REPORT

Proof Clean Bunes Beach, Lofoten

Further professionalization of coastal cleanup crews: testing the use of heavy machinery

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Sammendrag / Summary

Proof Clean Bunesstranda ble gjennomført som et oppfølgingsprosjekt til hovedprosjektet, Proof Clean 2017. SALT testet og evaluerte bruk av maskiner til fjerning av store objekt. Prosjektet ble gjennomført over seks dager på en stor sandstrand i Lofoten. En hjullaster muliggjorde fjerning av tråldeler på flere 100 kilo, men innebar mye logistikk og ekstrakostnader.

Proof Clean Bunes Beach was carried out as a follow-up to the initial Proof Clean 2017 project. SALT tested and evaluated use of machines in removing large objects of marine litter. The cleanup action lasted for six days at a large sand beach in Lofoten. A wheel loader enabled removal of trawl parts of several hundred kilos, but involved a lot of logistics and additional costs.

Prosjektleder / Project manager	**Kvalitetskontroll / Quality control**
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PREFACE

Proof Clean Bunes Beach, Lofoten was a follow-up project to SALT and Maritimt Forum Nord's 2017 project Proof Clean. The objective of Proof Clean was to test the efficiency of professional cleanup crews in removing marine litter from the coastline, both in terms of mitigation impact and cost. By the end of the project, a total of NOK 500 000 remained in the budget and SALT proposed to the Norwegian Environment Agency that these funds be used to clean Bunes Beach using heavy machinery, thus testing the efficacy of a professional coastal cleanup crew on a new level. For more extensive background reading, please see the original report (SALT 2017).

The following persons participated in the project:

Sverre Julian H. Håpnes	*Project manager*
Marthe Larsen Haarr	*Researcher*
Kjersti Tønnesen Busch	*Cleanup crew*
Ane Oline Roland	*Cleanup crew*
Emil Røthe Johannessen	*Cleanup crew*

On behalf of collaborators, SALT wishes to thank the Norwegian Environmental Agency for the financing of the project.

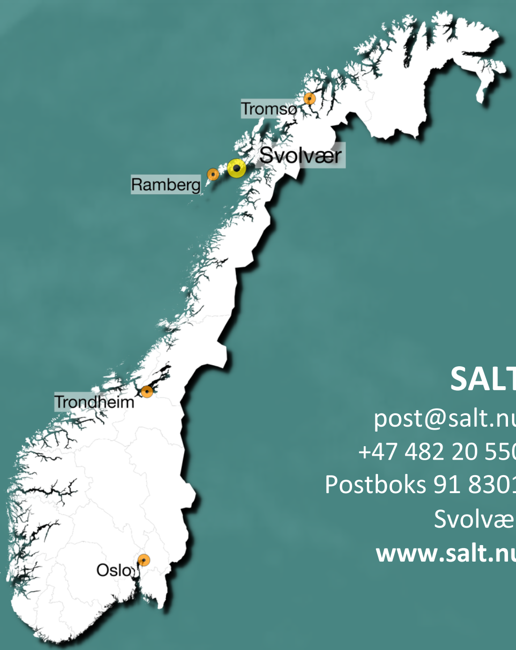
Trondheim, 21.12.18

Sverre J.H. Håpnes

Sverre Julian H. Håpnes

Project manager, SALT

Main chapters



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1. INTRODUCTION

In the project Proof Clean, SALT developed and tested methodologies for optimising coastal cleanup actions in a professional setting. In addition, approximately 12 tons of litter was removed from the banks of Vestfjorden. The project was carried out in inner parts of Vestfjorden along the axes Engeløy - Svolvær in the south to Barøya in the north. The project focused on testing the efficacy of different modes of beach access and practical strategies while in the field.

A natural follow-up to Proof Clean 2017 was to test how the additional use of machinery may affect cleanup efficiency. A small wheel loader with a forklift attachment, and a mini excavator were used in addition to manual cleanup. The follow-up, Proof Clean Bunes Beach, was conducted at Bunes Beach in the westernmost part of the Lofoten archipelago. Bunes is a large, very flat beach of approximately 0,4 km^2. It also lacks road access, requiring a 15 min boat ride from the village of Reine, followed by 45 min of hiking to reach. It is a highly popular tourist destination during the summer.

2. SUMMARY OF PROJECT OBJECTIVES AND OUTCOMES

The objective of this project was to test both the benefits and the functional limitations of machinery to aid in coastal cleanup actions, and how its use impacts a professional crew's efficiency. Specifically, we tested a small wheel loader with a forklift attachment, as well as a mini excavator.

Figure 1: Top: View down to Bunes Beach. Bottom: Collage of various shots taken on the beach. All photos by SALT / Marthe Larsen Haarr.

The project was carried out as a follow-up to the initial Proof Clean 2017 project where manual professional cleanup was tested. This further concept development was executed using to left-over funds from Proof Clean 2017, which arose because the taxation rate was lower than initially expected.

As the available funds were relatively limited, a single beach was chosen as a test site. Bunes beach on the northwest shore of the Lofoten archipelago (Figure 3) was chosen because several very large, partially buried items of litter impossible to remove by hand had been reported here. The beach was also chosen because of its inaccessibility, which poses a considerable challenge for volunteer cleanup actions as litter removal following collection is very difficult.

The operation lasted for six days and included, in addition to the actual cleanup action, reconnaissance and transport of staff, machinery, other equipment, and collected litter to and from Bunes Beach. The beach was reconnoitered upon arrival and objects of interest (OOIs) staked out. This was a necessary first step to plan the cleanup action ahead, prioritise litter items, and choose a strategic drop-off location for the machinery, which was transported to the site by helicopter.

In total, nearly 1.5 tonnes of litter was removed from Bunes Beach. The cleanup efficiency in terms of kilos collected per unit of time spent cleaning was similar to that of manual cleanup during Proof Clean 2017. Because the full week of cleanup action took place on a single large beach, more of the available time was spent actually collecting litter than during the 2017 pilot project where up to several small beaches/coves were cleaned daily, thus requiring more time on transport. However, the size of Bunes Beach also meant that the litter was dispersed over a larger area than on a smaller beach, even though the amount of litter per meter of coastline was high. Consequently, the cleanup efficiency was reduced somewhat by time spend moving around on the beach.

Access to machinery proved critical in removing large litter items, such as largely intact fishing gear. The wheel loader with the forklift attachment was the machine of choice. The mini excavator did not prove useful. It was too light to handle heavy litter items, yet too heavy to move easily on the sand. The forklift on the other hand, was highly useful for lifting and pulling fishing gear loose from the sand. For example, a 500 kg trawl net was successfully removed, which would have been near impossible to remove manually. However, the use of machinery was also very time consuming. Transport across the beach to reach different large items was slow. Considerable care and planning was also needed to avoid the machines getting stuck in the sand during both transport and operations.

3. OPERATION SETUP AND EXECUTION

3.1 Bunes Beach, Lofoten

The chosen location, Bunes Beach, is a sandy beach located on the western part of Moskenes Island, Lofoten (Figure 3). The beach covers an area of approximately 0.4 km^2 and is accessed by ferry from Reine to Vindstad followed by a 45 minute walk, first along a dirt road and then on a trail over the mountain pass separating the fjord (Vinstad) from the open ocean (Bunes). The beach itself and its surrounding area are popular recreational destinations for both locals and tourists (Figure 2); around 20,000 registered visitors took the ferry between Reine and Vindstad in 2017. The cleanup crew rented an apartment in the old school building in Vindstad and walked to and from the beach daily during the cleanup action.

Figure 2: Bunes Beach is a popular tourist destination in the summer despite its relative inaccessibility Photo by SALT / Marthe Larsen Haarr.

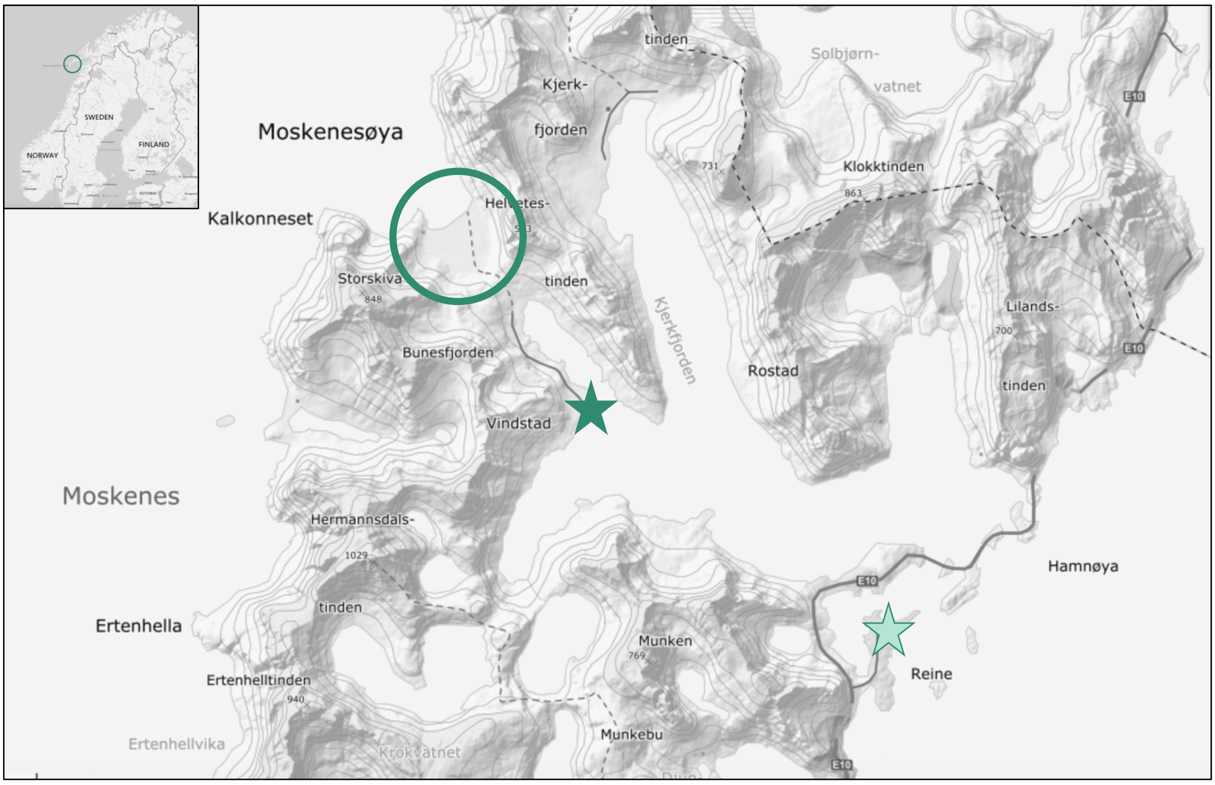

Figure 3: Map of study site. The inset at the top left shows the location of Lofoten on the Norwegian coast. The main map shows an excerpt of Mosknes Island. Bunes Beach, the cleanup location, is shown by the circle. The dark star shows Vindstad, the site of the crew basecamp. The light star shows Reine, from where transport to and from site was coordinated, and where the ferry to Vindstad departs from. The base map was obtained from www.ut.no.

3.2 Preparations and operational constraints

Planning a project of this magnitude, on a remote location and involving heavy machinery, required extensive preparations given the relatively short time scheduled for operations on site.

Obtaining permits to use machinery to remove litter from the beach proved a comprehensive task. It required obtaining permits from over 40 landowners with residential addresses not only locally in the Moskenes municipality, but also spread across Norway, Sweden, Denmark, Belgium and the United States. During the planning phase, the Norwegian government also approved the creation of Lofotodden National Park, which meant an additional permit had to be obtained from the county governor of Nordland. Dialogue was also initiated with the Norwegian Armed Forces and the local police to gain knowledge of known incidents and potential presence of military artifacts from World War II.

In an early phase of the project a small excavator was chosen as the favoured machinery to remove large litter items from the beach. It does not require a special licence to be operated and could thus be used by the entire cleanup crew. The excavator was to be transported by sea with a barge and tug boat operated by a subcontractor.

However, after talking to several professional machine operators, we understood that we would need a larger and more manoeuvrable machine to ensure efficient operation. It was then decided to hire a wheel loader equipped with both a bucket and forklift.

In this phase a new subcontractor and boat operator offering better terms was contacted to transport the equipment to the site. Collaboration with this second subcontractor was also terminated, however, due to perceived unreliability and potential inability to provide the needed services within an acceptable timeframe. Through these negotiations, it was also decided that the sea route was too unpredictable to rely on for transporting machinery and removing collected litter at the end of the cleanup action.

Figure 4: A miniature digger and wheel loader were brought in by helicopter. Photos by SALT / Marthe Larsen Haarr .

Consequently, it was decided to use a helicopter for transport of machinery and litter to and from the beach. This decision was made close to the implementation of the cleanup action, which meant some quick decision making by the SALT team to ensure all loads to be carried were within the weight capacity of the available helicopter. At this point, we therefore chose to rent two small machines, each weighing approximately 1200 kg: a small wheel loader and mini excavator (Figure 4).

3.3 Litter targeted

The primary target for the action was litter items too large to remove by manpower alone. Driftwood was not removed.

More specifically, we focused on large pieces of abandoned, lost or otherwise discarded fishing gear (ALDF). Items such as largely intact trawl nets are extremely heavy and difficult to handle, especially when partially buried in sand. Such items could also pose an entanglement risk for wildlife, and contribute to the formation of secondary microplastics when exposed to sunlight and abrasion by sand (Andrady 2011; Kühn *et al.* 2015).

The beach is a highly dynamic system, and the sand is continually changing the topography of the beach as litter is covered and uncovered. Large litter items may result in mounds or dunes on the otherwise largely flat beach as they are buried. Removing the litter would prevent this and hopefully contribute to returning the area to its natural state.

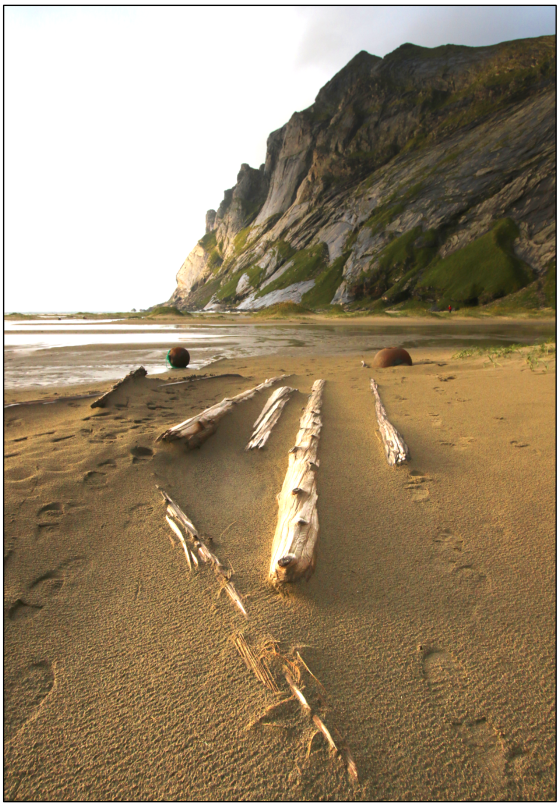

Figure 5: Driftwood was not collected during cleanup operations. Nor was priority given to the numerous metal bobbins. Photo by SALT / Marthe Larsen Haarr.

The county governor of Nordland also requested that we prioritise visible plastic-based ALDF, while metal trawl bobbins (Figure 5) should not be given priority as they pose little environmental risk in this context and has a certain cultural value on the site given the long and rich history of fisheries in the region.

4. CLEANUP EFFICIENCY

4.1 Amount and types of litter

In total, 1,441 kg of litter was removed from Bunes Beach, 60% of which was removed with the aid of machinery.

The vast majority of litter collected consisted of various fractions of rope. Nearly one tonne of rope material was collected, constituting 74% of the total litter removed. Half of this weight was made up by a single large trawl net (Figure 6).

Figure 6: The largest litter item removed, a 500 kg bottom trawl net. Only a fraction of the net was visible above the mound of sand. Photo by SALT / Marthe Larsen Haarr; taken in May 2018 during the initial reconnaissance of the beach.

Of the remaining litter collected, only 4% (50 kg) was able to be sorted as rigid plastics with the potential for being sent for recycling. One quarter (300 kg) of the litter collected was sorted as "mixed waste" with the potential for being sent to combustion in a waste-to-energy facility.

There were numerous deposits of litter on the beach, presumably compiled by well-meaning visitors wishing to engage in a cleanup action, but seeing no options for actually removing the litter collected they abandoned it. Some of these deposits appeared to also have been fire sites, possibly to attempt to burn the litter *in lieu* of transporting it off the beach. Consequently, large masses of melted plastics were found at times (Figure 7). Such masses of partially melted plastics could not be sorted for potential recycling.

Figure 7: What appeared to be the remnants of a fire where litter has presumably been attempted burned. Left behind is a large conglomerate of melted plastics. Photo by SALT / Marthe Larsen Haarr.

4.2 Efficiency of the cleanup

Using machinery during the operation resulted in two competing impacts on cleanup efficiency. The use of machinery enabled the removal of large items which would have been nearly impossible to remove by other means (Figure 8), and which did result in greater efficiency when using machinery compared to manual cleanup. However, the use of machinery also resulted in considerable amounts of time dedicated to logistics (Figure 9), such as the transport of equipment on the beach (see Chapter 5 for details), which reduced the overall efficiency of the crew despite the ability to tackle very large items.

During the initial Proof Clean pilot of 2017 (SALT 2017), the average efficiency of each crew member during manual cleanup was 115 kg per day. In comparison, during this trial at Bunes Beach, the average efficiency of each crew member was 100 kg per day. The access to machinery to aid in the removal of very large items therefore did not significantly improve the overall efficiency of the crew when considering the full week of operations and its activities.

Figure 8: Using the wheel loader to pull loose a large trawl net. The weight of this net (500 kg) combined with it being partially buried, made it almost impossible to remove by hand. Access to machinery increased cleanup efficiency by allowing such items to be removed. However, managing machinery on site does also cost considerable time during operations, reducing somewhat the gain in efficiency. Photo by SALT / Marthe Larsen Haarr.

It is important to note, however, that the above comparison cannot be made reliably based on a single test operation with machinery. This pilot test revealed several aspects of operations which can be streamlined, and earned the crew much invaluable experience with the possibilities and limitations of using machinery during coastal cleanups (see Chapter 5). Consequently, subsequent cleanup actions will likely loose less time to logistics on site.

Breaking the week of operations into its individual days, there were clear differences in time use, the amount of litter collected, and efficiency (Figure 9).

The first day of operations was dedicated to reconnaissance, and no litter was removed on this day. The second and last days were dedicated largely to getting machinery other equipment to and off site, as well as litter out on the last day. Any cleanup done during this time was carried out manually as the machinery was not available. Litter removal by machinery was carried out for three days. The amount of litter removed was low on the first day of machine use as it took the full day and some of the next to free the 500 kg trawl net using the wheel loader. Freeing this net was the reason for the large jump in total litter collected on the third day. Moving on from this first net to other items requiring machinery to free them was the reason for considerable amounts of time spent on logistics (*i.e.,* moving machinery around the beach) during the fourth and fifth days.

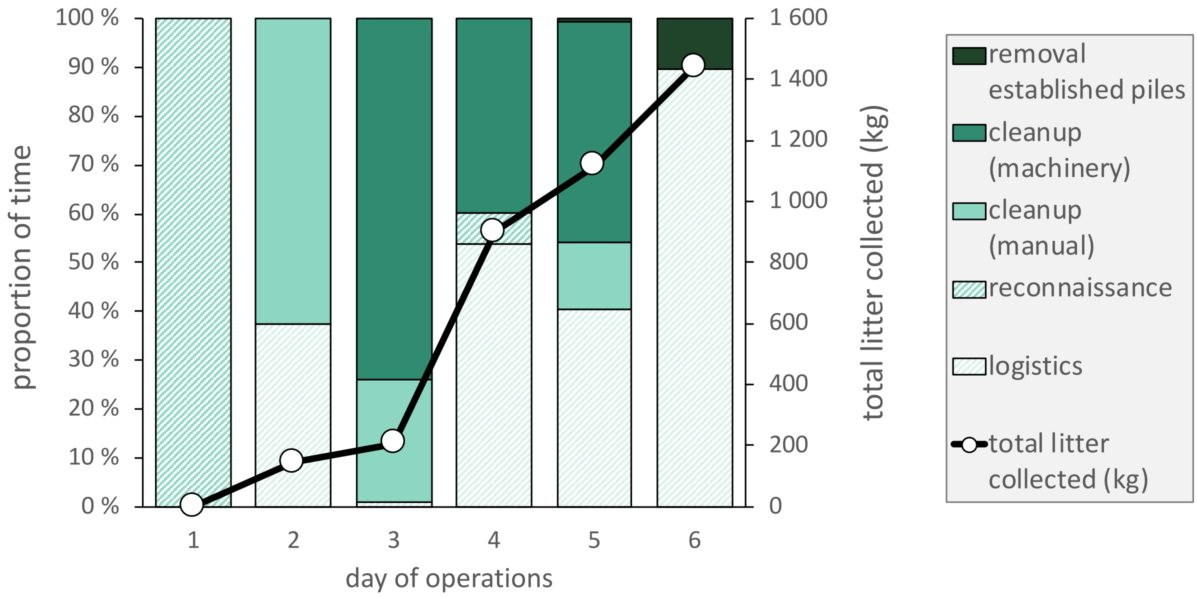

Figure 9: Overview of time use (stacked bar graph) and cumulative litter collected (line graph) during the week of operation.

This variability in time use on the beach was reflected in daily variations in efficiency, which ranged from 50 g to 1.2 kg per minute spent collecting litter. In comparison, the average efficiency during the 2017 Proof Clean pilot was 600 g of litter per minute of cleanup.

Figure 10: The sheer size of Bunes Beach meant considerable time was spent transporting the crew, litter and machinery around the beach. Photo by SALT / Marthe Larsen Haarr.

When comparing the efficiency of the purely manual cleanup actions of Proof Clean 2017 and this test of heavy machinery, the sheer size of Bunes Beach much also be given consideration. During the Proof Clean 2017 pilot, the crew cleaned an average area of 40,000 m^2 weekly; Bunes Beach is ten times this size. Of a hundred locations surveyed in Lofoten and Vesterålen, Bunes Beach is in the top 5 with respects to the total amount of litter observed per meter of coastline (SALT, unpublished data). However, because the beach is so deep, the litter is quite spread out and the beach was only ranked 20th of the hundred surveyed locations with respects to the density of litter per square meter (SALT, unpublished data).

Its size made the beach a suitable first test location for using machinery given it provided a large, flat area to work within without the need to transport machinery between sites. This was ideal for a first test to gain experience with the machines and better understand their limitations and opportunities. However, it also undoubtedly contributed to reduced cleanup efficiency as more time was spent on transport and movement on site compared to most other locations (Figure 10).

The effects of location size, both on the efficiency during individual cleanup actions and of operations as a whole, are readily visible when comparing weekly summaries of the Proof Clean 2017 pilot and Proof Clean Bunes (Figure 11). As already stated, the total amount of litter collected from Bunes Beach was comparable to an average week of manual cleanup (Figure 11a). Yet, the proportion of time spent on actual cleanup was much greater on Bunes Beach than it was at any time during Proof Clean 2017 (Figure 11b). This was despite the considerable amount of time spent on logistics on Bunes Beach (Figure 9), largely dealing with practical issues surrounding the machinery, such as transport between locations on the beach, which highlights the amount of time spent on tasks such as transport between locations, assessment of new locations, and securing collected litter for later pickup during the numerous smaller cleanup actions of Proof Clean 2017. Remaining in a single large location for several days therefore allowed much more time for cleanup than repeatedly moving between smaller locations.

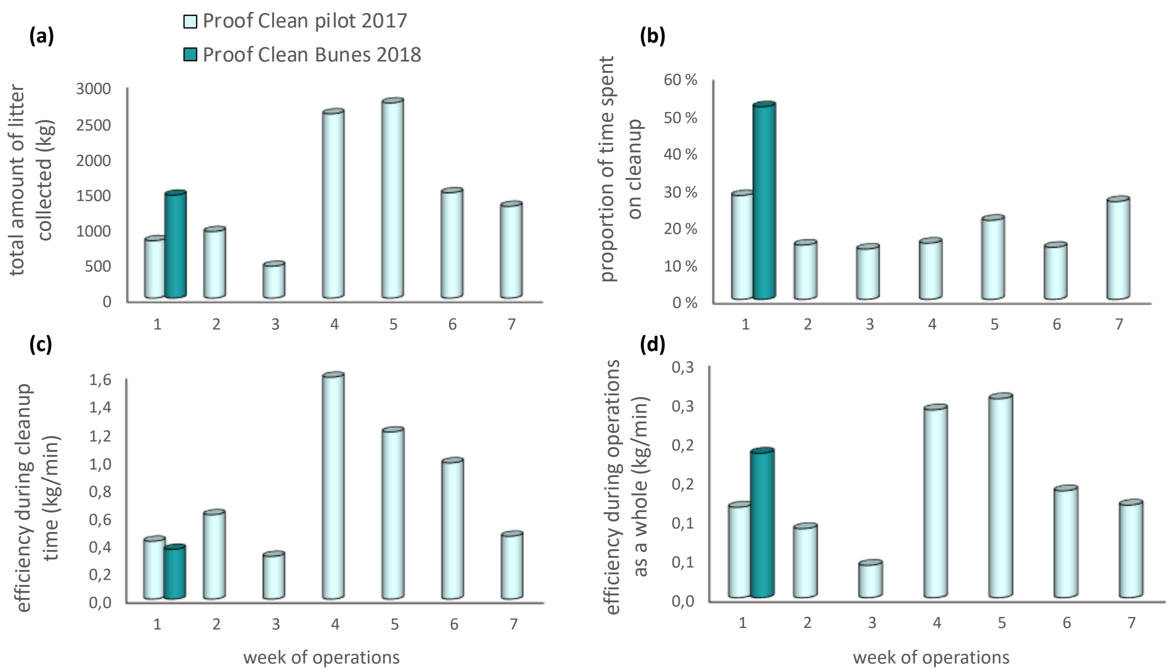

Figure 11: A comparison of weekly time use and efficiency between the purely manual Proof Clean 2017 pilot (7 weeks) and Proof Clean Bunes 2018 (1 week) with the aid of machinery. (a) The total amount of litter collected weekly. (b) The proportion of time each week spent directly on cleanup. (c) The efficiency, in terms of the amount of litter collected per unit time, during cleanup. (d) The efficiency, in terms of the amount of litter collected per unit time, of the operation as a whole (i.e., all time worked weekly).

However, the downside of the size of Bunes Beach is clear when comparing the cleanup efficiency during the time spent specifically on litter collection. Efficiency on Bunes was comparable to the least efficient manual cleanup actions of Proof Clean 2017 (Figure 11c), despite the aid of machinery to remove some very large and heavy items. This was undoubtedly due to a combination of considerable walking distances between dispersed litter items during manual cleanup, and the time necessary to safely dislodge partially buried ALDF with the forklift. Overall, however, when taking into account all work hours during the operation, the efficiency of the crew at Bunes Beach was among the highest in Proof Clean (Figure 11d).

Consequently, the use of machinery increased cleanup efficiency in some ways by allowing the removal of large and heavy ALDF that would otherwise not have been removed, but the time spent handling the various practical aspects of having machinery on site, combined with time associated with collecting litter dispersed over a very large area reduced the efficiency, resulting in little overall gain over manual actions. However, this must be interpreted with some caution given machinery was tried out in a single location only.

What we can conclude to date is that streamlining and optimising logistics on site, combined with critical evaluations of when machinery is both needed and possible to utilise, will be crucial to maximising the efficiency of professional cleanup crews and ensuring that items too large to be handled by volunteers can be removed.

5. PROS AND CONS OF USING MACHINERY

Utilising machinery during a beach cleanup had clear advantages, but also posed several challenges. Firstly, it did allow the removal of items, specifically large ALDF, that would otherwise have been impossible to remove. At the same time, it became abundantly clear that there are numerous challenges in operating machinery on the beach, particularly with respects to mobility, and that choosing the correct machine – as well a critical evaluation of when one is actually needed – is crucial.


Figure 12: One of the challenges of using machinery was finding safe paths for it to follow during transport on the beach as they got easily stuck in too soft sand. Photo by SALT / Marthe Larsen Haarr.

A wheel loader and excavator of approximately 1,200 kg each were transported to Bunes Beach. However, only the wheel loader was used during the operation. The mini excavator was quickly deemed not useful due to poor maneuverability, low cruising speed, and a propensity to get stuck. It seems a continuous track vehicle is unsuited for operations on sand. There may be exceptions to this depending on how hard packed the sand is, but in general mobility of this type of vehicle will likely be an issue. Low cruising speed also meant using the excavator was too time consuming to use over such a large area as Bunes Beach. Furthermore, the mini excavator was too light and the bucket too small to handle the weight of most large ALDF needing removal.

In comparison, the wheel loader was highly manoeuvrable, and the relatively high cruising speed enabled good coverage of the beach. Its wheels were also much less prone to getting stuck than the continuous track of the excavator. Nevertheless, getting stuck was still a very real concern, especially where the sand was very loose or very wet, and during litter removal with additional weight on the machine. Consequently, it was vital to scout and plan all transport routes on the beach ahead of moving the machine between locations. Wooden planks were used successfully to spread the weight of the machine and provide a solid surface to drive on, and pieces of fishing net were also used to help prevent the wheels from spinning (Figure 13). During future operations, however, traction mats will be considered an essential piece of equipment.

Figure 13: Preventing the wheel loader from getting stuck during operations required fishing net mats to reduce spinning of the wheels (bottom), and most often also wooden planks beneath the wheels (top) to spread the machine's weight and provide a solid surface to drive on. This was increasingly important as the sand around the item being dislodged became disturbed, and to allow the wheel loader to get close enough to the edge of the mound.

As the wheel loader was equipped with both a bucket and a forklift, we could choose to either dig, lift or pull litter loose from the sand. However, given the sheer size of some ALDF, using the bucket to dig and lift was not practical. Using the wheel loader to pull items loose by tying it to the machine and slowly driving away may be effective in certain settings, but was generally not successful as the wheels were extremely prone to spinning and getting dug into the sand with the extra strain. This approach was therefore quickly abandoned, and the forklift was used instead with the machine stationary.

When lifting loose partially buried ALDF with the forklift, small slits were made in the net to fit the prongs of the forklift and/or slings and ropes were used for attachment. The latter was useful to increase the reach of the machine. The net could then be lifted loose of the sand in a controlled manner (Figure 14). The weight of net while lifting quickly caused the wheel loader to become unbalanced given disproportionate weighting of the front. Consequently, during particularly heavy (*i.e.,* high) lifts the rear end of the machine would lose ground contact. To avoid this potentially dangerous situation, the net would have to be lifted loose

Figure 14: Photo sequence showing how partially buried ALDF was lifted loose from the sand with the forklift. This was done incrementally by repeatedly reattaching the forklift lower down on the net after releasing a section, as well as moving the wheel loader around the mound to dislodge different parts of the net.

in small increments. resulting in repeated lifts to free it from the sand. Each time the forklift's capacity was reached, the net would be freed from the prongs and reattached lower down to repeat the process. The wheel loader was also moved around the net to lift different sections in this manner. The process was effective, but still time consuming. The largest net removed (500 kg) took one and a half days to dislodge.

In summary, the wheel loader turned out to be a highly useful tool when operating whilst stationary (*i.e.,* lifting from a stand-still, not pulling items loose). It thus enabled removal of items which would have been impossible or too time consuming to handle otherwise. However, operations were also time consuming, especially considering the care and planning necessary to move the machine around on the beach. Some of the advantages, disadvantages and necessary precautions of using machinery during beach cleanups are summarised in Figure 15.

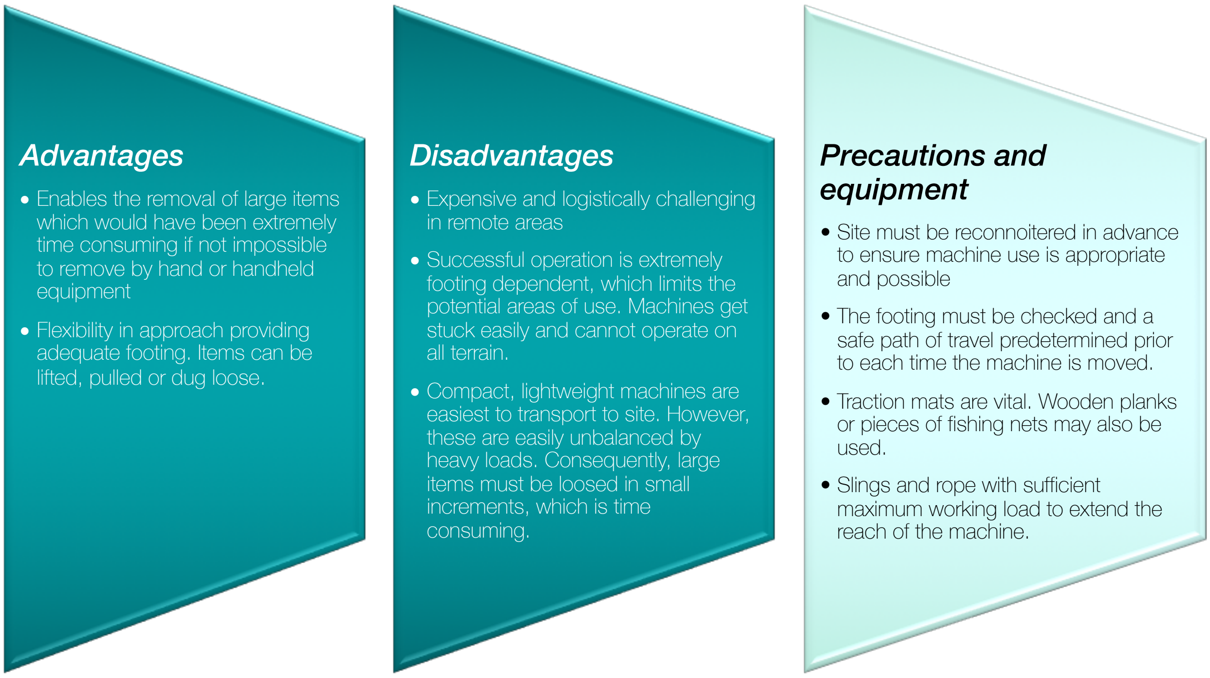

Figure 15: A brief overview of the general advantages and disadvantages of using machinery, as well as some of the necessary precautions and equipment. For comments on differences between machines, see text.

6. FURTHER DEVELOPMENT OF THE PROFESSIONAL CLEANUP CREW

There are several features of the ideal professional coastal cleanup crew (Figure 16). The 2017 Proof Clean pilot and Proof Clean Bunes Beach have both contributed invaluable experience towards obtaining this skill level and effectiveness. Nevertheless, further work is still needed to optimise the concept of professional coastal cleanup crews.

1. *The ability to maintain Occupational Safety and Health (OSH) standards even in challenging locations and when handling large and/or potentially dangerous litter items.*
2. *The ability to work efficiently by maximising the amount of time spent on litter removal and minimising the amount of time spent on logistics and other activities.*
3. *The ability to remove all litter items deemed necessary/desirable to remove from the environment, including large, heavy, lodged and partially buried items*
4. *The knowledge and experience to optimise the mitigative effect of cleanup actions through the right choices of locations and strategy on site.*

Figure 16: Key features of the ideal professional coastal cleanup crew.

Firstly, one of the key advantages of professional vs. volunteer cleanup crews, is the greater control and oversight with respects to safety (see the Proof Clean 2017 report [SALT 2017]). Occupational Safety and Health (OSH) should be a major consideration during coastal cleanup actions, particular in remote locations and/or locations with challenging substrate, such as cobble and boulders. Safety is also paramount when attempting to remove certain items where either the item itself may be dangerous, or its removal could be hazardous for the involved cleanup crew, for example if the item is very heavy and/or requires the use of additional equipment to lift or dislodge. Consequently, it would be of great advantage to further develop OSH guidelines for coastal cleanup actions and possibly training courses for both professional crew members and regular volunteers/volunteer coordinators.

Secondly, work is still needed to optimise time use during cleanup actions. This is particular important in remote locations where time available for operations may be limited to strict timeframes. There is great potential in particular to reduce the time spent on logistics before, during and after cleanup actions. During the 2017 Proof Clean pilot, considerable time was spent on transport, preparations when arriving at a new location, and securing of litter for later removal post-cleanup given the frequent smaller cleanup actions (*i.e.,* a focus on smaller depositional coves rather than large beaches, often resulting in multiple locations cleaned daily). During Proof Clean Bunes, considerable time was spent on logistics connected to the transport to and off site of machines, as well as the logistics of operating machines on the beach. In both cases, the proportion of work time spent on actual litter removal could have been considerably higher. This could be improved by developing more efficient methods of site selection and reconnaissance, and standardised planning and execution procedures. The latter should include a critical evaluation of whether or not machinery is needed to remove all litter from a location and possible to operate on site, as well as how to approach obtaining the information needed to make this decision. The use of machinery requires considerable time and effort in advance of an action due to additional permits needed, as well as time to operate and manoeuvre on site, and its use should therefore be limited to when absolutely necessary. The objective is to facilitate as efficient cleanup operations as possible where the majority of time is dedicated to actual litter removal.

Thirdly, in order to achieve point #3 (Figure 16; the ability to remove any litter item) while still maintaining optimal efficiency as per point #2, further experimentation with alternative tools and equipment is necessary. Using heavy machinery enables the removal of large pieces of ALDF, but logistics before, during and after the cleanup action are time consuming. Consequently, we suggest testing techniques for handling larger litter items with manual tools. Less complex equipment, such a manual jack or winch, may make operations more predictable if crew are properly trained in safe and effective use as the logistics of use are generally less comprehensive than when using heavy machinery. The development of more advanced manual equipment use will need to be closely tied to the development of OSH guidelines.

Lastly, guidelines should be developed for how professional (and volunteer) coastal cleanup crews should prioritise during litter removal. Time constraints mean a location will hardly ever be restored 100% to its natural state; it is almost impossible to remove all litter. A detailed literature review of the impacts of different types of litter in the coastal zone and in different habitats should be conducted and used to device a protocol for assessing litter on site and the cleanup strategy which will produce the greatest mitigative impact, as well as identify any key knowledge gaps in this regard. Cleanup efficiency is typically measured in tonnage, but it is not immediately clear whether this is the optimal measure. Emphasis should also be placed on litter harm reduction, which may mean greater focus on removing smaller items more readily consumed by wildlife and types of cordage (ropes and nets) most likely to post entanglement risks. Such considerations may also vary greatly with the type of habitat, size of location and density of litter. Consideration should also be given to whether the removal of certain items, such as litter partially buried beneath vegetation, causes more harm than benefits. A rigorous review of the topic will provide cleanup crews with a better knowledge base up on which to make decisions in the field.

LITERATURE CITED

Andrady, A.L. 2011. Microplastics in the marine environment. Marine Pollution Bulletin 62: 1596-1605.

Kühn, S., Rebelledo, E.L.B., og Frankener, J.A. 2015. Deleterious effects of litter on marine life. *In* Marine Anthropogenic Litter (*eds* Bergmann, M, Gutow, L., and Klages, M.). Springer International Publishing AG Switzerland. Pp 75-116.

SALT. 2017. Proof Clean – the development of a professional coastal cleanup crew. SALT rapport nr. 1019. Rapport til Miljødirektoratet.

SALT kunnskap – friske ideer

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