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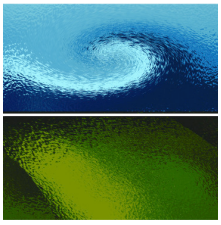

RESEARCH ARTICLE

MANOSS - a manually operated suction sampler for hard bottom benthos

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Abstract

1 - The design and construction of MANOSS, a manually operated suction sampler, is described. The sampler is designed for sampling aquatic epibionts on hard substrates and is manually operated by SCUBA divers.

2 - Building upon the basic design of a slurp gun, it allows for sequential pump actions to effectively scoop a certain sampling area and incorporates easily interchangeable sample collection pouches. Its simple construction, independent from air supply or motorised pumps, makes it compact, lightweight and easy to handle. A relatively large diameter of the intake nozzle (4.5 cm) permits the collection of large fragments of algae or even small pebbles without blocking the valves.

3 - Preliminary tests comparing the new sampler to those hitherto in use indicate efficiency of sampling and satisfactory levels of effort during underwater manipulation. The sampler is inexpensive and easy to rebuild following the detailed description and illustrations provided in the manuscript.

Keywords: hard substrate; biodiversity; monitoring; SCUBA; diving; slurp gun; methodology; techniques.

Introduction

In the last decades, human-induced environmental and climatic changes have resulted in unprecedented fragmentation and loss of natural marine habitats (Lotze *et al.*, 2006; Reid *et al.*, 2011). Structurally complex coastal habitats, such as wetlands, rocky shores or seagrass meadows are especially vulnerable to the combined climatic and anthropogenic pressure. For example, it is estimated that since the 1960s over 50 percent of the coastal wetlands and seagrass areas in Europe have been lost, with many regions reporting numbers as high as 80 percent (Airoldi and Beck, 2007). Regular monitoring of such areas and habitats of high biodiversity emerges, therefore, as a top priority for their conservation and management. Reliable and

efficient sampling methods play a vital part in the implementation and effectiveness of these tasks.

The vast majority of marine surveys, however, focus on soft substrate macrofaunal communities, whereas biodiversity-rich rocky shores and seagrass habitats are much less investigated. This is due to the fact that for soft substrates a vast number of surface-operated sampling devices such as grabs, corers, dredges and trawls have been devised (see Eleftheriou and Moore, 2005), whereas subtidal hard substrates and seagrass formations usually have to be sampled by divers. The irregular structure of these bottoms does not allow penetration by remotely operated samplers and thus the collection of quantitative samples requires human supervision. However, the collection of quantitative epibiotic samples by divers can be cumbersome, since dislodged specimens are often dispersed by the force needed to detach them from the solid substrate and by water movements. Several diver-operated sampling devices have therefore been proposed in the past, specifically addressing the specific characteristics of the rocky habitat (Rostron, 2001).

Suction sampling devices operated by divers have been used since the use of scuba equipment became common in the 1960s and can be broadly classified into two categories: airlifts and slurp guns. The earliest designs were modifications of the standard underwater airlift, relying on the flow of compressed air through a pipe to create an aspirator effect through the Venturi principle (Brett, 1964; Barnett and Hardy, 1967) or directly pumping seawater with motorised pumps (Emig and Lienhart, 1967). Due to their intrinsic design, however, these devices aimed at sampling soft substrates (*e.g.* sand), and were ineffective for sampling organisms dwelling on rock and other irregular hard formations. The first suction device specifically aiming at collecting hard substrate organisms was designed by Hiscock and Hoare (1973); it consisted of a metal intake which also served as a scraper for the sample, a main chamber with interchangeable sample collection mesh, and a suction chamber connected to a compressed air cylinder. Notable variations of this concept are the bucket sampler and the John Woolford miniature sampler (see Rostron, 2001), while a more complicated domed suction sampler, designed to sample cobble-gravel substrate, has been introduced by Gale and Thompson (1975).

In contrast to the above mentioned variations of the airlift, slurp guns are not based on the Venturi principle; they are simple piston pumps, resembling the function of a syringe. The basic components of a slurp gun are a cylinder and a piston which, when pulled, creates suction at the front intake of the device. Slurp guns are traditionally being used commercially for harvesting burrowing crabs on sand, but have been rendered valuable tools for scientific sampling, allowing selective underwater collection of active swimmers (*e.g.* fish, shrimps) or dwelling organisms (Munro, 2005). Although slurp guns are usually manually operated using a handle to move the piston, automated versions have also been proposed, using a pneumatic piston with compressed air supply (Wilcox *et al.*, 1974), or a battery-operated electric pump (Lønne, 1988). The main drawbacks of unmodified standard slurp guns for underwater sampling of benthic epibionts (not individual organisms) are: (a) the amount of sample collected is limited to a single stroke of the pump; (b) organisms are able to escape, once collected, through the open front nozzle; (c) no interchangeable containers can be used for the collection of multiple samples.

In the past years, the scientific diving team of the Hellenic Centre for Marine Research has developed and used a compact variation of the airlift as a suction sampler for quantitative sampling of hard bottom epibiota

in the framework of the NaGISA (National Geography in Shore Areas, http://www.nagisa.coml.org) project (Chatzigeorgiou *et al*. 2012). However, during the use of this device several disadvantages became apparent: (a) the complete unit, including a dedicated compressed air cylinder and buoyancy device, was strenuous for the diver to operate; (b) the thin (2.4 cm) cross-section of the pipe caused frequent clogging by dense algal thalli; (c) the compressed air bubbles escaping through the collecting mesh partially damaged the fragile organisms. With these shortcomings in mind, we developed and tested MANOSS (MANually Operated Suction Sampler), a novel sampler for hard-bottom epibiotic organisms that combines elements from a slurp gun and an airlift. The main guiding considerations were: (a) compact size and reduced weight; (b) manual operation without aid from air cylinders or electric devices; (c) easily interchangeable sample containers; (d) adequate diameter of all active cross-sections to receive larger organisms; (e) minimum physical impact to samples.

Methods

Design of the sampler

The sampler works similarly to a slurp gun, using a piston-generated suction effect to collect the sample. However, in contrast to the classical design of a slurp gun, MANOSS has two alternately operating one-way valves which direct the sample into a collection sock when the plunger is pushed. The main parts of the system are thus (numbers in brackets refer to sampler parts as depicted in Figure 1): (1) a barrel; (2) a plunger, consisting of a rod and a piston; (3a, b) two one-way valves, placed in a way that only one valve is open at any time; (4) a collection sock. To collect a sample, the diver pulls the handle of the plunger, causing the inlet valve (3a) to open and the outlet valve (3b) to close. The sample is pulled into the sampler; the filter mesh (5) prevents the sample from entering the barrel and being damaged by the movements of the plunger. When the plunger is pushed, the inlet valve closes and the outlet valve opens, pushing the sample into the collection sock. The collection sock is secured to a short connector tube (6) with a cable binder, forming the sample container. This container snaps into an adapter, its tight fit ensured by two O-rings on the connector tube and a thumbscrew (Fig. 2, 3). To collect multiple samples during one dive, the desired number of collection socks are prepared. After completing the collection of a sample, the connector tube is detached from the sampler and immediately sealed with a fitting cap (7), likewise equipped with a thumbscrew to secure the cap in place, and a new sample container is fitted to the sampler.

The sampler has been constructed from polyvinyl chloride (PVC) to reduce its weight (the only exceptions are the metallic valves and plunger rod) and has total length of 84 cm and a weight of 4.2 kg at the surface (at 0.5 m depth the weight is reduced by 30%). A description of the secondary parts, as well as their dimensions are provided in the explanation of Figure 1.

Autodesk Inventor 2013 was used to design the sampler and create illustrations, videos and three-dimensional models. To create the interactive model embedded in this publication (Fig. 2), the model was exported as a STEP file from Autodesk Inventor and embedded into the PDF file using the Acrobat X Pro 3D PDF Converter Suite. The 3D Reviewer module was used to define colours and materials.

Test sampling

To test the performance of the sampler in the field and compare it to other methods, an experiment was conducted by taking 10 replicates (5 replicates during each of two

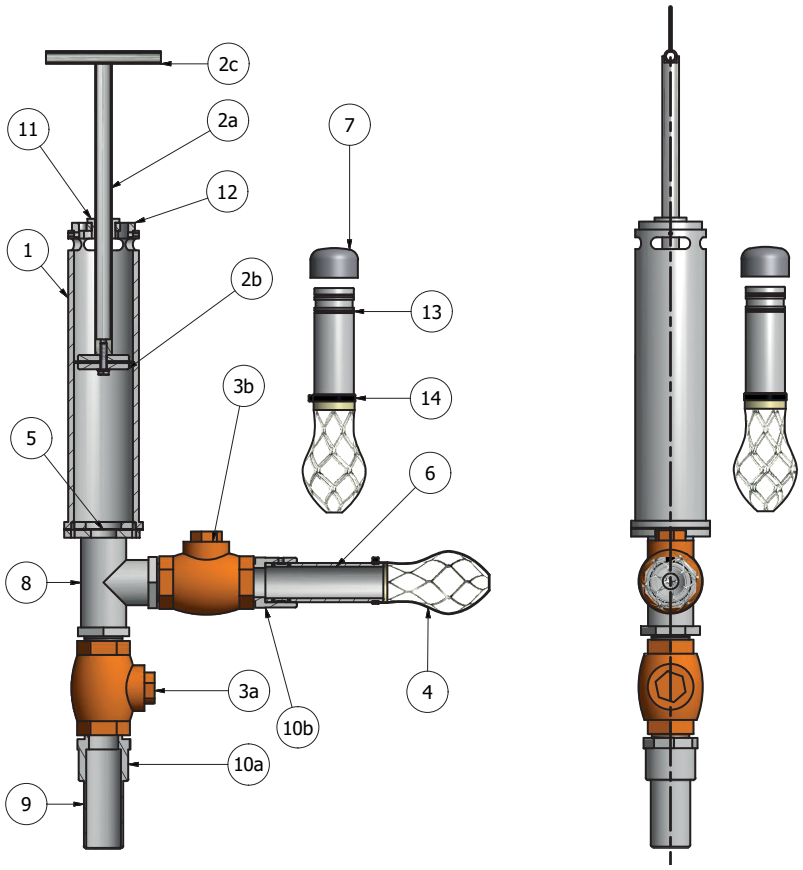

Figure 1. Schematic drawing of the sampler. A: side view; B: top view. Numbers indicate the following parts: (1) barrel (length 38 cm, inner diameter 7.5 cm; volume 1.7 l), with openings near the rear end to facilitate water flow; (2) plunger, consisting of rod (length 42 cm), T-shaped handle and piston (rubber membrane enclosed by two smaller plastic disks, connected to rod with a bolt; diameter of piston: 7.5 cm); (3) one-way valves (inner diameter 4.5 cm) for (a) input and (b) output; (4) collection sock (mesh size 63 µm, volume can be adjusted according to the expected sample volume); (5) filter mesh (mesh size 63 µm); (6) connector tube (length 15 cm, inner diameter 4.5 cm); (7) cap of connector tube, equipped with thumbscrew to secure the cap onto the connector; (8) T-shaped connector; (9) nozzle (length 14 cm, inner diameter 4.5 cm); (10) adapters (PVC connections) between T-shaped connector and (a) nozzle, (b) connector tube of sampling sock; (11) plunger guide (short PVC cylinder) to keep the plunger centered within the barrel during pumping; (12) rear-end cap with four large holes to facilitate water flow; (13) two O-rings to ensure tight fit of connector tube and adapter or tube cap; (14) cable binder, strapping the collection sock to the connector tube.

subsequent dives) from a rocky substrate with dense algal coverage at 12 m depth with each of the following three samplers: (a) a frame with an attached collection bag into which the sample was scooped by hand; (b) an airlift (Chatzigeorgiou *et al.* 2012); (c) MANOSS. In all cases, a 25 x 25 cm plexiglas frame with a net (63 µm mesh size) attached to its upper end (Chatzigeorgiou *et al.* 2012) was placed firmly on the rock. The epiphytes on the rock were scraped with a spatula and collected with the respective sampler. The time required to take each replicate (from the beginning of scraping until the closure of the sampling container) was measured, as well as the operating diver's air consumption after

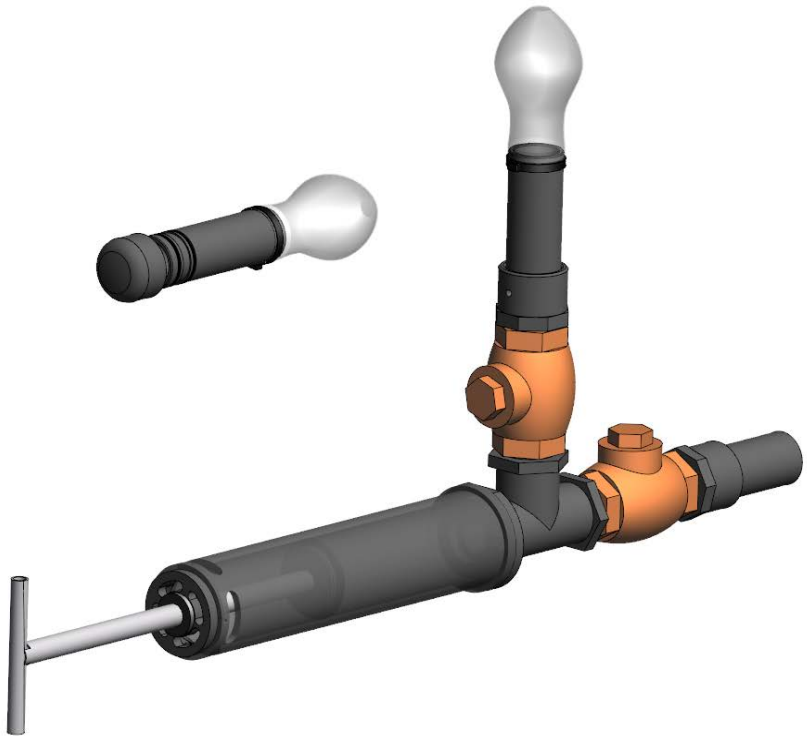

Figure 2. Interactive model of the sampler. If viewed with Adobe Reader (version 8 or higher), the interactive 3D-mode can be activated by clicking on the image, allowing the user to rotate, move and magnify the model. By clicking the "tree" icon in the 3D toolbar, individual items can be isolated, revealing the internal parts of the sampler.

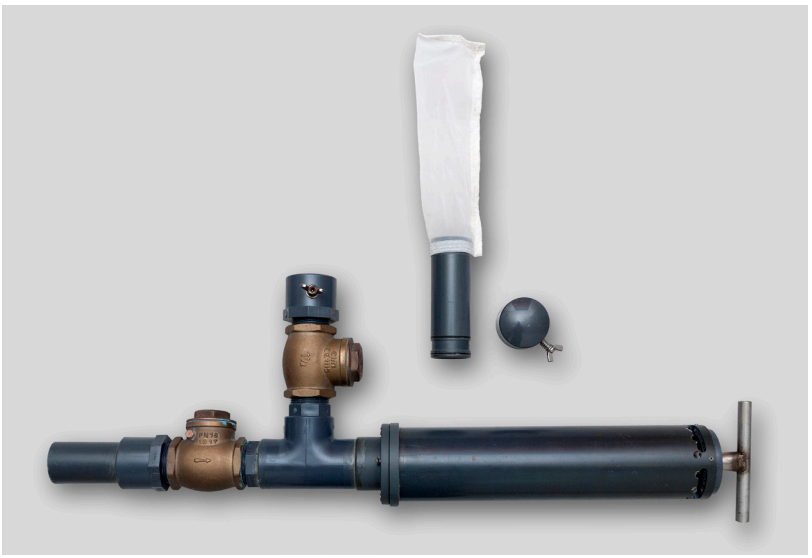

Figure 3. Photograph of the sampler.

five replicates with each sampler. To avoid bias resulting from the individual skills of the diver, all samples were taken by the same diver, and samplers were employed in reverse order during the second dive to avoid bias resulting from the diver's exhaustion at the end of each dive.

The samples were sieved through a combined sieve system with mesh sizes of 500 µm and 45 µm to separate macro- and meiobenthic organisms and subsequently fixed in 4% formalin buffered in sea water. Samples were stored and await laboratory analyses to assess the sampling effectiveness of all three samplers as well as the damage induced to the collected organisms.

Results and Discussion

The new sampler combines elements from a slurp gun and an airlift, using the syringe principle to collect the sample and a system of alternately operating valves to direct it into a collection pocket. The compact size and low weight of the sampler allow easy transportation and handling during a dive. These properties provide a clear improvement over some of the early suction samplers such as the one designed by Hiscock and Hoare (1973), which weighs 25 kg on land and 5 kg underwater. Furthermore, MANOSS is operated entirely by a manual pumping movement, thus the number of samples that can be collected during a dive depends only on the air consumption and allowed bottom time of the diver, not on the provision of additional sources of compressed air or electricity from batteries, as it is the case in many existing systems (*e.g.* Hiscock and Hoare, 1973; Lønne, 1988; Chatzigeorgiou *et al.*, 2012). Manual pumping requires a certain physical effort; however, any diver in a good physical condition should be able to collect samples efficiently, and air consumption data acquired through our initial testing show that the physical effort is comparable to other sampling activities (Table 1). The sampling time was slightly longer for all samplers during the second dive due to increased fatigue of the divers, however, compared to the airlift or the frame, the time needed for MANOSS to collect the full sampling volume was shorter during both dives (Table 1). Collection time is therefore not a restricting factor for the maximal number of samples, and under the circumstances of the test dive (12 m depth, 15 l dive cylinder with compressed air, bottom time calculated according to NOAA's No-Decompression Air Table — http://www.ndc.noaa.gov/pdfs/NoDecoAirTable.pdf), we can assume that the operating diver would have been able to collect 10–15 samples before his/her air supply ran low.

Table 1 - Average time (mean ± standard deviation from five replicates) required to collect one sample (from the beginning of scraping the sampling area until sealing the sampling container) and air consumption of diver after collection of five replicates at 10 m depth, for each of the three samplers.

	Dive 1: Time (seconds)	Dive 2: Time (seconds)	Dive 1: Air consumption (bar)	Dive 2: Air consumption (bar)
MANOSS	43.4 ± 11.5	53.0 ± 9.8	60	64
Airlift	48.8 ± 10.4	56.8 ± 10.2	62	63
Frame	73.0 ± 31.9	73.4 ± 17.6	57	59

Interchangeable sample containers are easily attached to the sampler by a snapping movement (optionally secured by one turn of the thumbscrew), thus their swapping can be performed in just a few seconds. However, this design introduces a restriction on the usage of the sampler: if the connector tube with the collection sock is directed downwards, the valve taps remain open and pumping does not result in effective sample collection. The diver operating the sampler has therefore to ensure that the collection tube is positioned at an angle greater than 90° to the gravity vector.

Thorough accumulation of a sample can be performed with MANOSS through repeated strokes of the pump; this is a clear advantage over most standard slurp guns where the sample volume is limited to a single stroke. Apart from our design, this has previously been addressed through the sophisticated slurp gun variation proposed by Tanner *et al.* (1977), which employs a collection bottle located at the rear end of the barrel and a system of rubber one-way valves; this apparatus was proved effective for sampling minute and fragile filamentous algae, and was recently further refined by Vandermeulen *et al.* (2011). However, both these approaches target samples consisting of soft, compressible or small-sized objects. They would be ineffective for general sampling of hard-bottom epibionts, as the rubber valves would be easily damaged or clogged by large, stiff thalli of *Sargassum* and *Cystoseira* or small stones and hard shells of mollusks. MANOSS has therefore been designed as a heavy-duty sampler, with a relatively large nozzle opening (4.5 cm) and stout metallic valves that are unlikely to be blocked by large pieces — in fact, large thalli of algae (> 3–4 cm diameter, up to 8–10 cm long) and even pebbles were sampled efficiently during our initial tests without clogging the sampler. In case blocking occurs, nevertheless, the affected sampler part can be easily disassembled during the dive without any additional tools and the obstacle can be removed by hand.

The first results of the ongoing laboratory analysis of the samples indicate that the samples collected with MANOSS are comparable, if not superior, to those collected with hitherto established methods concerning the diversity, abundance and condition of organisms. However, these results are only indicative since the full set of samples needs to be processed to allow a decisive evaluation of the sampling effectiveness of MANOSS (Keklikoglou *et al.*, in preparation).

Although it is obvious that several solutions have formerly been proposed to assist sampling of hard bottom epibiota, a number of relevant studies in peer-reviewed journals indicate sampling by means of a standard frame, providing no further specifications — hence implying that samples were scraped and collected by hand into a collection bag (*e.g.* Antoniadou and Chintiroglou, 2005; Chenelot *et al.*, 2011; Herkül and Kotta, 2012). The rationale behind this choice is apparently related to the nature of underwater sampling itself: being a demanding, effort-consuming activity with strict time limitations, the additional burden of having to manipulate a heavy, bulky and complex device appears discouraging. Therefore, MANOSS may provide a solution to these obstacles, being a compact, lightweight sampler that is easily transported and operated and requires no additional supporting equipment. It has a simple design, with most parts being inexpensive and commercially available, allowing even laboratories with limited financial resources to rebuild and adopt the instrument for their sampling purposes.

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Supplementary Material

1. A STEP (*.stp) file of the 3D model of the sampler can be downloaded from the journal's website.
2. A video showing the assembly of the sampler's individual components is available at http://youtu.be/nF1wQThfCNc.

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