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10 Corers and grabs

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Abstract:

A range of grabs and corers have been used for sampling deep-sea sediments. Grabs are comparatively cheap and simple compared to corers. With the advent of video-guided sampling, more sophisticated grab systems are being developed. Grabs, with their scooping action, return rather disturbed samples that should be regarded as semi-quantitative in nature. Corers collect higher quality samples more suited to quantitative projects. Box- and multiple-corers are most commonly used by deep-sea ecologists, and are employed for the collection of macro-, meio- and micro-benthos, as well as a wide range of environmental samples. Here we review the range of sediment samplers used in deep-sea studies, providing some general recommendations and
guidelines for their operation. Methods for processing samples taken by box-corders and multiple
corders are also detailed.

10.1 Introduction

Historically the first attempts at sampling the deep-sea benthos were undertaken using a
variety of trawling nets that had large mesh sizes. This resulted in the majority of individual
specimens passing through the nets and the assumption that benthic abundance and hence,
diversity in the deep sea was low (Gage and Tyler 1991). Furthermore, mean individual size
decreases with depth so that the early use of coarse nets led to lower estimates of diversity
(Gage and Tyler 1991). Hessler and Sanders (1967) designed an epibenthic sled with a fine
mesh to collect relatively large samples of the fauna that were sparsely distributed in the
sediments and across the sediment-water interface (see Chapter 9). The drawback of the deep-
sea epibenthic sled system is that it is essentially a qualitative, or at best, a semi-quantitative
 sampler. In order to quantify faunal richness and abundance, the size of area or volume sampled
must be accurately known and the sampler must efficiently collect specimens from that area or
volume.

The first benthic grab was designed for use in shallow waters (Petersen and Boysen Jensen
1911), but beginning in the 1950s larger and heavier variants were used to sample the deep sea.
These included a modified Petersen grab (0.2m²) used on the Galathea Expedition (Spärck
1956), and the Okean grab (150kg, 0.25m²) (Lisitsin and Udintsev 1955) used extensively by
the Soviets in their worldwide sampling of the deep-sea floor over a number of decades. Grabs
are simple devices, so they can achieve high sample recovery rates. However, whilst the area of
seafloor surface sampled can be determined, the scooping action of the grab means that the
depth of the sample is uneven. This limitation to the quantitative nature of the grab prompted the
development of coring devices for taking of benthic samples. Early corers that influenced later
designs include the Reineck box-corer (Reineck 1963) and the Craib tube corer (1965).
However, both of these corers only sampled a relatively small area of seabed, were relatively light-weight and as such were not particularly suited to recovering samples from the deep sea. More recently, large versions of van Veen and Day grabs (0.2 – 0.25m²) have also been used to collect samples (McIntyre et al. 1984) (Figure 10.1a). Hessler and Jumars (1974) in conjunction with the United States Navy Electronic Laboratory designed the USNEL box-corer, which was essentially a larger and heavier version of the Reineck box-corer. USNEL-type box-corers (Figure 10.1b) have become popular and widespread over time. Other varieties of box-corer that have been designed for sediment sampling in the deep sea include, for example, the Gulf of Mexico (GOMEX) (Boland and Rowe 1991) and Nederlands Instituut voor Onderzoek der Zee (NIOZ) box-corers (see e.g. Gage and Bett 2005) (Figures 10.1c, d). The comparatively large area sampled (0.06-0.25m²) allows for more specimens to be collected in a quantitative fashion, allowing for a range of ecological parameters to be determined. However, the potential drawback of using a box-corer is that they may create a bow wave, resulting in disturbance of surficial sediments and the potential loss of associated fauna (Bett et al. 1994).

Multiple-corers (see e.g. Barnett et al. 1984) (Figure 10.2a), based on the principles of the Craib tube corer (Craib 1965), were built to collect samples that were virtually free from the effects of a bow wave. These corers are hydraulically damped, allowing for the collection of fauna at the sediment-water interface, including flocculent material such as phytodetritus (Billett et al. 1983) that can be easily re-suspended and blown aside by box-corer bow waves.

Corers that are not directly connected to a surface ship are also used to collect samples in the deep sea. So-called free- or boomerang-corers, descend independently to the seafloor to take a small sample (6.6 cm diameter) before returning to the surface following the contact-release of ballast weight. They were designed and used in the 1960s to depths of 6400m (Bowen and Sachs 1964). However, these devices have not been widely used since in the deep sea. More recently, various “mini-corers” have been designed for use by the manipulator arms of submersibles and Remotely Operated Vehicles (ROVs). Push corers are the simplest and most
widely used form, having a simple flap valve at the top to aid recovery of the sediment column and protect it during return to the surface. A range of other devices have been developed for the collection of larger samples including the modified Birge-Ekman box-corer, as described by Rowe and Clifford (1973) and the ‘pot sampler’ of Van Dover (2002) designed to operate in hydrothermal vent mussel beds (see Chapter 13 for details regarding ROV sampling).

Methods for processing samples taken by grabs and corers for macrofauna, meiofauna and microbes have not changed a great deal since at least the 1970s. However, there has been an ever increasing need to standardise processing techniques as more institutes across the world undertake deep-sea sampling surveys, and the need for comparable data as part of global data analysis initiatives grows.

Below, we describe the main grab and corer gear types, their operation and sample data. We note that useful complementary information can also be obtained from various chapters in benthic sampling textbooks by Eleftheriou and McIntyre (2005), Danovaro (2010) and Eleftheriou (2013).

10.2 Description of gear types

10.2.1 Grabs

Grabs typically consist of two quarter-circle buckets or scoops that pivot around a central hinge; although there are versions that comprise of single or multiple scoops. For most types of grabs the buckets are held open during descent to the seabed and close on contact with the bottom after the tension on the lowering wire is released. The buckets are brought together to enclose a sediment sample when the wire is raised towards the surface vessel. A variety of mechanisms have been designed for assisting the opening and closing procedure, to produce a number of different grab types. Larger variants of shallow water grabs are used for sampling the deep-sea benthos. These include the previously mentioned Petersen, Okean, Day and van Veen grabs, as well as Campbell grabs (410kg, 0.55 m²) (Hartmann 1955). Grabs are not particularly
well-suited for quantitatively sampling coarse sediments, and, even in soft sediments, maximum penetration depths are typically less than 20cm. In addition, the ‘bite’ profile of a grab is uneven (Riddle 1989). The top of the grab buckets usually have ports covered with wire mesh or one-way opening flap that are included in an attempt to reduce the bow wave that precedes the device as it is lowered to the seafloor. Sample integrity can be compromised by ‘washout’ through these ports or the gap between poorly sealed closed buckets. Meaning that generally vertical structure in a grab sample from the deep sea is often lost or severely affected.

Several research groups / workers have employed video-guided grab systems, using a live video feed to the surface vessel to guide sample collection. These vary from simple light-weight systems, such as that described by Mortensen et al. (2000), to larger versions such as the Russian GTVD-2/Pressaug grab (Sheremet and Efimova 1996) and the IFM-GEOMAR TV-Grab (2000kg, 1.8m²) (Figure 10.2b) often used on the German research vessel Sonne. More sophisticated systems are now available, such as the National Oceanography Centre, Southampton’s HyBIS, Hydraulic Benthic Interactive Sampler (Figure 10.2c) (Murton 2010). HyBIS has an hydraulically activated 0.3m³ double jaw grab that can be repeatedly closed and opened at depth, while the instrument module above the grab carries a number of cameras, arranged both vertically and obliquely, and a set of ROV-type thrusters that permit fine-scale positioning of the grab (rather than relying on the surface vessel’s positioning alone as with most video grabs).

Large, hydraulic, video-guided grabs are used habitually for geological sampling in the deep sea and can be useful tools to recover associated biological material from patchy habitat such as sulphide-rich deposits. However, they are expensive to operate and are not considered the ideal choice for quantitative sampling of benthic organisms in the deep sea. Although grabs can be used to make collections of deep-sea fauna in locations or sediments that are not ideal for operating corers, box-corers and multi-corers should be used whenever possible for quantitative research. As such, no additional operational detail will be provided here for grabs.
10.2.2 Box-corners

Large box-corners generally comprise: (i) a removable square / round sample box, attached below (ii) a weighted central column carrying the box closure mechanisms that may move through (iii) a gimballed support frame. These devices are generally large and heavy, and best deployed from the side gantry of a research vessel. Deployment from stern gantries is possible, but likely to significantly reduce success rates as a result of the greater heave (vertical motion) at the stern compared with amid-ships positions. Technical specifications of selected examples of box-corners are given in Table 10.1.

10.2.2.1 USNEL Mk II box-corer

The USNEL Mk II deep-sea box-corer (Hessler and Jumars 1974) has a detachable, square, open-ended steel sample box with a removable spade closure for the bottom of the box (Figure 10.1b). Vents above the top of the box are held open during the descent of the corer in an attempt to reduce the effect of a bow wave. Contact of the corer with the seabed triggers mechanical actions to close the top vents and allow the spade closure system to activate. The standard USNEL Mk II box-corer collects samples with a core length of about 40 – 50 cm with an area of 0.25 m² in “typical” deep-sea sediments.

10.2.2.2 NIOZ box-corer

The basic concept and operation of the NIOZ box-corer (Figure 10.1d) is very similar to the USNEL Mk II. However, its major design variations include: (a) a counter balance arm that operates in opposition to the spade bottom closure arm; (b) a valve-like top closure; and (c) optional use of square or round cross-section ‘boxes’. The balance arm was added to counteract the turning force of the spade closure action, and is thought to reduce sediment column distortion as a result. The improved top closure is designed to improve bottom water retention.
The NIOZ box-corer is available with both round and square ‘boxes’ in two sizes giving samples of an area 0.06-0.25m² with a maximum core length of 55cm.

10.2.2.3 GOMEX box-corer

The comparatively small GOMEX box-corer (Figure 10.1c) (Boland and Rowe 1991) was developed from a corer originally described by Jonasson and Olausson (1966). The GOMEX corer has a fixed sample box, a double jaw bottom closure and a flap lid top closure. Contact of the corer with the seabed triggers mechanical actions to close the lid and transfers the ballast weight to act to close the jaws. The corer is available in different sizes offering sample areas of 0.06 and 0.16m² with a potential core length of ca. 40cm. It should be noted, however, that current commercially available versions of the GOMEX box-corer may differ to that described by Boland and Rowe (1991).

10.2.4 Multiple box-corners

A multiple box-corer has been designed and used in a limited number of studies (Gerdes 1990). This device has not been widely adopted by deep-sea scientists, most probably due to the difficulties inherent in operating such a large and complicated device as well as issues of pseudo-replication (see also section on Multiple corers and Chapter 3).

10.2.3 Multiple corers

Multiple corers essentially comprise: (i) a coring head that carries a number of core tubes (ranging from 4-12), together with their individual top and bottom closure mechanisms, and which is connected to (ii) a hydraulic damper system, that in turn is connected to (iii) a seafloor landing frame. These devices can be almost as large and heavy as box-corners, and are generally
best deployed from the side gantry of a research vessel for the same reasons as outlined for box corers. Technical specifications of selected examples of multiple corers are given in Table 10.1.

11.2.3.1 The Multi-corer

The Scottish Marine Biological Association (SMBA) multi-corer (Barnett et al. 1984) is in essence a scaled up multiple version of the Craib tube corer (Craib 1965). The frame carries 12 cores, each with an approximate internal diameter of 5cm, each with its own top and bottom closure mechanisms (Figure 10.2a). When the external frame lands on the seafloor, the coring head begins to descend slowly, against the resistance of the hydraulic damper. When the coring head encounters sufficient resistance as a result of sediment penetration a mechanical trigger activates the release of the top and bottom closure mechanisms. The bottom closures initially fall to the sediment surface, only swinging fully into place as the coring head is drawn back out of the sediment as the ship’s winch slowly takes up tension on the wire. Several variants of the original SMBA-pattern multiple corer have been developed, including: (a) a frame design modified to reduce deck footprint and height; and (b) a core head design modified to carry fewer, larger core tubes (e.g. 4 x 25cm diameter).

10.2.3.2 Megacorer

The Bowers and Connelly megacorer (see Barnett et al. 1984) is conceptually identical to the SMBA multiple corer, but has been extensively re-engineered to produce a much more compact device. In its standard form it carries a maximum of 12 cores each with an internal diameter of 10 cm, and each core is housed in an independent unit together with its top and bottom closures. The use of independent core units introduces a useful flexibility to the corer, offering the option to: (a) reduce the total number of cores deployed, thereby increasing the sediment penetration force if required; and (b) switch or mix between 10cm and 5cm diameter cores to meet
particular sampling needs. In its standard arrangement (12 x 10 cm cores) it will return c. 40 cm long cores in ‘typical’ deep-sea sediments.

Table 10.1. Specifications of selected deep-sea corers

<table>
<thead>
<tr>
<th>Corer type</th>
<th>Cross-section shape</th>
<th>Dimensions (W, B, H, cm)</th>
<th>Area (cm²)b</th>
<th>Typical laden weight (kg)c</th>
</tr>
</thead>
<tbody>
<tr>
<td>USNEL box-corer</td>
<td>Square</td>
<td>50 x 50 x 50</td>
<td>2500</td>
<td>1000</td>
</tr>
<tr>
<td>GOMEX box-corer</td>
<td>Square (small)</td>
<td>20 x 30 x 50</td>
<td>600</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Square (large)</td>
<td>40 x 40 x 50</td>
<td>1600</td>
<td>650</td>
</tr>
<tr>
<td>NIOZ box-corer</td>
<td>Cylindrical</td>
<td>Ø 30 x 55</td>
<td>707</td>
<td>1100</td>
</tr>
<tr>
<td></td>
<td>Square</td>
<td>30 x 20 x 55</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cylindrical</td>
<td>Ø 50 x 55</td>
<td>1964</td>
<td>1600</td>
</tr>
<tr>
<td></td>
<td>Square</td>
<td>50 x 50 x 55</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>Multi-corer</td>
<td>Cylindrical</td>
<td>Ø 5.65 x 65</td>
<td>25.1 x 12</td>
<td>900</td>
</tr>
<tr>
<td>Megacorer</td>
<td>Cylindrical</td>
<td>Ø 10 x 60</td>
<td>78.5 x 12</td>
<td>900</td>
</tr>
</tbody>
</table>

a For multiple corers, the size of one sampling unit (tube) is given; for box corers, W = width, B = breadth, H = height.
b For multiple corers, the area of one sampling unit x number of units

c Weight of corer with standard ballast and sample

Ø = diameter

10.2.4 Choice of a corer

The key attribute of any sampling device is that it should return a representative sample of the target benthic assemblage (see Table 10.2 for the pros and cons of each coring system).
very simple terms, for a representative biological sample, a core (and its subsequent processing) must therefore return all of the specimens present in the sediment volume notionally sampled by the device. This completeness is not the case for USNEL-type box-corers, and by analogy, likely not to be the case for the NIOZ box-corer. Tests of meio-benthos data indicates significant under-sampling by USNEL-type box-corers relative to SMBA pattern multi-corers (e.g. Bett et al. 1994). Similarly, tests of macro-benthos data indicate significant under-sampling by USNEL-type box-corers relative to Megacorers (e.g. Gage and Bett 2005; Narayanaswamy and Bett 2011). This apparent loss of specimens is thought to be the result of the bow wave effect. The simple open design of the GOMEX box-corer suggests that it may not suffer to such a large degree of this. Boland and Rowe (1991) present data that suggest a greater number of individuals were collected using a GOMEX corer compared to an USNEL-type corer at the same depths and in the same locality.

Under-sampling will obviously underestimate the true standing stock (abundance, biomass) of the benthos. Loss of specimens from a sample is likely to occur in a non-random fashion, e.g. surficially distributed and small bodied specimens are more likely to be lost than larger infaunal organisms. As a consequence, species diversity and species composition assessments from such samples are like to be biased (i.e. non-representative). While it might be reasonable to apply a correction factor to standing stock estimates (see e.g. Narayanaswamy et al. 2005), it is very unlikely that any useful correction could be made to biased species diversity and species composition data. Therefore great caution should be applied when attempting to compare or compile data from sampling coring devices with different sampling performances.

While multiple corers are not a universal panacea for deep-sea sampling problems, they should be regarded as the first choice instrument wherever they can be practically employed. This recommendation applies equally to biological (micro-, meio-, and macro-benthos) and environmental sampling of the sedimentary environment. However, the availability of multiple non-independent samples can introduce the issue of pseudo-replication if more than one core
from a single deployment is used to determine mean measures for any parameter (e.g. abundance, diversity etc) (see section 10.5 and Chapter 3).

Table 10.2. Discussion on the merits of the various corers.

<table>
<thead>
<tr>
<th>Corer type</th>
<th>Pros</th>
<th>Cons</th>
<th>Habitat suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>USNEL Mk II box-corer</td>
<td>Large sample area.</td>
<td>Large/heavy.</td>
<td>Efficient in a wide range of soft sediments. Can also be used in relatively coarse sediments and in most deep-sea environments. However, difficult to sample steep/rocky outcrops</td>
</tr>
<tr>
<td>NIOZ box-corer</td>
<td>Large sample area.</td>
<td>Large/heavy.</td>
<td>As above.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bow wave problem.</td>
<td></td>
</tr>
<tr>
<td>GOMEX box-corer</td>
<td>Relatively small/light.</td>
<td>Small sample size.</td>
<td>As above</td>
</tr>
<tr>
<td></td>
<td>Little bow wave effect.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMBA Multicorer</td>
<td>Little bow wave effect.</td>
<td>Small sample size.</td>
<td>Efficient in a wide range of soft sediments. Can be used in many deep-sea environments. Care must be taken when sampling in rocky terrain.</td>
</tr>
<tr>
<td></td>
<td>Long history of use.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Megacorer</td>
<td>Little bow wave effect.</td>
<td>Small sample size.</td>
<td>As above.</td>
</tr>
<tr>
<td></td>
<td>Relatively compact.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexibility of use.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
10.2.5 Additional Sensors

The most commonly used additional item of equipment is the “pinger” (or near-bottom echo-sounder). This sensor is typically attached to the wire about 50m above the corer and enables the operator to determine the distance of the corer from the seabed as it approaches the bottom [see Gage and Bett (2005) for the theory of operation]. The pinger’s function can also be fulfilled by an ultra-short baseline (USBL) transponder capable of acoustically telemetering depth data to the surface vessel, having the additional value of providing more precise navigational data for the coring site. However, present USBL technology is limited to a depth of 6000 m.

A variety of other equipment may also be directly attached to the corer. For example, self-contained Conductivity-Temperature-Depth (CTD) instruments and water bottles may be employed to assess the bottom water conditions. Other common additions include still and video cameras together with their associated lighting. Such equipment is variously operated: (a) continuously from launch, (b) on a timer delay, (c) by linkage to the corer’s trigger mechanism, or (d) by independent bottom-contact trigger (e.g. suspended below the corer). Images of the coring operation and the sediment surface allow an appreciation of the effectiveness of the sampling, and provide information on the assemblage.

10.3 Sampling operations

10.3.1 Essential information

As in all scientific operations, it is extremely important to keep comprehensive notes on all aspects of sampling operations (see Table 10.3), and to ensure that all relevant metadata can be uniquely linked to the resultant samples. Most regular sea-going institutions have developed
their own in house log sheets to help ensure that standardised records are kept. Custom databases are also available (see e.g. ‘Biocean’, Fabri et al. 2006).

Table 10.3. An example of potential headings in a coring log sheet.

<table>
<thead>
<tr>
<th>Record</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship name / cruise number</td>
<td>Sufficient to identify the vessel and its particular cruise</td>
</tr>
<tr>
<td>Deployment number</td>
<td>Sufficient to identify a particular deployment</td>
</tr>
<tr>
<td>Gear</td>
<td>Sufficient to identify a particular piece of equipment in its ‘standard form’</td>
</tr>
<tr>
<td>Gear modifications</td>
<td>Note any variations from ‘standard form’, e.g. number and size of core tubes, ancillary equipment attached, etc.</td>
</tr>
<tr>
<td>Date / time launch</td>
<td>Used to determine total operation time for use in future planning</td>
</tr>
<tr>
<td>General pay out speed</td>
<td>Speed that wire is paid out during the majority of the descent</td>
</tr>
<tr>
<td>Final pay out speed</td>
<td>Speed that wire is paid out during the final approach to the seabed</td>
</tr>
<tr>
<td>Date / time bottom contact</td>
<td>This is taken to be the sample time, and so that of the navigation and depth data</td>
</tr>
<tr>
<td>Ship’s position</td>
<td>Ship’s position at sample time</td>
</tr>
<tr>
<td>Ship’s sounding</td>
<td>Ship’s echosounder depth at sample time</td>
</tr>
<tr>
<td>Gear’s position</td>
<td>When available, absolute or ship-relative position of gear at sample time</td>
</tr>
<tr>
<td>Gear’s depth</td>
<td>When available, telemetered depth of gear at sample</td>
</tr>
<tr>
<td><strong>Parameter</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Initial haul speed</td>
<td>Speed of wire recovery during pull out phase</td>
</tr>
<tr>
<td>Pull out tension</td>
<td>Maximum wire tension during pull out phase</td>
</tr>
<tr>
<td>Final haul speed</td>
<td>Speed that wire is hauled in during the majority of the ascent</td>
</tr>
<tr>
<td>Date / time recovered</td>
<td>Used to determine total operation time for use in future planning</td>
</tr>
<tr>
<td>(Degree of) gear triggered</td>
<td>Gear triggered / not triggered; number of core units triggered</td>
</tr>
<tr>
<td>(Degree of) sample success</td>
<td>Sample recovered / number of samples recovered</td>
</tr>
<tr>
<td>(Degree of) gear damage</td>
<td>Any damage to the deployed equipment</td>
</tr>
</tbody>
</table>

### 10.3.2 Generalised protocols for box-corer operation

Even among USNEL Mk II corers there can be significant variations in their detailed mechanical arrangements as supplied by different institutions / manufacturers. It is therefore very important that all involved with the sampling operation are familiar with the detailed mechanical arrangement of the specific corer in use. This is, particularly critical for safety, including: (a) use of ‘safety pins’ that prevent triggering and the descent of the coring head, (b) pre-triggering precautions to reduce risk of triggering during launch and/or deployment; and (c) method or mechanism to lock the spade arm(s) of box-corers in the fired position during the sample removal phase. Below we provide generalised notes on the operation of a large box-corer such as the USNEL type (see also Figure 10.3).

#### 10.3.2.1 Deployment of the box-corer

1) The corer should have its safety pins in place and the spade arm(s) lashed or locked in the up / fired position.
2) The core box is fitted, note the box is likely to have a specific orientation (consider the location of fixing points, any opening panel, any draining panels, etc).

3) The spade is fitted; note the spade is likely to have a specific orientation (i.e. the leading, sharpened edge must be facing downwards once the spade arm is swung to the horizontal).

4) The spade arm(s) is freed and carefully swung to the horizontal while feeding the 2.5 m activating wire warp(s) through the upper trigger mechanism.

5) The termination of the activating warp(s) is carefully located in the upper trigger mechanism and the securing bolt drawn through it.

6) The securing bolt is locked in place by cocking the trigger lever.

7) Water venting mechanisms should be opened and locked in place (‘bow-wave effect’ reduction).

8) Pre-trigger precautions are applied at this time (these may include wiring the trigger lever, or its linkage, to the central column to increase the resistance to firing; lashing the spade to the support frame with light twine to reduce swinging action).

9) With the agreement of the Officer of the Watch the corer can now be lifted from the deck and swung just outboard.

10) Once outboard the safety pins are removed.

11) The winch pays out wire slowly; pay out speed is increased gradually to a maximum of c. 60m/min. There is a danger, if the wire is paid out too fast, that the wire may ‘overtake’ the descending corer and cause a ‘snag’. Mid-water tripping can also be an issue if the wire is paid out too fast; with the slackening and tightening of the wire during the passage of significant swell waves leading to the firing of the corer before it has reached the seafloor.

12) When the corer is c. 50m above the seabed\(^1\), (determined by wire out, ‘pinger’ or other telemetry system), the pay-out speed is reduced to c. 10m/min for the remainder of the descent.

At 50 m above the seabed, the wire pay out can also be momentarily ceased to allow the corer to

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\(^1\) Determined by wire out, “pinger”, or other telemetry system.
straighten up on the end of the wire prior to the final descent at the slower payout rate. In higher sea states/swells a final pay out rate of up to c. 20m/min is sometimes used to reduce the likelihood of triggering during a glancing touchdown on the seabed; however, this may well exacerbate the ‘bow-wave effect’.

13) On bottom contact (determined by wire tension), a maximum of 10 m of additional wire may be paid out to reduce the effect of the corer being pulled over by the drift of the ship.

10.3.2.2 Collection of box-corer sample

1) As the corer touches the seabed, the spring-loaded cocking bar, which has been locked into position, is then released by the linkage mechanism as the weighted central column of the corer passes through the gimbals, thus allowing the heavy box to sink into the sediment.

2) The top of the box, open during the descent of the corer, also closes once the corer is on the seabed.

3) The corer is allowed to settle for a few seconds.

4) The spade arm activating wire warp is hauled in allowing the spade to close under the box once heaving commences. The sediment core is then effectively sealed within the corer.

5) As the corer is pulled out of the sediment, there is a marked increase in tension recorded, and as the corer is freed from the sediment the tension notably decreases. These changes in wire tension are useful indicators that the corer has arrived on/lifted from the seafloor.

10.3.2.3 Retrieval of the box-corer sample

1) Wire is then recovered at a slow rate (c. 5m/min) with low tension on the winch until the weight has been taken up on the wire allowing time for the spade to close under the box. Any haul rate will be additional to the ship heave rate.
2) When the corer is clear of the bottom\(^2\), the wire hauling rate is increased gradually to a maximum of c. 60m/min.

3) On approach to the surface, hauling rate is reduced.

4) With the agreement of the Officer of the Watch, the corer can now be lifted from the water.

5) Resist any temptation to insert the safety pins at this stage – it will likely result in loss of sample. *(Should the corer return un-triggered exercise extreme caution - the safety pins should be re-inserted with the corer still outboard and certainly before the corer comes in contact with the deck).*

6) Note that the corer should be landed in an appropriate orientation, i.e. with the side of the box that can be removed, facing a sufficiently large area of open deck.

7) The spade arm(s) must be firmly secured in the fired (up) position at this time (a **serious** accident may occur at step 12 below if this is not done).

8) Details of core box removal vary between models, but may include: removal of a section of the support frame (and lazy spade) to permit trolley access, locating trolley to lift spade and box (where a simple pallet truck is used wooden wedges may also be required), disconnecting spade from its arm, disconnecting box from corer column, and/or opening water venting mechanism.

9) The corer is then hoisted slowly on the main wire to give clearance (e.g. 5cm) between the corer column and the disconnected box and spade.

10) The core box is then gently pulled clear from the corer.

11) **Insert safety pins at this point.**

12) The corer can now safely be lowered back to the deck and slack wire paid out.

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\(^2\) Determined by wire out or wire tension monitor.
10.3.3 Multiple-corer operation

The classic SMBA pattern multiple corer (as described by Barnett *et al.* 1984) has been produced by several manufacturers, introducing a number of variants. The original design has also been substantially modified by a number of manufacturers, particularly with respect to the style of the support frame and the number / diameter of core tubes carried. Similarly, the Bowers and Connelly Megacorer represents a wholesale re-engineering of the original concept. It is therefore very important that all involved with the sampling operation are familiar with the detailed mechanical arrangement of the specific corer in use. This familiarity is critical in regard of the ‘locking-up’ of the coring head, such that it is unable to descend through the support frame. Below we provide generalised notes on the operation of a multiple-corer (see also Figure 10.4).

11.3.3.1 General multiple-corer deployment

1) The head lock-up mechanism must be securely in place prior to any preparatory work.

2) Clean core tubes are fitted and secured with locking collars or similar.

3) The individual top and bottom closures for the cores are now cocked to the armed position. The order and manner in which this is done varies substantially between systems. For examples with the SMBA multi-corer, tops must be done first; on megacorers, bottoms must be done first.

4) The corer can now be lifted from the deck and swung outboard.

5) The head lock-up mechanism can now be released.

6) The winch pays out wire slowly; pay out speed is increased gradually to a maximum of c. 60m/min (or lesser speed with lighter corers / wires, or in higher sea states).

7) When the corer is c. 50m above the seabed (determined by wire out, “pingel”, or other telemetry system), the pay-out speed is reduced to c. 10m/min for the remainder of the descent. At 50 m above the seabed, the wire pay out can also be momentarily ceased to allow the corer to straighten up on the end of the wire prior to the final descent at the slower payout rate.
10.3.2.2 Collection of multiple-corer sample

1) On bottom contact (determined by wire tension monitor), wire pay out continues for a further 5-10m.

2) The corer is left on the seafloor for 1-2 minutes to enable the hydraulically damped descent of the coring head to take place.

11.3.2.3 Retrieval of the multiple-corer sample

1) Wire is then recovered at a slow rate (c. 10m/min) with low tension on the winch until the weight has been taken up on the wire. This reduces sample loss that can occur when the corer is pulled out quickly and under tension from the sediment.

2) When the corer is clear of the bottom, the wire hauling rate is increased gradually to a maximum of c. 60m/min (or lesser speed with lighter corers / wires, or in higher sea states).

3) On approach to the surface, hauling rate is reduced.

4) The corer can now be lifted from the water.

5) Where possible the head lock-up mechanism should be engaged with the corer still outboard; however, many designs require the corer to be swung aboard and allowed to just touch deck (i.e. with their weight still taken on the wire) before the head lock-up mechanism can be engaged.

6) With the head lock-up mechanism securely engaged the corer is fully landed on deck and slack wire paid out.

7) Prior to any attempt to remove samples, the performance of each coring unit should be assessed and recorded (e.g. top and bottom closures fired, core recovered, its length, clarity of supernatant water, noting of any obvious core surface and profile features).

8) Depending on the corer design, cores may be removed whilst still attached to the instrument or the entire tube closing mechanism can be taken from the corer and hung on a rack for...

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3 Determined by wire out, wire tension monitor.
processing. The detailed methodology of core removal will depend on the specific instrument, in
general terms the following approach should work well with two people. The first operator
applies downward pressure to the top cap, to ensure a good seal and limit any core slippage at
the next stage. With an appropriate bung in hand, the second operator swings away the bottom
closure and quickly positions the bung in its place. The top closure is then opened and the
second operator pushes the bung firmly into the base of the core. The core locking collar is then
removed; the core is eased from its holder and carefully passed to the first operator.

9) The core should be transferred to an appropriate rack and some form of top cap or bung put
in place.

10.4 Sample processing

10.4.1 Assessing core suitability

When to accept or discard cores collected can be quite subjective. Researchers from Scottish
Association of Marine Science (SAMS) and Institut Français de Recherche pour l'Exploitation
de la Mer (IFREMER) have used the following categories and criteria for acceptance/rejection
of cores (Table 10.3) – primarily collected by the box-corer.

Table 10.3. Criteria used for the acceptance/rejection of cores based on quality.

<table>
<thead>
<tr>
<th>Category</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accept</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Reject</td>
<td>3</td>
</tr>
</tbody>
</table>
surface obviously disturbed, no delicate organisms present

4 Core shallow or with sediment surface obviously disturbed, no overlying water, no delicate organisms present

10.4.2 Sub-coring the box-core

Large box-core samples are frequently sub-sampled; this can be achieved either in situ or on deck after recovery of the corer. The best known of the in situ techniques is generally referred to as the “vegematic”. This comprises a 5x5 array of 10x10cm square sections that are fitted within the main core box. On recovery of the corer the individual sub-core rectangular sections can be removed and processed separately for different samples. However, when using this technique, Jumars (1975) established that the outer 16 sub-cores of the array returned fewer macrofaunal specimens compared to the inner nine sub-cores and attributed this finding to the bow wave effect. The presence of the sub-core array most likely exacerbates the bow wave effect by further restricting water flow through the main core box during its descent.

Post-recovery sub-sampling of the box-core can be achieved by various means, including vegematic inserts, simple push cores, syringe-based piston cores, and box quadrats. The overlying surface water should only be siphoned off once the vegematic inserts or sub-cores are placed into the box after recovery, and the material in the water collected on a sieve with the pre-determined mesh size for the target fauna. Once the sub-core is removed from the box-corer, the sediment is extracted by placing the corer on an extruder which forces the sediment up into a metal/plastic collar which has been pre-cut or marked to the depths required. The sediment is sliced using a thin metal or plastic slicing plate and then placed in a sample vessel with a preservative or filtered seawater prior to sieving. Delicate surface fauna are removed prior to slicing and stored in separate jars with formalin. Sediment from each core and each fraction should be kept separate.
10.4.3 Sub-sectioning multi-cores

Prior to each multi-core being removed from the coring unit, the length of the core should be measured, and any features that are easy to see on the surface, recorded. The overlying surface water from the individual core should be siphoned off and the material in the water collected on a sieve with the pre-determined mesh size for the target fauna. The core is then placed on an extruder and gently extruded from below. As the sediment reaches the top of the core any visible delicate fauna can be removed and added to the overlying surface water material. This is then generally preserved in formalin. The core is further extruded into pre-cut polycarbonate collars marked with the required depth, the sediment sliced and put in a sample vessel and depending on the depth horizon, usually preserved in formalin (particularly for the upper depth horizons prior to sieving) or filtered seawater (used for lower depth horizons prior to sieving). Sediment from each core and each fraction should be kept separate.

11.4.4 Whole box-core processing

Once the box-core is back on deck, the overlying surface water is gently siphoned off and the material in the water collected on a sieve with the pre-determined mesh size for the target fauna. Then the front of the box can be removed allowing for initial general observations to be made followed by extraction of the material. General notes are made of any features that are of interest e.g. tubes, burrow openings etc. on the surface of the core, the overall surface condition e.g. does it slope in any direction and finally measure the depth of box penetration into the sediment. Any delicate surface fauna (e.g. xenophyophores) and any tubes are removed and placed in a separate sample vessel prior to any further processing.
10.4.5 Macrofaunal protocols

Typically, cores processed for macrofauna are sliced into depth horizons. The vertical intervals of the slices taken from cores depend on the level of analysis required, the time available on the ship and the number of operators who can process the samples. Ideally, the sediment is sliced into 5 or 6 depth strata: 0-1 cm, 1-3 cm, 3-5 cm, 5-10 cm, 10-15 cm and >15 cm.

Whole box-cores are sliced by eye using builder’s trowels once the depth horizons are marked by scoring across the exposed sediment profile after the front side is removed (note this approach is not possible with the circular NIOZ box). The precision of the desired horizontal sectioning is easier to achieve when using multi- or mega-core samples since appropriately marked sections of core tubing can be placed over the sample cores and the desired sample extruded into the graduated tube. A variety of pistons mounted in different ways are used to push the sediment out of the core tube. Multi- and mega-core fractions are small enough for the entire sample to be placed in formalin (or preservative of choice) and processed some time later after fixation. For sections from whole cores, the upper two sediment fractions may be placed immediately in with the lower fractions being sieved first in filtered seawater. This allows time for tissues of fauna in the top fractions to be fixed before washing which reduces damage to delicate animals.

10.4.6 Meiofaunal protocols

Collecting meiofauna from a box-core generally requires the use of a plastic core or syringe sub-core, which can have internal diameters of 3.6, 4.5 or 5.0 cm. The sub-core is pushed into the sediment and a stopper (either a rubber bung or film) is placed over the top so that no air is present, allowing for removal of the core. Once the sub-core is removed a bung is placed at the bottom of the core to prevent the sediment from falling out. The sub-core is required to be kept vertical to prevent the sediment layers from mixing and thus altering the distribution of the meiofauna themselves. The questions posed at the start of the study will influence the number of
depth horizons that the sub-core is sliced into. Multi- and mega-cores taken for meiofauna are also typically sectioned. If the vertical distribution of the meiofauna is a priority, then sectioning at 0-1 cm, 1-3 cm, 3-5 cm, 5-10 cm, >10 cm should be sufficient. The sediment core is extracted by placing the core on an extruder which gently forces the sediment up into a plastic collar which has been pre-cut or marked to the sections required. A thin metal or plastic plate is then used to section the sediment into the different depth horizons and each sediment horizon is placed into a separate sample vessel with the addition of preservative or formalin. Shake the sample vessel gently to ensure that all the sediment and fauna comes into contact with the preservative or formalin. If section slicing is not able to be undertaken immediately, the entire core can be frozen at -20°C to prevent the movement of the meiofauna through the core; this is particularly important if analysis of the vertical distribution of the meiofauna is to be undertaken.

10.4.7 Microbial protocols

The methodology used for collection of microbial fauna, depends on what groups are of interest. The main microbial organisms commonly sampled are the viruses, Archaea and bacteria, algae, protozoa and their resting stages. Collecting microbial samples from a box-core can be achieved in several ways, but laboratory gloves should always be worn by the person carrying out the sampling. A volumetric spoon, cut-off sterile syringe, or small, sterile plastic sub-core can be used to sub-core the desired volume of sediment. If the aim of the research is to determine microbial community distribution and diversity across a sediment depth profile, a sub-core should be sliced as described above, and quantitative samples taken from the desired depth horizons using either a cut-off sterile syringe or a volumetric spoon.

Collecting microbial samples from multi- and megacores requires the cores to be extruded as described above. Sub-samples can either be taken from the upper part of the core using a cut-off, sterile syringe, once the surface of the sediment has been extruded to a point where the sediment
surface is level with the coring unit, or preferably, from slices of different depth horizons. When
slicing cores from the multiple corer, the polycarbonate collars and slicers should be cleaned
with seawater and then rinsed in 80-100% ethanol prior to beginning to slice as well as between
each depth strata. If the vertical distribution of the microbial community is a priority then
selecting 5-6 strata should be sufficient, e.g. 0-1cm, 2-3cm, 3-4cm, 5-6cm, 7-8cm, 9-10cm. If
comparisons with meio- or macrofaunal distributions are to be performed, select depth strata
that correspond with these sampling protocols. The simplest way to collect the sub-samples is to
sheer the slices off directly into a sterile ziplock bag/ sampling bags with a wide opening.
Alternatively, a sterile wide-necked container can be used. For most post-sampling analytical
procedures, it is necessary to know the weight and/or volume of the sediment sub-sample
collected, therefore, it is extremely useful to have pre-weighed, labelled and documented the
collection containers prior to filling them with sediment. It is also important to have some spare,
pre-weighed containers in reserve in case extras are required.

The sub-samples should then be preserved and homogenised. Rapid freezing in liquid
nitrogen is necessary when virus and bacteria samples cannot be processed within 24 hours.
However, it is important to note that when defrosting microbial samples for which cell integrity
is important, it should be done slowly, overnight in a refrigerator to avoid cell lysis.

10.4.8 Sampling for molecular analyses

Sampling for future molecular analysis requires slightly different protocols. Care should be
taken to ensure that sub-corers and sample containers are sterile (either manually pre-sterilised
or purchased as such), that laboratory gloves are worn by the person carrying out the sampling
and as few transfer steps as possible are employed. When slicing cores from a multi-corer, the
polycarbonate collars and slicers should be cleaned with seawater and then rinsed in 80-100%
ethanol prior to beginning to slice as well as between each depth strata. The sediment slices
should then either be slid directly into a sterile bag (sterile Whirl-pak® bags are ideal for this
purpose). If a smaller volume is required, the slice can be sub-sampled using a metal spatula (the spatula should be flamed with ethanol immediately prior to sub-sampling) and the sediment sample placed in sterile 50ml Falcon tubes. Depending on the molecular procedure to be carried out, the desired fixative should be added prior to sealing the bag/tube, and the sediment stored in a cool, dark place. If there is going to be a significant delay between sampling and laboratory processing, it is recommended that molecular samples are stored frozen at -80°C. If liquid nitrogen is available this is the preferred rapid freezing procedure. Once frozen, samples can then be transferred to a -80°C freezer for longer term storage. If neither liquid nitrogen nor a -80°C freezer is available, the samples can be frozen at -20°C and transferred to -80°C later.

10.4.9 Sediment parameters

The sediment of the sampled core can be analysed for a range of environmental variables (e.g. dissolved oxygen in porewater, levels of chemicals such as sulphides etc). Most commonly, sub-cores of sediment are taken for granulometric analysis (particle size determination), organic matter determination (CHN), and/or pigment analysis (chlorophyll a etc). Sediment collected for pigment analysis on board should be stored “live” in the dark at 4°C short-term (<24h) or in the dark at -20°C long-term until extraction and post-processing can take place (same for later particle and organic matter analysis). If the aim is to target resting stages, such as eggs, sediment should be stored “live” prior to post-processing using, e.g. sugar floatation (Onbé 1978) or Percoll separation (Epstein 1995).

10.4.10 Sieving

10.4.10.1 Choice of mesh size

The questions asked at the outset of the research programme and the fauna that are being targeted generally dictates what size of mesh should be used to collect the infauna. For the macrofauna, the smallest mesh size currently used is 250µm (typically 300 µm), whilst for the
meiofauna it is 20µm (typically 32 µm). Sieving the fauna directly on the smallest mesh size may appear from the outset to be advantageous. However, by sieving through stacked sieves, less material is retained on an individual sieve, and it is easier to sort specific size fractions. If time is short, a decision can be made to look at one specific size fraction without the need to re-sieve the whole sample through stacked sieves and potentially damage the individuals. The disadvantages of stacked sieves are: the need for a series of sieves with different mesh apertures, and the requirement for more than one set of stacked sieves to allow for more than one operator to sieve the material. Both cases can be expensive.

10.4.10.2 Elutriation and washing techniques

Washing or elutriating samples on board ship must be undertaken using filtered seawater. Filtered seawater prevents the contamination of the sediment sample with planktonic organisms found in the water column. Portable filtration units (generally with a mesh size between 20 and 50 µm) can be inserted between the ship’s deck hose and the ‘garden-type’ hoses used for washing or elutriating the samples.

A gentle method used for elutriating box-core samples, initially described by Sanders et al. (1965), is to use a large bucket/dustbin with two hose nozzles made near the top. A hose is connected to the slightly higher inflow nozzle allowing a continuous input of filtered seawater to fill the bucket. Water and suspended sediment and fauna flow through the outflow nozzle onto the sieve below. A secondary hose can be used in the bucket to gently break down large sediment aggregates whilst under water. Care needs to be taken when using this method if the sediment contains glass sponge spicules; these have the ability to block the sieve very rapidly. Material residue on the sieve should be periodically removed and stored in a sample container. Once elutriation is complete the entire residue can be preserved in the sample container and mixed gently to ensure that all material comes into contact with the fixative.
The method for elutriating multi- or mega-corers samples is to place each core sample individually into a round bottom glass distillation flask. As with the larger setup for box-cores, there is both an inflow of water and an outflow of water and sediment sample. The inflow of water from above gently and continuously washes and agitates the sediment. This process results in the small fauna being gently elutriated out of the flask and on to the sieve below. The material residue on the sieve can be periodically removed from the sieve and stored in a sample container. When the water runs clear, or no more animals are elutriated out of the distillation flask, the entire residue can be preserved in the sample container.

Washing of the sample on a sieve can be undertaken without using elutriation. Commercial or institute-built “auto-sievers” use upwardly rotating water jets which gently wash the underside of the sieve. The whole system is held in a stainless steel deck table. The continuous pressure of water from underneath prevents the mesh of the sieve from becoming blocked. The sieve is fitted with a lid which seals the sample inside allowing the operator to slightly increase the water pressure. The centre of the lid is also fitted with a small hole covered by a mesh which allows for water to overflow, but prevents the loss of fauna in the event of the sieve being overfilled with water. Auto-sievers are particularly useful if a large quantity of sediment needs to be processed. Sieve size is generally 33cm in diameter, and mesh sizes are typically 250μm, 0.5mm or 1mm. The resulting residue can be stored in a sample container with fixative/preservative and mixed gently.

It is important the sample containers should be labelled on the outside, as well as water- and preservative-proof sample labels being placed on the inside of the container. The labels should contain some of the information highlighted in Table 10.4.

10.4.11 Fixation and Preservation

In general, macrofauna and meiofauna samples are initially fixed in a buffered seawater solution of commercial grade formalin (equivalent to 10%). Borax powder is added as a buffer
to prevent decalcification of shelled organisms as the mixture is otherwise quite acidic. Often samples are sieved prior to being fixed in formalin; however, there is a suggestion that first fixing the un-sieved sediment leads to more intact specimens being recovered and a reduction in the number of animals lost (Degraer et al. 2007). Sieving prior to fixation leads to smaller quantities of formalin being required, thereby reducing the demand for storage space on board ship. However, fixing prior to sieving is extremely useful for the more fragile fauna often found in the top 3 cm of sediment and should be used just for this uppermost fraction whenever possible. Careful on-deck treatment of the sample that results in better specimens can save hours of work in the laboratory dealing with poor material. Once the specimens in the sample have had time to be fixed in formalin for several days, the sample can be washed with filtered seawater and transferred to alcohol to which 10% propylene glycol is added. The addition of propylene glycol will prevent irreversible damage to the specimens if for some reason the sample dries out.

Virus, Archaea and bacteria samples should be fixed with glutaraldehyde (Noble and Fuhrman 1998) to a final concentration of 1% v/v. Ideally EM-grade glutaraldehyde should be used if viruses are to be enumerated. Algae and Protozoa can be preserved in a number of ways depending on their end use (see Alongi 1993, Wickham et al. 2000). Fixing in glutaraldehyde or formalin to a final concentration of 1-2% v/v is common. Lugol’s iodine (final concentration 2-5% v/v) is also used regularly by microbiologists investigating, for example, ciliates and dinoflagellates, whilst foraminifera samples should be preserved in formalin buffered with sodium borate (final concentration 2-8% v/v) and are often stained with Rose Bengal to distinguish protoplasm that was alive at the time of collection (1g Rose Bengal and 10g phenol in 1 litre of tap water) (Gooday et al. 2001). Once the fixative of choice has been added the sample container should be gently agitated to mix sediment and fixative. If bags have been used, these can be gently massaged to achieve homogenisation.

See Chapter 15 for further information concerning the fixing and preservation of samples.
10.5 Data Interpretation

Prior to sampling, consideration should be given to what sampling equipment to use. Some of this is influenced by the questions being asked, the environment that is being sampled and the availability of equipment. The first question to ask is whether a quantitative or qualitative sample is required. Non-quantitative or semi-quantitative samples may be sufficient, for example, when the main objective is to provide an inventory of species. In such cases, large grabs may provide suitable samples even from coarse sediments. If quantitative samples are needed, the next issue to consider is the type of sediments being sampled. Sediment type has a major influence on what equipment can be used; for example if the sediment is quite coarse then the use of a multiple corer is not appropriate; the core tubes can be broken and the closing mechanism will not be able to retain a core very easily. However, if the sediment is finer, then a multiple corer is better than a box-corer for undisturbed samples of the macrofauna and meiofauna.

When both box-corers and multiple corers are suitable, the last consideration is whether accuracy or precision is of prime interest. Accuracy is defined as the closeness of an estimate to the true value of the parameter being estimated (Andrew and Mapstone 1987). Box-corers induce a bow-wave effect that flushes the semi-liquid layer on top of sediments and its associated fauna. Multiple corers do not have this bias and thus are more accurate than box-corers (e.g. Bett et al. 1994). Precision, on the other hand, is defined by the degree of concordance among a number of estimates for the same population (Andrew and Mapstone 1987). The precision of a density estimate from a sample is computed by dividing standard error by mean density (Elliot 1977) and standard error is a function of both variance and the number of replicate samples. Consequently, precision increases with densities and with the number of replicate samples. Box-corers, due to their large size, allow achieving a desired level of precision with a lower number of replicate samples than do multiple corers. In environments where macrofauna densities are naturally very low such as in the abyss, box-corers may be the
only option. However, the use of multiple corers may be a more efficient means of obtaining
sufficient samples for meiofauna studies. While individual cores on a single multiple-corer cast
are not independent and are not typically considered replicates for macrofauna studies (i.e. they
are pseudo-replicates), they are sometimes considered as replicates for meiofauna studies. This
is because patchiness in the distribution of, say nematodes, occurs at a smaller spatial scale than
the distance between cores on a multiple-corer.

There are a number of methods that have been proposed to optimize sampling design and
achieve the best trade-off between the size of a sampling unit and the number of replicate
samples, from the most simple, based on precision (e.g. Elliot 1997, McIntyre et al. 1984) to the
more complex involving power:cost analyses (e.g. Ferraro et al. 1989).

In conclusion, a sampling scheme will always be a matter of trade-offs between a desired
level of accuracy, a desired level of precision but also practical, logistical or financial
constraints. In the deep sea, these later constraints are usually quite large and in many cases
unfortunately remain the first order consideration in the design of a sampling scheme (see
Chapter 3).

10.6 References


using discontinuous sucrose and isopycnic percoll gradients. Journal of Parasitology, 73, 314-
319.


**Figure Legends:**

Figure 10.1. a) van Veen Grab (Image courtesy of D Stevens, © NIWA, New Zealand); b) The USNEL Mk II box-corer (Image courtesy of B Bett, © National Oceanography Centre, UK); c) The GOMEX box-corer ready for deployment (Image courtesy of G Rowe, © Texas A&M
University, USA); d) The NIOZ box-corer being deployed (Image courtesy of M Smit, © Royal Netherlands Institute for Sea Research, the Netherlands).

Figure 10.2. a) The classic SMBA multiple corer being deployed (Image courtesy of B Bett, © National Oceanography Centre, UK); b) The giant TV-controlled grab sampler (GTVD-2 / Preussag), frequently employed on Unesco / IOC “Training Through Research” cruises [from IOC picture library, http://193.191.134.30/photolibrary/index.php?option=com_joomgallery&func=detail&id=381&Itemid=59]; d) HyBIS, Hydraulic Benthic Interactive Sampler – a modern video grab (Image courtesy of B Murton, © National Oceanography Centre, UK);

Figure 10.3. A schematic showing the operation and collection of sediment using the USNEL Mk II box-corer (sequences 1-4).

Figure 10.4. A schematic showing the operation and collection of sediment using the SMBA multiple corer (sequences 1-4).

Figure 10.5. Elutriation of sediment samples at sea (Image courtesy of P Lamont © Scottish Association for Marine Science, UK)
Fig. 10.1 (a) van Veen Grab. (Photograph by D Stevens. c NIWA, New Zealand. Reproduced with permission.) (b) The USNEL Mk II box-corer. (Photograph by B Bett. c National Oceanography Centre, UK. Reproduced with permission.) (c) The GOMEX box-corer ready for deployment. (Photograph by G Rowe. c Texas A&M University, USA. Reproduced with permission.) (d) The NIOZ box-corer being deployed. (Photograph courtesy of M Smit. c Royal Netherlands Institute for Sea Research, the Netherlands. Reproduced with permission.)
Fig. 10.2 (a) The SMBA multiple corer being deployed. (Photograph by B Bett. © National Oceanography Centre, UK. Reproduced with permission.) (b) The IFM-GEOMAR TV-Grab ready for deployment deployed. (Photograph by D Bowden. © NIWA, New Zealand. Reproduced with permission.) (c) HyBIS, Hydraulic Benthic Interactive Sampler – a modern video grab. (Photograph by B Murton © National Oceanography Centre, UK. Reproduced with permission.)
Fig 10.3 A schematic showing the operation and collection of sediment using the USNEL Mk II box-corer (sequences 1–4). (Image by B Bett. c National Oceanography Centre, UK. Reproduced with permission.)
Fig. 10.4 A schematic showing the operation and collection of sediment using the SMBA multiple corer (sequences 1–4). (Image by B Bett. © National Oceanography Centre, UK. Reproduced with permission.)
Fig. 10.5 Elutriation of sediment samples at sea. (Photograph courtesy of P Lamont © Scottish Association for Marine Science, UK. Reproduced with permission.)