematic surveys to quantify the extent of pollution and employed innovative waste collection and removal strategies.

##### 3.1.2. Alaskan coast: Kruzof Island case study

Kruzof Island located in Southeast Alaska approximately 16 km west of Sitka, is known for its rugged, rocky shoreline, shown in Fig. 3. Although the island has no permanent residents, it accumulates significant amounts of plastic debris carried by ocean currents from distant sources across the Pacific. The island supports large populations of brown bears, Sitka black-tailed deer, bald eagles. Surrounding waters are rich in biodiversity, hosting all five species of Pacific salmon, migrating humpback and gray whales, sea otters, and Steller sea lions. These waters have been important subsistence fishing and harvesting grounds for the Indigenous Tlingit people for over 10,000 years. Adjacent to Kruzof Island lies St. Lazaria Island, a 65-acre island home to over 500,000 breeding seabirds and part of the Alaska Maritime National Wildlife Refuge.

The island's environment, characterized by dense forests, rocky shores, and unpredictable weather, presents significant challenges for landing, collection, and removal of debris. The problem of plastic pollution in Alaska has been documented for decades (Merrell, 1984) and over 10,000 kg of debris was collected from five Alaskan national parks in 2015 (Polasek et al., 2017) and microplastics have been found throughout the state in waterways and snow (Dev et al., 2024).

Cleanup operations on south Kruzof Island occur approximately once a year and are led by the Sitka Sound Science Center and Ocean Conservancy. The results presented in this paper are taken from numerous years of cleanup experience, with specific references to the latest cleanup in August of 2024. The goals of cleanups on south Kruzof, for example at Shoals Beach, are to remove as much debris as possible, raise awareness of marine debris by engaging 30–50 local community volunteers, and to monitor the re-accumulation of debris over time. Planning these cleanup expeditions involves integrating local knowledge, building partnerships with organizations, Tribes and relevant local authorities, and preparing adaptive strategies to address the logistical difficulties of working in unpredictable conditions typical of Alaskan coasts.

#### 3.2. Comparative methodology

The paper utilized lessons learned from expeditions to the Pacific and Alaska and relies on first-hand experience and accounts. Remote cleanups follow similar logistical steps, but challenges vary by location. Geography and ecology dictate tailored strategies for waste collection, removal, and monitoring. The general remote cleanup operational steps include:

1. Arrival and landing at the site - Access to remote beaches requires careful planning for safe arrival. Landings must consider weather, tide conditions, shoreline topography, and potential ecological sensitivities.
2. Collection and transport of collected waste - Waste collection requires manual or assisted aggregation of waste, sorting and transporting. Transport can be challenging due to remoteness and the hazards of moving large amounts of debris.
3. Monitoring and surveying - Monitoring involves surveying the types, amounts, and sources of waste, providing data on trends, accumulation and supporting future planning (Falk-Andersson et al., 2023). Falk-Andersson et al., 2023).

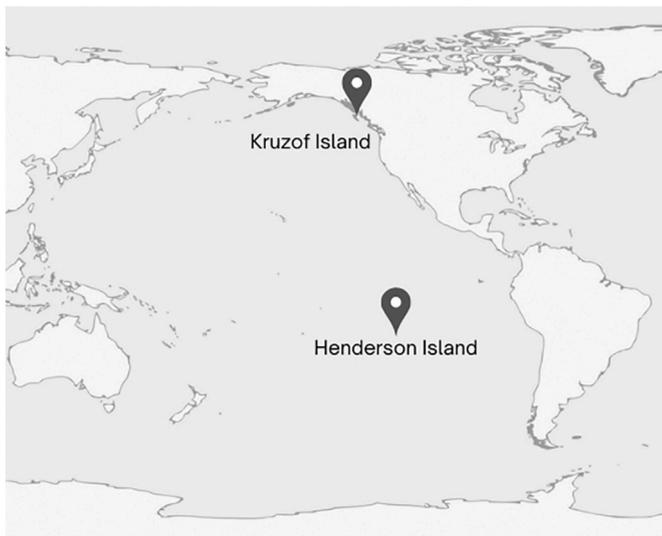


Fig. 1. Location of Kruzof and Henderson Islands. Maps Data : Google, © 2025.

<sup>5</sup> Details on the 2024 expedition can be found on [hendersonisland.plasticodyssey.org](https://hendersonisland.plasticodyssey.org)



Fig. 2. Henderson Island and East Beach, left map : Google,© 2025, center image: Google,© 2025 Airbus, Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Maxar Technologies, right photo by Hanna Dijkstra.



Fig. 3. Kruzof Island, left map: Google,© 2025, center image: Google,© 2025 Maxar Technologies, Airbus, right photo by Kristina Tirman.

4. Removal of waste and leaving the site - Removing of large amounts of debris in requires precautions to avoid disturbing wildlife and ecosystems.
5. Recycling and determining end-of-life strategies - Recycling or reusing collected waste is not always possible, given the nature of collected environmental waste (Peña-Rodríguez et al., 2021). Decisions involve trade-offs in terms of cost, environmental and community impact, and logistics.
6. Communications and storytelling - Knowledge generation and movement building can be an outcome of cleanup efforts (Jorgensen

et al., 2021). Effective storytelling, can increase awareness create wider impact.

Each cleanup requires an extensive planning stage, to prepare logistics, gather necessary permissions and access to the islands. This stage is not included in the analysis but is critical to the success of any cleanup. Each step in the cleanup process offers opportunities for innovation, there are trade-offs associated with choosing specific strategies. For instance, technologies like GPS mapping and drone surveys can improve monitoring accuracy but require upfront investment and training.

Similarly, social strategies that engage local communities can be effective for sustained cleanups and triggering ownership but require availability and interest of nearby populations.

### 3.3. Data collection and analysis

The study applied a qualitative comparative case study analysis (Yin, 2003), an established approach for examining environmental interventions across different contexts. Data was collected through structured observations, participant interviews, and direct measurement of collected waste. Field observations were used to document logistical challenges, ecological impacts and engagement strategies. Ad-hoc interviews were conducted with cleanup participants, expedition organizers and local stakeholders to assess perspectives on feasibility, challenges and impact. Data was recorded using field journals, photographs and reports. Marine debris data were recorded using standardized monitoring protocols from NOAA and Ocean Conservancy. The authors each participated in the cleanups (K. Tirman on Kruzof Island and H. Dijkstra on Henderson Island) and collated data and notes within an effectiveness framework to provide synthesized recommendations.

The effectiveness of strategies was compared using four key indicators:

1. Feasibility - Operational ease, efficacy for the geography and litter characteristics (Falk-Andersson et al., 2020)
2. Cost-effectiveness - Resource expenditure versus environmental benefits (Brouwer et al., 2023; Nikiema and Asiedu, 2022)
3. Potential harm - Ecological disturbance and unintended consequences (Falk-Andersson et al., 2023; Nikiema and Asiedu, 2022)
4. Co-benefits - Awareness raising, community engagement, and data collection opportunities (Haarr et al., 2024; Wyles et al., 2017)

This multi-criteria approach was adapted from previous assessments of cleanup trade-offs and effectiveness (Falk-Andersson et al., 2020; Nikiema and Asiedu, 2022). Data were analyzed through qualitative coding and cross-case comparative analysis to identify patterns and key lessons (Yin, 2003).

## 4. Case study results

The following section first goes through the six steps of remote islands cleanups Henderson Island and Kruzof Island using practical examples. This answers the first research question on which strategies can be used for remote cleanups. Then, we present a comparative analysis of trade-offs and effectiveness, to answer the second research question.

### 4.1. Henderson Island

#### 4.1.1. Arrival and landing

Henderson Island is one of the most remote places on earth. The island is located midway between the coast of South America and New Zealand. This field expedition was conducted in February 2024 by Plastic Odyssey and Howell Conservation Fund and access and permits were provided by the Pitcairn Island Government and the department of Environmental, Conservation and Natural Resources. The Plastic Odyssey vessel is sailing around the world raising awareness on plastic pollution and solutions. To get to Henderson, the vessel picked up crew members, supplies and fuel in Mangareva and sailed for two days over a distance of 644 km.

Henderson Island, like many Pacific islands, is fringed with a coral reef but has no channel for boats to cross the reef. The team prepared two plans to land on the island. The first was to cross the reef using rafts and small boats to land on East Beach. The second was to land on the calmer North Beach and cross the island to East Beach by foot, if necessary. The first plan was successful, using a paddleboard raft to set

up a mooring line. Then, a rudderless rubber zodiac was pulled over the reef and through the waves to land personnel and supplies. A motorized winch system to ease transport was unsuccessful. Some teammates were dropped by a steel jet boat, which was manned by local islanders who knew the area and were at the island for one day. In total, 13 teammates landed on the to camp for eight days, bringing all their own food, water and camping gear, including a dry-toilet system.

#### 4.1.2. Collection and transport of waste

The cleanup on Henderson Island in 2024 was unique as a previous expedition in 2019 had succeeded in collecting, separating and bagging 5.6 tons of waste, but had not been able to remove it off the island. The 2019 waste had been left in 13 locations, bagged in super sacks and dragged above the tide line. Thus the 2024 cleanup had three tasks to be able to remove all the plastic waste off the beach. First, find the 2019 waste sites and prepare the super sacks for removal, second, collect all new debris deposited since 2019, and third, aggregate all 2019 and 2024 waste for removal off the island. The super sacks from 2019 were completely disintegrated and many had been completely overgrown by vines and bushes. The team spent a significant amount of time re-bagging the waste into new super sacks and dragging the bags to a central point on the beach.

Creative strategies improved waste transport, such as makeshift rafts made from paddle boards, bamboo poles, and inflatables. These rafts carried super sacks through shallow water to a central site. Additionally, buoys were strung onto salvaged ropes to make garlands which could be dragged through shallow water, as well as Fishing aggregate devices (FADs) that were still buoyant.

The cleanup of new waste was entirely manual, and the team spent days fanned across the 2,5 km beach gathering debris larger than a bottle cap. Camping on-island maximized time on the beach and allowed for work in the early morning, to avoid the extreme afternoon sun.

#### 4.1.3. Monitoring and surveying

The team included a scientific plan, to gather data to add datasets from studies conducted in 2015 and 2019 (Lavers and Bond, 2017; Nichols et al., 2021). The monitoring strategy was frugal with time and resources to not detract from the primary objective of cleaning the beach (See Dijkstra, forthcoming, for the results of the long-term monitoring studies). The monitoring protocol was based on NOAA's Marine Debris Monitoring Protocol (MDMAP)<sup>6</sup> applying transects and litter counts along a stretch of beach. Technical monitoring tools reduced the time needed for monitoring and provide advanced data analysis opportunities. Recording forms were pre-uploaded into a Trimble environmental monitoring GNSS system<sup>7</sup> with geolocation and a camera.

Two weighing tools were used to collect weight data; handheld spring scales for small debris, which required careful use to reduce exposure to salt and sand, and fishing scales, which were durable and effective for heavy debris such as buoys, fishing gear and super sacks.

#### 4.1.4. Removal and leaving the site

The fringing coral reef severely limits removal options and the 2024 team prepared numerous plans to mitigate risk. The Plastic Odyssey team brought numerous rafts and floating devices, including paddleboards, inflatable rafts, a large pontoon, bamboo rafts, small rubber zodiacs, winches and ropes. Additionally, a parasail system was designed to lift super sacks of plastic over the coral reef, powered by a motorcycle-winch on the deck of the Plastic Odyssey vessel. This innovative strategy was devised specifically for Henderson Island as a backup plan in case the reef was impassable.

Fortunately, the team was able to set up a mooring system through a

<sup>6</sup> <https://marinedebris.noaa.gov/monitoring/marine-debris-monitoring-and-assessment-project>

<sup>7</sup> <https://geospatial.trimble.com/en/products/hardware/gnss-systems>



Fig. 4. Top photo - parasail removal of waste using vessel, winch and raft. Left photo - floating pontoon with super sacks. Middle photo - removal of buoy garland. Right photo - onboard recycling of hard plastics. All photo credits © Olivier Löser.

shallow channel. Super sacks were loaded onto a floating pontoon, then a team member would pull the pontoon through the waves, over the coral reef, along the mooring rope. A motorized boat would meet the pontoon and drag it to the vessel. The parasail system was piloted, and, after a number of attempts, successfully carried 2–3 super sacks of waste over the coral reef. This was the first successful deployment of a parasail to remove waste which could be feasible for locations with logistical obstacles. Fig. 4 depicts the parasail as well as other collection and removal strategies deployed on Henderson Island.

Additionally, the Silver Supporter - the supply and research vessel for Pitcairn Island assisted in transporting waste from Henderson Island. The Silver Supporter visited Henderson on the first and fifth day of the expedition and was able to carry approximately 5 tons of waste to Pitcairn Island. This was a coincidental overlap with the planned expedition, and it may not have been possible to remove all the waste only using the Plastic Odyssey boat.

#### 4.1.5. Recycling and determining end-of-life strategies

In total, nine tons of waste was removed from East Beach, comprising of 2019 and 2024 collected debris. The Plastic Odyssey vessel has an on-boat recycling workshop, and team members began processing waste as soon as it was landed on deck. The marine plastic collected from the beach was almost all severely degraded and dirty. Hard plastics made of PP and HDPE were separated, cleaned and shredded. The shredded plastic was dried and then sent through an extrusion system to create plastic beams. In total, 1.5 tons of waste was recycled into beams on the boat.

The expedition visited Pitcairn Island after leaving Henderson, where a community of around 50 people live. Local islanders and team members built products out of the plastic beams, including a large novelty chair, a beekeeping tray, a bench and a garden planter. The rest of the waste was left in the Pitcairn Island landfill, where buoys and fishing nets could be salvaged and reused. Team members helped Pitcairners set up a shredder and trained the community in processing

waste. Due to challenges with import and export laws, the waste could not be easily transported to other locations to be managed, since the Plastic Odyssey vessel was continuing to French Polynesia and the Silver Supporter to New Zealand.

#### 4.1.6. Communications and storytelling about the cleanup

Telling the story of the Henderson Island expedition was a combination of local and international storytelling and media. On Pitcairn Island, there were numerous workshops, meetings and trainings held to share knowledge and increase technical capacity for islanders. On an international level, the expedition created a customized website and phone app which documented the daily expedition, including updates from the crew, information on the amount of plastic being collected, transported and recycled. The expedition included photographers and videographers to document the remote cleanup and produce media content about the cleanup.

## 4.2. Kruzof Island

### 4.2.1. Arrival and landing

Reaching Kruzof Island for cleanup efforts requires organizing transport from Sitka, Alaska, usually via a chartered vessel with a local captain. Most boats available in Sitka accommodate around six passengers, although some larger vessels, like those from Allen Marine Tours, can carry anywhere from 24 to 150 passengers but have limitations on shore drop-offs, often restricting access to larger coves in protected areas. Smaller chartered vessels are preferred for this reason, as they can navigate into Kruzof's smaller, more exposed coves where debris is concentrated, especially along the southern coast, which has difficult access but contains the highest waste accumulation.

Kruzof Island lies roughly 12 nautical miles from Sitka, and its remote, exposed beaches present multiple logistical challenges. The southern coastline is defined by rugged volcanic reefs, sandy beaches with strong waves and surf, large driftwood piles, rocky outcrops, extreme tidal changes, and unpredictable weather. Cleanup crews typically transfer from the main vessel to inflatable zodiac rafts with oars to reach these challenging shores. Each zodiac, accommodating two to four people, must be manually carried above the tide line upon landing and securely anchored to prevent drifting. Once secured, the team establishes their cleanup operation base on the beach.

### 4.2.2. Collection and transport

Debris collection on Kruzof is entirely manual. Crew members wear gloves to gather waste by hand and deposit it into garbage bags, using plastic bags or repurposed grain bags from a local brewery. Larger items like hard plastic buoys are strung along ropes to maximize space and facilitate transport, while oversized items such as polystyrene dock pieces, barrels, and fish totes are left outside of bags. All plastic water bottles with visible clear liquid are emptied on-site to prepare them for recycling, but other containers are left sealed to prevent leakage. The gathered debris is then hand-carried to a designated drop-off point, ready for loading back onto the vessel.

### 4.2.3. Monitoring and surveying

Monitoring and data collection during the Kruzof cleanup follows standardized protocols, primarily utilizing either Ocean Conservancy's Arctic/Alaska Ocean Trash Data Card or Form 2, developed by the Alaska Marine Stewardship Foundation. Ocean Conservancy's card allows for itemized counting and weighing of each debris category, while Form 2 provides a simpler total weight tally by category.

The data collection process offers flexibility, with three options for gathering data. The first option involves collecting data as crews gather debris, minimizing handling but limiting how much waste each team member can collect. The second option has data recorded on the beach after collection, where bags are emptied onto a tarp for assessment, providing accuracy but requiring time in the field. Finally, a third option

is to collect data back in Sitka after transporting debris, which maximizes cleanup efficiency on the beach but requires additional handling and a day of sorting in town.

Ocean Conservancy stores cleanup data on their TIDES<sup>8</sup> database which aggregates detailed ocean trash data inputted from official and voluntary cleanups around the world. This data allows for comparison between sites and over time, to identify litter hotspots, assess accumulation and the effectiveness of cleanups.

#### 4.2.4. Removal and leaving the site

Waste removal on Kruzof Island uses two methods: hand-carrying debris to a pickup point for transfer to Sitka or airlifting via U.S. Coast Guard helicopters. At the pickup location, cleanup crew members form a chain to load bags onto the inflatable raft, which transports them to the main vessel anchored nearby. The raft shuttles back and forth until all debris is loaded, followed by the team and remaining gear. Upon reaching Sitka, the vessel is docked, and the crew offloads the debris into trucks, securing it with rope and ratchet straps for transport to a temporary storage facility.

A second removal option, typically available once a year, enlists the support of the U.S. Coast Guard Air Station Sitka to airlift the collected debris by helicopter. In this scenario, individual trash bags and large debris are consolidated into “super sacks,” which are dragged to a landing area. The Coast Guard uses a cargo net to sling-load 2–4 super sacks at a time back to Sitka. Cleanup crew members then return to town via boat, where they meet Coast Guard personnel at the Sitka Air Station to transfer the waste into trucks for additional sorting and disposal. Fig. 5 shows the helicopter removal, as well as other collection and removal strategies on Kruzof Island.

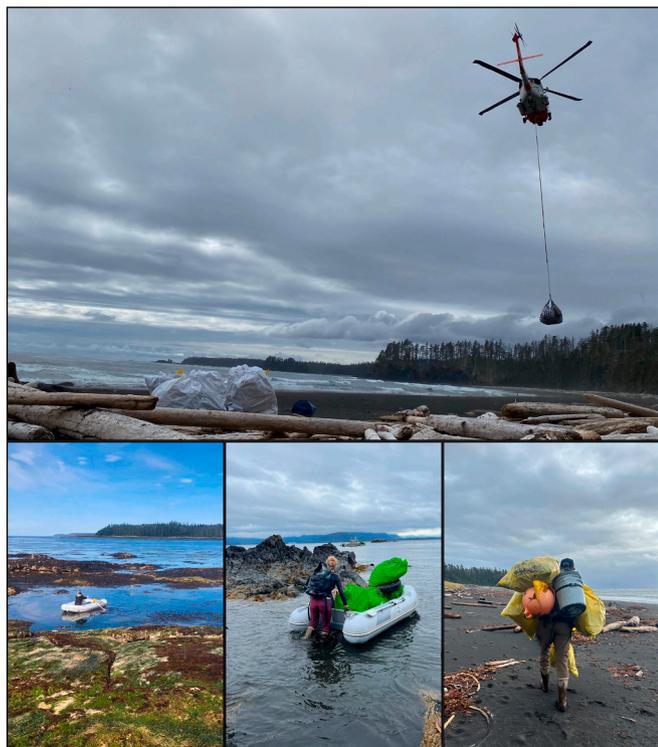


Fig. 5. Top photo - Helicopter removal. Left photo – rowboat arrival. Middle photo – rowboat removal. Right photo – manual collection of debris. All photo credits Kristina Tirman.

#### 4.2.5. Recycling and determining end-of-life strategies

In Sitka, the most accessible disposal solution is the local transfer station, which charges around \$0.08 per pound to ship waste off-island to a landfill in Eastern Washington. Recycling is also an option, with Sitka's recycling center accepting certain plastics (#1, #2, and #5), tin, aluminum, glass, and cardboard. During the cleanup, recyclable items are sorted separately from non-recyclables. However, it is often challenging to identify resin codes on fragmented plastics, leading some recyclables to be sent to the landfill.

Select items are salvaged for reuse in the local community. Hard and soft buoys, for example, are repurposed by local artists, who paint or engrave designs on them. Some discarded ropes and nets, if in usable condition, are reclaimed by fishermen or transformed into hammocks for private yards.

#### 4.2.6. Communications and storytelling about the cleanup

To share the story of the Kruzof Island cleanup, various communication strategies are employed, focusing on engaging both local and broader audiences. Social media updates within the community highlight the progress and outcomes of the cleanup, while data summaries and story maps provide a detailed look at the impact and efforts made. Additionally, videos documenting the cleanup are occasionally produced, visually capturing the challenges and accomplishments of the Kruzof expedition. These storytelling efforts help foster local involvement, increase awareness of marine debris issues, and inspire continued environmental stewardship within the community and beyond.

### 4.3. Comparative analysis of case studies

The following table compares different strategies deployed at both case study locations for each of the cleanup stages. The strategies are compared based on feasibility (how effective, resource and labor intensive the strategy is), cost effectiveness (the cost compared to output), potential harms (such as ecological disturbance) and co-benefits (positive impacts beyond collection). Table 1 highlights both conventional and unique strategies to consider if planning a cleanup in a remote context and demonstrates the trade-offs between choices.

The comparative analysis highlights advantages and challenges of each approach in remote settings. Manual collection is the most adaptable and least disruptive method, but is highly labor-intensive. Mechanical removal increased efficiency, but posed risks to fragile ecosystems, making it less suitable for ecologically sensitive areas like Henderson Island. A hybrid approach, combining manual sorting with low- and high-tech support tools, can balance efficiency with minimal environmental impact. Cost-effectiveness varied significantly, with logistics and transportation expenses being major constraints in both case studies. Additionally, community engagement and awareness-building emerged as important co-benefits, reinforcing the role of cleanups beyond debris removal. These findings emphasize the need for context-specific cleanup strategies that consider ecological, logistical, and social factors.

## 5. Discussion and conclusion

### 5.1. Co-benefits of cleanups

These case studies show that cleanups do more than remove litter - they also raise awareness among participants and the public. Environmental storytelling can increase knowledge. A study on the influence of Blue Planet 2 found significant increase in environmental knowledge of viewers, however it did not lead to behavior change effects (e.g. those who watched did not significantly change their plastic consumption) (Dunn et al., 2020). However other studies have identified links between knowledge and behavior, suggesting that media and storytelling can be a tool to generate pro-environmental behavior (Barberá-Tomás et al., 2019; van Oosterhout et al., 2023). Many studies into citizen science,

<sup>8</sup> <https://www.coastalcleanupdata.org/>

**Table 1**  
Comparative analysis of strategies deployed at different stages of remote island clean-ups.

Phase	Strategies	Feasibility	Cost effectiveness	Potential harms	Co-benefits
Arrival	Non-motorized transport (e.g. kayaking, hiking)	Can accommodate more team members, but not always feasible for remote locations	Cheapest option but also limits the amount of waste that can be removed and tradeoff between transport time and cleaning time	Minimal if using established trails and following environmental protocols	Can conduct other environmental assessments during transport e.g. whale counts or other species monitoring
	Motorized boat	Can be used in many contexts with varied boat sizes/types and accommodate single or multi-day expeditions. Suitable weather necessary	Highly dependent on boat size but will increase ability to remove large amounts of debris. Generally moderate costs and fuel expenses	Requires fuel and creates noise pollution and potential disturbance to aquatic and beach life.	Support local economy and engaging with community members (hiring boats).
	Small aircraft (e.g. planes, helicopters)	Necessary for certain remote contexts. Not feasible for many contexts.	Very high cost, only justifiable in extreme cases	Requires fuel and creates noise pollution and potential disturbance to wildlife.	Partnerships with agencies (e.g. Coast Guard) to supply helicopter trips
Monitoring	Collecting cleanup data	Calculating aggregate cleanup data is feasible for most expeditions and can be tailored to expedition needs	No cost, little time required	Potential habitat disturbance during data collection	Supports long-term planning, data for environmental assessment. Citizen science benefits for those conducting monitoring
	Conducting monitoring studies (manual or software assistant)	Conducting monitoring studies requires dedicated time and effort for counting debris. Need for trained or specialized teams	Moderate cost and time requirements depending on tools used	Potential habitat disturbance during data collection	Supports long-term planning, data for environmental assessment. Citizen science benefits for those conducting monitoring. Potential integrations with software and hardware to create map
	No monitoring	No training or protocols required	No cost, no time requirement	Lack of data means no knowledge is gained and there is no insight about the severity of pollution	
Collection and transport	Manual collection	Feasible but labor-intensive. Limited by the terrain.	Low-cost, though may be more time-intensive	Potential habitat disturbance during litter collection	Awareness raising and engagement with volunteers participating
	Non-motorized support (e.g. handcarts, rafts, buoy garlands)	Feasible and increases efficiency. Limited by the terrain.	Low-cost, eco-friendly	Potential habitat disturbance during litter transport	
	Motorized support (e.g. ATVs, carts)	Feasible and increases efficiency. Limited by the terrain.	Cost dependent on location and availability of vehicles	Habitat disturbance, noise and fuel requirements	Support local economy and engaging with community members (renting or hiring ATVs).
Removal	Non-motorized strategies (e.g. inflatable zodiac raft, paddle board, kayak)	Feasible in accessible areas. May leave some waste behind due to physical limits	Low-cost, labor-dependent	Minimal disturbance	
	Motorized strategies (e.g. winches, parasail, boats)	Feasible but dependent on resources and conditions. Increases waste removal efficiency	High cost for equipment and fuel	Possible habitat impact, fuel use	
End of life	Recycling	Feasible for certain waste if adequate recycling facilities exist or if funding for transport to recycling facilities exists	Waste needs to be separated and processed. Higher cost to transport to recycling facilities and more time to coordinate logistics	Dirty or degraded plastics may be more toxic or hazardous to process	Awareness raising and communication benefits from demonstrating value from collected waste; takes burden away from local community to deal with waste
	Reuse	Feasible for select items that can be repurposed locally	Low-cost, eco-friendly	Degraded plastics (nets, buoys) may shed microplastics	Awareness raising and communication benefits from demonstrating value from collected waste; engagement with local artists
	Landfill	Most feasible, appropriate landfill must be identified before cleanup	Low-cost; often easier logistics to coordinate (less time)	Adds to landfill burden (especially in rural areas where landfills are space-limited and often unlined), potential microplastic leakage	
Communication	Social media, phone apps	Highly feasible with internet access during or after cleanup	Low-cost, high outreach potential		Awareness raising, public engagement, monitoring progress
	Community engagement	Highly feasible if local communities are accessible; may require coordinators and translators	Cost-effective if can use existing community networks	Risk of cultural misunderstanding or helicopter science, complexity of waste impacts	Builds local knowledge, fosters community stewardship, and encourages ongoing local conservation efforts
	Scientific articles	Requires partnerships or funding for researchers	Moderate to high costs for time and publishing fees	Limited accessibility and audience	Provides rigorous documentation, contributes to the scientific record, and informs future policy and research efforts

monitoring and cleanups cite awareness raising as a main outcome and goal of cleanup campaigns (Jorgensen et al., 2021; Locritani et al., 2019; Syberg et al., 2018). However, less attention has been given to the potential awareness raising benefits for those not directly involved but who learn about them from social media or campaign. The cases in this study explicitly included storytelling as a strategy, and if significant awareness was raised (and potentially also behavior change), this may add further justification for the high costs of remote cleanups. For example, the Henderson Island cleanup results were presented to the Pitcairn Islanders, who were interested in conducting further research and management activities.

Additionally, community empowerment can be stimulated by including local citizens in collection or in education programs, even in remote contexts (Haarr et al., 2024; Wyles et al., 2017). Communities have local, Indigenous or ancestral knowledge on the geography and climate and are important stewards of the land and should be included as active participants in environmental management (Fuller et al., 2022; Liboiron and Cotter, 2023). It is good practice and can increase efficiency to utilize local knowledge rather than bringing in foreign individuals, though in some cases extra capacity or financing may be needed for cleanups to occur (Burt et al., 2020).

Cleanups must strike a balance between collecting debris and collecting data, as these are activities that can be difficult to conduct simultaneously. Data collection is time and resource intensive, due training team members, aggregating and verifying data. Especially if cleanups are going to occur longitudinally, time-series data can be used to study re-accumulation rates and monitor the effectiveness of cleanups or policy (Alkalay et al., 2007; Baxter et al., 2022).

Monitoring data supports advocacy, as seen in Ocean Conservancy's ICC, which has mobilized 18 million participants in 155 countries to remove 380 million pounds of debris over 40 years (Ocean Conservancy, 2024). Each year Ocean Conservancy publishes an annual report that lists the top 10 items found globally, regionally and by state.<sup>9</sup> These data are used by government officials, researchers, educators, students, and non-profit and Tribal entities to enact change. For example, three decades of ICC data on balloons collected in Virginia helped pass legislation in 2021 banning intentional balloon releases outdoors. A European Union study on the top ten littered items on European beaches was used to design the EU Single Use Plastics Directive, banning polluting single use items (Addamo et al., 2017). Utilizing data collected during remote cleanups maximizes co-benefits and can justify the costs and logistical challenges associated with them.

### 5.2. Trade-offs in cleanups

The main trade-off in remote island cleanups lies in the decision to conduct a cleanup, and whether the cost and disturbance creates more benefits than harms (Burt et al., 2020; Falk-Andersson et al., 2023; Zielinski et al., 2019). A study into the plastic accumulation in the North Pacific Garbage Patch over time has found that, though the concentrations of large debris has not significantly changed between 2015 and 2022, smaller debris appears to be increasing (Lebreton et al., 2024). The authors hypothesize that macroplastics are breaking down into microplastics, which are more difficult to collect, monitor and manage. The same conclusions have been reached by scientists specifically studying Henderson Island (Ryan and Schofield, 2020). Microplastics are particularly insidious, they are easily ingested by marine life, can have high levels of toxicity and impact biotic health (Lambert and Wagner, 2018; Mohamed Nor et al., 2021; Nelms et al., 2018). Thus, prevention of microplastics is critical and Ryan and Schofield (2020) put it simply 'We support macroplastic collections at the island, to prevent the formation of microplastics (p.5).

<sup>9</sup> See <https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/> for annual reports and data

Extensive beach cleaning or 'grooming' can harm ecosystems (Zielinski et al., 2019). Research in the Caribbean shows that removing algae and seaweed using machines or manpower improves aesthetics but reduces ecological benefits<sup>10</sup> (Hinds et al., 2016; Rodríguez-Martínez et al., 2023). Extensively cleaned sites may lead to reductions in ecological benefits, but studies have also suggested it leads to higher use and higher value of litter-free beaches (Leggett et al., 2014; Zielinski et al., 2019).

While beach cleanups remove hazardous debris, they may also disrupt fragile coastal habitats. For instance, trampling vegetation on Henderson Island could disturb nesting seabirds or turtles, and helicopter landings can disrupt coastal ecology on Kruzof Island. Economically, remote cleanups incur high costs due to transportation, labor, and equipment expenses (Burt et al., 2020). In both Alaska and Pitcairn, the local community and support organizations are in favor of continued cleanups despite the logistical challenges. The amount of plastic collected on both islands is seen as an environmental problem, but the fact that it was cleaned up leads to a sense of empowerment and stewardship.

### 5.3. Future research and political implications

Research has identified the negative economic impacts of plastic litter in the environment, for example Beaumont et al. (2019) found \$3300 - \$33,000 cost per ton of litter in the ocean. However, a direct link to the cost of cleanups, including all the potential positive and negative impacts, has not yet been made (Wyles et al., 2017). Remote cleanups are expensive, but may lead to large ecological gains, aesthetic improvements, movement building and awareness raising. Further studies can adopt social cost-benefit analyses or optimization models, comparing a wide range of direct and indirect impacts, to determine the most feasible cleanup strategies. Due to the complex relationship between continued plastic production, leakage, policy change and local behavior, it is difficult to determine if a cleanup leads to a consistent reduction in marine plastic. Additional work is needed to develop quantitative indicators to measure cleanup effectiveness.

Future cleanups can benefit from technological advances to reduce costs and improve effectiveness. Consider proposals to develop vessels that can be deployed along coastlines or within gyres and utilize waste to energy to manage collected pollution (Belden et al., 2021; Nevrlý et al., 2021). There has been significant technological progress in remote monitoring on beaches, using drones, satellites and machine learning algorithms (Veetil et al., 2022). These advances can optimize cleanup planning and preparation, allowing practitioners to consider the seasonality of litter but also monitor potential ecological harms such as identifying nesting sea turtles (Dasgupta et al., 2022; Maneja et al., 2021). These tools can be used to gather data in places that humans may not be able to easily reach, and in the future, technologies may even replace manual collection.

Although international policies such as MARPOL Annex V and the EU Marine Strategy Framework Directive (MSFD) have established regulatory measures to mitigate marine litter, their effectiveness remains limited. As demonstrated in both case studies, even with strict regulations, plastic debris continues to accumulate on remote shorelines. These results reinforce the need for enhanced enforcement of MARPOL Annex V, particularly through improved waste tracking, port reception facilities, and expanded international cooperation (Ryan et al., 2019). Given ongoing accumulation, cleanups will remain an important element in marine debris management, which is likely to be included as an article in the UN Global Plastics Treaty (Scientists' Coalition for an Effective Plastics Treaty, 2024). While cleanup efforts are often framed as reactive

<sup>10</sup> See, for example, the EPA's page on 'Sargassum Inundation Events (SIEs): Impacts on the Economy' found here <https://www.epa.gov/habs/sargassum-inundation-events-sies-impacts-economy>

rather than preventative, they reduce immediate harm, prevent microplastic fragmentation, and restore habitats (Browne et al., 2015). As demonstrated in this study, cleanup approaches must be optimized to ensure cost-effectiveness, minimize unintended environmental impacts, and integrate with broader waste reduction strategies.

#### 5.4. Conclusions

This paper presented two remote cleanup case studies, including traditional and innovative strategies and a set of criteria to consider when selecting cleanup strategies. Combining experiential insights from island cleanups on the Southeast Alaskan Coast and the middle of the Pacific Ocean, the case studies demonstrate that cleanups in opposite parts of the world share similarities as well as unique challenges. The study provides insights into which strategies are most effective for remote cleanups, and assessed tradeoffs between feasibility, cost effectiveness, potential harms and co-benefits. By considering these criteria while planning a cleanup, practitioners are encouraged to make strategic choices, deploy creativity, minimize harm and maximize benefits.

Looking at two very different case contexts, the analysis suggested that manual collection is inevitable, but certain high-cost strategies may be necessary to support removal and transport in remote locations. The cases also described how creativity, technological and social innovation can lead to successful cleanups, with many factors being out of control of even the best prepared plan (e.g. inclement weather, changing tides or a visiting research vessel providing extra support). Results show that tailored transportation, data collection protocols, local engagement and communication can increase the effectiveness, co-benefits and impact of any cleanup, whereas some technologies are only relevant in specific circumstances. The analysis confirmed that each remote context will require dedicated planning, local expertise and taking unique wildlife and geographical characteristics into account and to always 'expect the unexpected'.

#### CRediT authorship contribution statement

**Hanna Dijkstra:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Kristina Tirman:** Writing – review & editing, Writing – original draft, Investigation.

#### Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Hanna Dijkstra reports financial support was provided by Howell Conservation Fund. Hanna Dijkstra reports administrative support, equipment, drugs, or supplies, and travel were provided by Plastic Odyssey. Hanna Dijkstra reports a relationship with Earth Action that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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#### Data availability

Data will be made available on request.

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