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# The Ellrott grab: A small, lightweight sediment sampler for collecting undisturbed sandy sediments

**Chyrene Moncada, Andreas Ellrott, Dirk de Beer, Rudolf Amann, Katrin Knittel***
Max Planck Institute for Marine Microbiology, Bremen, Germany

## Abstract

Sampling sandy surface sediments is an important first step in understanding biogeochemical processes in these dynamic environments. However, sampling such sediments poses several challenges, especially when undisturbed samples with porewater are required. Several grab samplers are commercially available, but they are either prone to sample loss, too heavy or bulky for use in small vessels, or those with spring-loaded mechanisms present safety issues. Here, we present the Ellrott grab, a lightweight sediment sampler designed for collecting undisturbed surface sediments including porewater and overlying bottom seawater. The sampler consists of a frame and a rotating bowl that can collect 370 cm$^2$ of surface sediments up to 10 cm deep (2.5 liters total volume). The instrument is 40 × 60 cm in size, has a basic weight of 10 kg, with up to 20 kg additional weights for stability in sandy sediments. Two persons can operate the grab and it can be used on small boats with a crane and winch system or a hand winch. The grab is now in routine use in the Wadden Sea and in Isfjorden, Svalbard. The samples obtained from the grab were suitable for various geochemical and microbial analyses. Using microelectrodes, we found that in situ oxygen profiles were similar to ex situ profiles in cores subsampled from the grab, confirming that the grab causes minimal disturbance to the sample. Although the grab was designed for collecting sandy sediments, it could also be applied to silty sediments, allowing straightforward and efficient sampling of various sediment types.

Permeable sandy sediments cover at least half of the continental margins and are highly biogeochemically active because of their permeability. Due to the efficient sediment–water exchange of organics and electron acceptors, the mineralization processes occur at much higher rates than in silts or clays (Boudreau et al. 2001; Huettel et al. 2014). Because of this, shallow permeable sediments have been characterized as efficient biogeochemical filters for bioavailable compounds from the water column (Rocha 2008; Anschutz et al. 2009). Properly sampling these sediments is therefore a critical first step in understanding biogeochemical processes in benthic environments. However, sampling permeable sandy sediments and their associated porewater involve a number of challenges and is also often limited by many factors such as unavailability of large vessels, remote locations, and cost limitations.

The high permeability of sands challenges the sampling of sediments including the overlying water and the porewater. Today, there are several types of commercially available sediment samplers such as corers and grabs, but there are no options for a small and lightweight sampler that can collect intact and undisturbed sandy sediments. Corers are ideal for sampling sediment and porewater but are often less efficient in collecting sandy sediments than muddy or silty sediments because sands are less cohesive and impermeable (Anschutz and Charbonnier 2021). The bottom closing mechanism of corers is not always perfectly tight when sampling sandy sediments, causing porewater to leak out. Moreover, even a small core sampler like the MINIMUC (K.U.M Umwelt und Meerestechnik Kiel GmbH) has a relatively large footprint of 1 m$^2$. In addition, since it is pushed into the seafloor by gravity, a relatively large amount of ballast is needed, leading to a total instrument weight of 100–220 kg. Grab samplers collect a larger surface area of surficial sediment than corers (US EPA 2001). Hence, if the main interest of the study is surface sediments, grabs would be the preferred option over corers. Typically, grab samplers consist either of a pair of jaws that close and collect sediment or a bucket that rotates into the sediment (Mudroch and MacKnight 1994). The Van Veen, Ponar, Shipek, and Birge-Ekman grabs are the most

*Correspondence: kknittel@mpi-bremen.de

**Author Contribution Statement:** K.K. and R.A. designed the project. A.E. designed and built the grab with input from all coauthors, according to the sampling requirements of the project. All authors tested and deployed the grab in the field. All authors provided feedback for the improvement of the grab prototype. D.d.B. performed the microelectrode measurements and analyzed the data. C.M. wrote the manuscript with input from all coauthors. All authors approved the final version of the manuscript.

commonly used grab samplers. Of these, the Birge-Ekman is better suited for soft sediments (US EPA 2001). The Van Veen grab can be used to sample most types of sediment and is less susceptible to blockage and loss of sample than Ponar samplers (Klemm et al. 1990). However, the Van Veen grab is susceptible to either premature closing in rough waters or incomplete closure of its jaws, which results in sample loss (Lassig 1965; Environment Canada 1994). The Ponar grab, which is available in a standard (7.25 liters sample volume) and petite size (2.2 liter sample volume), is a versatile grab suitable for quantitative sampling on different substrata (Elliott and Drake 1981). Most Ponar grabs have a mesh screen and rubber flap as a removable lid which allows subsampling. However, Ponar grabs are also susceptible to incomplete closure, resulting in sample loss, and the petite size requires more deployments to obtain sufficient samples if many analyses are required (Klemm et al. 1990; US EPA 2001). The Shipek grab is a widely used surficial sediment sampler and has a sample bucket that can be opened for subsampling (Sly 1981). The grab operates through a spring-loaded mechanism which is quite reliable but is a disadvantage in terms of instrument weight and safety. The springs need to be very strong in order to provide sufficient force to rotate the metal half-cylinder through the sediment. To withstand these strong forces, the whole device is made of thick metal and, therefore, quite heavy. A false release of the spring mechanism could cause serious injuries. For safety reasons and to reliably activate the spring mechanism after ground contact, a heavy release weight is used in addition. This leads to a total instrument weight of approximately 60–80 kg. Moreover, a rigid large support frame and handle are needed on deck for safe preparation and spring wind-up.

Given all these limitations in existing grab samplers, there was a need for a lightweight sediment sampler with a small footprint that can collect overlying water, sediment, and porewater. To address this gap, we designed, built, and tested the Ellrott grab. The new sediment sampler was designed to fulfill the following key requirements (modified from US EPA 2001; Tuit and Wait 2020):

i. Avoids a pressure wave upon landing on the sediment and scoops sediment cleanly with minimal disturbance.
ii. Closes tightly and collects intact sediment samples, including the overlying seawater and porewater with no signs of channels or washout.
iii. Collects sufficient sediment volume but does not overfill the sampler with sediment (clear overlying water must be present and the surface of the sediment should not touch the lid of the sampler).
iv. Allows for subsampling.
v. Retrieves coastal sediment samples from a wide range of water depths.
vi. Have a small footprint and be suitable for use on smaller ships or research vessels with a crane and winch system or a hand winch.
vii. Lightweight, easily transported, and set up on the site. Additional weights can be added as needed.
viii. Safe to handle and can easily be operated by one researcher and one winch operator without the need for extensive training.
ix. Fast turnaround time between deployment, sample retrieval, subsampling, cleanup, and collection of the next sample.

Here, we provide a detailed description of the new grab sampler and demonstrate that the sample obtained through the grab is undisturbed by comparing in situ oxygen profiles and profiles from cores subsampled from the Ellrott grab.

## *Materials and procedures*

### Ellrott grab design

The parts of the Ellrott grab are illustrated in Fig. 1. The design of the Ellrott grab combines features from the Shipek grab and the much larger and heavier (150–350 kg) Hamon grab (Oele 1978; Boyd et al. 2006). The Ellrott grab follows a similar rotating mechanism as the Hamon grab, wherein the pulling of the rope rotates a lever arm, which drives a sampling bucket through the sediment. Similar to the Shipek grab, the sampling compartment of the Ellrott grab consists of a rotating sampling bowl. However, instead of a rotating metal half-cylinder as in the Shipek grab, the sampling container is constructed from two halves of a stainless steel bowl (Carl Roth, order number YH86.1), which were screwed together and sealed using a polyurethane sealant. The stainless steel is thin yet rigid enough to cut through the sediment with minimal force needed. It can collect approximately 370 $cm^2$ of surface sediment (Fig. 2a). The maximum sampling volume of the bowl is 2.5 liters, and it can sample sediments up to 10 cm deep. Unlike most grab samplers, there is no need for strong spring forces and, therefore, no need for any thick metal housing. Also, heavy trigger release weights are not necessary since it is not a spring-loaded device. With this, the Ellrott grab only needs enough weight to stay firmly on the sediment during bowl rotation.

The Ellrott grab is fixed on a stainless steel frame with lead ballast bars and ground spikes on both sides of the frame to stabilize the sampling device on the sediment. The ground spikes also prevent lateral motion of the instrument in the sediment. A custom-built offload hook (30 mm wide × 3 mm thick flat stainless steel) is used to connect the frame to the winch, and a rope with a stopper connects the offload hook to the lever arm of the grab. The lever arm rotates a cogwheel, which rotates the sampling bowl, scooping sediment in the process. The bowl has a removable lid and a rubber lip (Fig. 2b) that prevents the sediment, porewater, and overlying seawater from being disturbed or flushed during its ascent back to the deck. The lid is made of 3D-printed plastic (digital acrylonitrile butadiene styrene [ABS], Alphacam) with a 3D-printed seal below (TangoBlack, Alphacam). The rubber lip is made of 0.5-mm silicon sheet (MVQ Silicones GmbH). Near the edge of the bowl, there is a hole positioned higher than the lid that allows surface

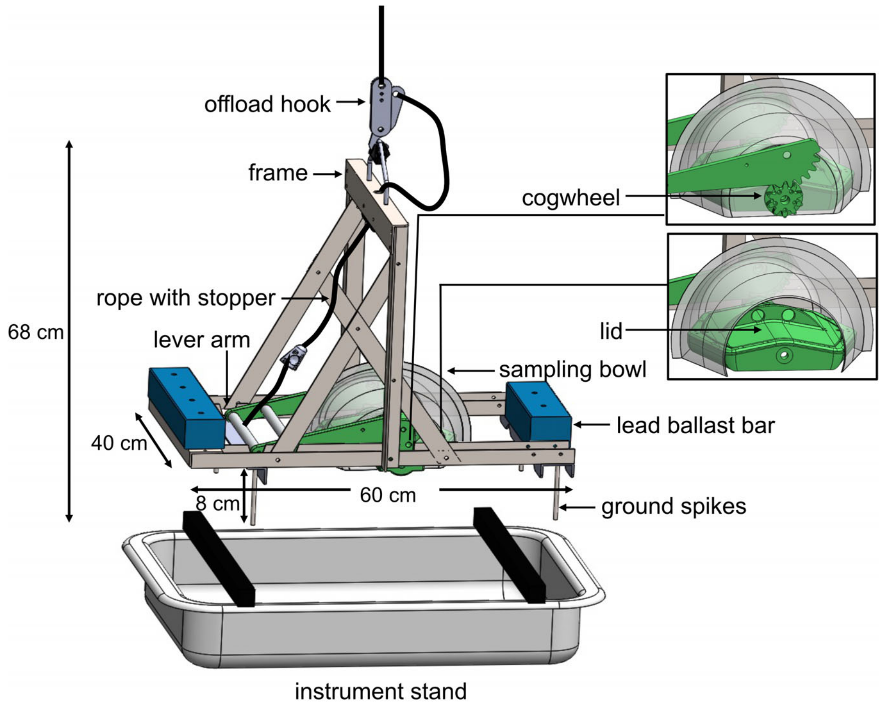


**Fig. 1.** Parts of the Ellrott grab. The instrument has a height of 74 cm including the instrument stand and has a basic weight of 10 kg. Lead ballast bars can be added to stabilize the grab on the sediment during bowl rotation.

seawater to flow out so that it does not mix with the bottom water when the lid is opened (Fig. 2a). The lid is attached to the bowl through a stainless steel toggle latch on each side (Part number GE18, Savigny) (Fig. 2b).

### Ellrott grab mechanism

The grab can be used on small boats with a crane and winch system or via a hand winch. The grab is hooked to a winch, and it is lowered to the sea floor (Fig. 3a). After the grab has settled on the sea floor, the offload hook releases automatically due to the absence of rope tension (Fig. 3b). The winch is stopped and is slowly operated in the reverse direction to pull the grab back to the surface. The rope tension pulls the grab lever arm, driving the rotation of the bowl. The sampling bowl cuts through the sediment and scoops the sediment sample (Fig. 3c). After the sediment is scooped, the rope

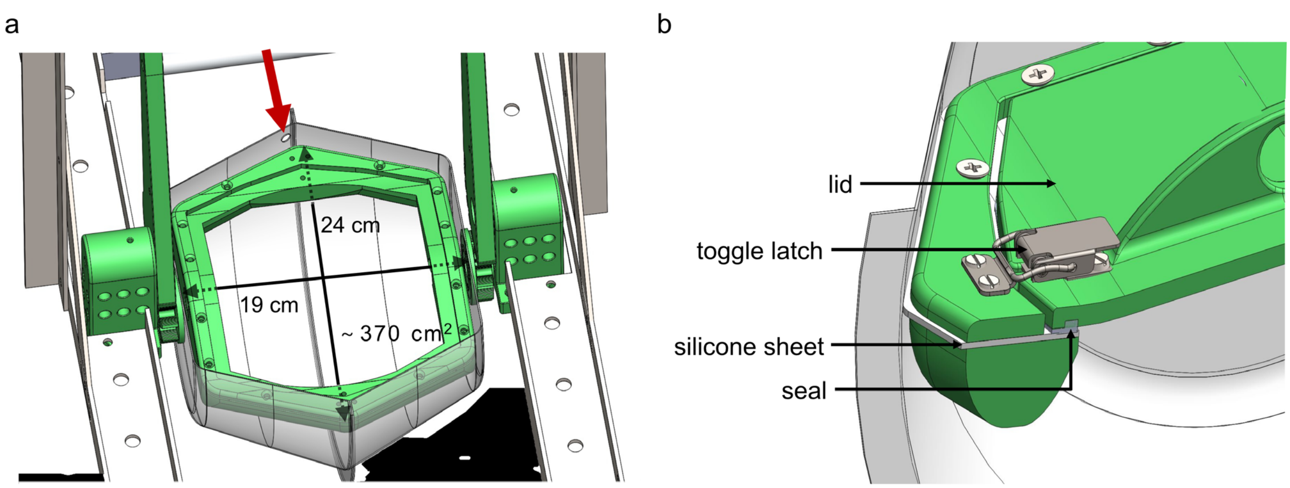


**Fig. 2.** Ellrott grab sampling bowl and lid specifications. (**a**) The grab can collect 370 cm$^2$ of surface sediments up to 10 cm deep (maximum 2.5 liters). A hole (red arrow) above the lid on one side of the edge of the rotating bowl allows surface seawater to flow out before the lid is removed, preventing contamination of the bottom water with surface seawater. (**b**) A 3D-printed plastic lid is attached to the bowl through a toggle latch. To prevent mixing of surface and overlying seawater, the lid is reinforced with a 3D-printed rubber-like seal made of TangoBlack material and a rubber lip cut from a silicone sheet.

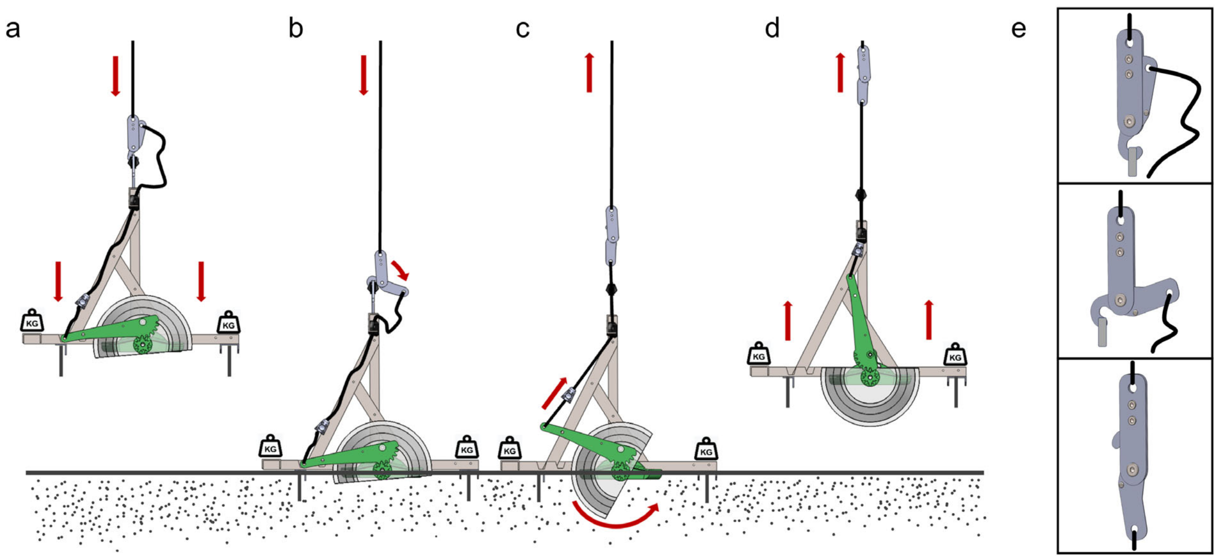


**Fig. 3.** Ellrott grab sampling principle. (**a**) Lowering of the grab onto the sediment; (**b**) release of offload hook causes loss of tension in the rope; (**c**) pulling of rope upwards causes the bowl to rotate, sampling sediment in the process; (**d**) the sample is lifted back on deck; (**e**) offload hook mechanism during grab deployment.

stopper blocks further rotation of the bowl, and the whole instrument is lifted upward (Fig. 3d). Figure 3e shows in closer detail the movement of the offload hook when the grab is lowered and reaches the sediment, and when the lever arm is pulled up.

## Dimensions

The grab has a basic instrument weight of 10 kg. Depending on the sampling site, lead ballast bars can be applied in addition. In our coastal sampling sites in the Wadden Sea and Isfjorden, Svalbard, where we sampled sandy sediments, 8–10 kg lead weights on both sides were optimal, leading to a total instrument weight of 26–30 kg. The footprint of the Ellrott grab is 40 × 60 cm, with an instrument height of 65 cm. We placed the grab on a 46 × 68 cm box with rails for secure transportation and to serve as a stand while on deck. The whole assembled setup fits into a 60 × 80 cm footprint aluminum hood box (Zarges).

## Preparation and deployment

While on deck, the grab can be placed on the instrument stand so that the device is not resting on the ground spikes. Before deployment, users must ensure that the lid is securely fastened to the bowl through the toggle latches on both sides and that the offload hook is connected to the winch and the frame. The bowl should be in the open position, with the bowl facing downward. The appropriate weights are fixed onto the frame with screws. Users should also make sure that

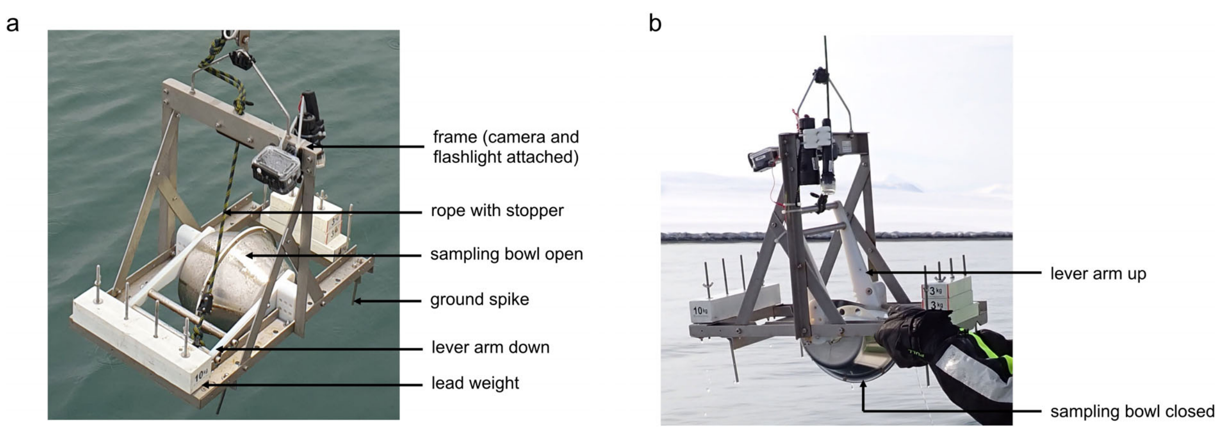


**Fig. 4.** The Ellrott grab before and after deployment. (**a**) Before deployment, the sampling bowl is in the open position, that is, facing down, and the lever arm is down. Additional accessories, such as a camera and a flashlight, are securely attached to the frame. (**b**) Upon retrieval of the grab, the lever arm is up, and the sampling bowl is closed.

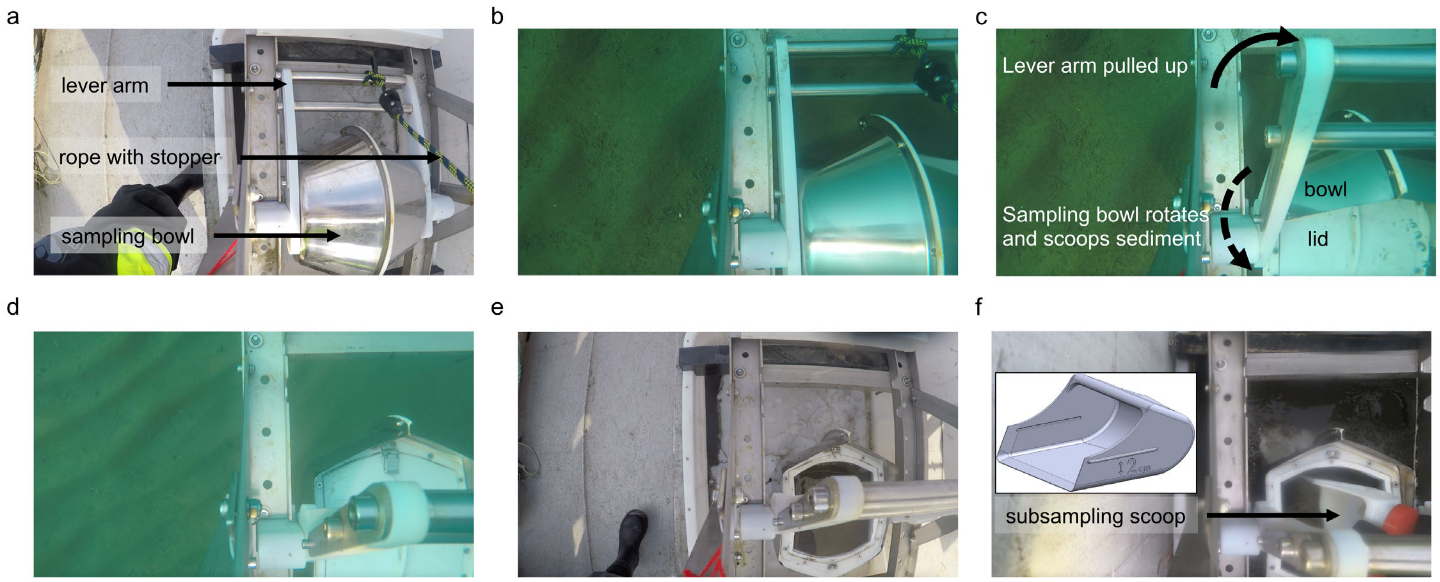


**Fig. 5.** Deployment of the Ellrott grab. (**a**) The grab is ready for deployment. (**b**) The grab is steadily lowered to the seafloor. (**c**) The sampler reaches the seafloor, causing the rope to lose tension. The rope is pulled back up, pulling the lever arm (solid black arrow) and rotating the bowl (dashed black arrow), scooping sediment in the process. (**d**) The device is pulled out of the water. (**e**) The grab is placed on the instrument stand, the lid is removed, and subsampling can be conducted. (**f**) When not using cores, a 3D-printed plastic scoop made of digital ABS is used to subsample the sediment and the associated porewater.

any additional accessories are fixed tightly on the frame. Once prepared, the device can be deployed by two people: one to operate the winch, and one to guide the grab while it is lowered and lifted. During deployment, the grab is slowly lowered until it reaches the sediment, and steadily raised once the rope loses tension. Once it is back on deck, it can be mounted back on the instrument stand. Figure 4 shows images of the grab before and after deployment.

### Subsampling

Upon retrieval of the grab, the lid can be removed, and subsamples can be taken directly from the bowl. This eliminates the need to transfer the sample to another container, which disturbs the sediment profile. We used 5–7 cm diameter cores to sample the sediment for oxygen concentration measurements. For other analyses, we used syringes to collect the overlying seawater, and either cut off syringes (as mini push cores) or a scoop to sample surface sediments.

## *Assessment and discussion*

### Field deployments

We deployed the Ellrott grab multiple times in 2021, 2022, and 2023 in the Wadden Sea and in Isfjorden, Svalbard, to collect coastal sandy sediments. From these deployments, we collected over 100 intact grabs with grain sizes ranging from fine to medium sand. The grab consistently collected intact sediment and the overlying seawater. Figure 5 shows a series of images of the grab being deployed. Collection of sediment at a water depth of 5 m had an average turnaround time of 3–4 min. When lowering the grab, we took the standard precautions when deploying grab samplers, that is, lowering the grab slowly to avoid disturbing the sediment–water interface and to prevent the formation of bow waves that could displace finer grains at the surface. During retrieval, the rope was steadily raised to minimize disturbance of the sediment. The maximum water depth the grab was tested in so far was 23 m, but it can be used to collect sediments at deeper stations. As with most grabs, the Ellrott grab works best under calm sampling conditions with low current velocity. Still, we did not face any issues with collecting sediment when there were swells or waves. This is because the rope connecting the offload hook and the lever arm is longer than needed to connect the two parts. This extra length provides leeway for the system so that the lever arm is not pulled immediately when there is vertical movement by the ship, for example, during wavy conditions. After the release of the hook, this extra length gives the system approximately 0.4 m of tolerance before it finally pulls the lever arm and starts the rotation. So far, the grab has been deployed at a maximum wind strength of 6–7 Beaufort (10.8–17.1 m $s^{-1}$) in the Wadden Sea, and it still managed to collect a good sample.

Upon retrieval, the contents of the sampler were always visually inspected to assess sample acceptability. In over 80% of deployments, the samples retrieved by the Ellrott grab fulfilled the criteria for an acceptable sample (key requirements ii and iii). In the few instances when the sample did not pass

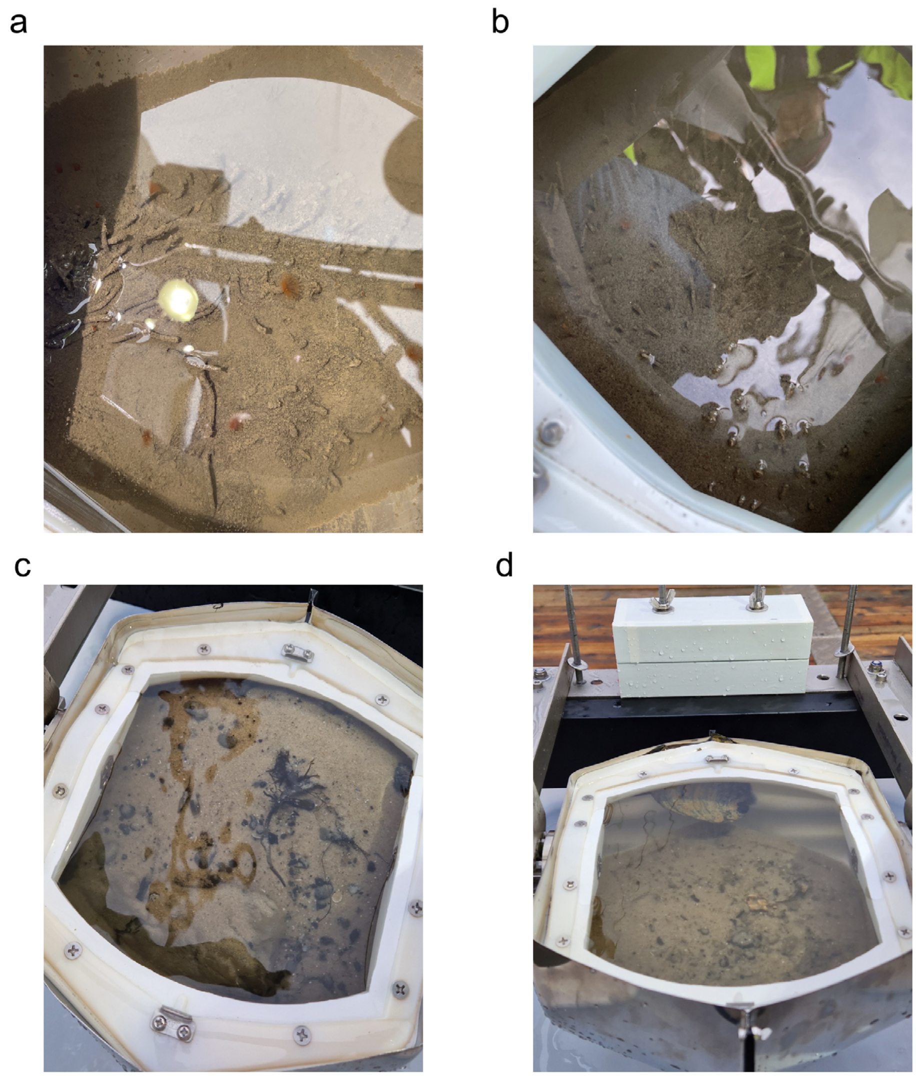


**Fig. 6.** Sediment grabs. (**a**,**b**) Benthic worms in the surface sediment sampled by the grab. (**c**,**d**) Sediment sample with stones, shells, other debris, and a bivalve shell.

the visual inspection, it was usually because of timing issues, wherein the grab was pulled back up when it has not reached the bottom yet. This could happen when there are strong currents that cause the ship to drift away from the originally intended depth. In these cases, the operator observes that the rope loses tension and calls for the winch operator to pull the grab back up, but during that time, the ship has drifted to a slightly deeper area, and hence the grab scoops little to no sediment. When this happens, the sample is simply discarded, and the grab is rinsed and prepared for another deployment. In Isfjorden, the grab also frequently sampled benthic fauna still burrowed in the surface sediment (Fig. 6a,b), which is indicative of the minimal disturbance by the grab as it lands on the sediment and scoops the sample. In some stations in the Wadden Sea, the sediment had shells and stones. This did not affect the quality of the grab, and it still managed to scoop a substantial amount of sediment (Fig. 6c,d).

### Oxygen profiles in situ vs. in cores subsampled from the grab

To further assess the integrity of the samples retrieved by the grab, we measured oxygen profiles in situ and compared them to ex situ profiles measured in cores subsampled from the grab. In June 2022, we deployed an in situ oxygen profiler in Isfjorden, Svalbard (78°06′N, 14°21′E) at 5 m depth which measured oxygen concentrations at the same station where we collected grab samples. Oxygen microelectrodes were made and used as described previously (Revsbech and Ward 1983). The tip diameters were ca. 100 $\mu$m, and the response time (t90) was less than 3 s. After mounting on a deep-sea profiler (Wenzhöfer and Glud 2002), the microelectrodes were

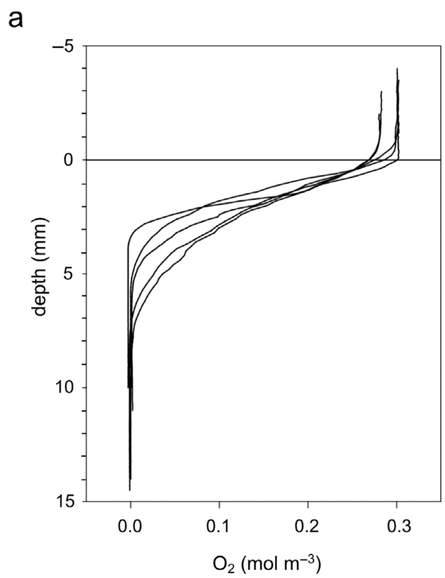


**Fig. 7.** Oxygen profiles measured by microelectrodes. (**a**) Ex situ profiles measured from five cores subsampled from multiple grab deployments. Each line represents one core. (**b**) In situ oxygen profiles from the same station where grab samples were collected. Each line is an individual measurement. The horizontal line at 0 mm indicates the sediment–water interface.

two-point calibrated in oxygen-free sodium ascorbate solution (1 M sodium ascorbate pH 11) and air-saturated water. Three microelectrodes were mounted on the bottom of the titanium housing. The titanium housing, containing amplifiers and a computer for data acquisition and motor control, could be moved vertically by a motor with 1 $\mu$m accuracy. We preprogrammed the profiler (home-build MPIbus software) so that it measures profiles over a distance of 10 cm, with a step size of 250 $\mu$m, after a waiting time of 15 min to allow deployment. We started the profiling program on deck and subsequently lowered the profiler through a cable. The profiling program lasted approximately 1 h after which the profiler was recovered and was immediately redeployed.

In parallel, we subsampled the sediment obtained by the Ellrott grab through cores and measured ex situ oxygen profiles in the cores. For use in the laboratory, microelectrodes were mounted on a motor-driven micromanipulator (PyroScience GmbH). Motor action and data acquisition were controlled using a computer and PyroScience software. The oxygen microelectrode was 2-point calibrated as described above. The microelectrode was held for 3 s at each step, obtaining one reading per step. With a dissection scope, we determined the sediment surface relative to the microelectrode tips. We calculated local diffusive fluxes (J) of oxygen from microprofiles according to Fick's first law of diffusion as described previously (de Beer et al. 2006). We estimated the effective diffusion coefficient from the salinity, temperature (Li and Gregory 1974) and porosity (Ullman and Aller 1982) and found the value to be $0.55 \times 10^{-9}$ m$^2$ s$^{-1}$.

The profiles measured by the in situ profiler and by the microelectrodes in cores are shown in Fig. 7. There was no significant difference in the oxygen penetration depths measured in situ vs. ex situ ($p = 0.75$). The in situ profiler measured an average oxygen penetration depth of $6.4 \pm 1.4$ mm, while ex situ measurements had an average oxygen penetration depth of $6.8 \pm 2.7$ mm. Diffusive oxygen uptake values measured in situ and in the cores were also not statistically significantly different ($p = 0.15$). From the in situ profiler, we obtained a diffusive oxygen uptake of $6.887 \times 10^{-8} \pm 3.24 \times 10^{-8}$ mol $O_2$ m$^{-2}$ s$^{-1}$ ($5.95 \pm 2.80$ mmol $O_2$ m$^{-2}$ d$^{-1}$), while from core measurements we obtained $5.042 \times 10^{-8} \pm 2.94 \times 10^{-8}$ mol $O_2$ m$^{-2}$ s$^{-1}$ ($4.35 \pm 2.54$ mmol $O_2$ m$^{-2}$ d$^{-1}$). Our parallel measurements show that the Ellrott grab indeed preserves the integrity of the sample, and subsamples or cores can be taken from the grab, which are representative of in situ conditions.

## Comparison with other grab samplers

Although there is no one type of grab sampler that satisfies all possible sampling requirements, we emphasize in this study that the newly developed Ellrott grab has key features that distinguish it from other commercially available grab samplers. Table 1 summarizes the key differences between the Ellrott grab and other grab samplers which can be used on smaller research vessels, namely the Van Veen, Ponar, Shipek, and Birge-Ekman grabs. Heavier and larger samplers, such as the Hamon, Day, or Smith-McIntyre grabs, as well as corers, are not included in the comparison.

In addition, most grabs fulfill most of the key requirements of an ideal sampler which we initially specified, but not all features. The Ellrott grab combines the key advantages of existing

**Table 1.** Summary of key specifications, advantages, and disadvantages of grab samplers commonly used in smaller vessels in comparison with the Ellrott grab (modified from US EPA 2001).

| Grab sampler (example of model and manufacturer, when applicable) | Maximum sample depth (cm) | Sample volume (liters) | Sampler footprint (length x width) (cm) | Instrument weight (and additional weights) (kg) | Infrastructure needed | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|
| Van Veen (SG-400, Aquatic BioTechnology, Spain)* | 20 | 5 | 34 × 22 | 11 (+ 4 x 1.2 kg) | Winch | Windows allow sample inspection and subsampling before opening the grab (not available in the smaller model, SG-200) | Prone to incomplete closure, which results in loss of sample† May close prematurely in rough conditions† |
| Ponar (PPG 15, Aquatic BioTechnology, Spain)‡ | 10 | 2.2 | 42 x 16 | 9 | Winch and crane optional | Can be used with a hand line Removable top screens for subsampling | Does not always reach desired sediment depth, especially in consolidated sediments† Prone to incomplete closure, which results in loss of sample† |
| Shipek (860-A10; Envco, New Zealand)§ | 10 | 3 | 47 × 64 | 62 | At least an 81-A10 crane | Allows subsampling Robust construction Can tolerate various sampling conditions Collects overlying water and sediment with pore water | Heavy, can only be used in larger boats with a crane and only in low waves Can result in the loss of the topmost 2–3 cm of very fine, unconsolidated sediment† Spring-loaded mechanism, a safety issue |
| Birge-Ekman (196-B12; Standard Ekman, Wildco)‖ | 15 | 3.5 | 24 × 22 | 3 (+ 3 kg) | None | Can be manually deployed Lightweight Allows subsampling | Not recommended for rocky or sandy bottoms as small pebbles may prevent proper jaw closure‖,¶ Porewater may also leak out during retrieval Can only be used in low current conditions due to its light weight |

(Continues)

**Table 1.** Continued

| Grab sampler (example of model and manufacturer, when applicable) | Maximum sample depth (cm) | Sample volume (liters) | Sampler footprint (length x width) (cm) | Instrument weight (and additional weights) (kg) | Infrastructure needed | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|
| Ellrott grab | 10 | 2.5 | 40 × 60 | 10 (+ up to 20 kg additional weights for sandy sediments) | Hand winch or winch/crane | Allows subsampling<br>Collects overlying water and porewater<br>Easy to operate and safe to use<br>Minimally disturbs the sediment upon landing and scooping<br>Preserves sediment water interface<br>Also suitable for collecting benthic fauna at the surface<br>Accessories, for example, camera, flashlight can be attached to the frame to document sampling | Additional weight may be needed when sampling deeper sediments<br>Currently, some parts are made of plastic and may be brittle in colder environments |

*https://aquaticbiotechnology.com/en/sediment-sampling/van-veen-grab (date accessed 27 July 2023).
†US EPA (2001).
‡https://aquaticbiotechnology.com/en/sediment-sampling/ponar-grab (date accessed 8 January 2024).
§https://envcoglobal.com/catalog/water/shipek-grab/ (date accessed 27 July 2023).
‖https://envcoglobal.com/catalog/water/ekman-bottom-grabs/ (date accessed 8 January 2024).
¶Tuit and Wait (2020).

grabs into one device and fulfills all our specified requirements when designing the new grab. As for key requirement iii, "collects sufficient sediment sample," this will vary depending on the research objectives. For our purposes, the grab recovered enough sediment for various geochemical and microbial analyses. When more sample is needed than the grab can collect in one deployment, the grab can be quickly deployed again to collect more samples. Lastly, although the initial purpose of designing the grab was to sample sandy sediments, it also works well in silty sediments.

### Construction and operation costs

The material cost for building the Ellrott grab was approximately 1000 Euros. This makes the grab comparable in price to other grabs with similar capacity mentioned in Table 1, although prices may vary across different suppliers. The grab is also cost effective in the sense that it only requires a small boat or research vessel with enough space for the 46 × 68 cm box where the grab is placed between deployments. Deployment via a winch or A-frame is ideal, and these equipment are typically available on most fishing vessels, small boats, or small research vessels. In addition, because of its light weight and small size, it also does not require several personnel for operation, further reducing the costs needed for field sampling.

## Comments and recommendations

Our coastal samplings with the Ellrott grab have demonstrated that the device is straightforward to use. Because of this, the main aspect where care must be taken is the timing and speed of lowering and raising the device during sampling. Moreover, for future users who may want to test the grab on other sediment types, optimization of the weight is ideal before proceeding with the sampling. Depending on the objectives of the sampling, additional accessories can be attached to the grab. For example, when a real-time feed is needed, a cable-connected camera can be mounted on the frame.

Lastly, some components of the Ellrott grab prototype, specifically the lever arm and cogwheel, are currently made of 3D-printed plastic (Digital acrylonitrile butadiene styrene [ABS], Alphacam). Using digital ABS enabled us to quickly and easily produce these parts without adding substantial weight to the grab, but we observed that in our polar sampling site where the water temperature was around 0°C and the air temperatures were between −15°C and 0°C, the material became brittle. Thus, in future versions of the grab, we will construct these parts from stainless steel for better durability. This version of the grab will only weigh 3–4 kg more than the current version.

## Summary

In summary, the Ellrott grab fulfills the key requirements for a lightweight sediment sampler. It was built to conveniently and safely sample intact sandy surface sediments along with the porewater and overlying seawater. The grab is now in routine operation in various coastal sites in the Wadden Sea and in Isfjorden, Svalbard. It was designed to combine key advantages of already existing grabs into one sediment sampler suitable for fieldwork on board smaller vessels. Ultimately, the new grab sampler will enable efficient sampling of intact surface sediments, which is the first step in gaining more insights into sediment biogeochemical processes.

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## Conflict of interest

None declared.

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