The soft, shallow seafloor

Common Module in Multidisciplinary Offshore Operations in Marine Science

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While sampling inshore and offshore for sediment/faunal samples it is important to understand and appreciate the soft seafloor as a habitat. The majority of animals in soft substrata live below the surface. To identify and count them, and to identify patterns in their distribution, it is necessary to remove them from the sediment by taking a sample of sediment and sorting it back on land. The nature of the sediment has a major influence on the organisms. A diverse array of sampling methods are available to identify, map and monitor soft-sediment habitats and their associated biological assemblages. The precise methods selected will depend very closely on the objectives of the study. No one method is suitable or appropriate for the complete characterisation of habitats or biological assemblages at all sites, and many biological problems will require a combination of methods. This online lecture gives a broad overview of the soft seafloor as a habitat for its resident communities. Understanding the nature of the environment, the habitats present, the relationships and successional events to colonisation will equip the researcher with the necessary tools in the form of ‘knowledge’ to design a survey, whether it is for information on an impact, monitoring of an area or in order to gather further information at a site.

The soft, shallow seafloor as a habitat

When we talk of the marine benthos we mean the seafloor i.e. the plants and animals at the bottom of the sea and those living on the intertidal sediments. Unlike the hard rocky seabed the sedimentary system is three-dimensional even though often only the surface features are seen. So the benthos implies the animals that live on (Epifauna) or in (Infauna) the seafloor.
We can separate the benthic organisms initially into the fauna and flora and then according to their preference for hard or soft seafloors/substrata. The strict sense of hard seabottom is viewed as an extension from and in the vicinity of coastlines, sea mouths and coral reefs. The primary hard bottom is differentiated from other substrates composed of hard artefacts which you find on the seashore such as mollusc shells, plastic debris, stones which you may find scattered on the primary substrate. Most of the seabed consists of sediments and only a relatively small proportion is rocky or constructed of coral. Soft seafloors encompass muds, sands, gravels, or even cobbles.

Sandy bottoms will be found where water movement prevents the definitive/permanent deposition of fine particles (fines – fine and very fine sand, silt and clay) but allows the deposition of granular material – medium and coarse sand through to gravels. Temporary deposition can occur during spring and neap tides.

Benthic ecology is the study of the organisms (living on and in the seafloor) the interactions between them and impacts on the surrounding environment. The commonest animals in sediment are the polychaete worms, followed by bivalve molluscs, amphipods and decapod crustaceans, burrowing holothuroid echinoderms, and an occasional burrowing anemone.

Infauna live in the seafloor
Faunal categories
The biologists have followed the geologists in using a decreasing geometric scale of screens (1mm, 0.5mm, 0.25mm, 0.125mm, 0.062mm, etc.). There are several classes of marine benthic organisms based on the size of the mesh used to retain them:

- Microfauna (<63µm)
- Meiofauna (63-500 µm)
- Macrofauna (500 µm – 5cm)
- Megafauna (>5cm)

Or on a taxon basis

- Microfauna: ciliates, rotifers, sarcodines
- Meiofauna: nematodes, oligochaetes, gastrotrichs
- Macrofauna: polychaetes, amphipods, bivalves
- Megafauna: echinoderms, decapods

Living between sand grains intertidally or subtidally or on muddy beaches within the mud are a whole variety of small animals that will pass through the meshes of a 0.5mm screen. These small animals are called meiofauna or interstitial fauna (living in the interstices between sand grains). The prefix meio comes from the Greek word meios meaning intermediate (between the macrofauna and the microfauna). The lower limit of the meiofauna size is set by use of a 0.062 mm screen, and usually consists of nematodes, harpacticoid copepods, turbellarians, and a phylum unique to the meiofauna, the Gastrotricha. The actual ratio of each type depend on the sediment type e.g. Microfauna being very common in fine sand but scarcer in mud, where macro- and meiofauna dominate.

Benthic Communities
Most classical benthic ecology implies that similar groups or communities of species consistently occur on similar substrates and that the type of sediment at least in part controls species distribution. Communities can be designated by their so-called characteristic species (i.e. one which is not seasonal and which owing to numerical or biomass dominance could be regarded as typical of a given assemblage) within a given habitat type (i.e. geographical location, physiographic features and the physical and chemical environment). Over the last few decades, many studies have correlated infaunal invertebrate distributions with sediment grain size, leading to generalization of distinct associations between animals and specific sediment types. However, populations of species are thought to be distributed lognormally along gradients of environmental factors in an
overlapping fashion and form a continuum. Each population will have an optimum somewhere along a gradient. Therefore, no single mechanism will be able to explain patterns observed across many different environments therefore, in addition to **grain size**; other proposed causative factors include **organic content**, **microbial content**, **food supply** and **trophic interactions** etc. In fact many species are not always associated with a single sediment type, and that suspension and deposit feeders often co-occur in large numbers.

Food is not the only limiting factor. One can expect and indeed find that there is intense **spatial competition** in sediment since niches overlap. No species is ever in the ascendancy for long enough to produce niche specialisation or competitive exclusion, but over short-time periods competition can be intense. Deposit feeders are not normally food-limited but are maintained below the carrying capacity of the environment by other species disturbing the sediment. In areas of subtidal sediments that were studied predation has relatively little effect on structuring the community.

**Grain Size**

The most obvious varying character, while characterising the sediment as a habitat for animals, is the grain size. Animal preferences are usually interpreted due to a grain size range, however other factors relating to grain size such as porosity, permeability and oxygen content may be the actual determinants as to why a particular species is attracted to that particular type of deposit.

Subtidal soft-substratum environments are influenced by many of the same physical and chemical forces that act on soft substrata in intertidal areas. These forces include currents, which erode and deposit sediments, determining their depth and particle size distribution. Particles of 0.8mm diameter are the easiest to move. Coarser particles are difficult to pick up and transport since they are dense, whereas particles finer than 0.18mm pack into a smooth bottom surface and are difficult to re-suspend. Thus, if sediment is composed largely of particles around 0.18mm diameter it can be expected to be the most stable of all, since where such sediments occur wave and current action must be minimal.

Subtidal soft substrata range from course sands in areas where water currents are strong, to fine muds. Fine sediments such as muds, which have grains tightly packed together, preclude the presence of an interstitial fauna and have poor water circulation and often low oxygen tension. Medium and fine sands usually have an abundant meiofauna and macrofauna, but because muds have more organic matter per unit area faunal densities are frequently highest here. The range of particle sizes in any give sediment may be broad (poorly sorted) or narrow (well sorted). Sandy areas are often patterned with ripples with wave lengths ranging from a few centimetres to several metres (megaripples).
Based upon the proportions of sand-, silt- and clay-sized particles, sediments are classified according to Shepard's diagram. Shepard's diagram is an example of a ternary diagram - a device for graphing a three-component system summing to 100%. In this case, the components are the percentages of sand, silt, and clay comprising a sediment sample. Each sediment sample plots as a point within or along the sides of the diagram, depending on its specific grain size composition. A sample consisting entirely of one of the components, 100% sand, for example, falls at the same-named apex. A sediment entirely lacking in one of the components falls along the side of the triangle opposite that apex.

To classify sediment samples, Shepard (1954) divided a ternary diagram into ten classes (see Fig. 1). Shepard's diagram follows the conventions of all ternary diagrams. For example, Shepard's "Sands" contain at least 75% sand-sized particles. "Silty Sands" and "Sandy Silts" contain no more than 20% clay-sized particles, and "Sand-Silt-Clays" contain at least 20% of each of the three components.

Sediment samples are rarely, however, made up of a homogenous sediment type. Mixtures of grain size are the rule. The degree of mixing of the different grain sizes can be represented by a sorting coefficient. Well-sorted sediments tending towards homogeneity are typical of high wave and current activity (high energy areas), whereas poorly sorted sediments are heterogeneous and are typical of low wave and current activity (low energy areas).
Fig. 2 Size and composition sorting (From Jones & Jones, 2003)

Grain size and sorting can vary over distances as small as a few centimetres, so in studying meiofaunal distribution patterns it is often necessary to record the fauna and grain size on the same sample. The dynamic mosaic of sediments which forms the seafloor exerts a profound influence on the distribution of animals according to their preferences in the different life stages.

While grain size and sorting are probably the two most important characters that can be measured on sediment samples, other biologically important properties include porosity and permeability which are particularly relevant for meiofauna studies.

**Organic matter**

In near shore environments the organic content of the sediment typically increases with the fineness of the deposit, since particles of sedimenting organic matter behaves as do sediment particles. The bulk of the organic material in sediments is derived by sedimentation from the overlying water column. In nearshore areas over the continental shelf, where plankton production is highest, the organic content of the sediment is similarly at its maximum.

The organic material arriving at the sediment surface is broken down by bacterial action. In the marine environment just as in the terrestrial, the carbon, nitrogen and phosphorus cycles operate. Primary production is limited by the availability of nitrogen rather than phosphorus and so the nitrogen cycle is very important.

Although a moderate amount of organic material may be beneficial, over fertilization results in extravagant growth of plants (dense blooms of phytoplankton) and the bacterial decay of dead plants falling to the seabed severely reduces the oxygen concentration in bottom
waters, and most benthic animals are killed or excluded from the area. This process is facilitated where a thermocline develops and the bottom water that receives the rain of decaying plant material is cut off from the atmospheric oxygen by the layer of less dense water floating above it. Deoxygenation of bottom waters has been recorded from many sea areas.

Probably the most universal pollutant affecting marine benthic communities is excess organic matter, which occurs primarily as sewage but can also include waste from paper mills etc. Sewage discharged into confined bodies of water frequently leads to eutrophication, resulting, in the most extreme cases in a total lack of oxygen and the presence of hydrogen sulphide in the sediment, with a corresponding absence of fauna. As one moves away from the source of pollution there is typically a sudden and rapid increase in biomass and abundance of the fauna. Tidal currents can both wash away some organic matter and renew the oxygen.

**Nutrient Recycling**

The ecosystem is defined as not only the organisms but also the complex of physical variables that make up the environment. Most of the organic matter in ecosystems is usually found as detritus. The organic matter arriving at the sediment surface is broken down by microorganisms (bacterial action) and the elements can then be recycled. In the marine environment just as in the terrestrial the carbon, nitrogen and phosphorous cycles operate. Carbon has been widely used in element budgets but there are advantages in using nitrogen. Nitrogen values can be used to measure excreted waste and furthermore nitrogen is often the nutrient that limits primary production in the sea and so the nitrogen cycle is very important. By calculating a nitrogen budget for a given species or the whole ecosystem more information on factors directly relevant to the functioning of the system are obtained.

![Fig.3. A simplified marine nitrogen cycle](image)
While sediments range from muds through to gravels there is an organic component that contributes to the structure of the benthic layer or benthic boundary layer and also either initiates or modifies the physical chemical processes that take place at the boundary. Ways in which these various processes inter relate are highly complex. Organisms that partake are highly diverse. Only the top few cms are colonised by most organisms, below this sediments are anaerobic, rich in methane, \( H_2S \) and in ferrous ions which result in biological activity.

Therefore of particular importance in marine sediments, is the sulphur cycle. In poorly drained sandy beaches and in nearly all muddy sediments a black layer or reduced sediment, smelling of hydrogen sulphide is common. The sulphate sulphide reduction is the most important in the chemistry of sediments since the pH and redox potential (Eh) of the sediment are determined by the bacterial responsible for sulphide reduction and from this reaction \( H_2S \) is produced. Between the aerobic layer and the anaerobic reduced layer there is a transitional zone with a steep gradient in redox potential. A grey layer of sediment marks this transition between oxygenated and reduced conditions. Here rapid change of redox potential with depth occurs. This is typically referred to as RPD (Redox Potential Discontinuity). In fine sediments the RPD layer is found closer to the surface than in coarser sediments. Ultimately the depth of the RPD layer is related to

1. Amount of organic material available for decomposition
2. Sediment pore space
[interstitial space between the sediment – function of sediment compaction]
3. Rate of \( O_2 \) diffusion
4. Sediment reworking – ‘Bioturbation’

Sulphide ions are nearly toxic to all aerobic species and so the RPD layer represents an important lower limit of depth distribution for many species that is unless they maintain tubes or construct burrows through which oxygenated water can be introduced down into the sediment. Although the RPD layer indicates and effective ecological barrier for most species, not all organisms are absent in the black layers. A whole group of specialised meiofauna have been found that occurs exclusively in this environment. This is a group of fauna called the ‘Thiobios’. Among other remarkable adaptations the group appears not to have mitochondria and it may be an extremely primitive group that thrives in the presence of sulfur.

Tube builders can also play an important role in the degradation of organic matter. This is because most tube-builders respire aerobically and actively pump the \( O_2 \) they need into the sediment, often causing brown oxidised areas down the sides of their tubes within the black anoxic layer.
Ecological assessment

There are four general types of ecological assessment namely Baseline studies, Impact studies, Monitoring studies and Patterns and processes. An Environmental Impact assessment (EIA) will take in the first three types of assessment.

Environmental Impact Studies

Environmental Impact Assessments (EIAs) investigate the physical, chemical and biological effects of anthropogenic influences of the natural environment. Typically these EIAs have a phased approach involving:

1. An initial characterising survey of the targeted area
2. Baseline phase
3. Application of the appropriate monitoring phase

Assuming that the main focus of interest is the seafloor the characterising survey must be designed to establish the nature of the benthos i.e. nature and distributional pattern of benthic communities and their associated habitats. Representative elements which are most amenable to ongoing studies and frequently elements with known sensitivities to the proposed inference are selected as the foci for the baseline study and monitoring protocol.

The Baseline study is intended to establish the types and the scales of change that can be expected in the system being studied if the investigator does not know what is natural to the system how can he possibly hope to register the anthropogenic effect. It is usually contended that a baseline study should endure at least as long as the lifespan of the ecological important species in the system. In some benthic scenarios that could be 10 years.

When a potential anthropogenic factor is introduced to a system, e.g. a factor with an outflow into the estuary/sea, then monitoring is introduced. Monitoring in an ecological context, and at its most simple, means the periodic measurement of selected environmental factors physical/biological/chemical overtime. By comparing the findings with the outcome of the baseline study monitoring becomes in essence an early warning system alerting to impending and possible harmful changes to the system. Emphasis on subtle changes!

Quantitative monitoring of macrobenthos from the soft seafloor is relatively easy however, it does require large vessels for sampling at sea and sample processing is labour intensive. Taxonomy of macrobenthic infauna has been quite well worked out and there is now an extensive research literature on macrobenthic effects. Therefore it it’s possible to use earlier work as a background to monitoring. Old records can be combined with latter-day findings and can be extremely valuable where the investigator has to contend with the reality that natural long term faunal trends may extend over years and sometimes decades. Enrichment and Eutrophication via a point source is one area that is often investigated through EIAs.
Benthic Colonisation - Succession

Knowledge of succession in benthic communities is extremely important when carrying out an EIA and in assessing the current state of the benthos. The early stages of succession in benthic communities are predictable and the same species dominate almost universally, but that later in the sequence the pattern is more varied. The pattern of benthic colonisation involves the so called r-selected, pioneering or opportunistic species which are perceived to have a high colonisation ability adapted to colonise this open new ground. As succession proceeds competitive ability becomes more important than colonisation ability and so species of later successional stages (k-selected or equilibrium species have competitive ability as their main attribute.

Attributes of R-selected species

- Short life spans
- Rapid development to reproductive maturity
- A number of reproductive periods per year
- Larvae present in the plankton for all or most of the year
- High death rates
- Typically they have little or no powers of locomotion

Attributes of K-selected species

- Long life-spans
- Long development to reproductive maturity
- Typically one although can have more reproductive periods/year
- Low death rates
- Typically larger than r species
- More often than not they are mobile

Opportunistic species are favoured where substrate (soft-sea floor) is subject to interference. Interference is not just anthropogenic effects, but also interference in the normal course of events i.e. waves currents, sediment deposition and bioturbatory effects. This leads to the death of residents producing so called open areas which are rapidly resettled by r-selected species reflecting primarily the perennial availability of their larvae in plankton. Even in the face of frequent disturbance the r-species with their rapid development can have reproduced successfully before the next catastrophe.

Primary succession shown in the figure below can be described as the predictable appearance of macroinvertebrates belonging to specific functional types following a benthic disturbance model. The model or paradigm shown here has been found to characterise the soft sea floor i.e. soft muddy sands in temperate latitudes.

Note: While different taxa participate in the different stages of infaunal colonization from place to place the organism/sediment relationships are seen to be similar and because it is the functional types that are the biological units of interest or concept/model of succession does not call for the predictable appearance of specific species or genera.
Fig. 4. Pearson-Rosenberg Community Structure along a Temporal or Spatial gradient of Organic Enrichment. Right to left – changes on a soft bottom community with time after a discrete physical disturbance.

**Stage 1: pioneering community**

Typically consists of near surface aggregations of tube dwelling polychaetes and/or bivalve molluscs. These functional types are typically associated with a shallow RPD. While sediment populated by stage 1 community may contain large inventories of nutrients [may be the very nature of the disturbance]. The recycling of these nutrients back to the water column will be largely controlled by molecular diffusion; in fact the influence of r-macrofauna on nutrient recycling and sediment aeration is not very significant. Such systems then are potential storage systems. Within the sulphide reduction and methanogenesis these predominate over oxygen metabolism.

**Stage 2: intermediate community**

This is something of an arbitrary stage applied to the start of the infaunal process which follows stage 1 after the absence of further disturbance and includes shallow dwelling bivalves and tubiculous amphipods and polychaetes.
**Stage 3: equilibrium community**

Taxa tend to be fully infaunal with many feeding in depths of sediment – head down orientation resulting in deep biogenic irrigation of sediment column which increases pore water oxygen and as a consequence pushes the RPD layer deeper into the sediment. Movement of water and dissolved constituents in and out of sediment can be orders of magnitude greater than that resulting from simple diffusion.

Sediment colonized by stage 3 can be considered as purging or recycling systems. In fact under enriching conditions the macrofaunal balance the potentially harmful effects of organic inputs by stimulating microbial processes – How?

1. By increasing surface particle areas
2. Grazing activities
3. Flushing out metabolites through bioturbation
4. Secreting mucus to provide new reactive surfaces
5. By subducting/pulling down organic matter to be metabolised at depth within the sediment.

In stage 3 oxidative metabolism dominates over sulphate reduction and methanogenesis.

**Enrichment and Eutrophication via a point source**

The effect of a hypothetical point source input of organic matter on seafloor processes. Note drawings are not to scale. The water column has been compressed vertically and the sediment column has been expanded vertically to facilitate presentation.

Before enrichment, the depth of mixing of bottom sediments (bioturbation depth) by seafloor organisms is commonly 10 – 15 cm deep. Most reactive organic matter is rapidly broken down aerobically in this interval and respired as carbon dioxide.
Introduced particle matter (e.g. sewage) settles to the bottom in a gradient leading away from the effluent. This organic detritus initially stimulates increased abundances of sediment-eating biota and the bioturbation depth near the effluent increases. No adverse impacts to the water column can be measured at this stage.

Nearest to the effluent, where the organic loading rate is highest, continued loading kills-off many bioturbating biota. The capacity of the bottom to recycle organic matter is compromised. The bioturbation depth increases and oxygen is used at an ever increasing rate in the decay process. Anaerobic decay within the deposit may liberate hydrogen sulphide, ammonia and methane gas.

Continued loading may result in storage or organic matter near the effluent resulting in depletion of oxygen. Large fluxes of methane gas, ammonia, and sulphides may evolve from the bottom. These extreme conditions may result in physiological stress, disease, or death of ambient fish and invertebrates.
Survey Design
The choice of sampling method and allocation of sampling effort depends on the purpose of the study. One of the major points in deciding on a design is to be sure that the samples really represent what you assume they do.

There are two general approaches to sampling temporal and spatial patterns of organisms. The first is to identify patterns with no *a priori* assumptions of structure (potential sampling strata) in the environment. The second is to test mensurative hypothesis based on identifiable strata) in the environment. Where no structure is identified, as often occurs in the open ocean or sediment flat environments, regular (e.g. grid) or random (on random co-ordinates) sampling may be appropriate.

Fig.5. Grid sampling (Source: [http://www.agronomicsolutions.com/gps-soil-sampling.cfm](http://www.agronomicsolutions.com/gps-soil-sampling.cfm))

However, where an environmental mosaic is known from previous work by others, or from your own preliminary sampling, the appropriate design would be a stratified or structured one. This is clearly the case with open coastal reef environments, where subtidal and intertidal habitats can be demarcated according physical and biological features.

Fig.6. Stratified Random Sample. (Source: [http://www.behav.org/ecol/wildlife/w_05_design.htm](http://www.behav.org/ecol/wildlife/w_05_design.htm))

If you want to compare the seabed around a sewage fall, as illustrated above, with another area of the coast where there is no outfall (a control site) then does your set of samples taken from the outfall represent the area in general or just a small patch of seabed near the outfall? If the latter, then any effects of the outfall may be confounded with differences amongst patches.
Benthic Sampling

Two important steps in an ecological assessment are to:

1. Determine the most appropriate technique to use
2. Organise the deployment of the technique in the field

No one method is suitable or appropriate for the complete characterization of habitats or biological assemblages at all sites, and many biological problems will require a combination of methods. The choice will depend on a number of factors. In particular the quantity and quality of the information needed to address the aims of the sampling programme, the resources available for collecting and processing the data, as well as the physical nature of the site. The most appropriate technique will determine the results of the survey and is key to answering the critical research question. Several survey designs have commonly been used in sampling of subtidal soft sediment including random sampling, stratified random sampling, distribution of samples on a grid pattern and sampling along transects. While each is appropriate the researcher must be wary to ensure that their design will provide the information in the form of samples which will allow the question set to be answered. Assessing the results the researcher relies on both previous knowledge attained e.g. benthic successional stages, concentrations of organic matter recorded in the sediment etc. and expert judgement.

Benthic Sampling techniques

The choice of equipment depends largely on the type of survey required (qualitative/quantitative, baseline/monitoring), on which group of organisms being targeted (macrofauna – microfauna) and on the local conditions and the available resources (e.g. size of boat, level of exposure, water depth, substratum).

The basic necessities required on board for sampling the seafloor is a winch and a seawater hose. However ideally the winch is attached to a moveable A-frame and the water pressure in the hose is controllable. The rest of the equipment you will be expected to bring on board.

Qualitative

Dredges

Where the substratum is not suitable for grab sampling (i.e. difficult to penetrate), dredge sampling may be the only viable method available. Dredges have a heavy metal frame and are designed for breaking off pieces of rock, scraping organisms off hard surfaces, or for limited penetration and collection of sediments. The dredge is usually about half as deep as it is wide, the mesh varying according to circumstances. Machine-made netting of mesh 10-12 mm
knot-to-knot is generally suitable. For collection of sediment the bag can be lined with an inner bag of sacking. Impervious material such as canvas should not be used, as water must drain away when the dredge comes on board. The net should be open-ended and tied at the bottom with a rope, which is untied to release the sample. In order to protect the net bag from tearing on rocky substrata, coarse material such as carpet may be fitted to the outside of the net bag. It is advisable to bring string/thick thread and thick needle to mend the dredge net while on fieldwork.

The dredge should be deployed from a boat fitted with a pot hauler or winch suitable for retrieval. Deployment is usually over the side or stern of the boat for between three and 11 minutes (or may be hauled almost immediately on some grounds, e.g. mud), while the boat drifts or steams slowly (1-2 knots). This minimises the distance the dredge is dragged over the seabed allowing a sample to be taken from a relatively small area and thus reducing the chances of several habitat or biotope types being sampled. The performance of the dredge should be constantly observed by the angle of the warp and any jerks or vibrations monitored.

Anchor dredges are useful for semi-quantitative sampling of sands and other firmly-packed deposits. The size of dredge used will depend on the size of boat and availability of winches, wire ropes etc.

Material collected should be sorted on board and the relative abundance of conspicuous fauna and flora species recorded. Where possible, notes on the substratum type are recorded. If the dredge is retrieved full of sediment it can be washed through a 2 mm. sieve. When trawling, standardising conditions and duration of tow helps to obtain comparative estimates of population density. The use of a safety rope and buoy connected to the dredge is useful for retrieving the equipment if the main rope snaps or the dredge becomes snagged. However, there can be disadvantages with the safety rope getting caught in the propeller. Use of a safety rope should be discussed with the boatman. The operation of a Rallier-du-baty dredge can be seen on line http://vimeo.com/58003307

Trawls

Beam, Agassiz and otter trawls may be used for qualitative sampling of the epifauna. These nets are designed to skim over the surface of the bottom, and because of the large area covered, are useful for collecting scarcer members of the epifauna, and species of fish, cephalopods and crustaceans associated with the bottom.

The beam trawl is used commercially for fishing for shrimps, prawns and flatfish. The mouth of the net is held open by a beam of 2-10 m length, with a long net of mesh about 12.5 mm knot-to-knot. A chain attached to one side of the net is to keep it on the seabed while floats are often attached on the opposite side to keep the mouth open.
Otter trawls used for commercial fishing also capture members of the invertebrate epifauna, but because of the rather large meshes only the larger animals are retained. Epibenthic sledges have a heavy frame enclosing a net, and are particularly useful for deep-sea sampling.

Modified Agassiz trawl - approximately 2 m wide are often employed by researchers. The metal frame is designed to keep the attached net aligned on the seafloor and no matter what way it lands on the seafloor it will gather a successful trawl; however it is not as efficient as a Beam Trawl in catching fish. The net is 3.5 m long with a 1 cm mesh cod end. Depending on the substrata and expected abundance of fish, the net is trawled for 15 minutes at approximately 2 knots. This can be adjusted for individual projects. So as data between sites can be compared, the same combination should be used for all sites on a project where possible. Alternatively, the net can be towed for a set distance (e.g. 500m).
Remotely Operated Vehicle (ROV)
The use of an ROV in addition to grab or dredge sampling can gain valuable additional data in terms of the biotopes that are present. A VideoRay ROV can aid in visually inspecting a survey sample station prior to grab or dredge samples being taken. The ROV consists of a full colour video camera, with twin variable illumination halogen lights, a depth gauge and a compass. Twin horizontal thrusters and a vertical thruster manoeuvred the ROV underwater. The unit is controlled from the surface via a video monitor, with footage recorded directly onto DVD. The high manoeuvrability and portability of the ROV enables a comprehensive survey of the marine flora and fauna within the area of each station. The video samples are returned to the laboratory for examination to identify and describe the marine habitats and species present.

Fig. 10. A VideoRay ROV (Source: [http://www.marinearcheology.org/UWVideo.htm](http://www.marinearcheology.org/UWVideo.htm))

Quantitative Grabs
Quantitative samples of animals inhabiting muddy – sandy sediments are usually taken by grab sampling. The grab, captures slow-moving and sedentary members of the epifauna, and infauna to the depth excavated. Most grabs collect sediment to a depth of approximately 10-15 cm, deeper burrowing fauna are therefore not sampled. The grab should be deployed from a boat fitted with a pot hauler or winch suitable for retrieval. Ideally the boat should be anchored and/or the grab deployed on the leeward side of the boat so as to allow the grab to drop as vertically as possible. On retrieval the sample should be accepted or rejected according to procedures set for the survey (generally a minimum of a 7 cm deep even bite unless very coarse material where 5cm is accepted), and passed through a suitable sieve (1 or 0.5 mm).
For sampling the macrofauna, grabs covering a surface area of 0.1 or 0.2 m$^2$ are commonly employed, several samples being taken to aggregate to 0.5 m$^2$ per station. Samples of this total size are usually considered adequate for quantitative determinations of the commoner species, measurements of biomass etc. Types of grab available include the van Veen grab, Petersen grab, Ponar grab, Smith-McIntyre grab or day grab. The Ekman grab is smaller and more suitable for mud and collection of smaller organisms. A 0.1 m$^2$ van Veen grab is usually suitable for invertebrate sampling and is most commonly used. Two sets of weights are available with this grab for penetration into varying substrata. An online video of the grab in action can be seen at [http://www.youtube.com/user/smartseaschool/videos](http://www.youtube.com/user/smartseaschool/videos).

**References**


