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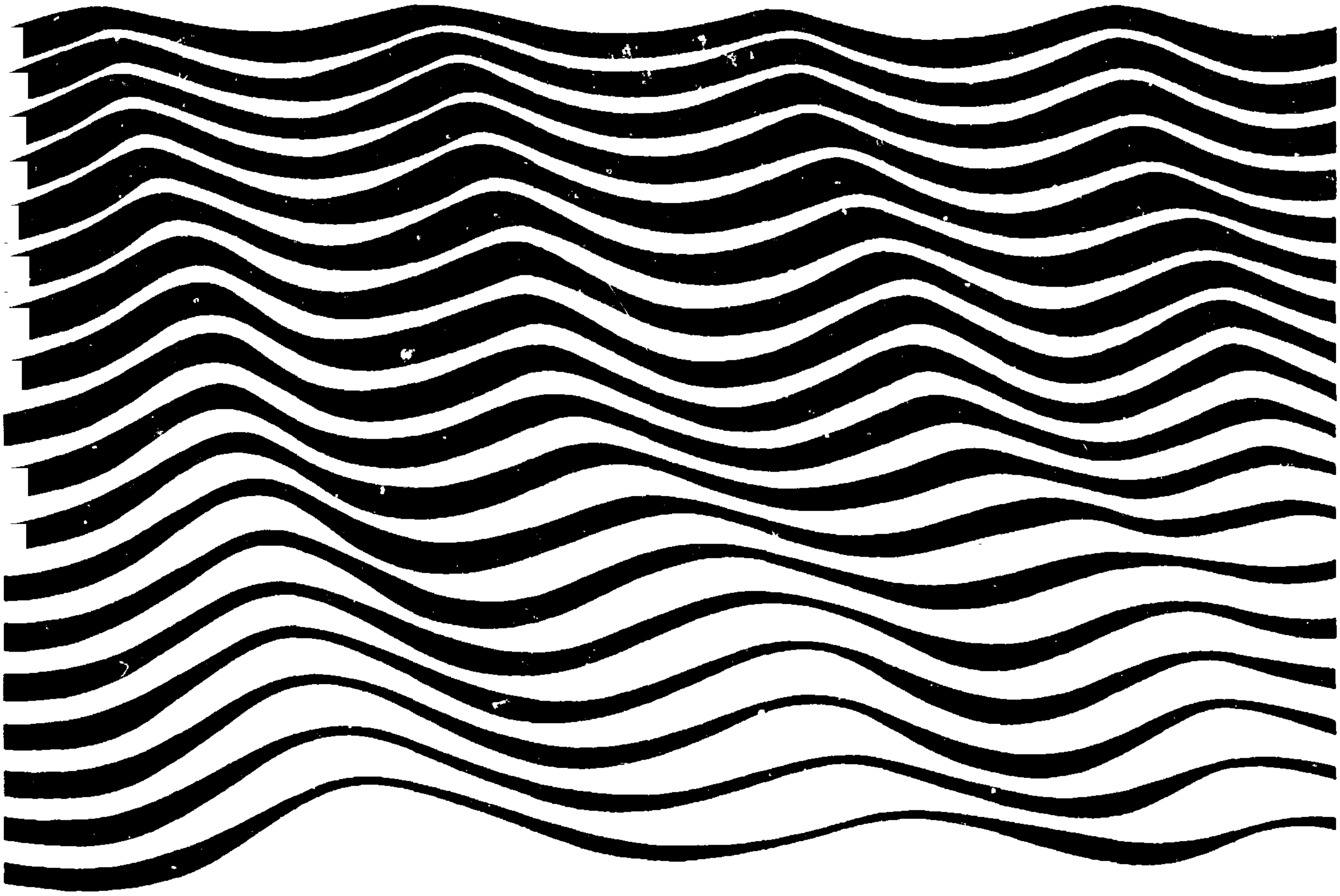
Manual on marine experimental ecosystems

Prepared by
SCOR Working Group 85



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36	The practical salinity scale 1978 and the international equation of state of seawater 1980. Tenth report of the Joint Panel on Oceanographic Tables and Standards, (JPOTS). Sidney, B.C., Canada, 1-5 September 1980. Sponsored by UNESCO, ICES, SCOR, IAPSO. Available in Ar, Ch, F, R, S (*Примечание:* Этот доклад (текст идентичен) был первоначально издан только на английском языке под заголовком *Tenth report of the Joint Panel on Oceanographic Tables and Standards* (Десятый доклад Объединенной группы по океанографическим таблицам и стандартам)). Имеется на арабском, испанском, китайском, русском и французском языках.	1981	WG 10
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PREFACE

This series, the *Unesco Technical Papers in Marine Science*, is produced by the Unesco Division of Marine Sciences as a means of informing the scientific community of recent advances in oceanographic research and on recommended research programmes and methods.

The texts in this series are prepared in co-operation with non-governmental scientific organizations. Many of the texts result from research activities of the Scientific Committee on Oceanic Research (SCOR) and are submitted to Unesco for printing following final approval by SCOR of the relevant working group report.

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ABSTRACT

This SCOR WG 85 report describes various kinds of experimental enclosures for the study of marine ecosystems. The report starts with the recommendations regarding choice of different experimental ecosystems including sections on design and operation. Illustrations are given of approximately 50 different types of experimental ecosystems, including details of application, a contact address and key references regarding the use of each specific ecosystem.

The range of experiments covered in the report includes pelagic, soft and hard bottom benthic ecosystems, microcosms (less than l m^3), mesocosms (1 m^3 to 10 m^3) and macrocosms (greater than 10 m^3). An index and table of contents is provided for ready reference.

T. Parsons

RESUME

Le présent rapport du Groupe de travail 85 du SCOR décrit différentes sortes de dispositifs expérimentaux destinés à l'étude des écosystèmes marins. Il commence par des recommandations concernant le choix de différents écosystèmes expérimentaux, y compris des sections sur leur conception et leur fonctionnement, comporte des illustrations pour environ 50 types de systèmes différents, donne des détails sur leurs applications, indique un point de contact et mentionne les principaux ouvrages de référence relatifs à l'utilisation de chacun d'eux.

L'éventail d'expériences décrites dans le rapport couvre des écosystèmes pélagiques, des écosystèmes benthiques des fonds meubles et solides, des microcosmes (moins de 1 m3), des mésocosmes (de 1 à 10 m3) et des macrocosmes (supérieurs à 10 m3). Un index et une table des matières permettent de compulser facilement le rapport.

T. Parsons

RESUMEN

En el presente informe, SCOR WG 85, se describen diversas clases de espacios delimitados para experimentación, destinados al estudio de los ecosistemas marinos. El informe comienza con recomendaciones relativas a la elección de distintos ecosistemas experimentales, que comprenden secciones dedicadas a su diseño y funcionamiento. Se proporcionan ejemplos de aproximadamente 50 tipos de ecosistemas experimentales, con informaciones sobre sus aplicaciones, una lista de contactos y referencias esenciales vinculadas a la utilización de cada ecosistema.

Los experimentos expuestos en el informe abarcan los ecosistemas pelágicos, los ecosistemas bentónicos de fondo blando y duro, microcosmos (de menos de 1 m^3), mesocosmos (de 1 m^3 a 10 m^3) y macrocosmos (de más de 10 m^3). Se incluye un índice y un índice de materias a fin de facilitar la búsqueda de información.

T. Parsons

РЕЗЮМЕ

В настоящем докладе Рабочей группы СКОР 85 описываются различные виды экспериментальных огороженных участков для изучения морских экосистем. В начале доклада содержатся рекомендации, касающиеся выбора различных экспериментальных экосистем, включая разделы по разработке и оперативной деятельности. Приводятся примеры приблизительно 50 различных типов экспериментальных экосистем, включая подробности их применения, адреса для установления контактов и основные данные, касающиеся каждой конкретной экосистемы.

Эксперименты, описанные в докладе, включают пелагические экосистемы, бенетические экосистемы с мягким и твердым дном, микрокосм (менее 1 м^3), мезокосм (1 м^3 - 10 м^3) и макрокосм (более 10 м^3). В качестве справочных материалов приводится указатель и содержание.

Т.Парсонс

الخلاصة

يتضمن تقرير فريق العمل التابع للجنة العلمية لبحوث المحيطات (سكور) لعام ١٩٨٥ وصفا لأنواع مختلفة من الحظائر التجريبية لدراسة النظم الايكولوجية البحرية . وقد استهل التقرير بتوصيات تتعلق باختيار النظم الايكولوجية التجريبية المختلفة بما في ذلك أقسام عن التصميم والتشغيل . ويقدم التقرير بيانات ايضاحية لنحو ٥٠ نوعا مختلفا من النظم الايكولوجية التجريبية بما في ذلك التفصيلات العملية وعنوان للاتصالات ومراجع رئيسية بشأن استخدام كل نظام ايكولوجي .

أما عن نطاق التجارب التي يتضمنها التقرير فتشمل النظم الايكولوجية لقيعان المحيطات الواقعة على أرض لينة أو صلدة ، والعوالم الصغيرة (أقل من ١م^{٣}) والعوالم المتوسطة (١م٣ الى ١٠م^{٣}) والعوالم الكبيرة (التي تتجاوز ١٠م^{٣}) ويحتوى التقرير على كشاف وقائمة محتويات تيسيرا للرجوع اليه .

ت . بارسنس

摘　　要

海洋研究科学委员会85工作组的这份报告记述了研究海洋生态系统的各种试验围场的情况。本报告首先提出了关于选择不同实验生态系统的建议，其中包括有关设计和操作问题的若干章节。附有大约50种实验生态系统的实例，包括应用细节、联系地址和各具体生态系统使用方面的重要参考材料。

本报告所涉及的试验范围包括浮游的，软硬海底的生态系统，微观世界（小于1 立方米），中观世界（1 至10立方米）和宏观世界（大于10立方米）。为方便查找，附有索引和目录。

T · 帕 森 斯

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This is the second of 2 reports by SCOR WG 85. The first report entitled Enclosed Experimental Ecosystems: A Review and Recommendations was published by Springer-Verlag (N.Y.) in the summer of 1990.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

1. INTRODUCTION

Experimentation, which is a vital requisite of marine research, ranges from traditional laboratory experiments through experimental ecosystems and field experimentation to computer simulation models. Experimental ecosystems comprising enclosed natural or artificially composed communities, are now recognized as valid tools both for exploratory research and for hypothesis testing. The range of existing designs is illustrated in the catalogue included as Section 6 of this Manual. In the realization that such designs are and must be tailor-made to each specific purpose, we feel that certain general recommendations should be given as to when and how to use experimental ecosystems.

The purpose of this manual is to give a series of such guidelines for the application of experimental ecosystems in biological oceanographic research.

The types of experimental ecosystems range from small bench-top containers, through land-based basins, ponds and *in situ* enclosures of pelagic and/or benthic communities, to sealed off bays and fjords. Not all systems called "experimental ecosystems" should be regarded as such, and the SCOR WG 85 has adopted a set of criteria for proper experimental ecosystem design. Ideally the system should be physically confined, self maintaining, multitrophic, and of a size sufficient to allow for meaningful sampling and measurements without having a detrimental effect on the structure and dynamics of the system. Ideally the experiments should have a duration exceeding the generation time of the penultimate trophic level present.

It was considered practical to subdivide the size range of systems into broad size classes as follows:

Microcosms:	<1 m^3 (pelagic) or <0.1 m^2 (benthic)
Mesocosms:	between 1 and 1000 m^3 or between 0.1 and 100 m^2
Macrocosms:	>1000 m^3 or >100 m^2

2. TYPES OF ECOSYSTEMS

The differences in the physical and biological nature of marine ecosystems together with the particular objectives of the investigations have led to the design of many radically different experimental ecosystems. Currently experimental ecosystems can be classified into the eight different categories listed below.

(1) Pelagic coastal
(2) Pelagic oceanic
(3) Pelagic plus benthic
(4) Estuarine
(5) Littoral, soft bottom
(6) Littoral, hard bottom
(7) Sublittoral, soft bottom
(8) Sublittoral, hard bottom

2.1 Pelagic coastal

Floating columnar mesocosms have been used extensively for studying ecosystem processes in pelagic coastal environments. Given sufficient protection from wave action, experimental systems can survive for several months; their duration being limited only by the extent of fouling or the structural integrity of the plastic sheeting. The need for protection, however, limits their deployment to sheltered areas such as fjordic inlets (which are also deep), bays or harbours. However, such sites have their own inherent problems including density - induced stratification due to freshwater runoff and, in harbour situations in particular, the proximity to traffic and sources of pollution.

As with oceanic systems, coastal mesocosms offer many advantages including the opportunity to (1) measure fluxes and processes in naturally advective systems, (2) test the effects of pollutants and other perturbates on multitrophic systems, (3) make comparisons between natural variations within the ecosystem and (4) carry out rigorous tests of hypotheses.

Such systems do have serious deficiencies. They are isolated from their natural sources of nutrients, *i.e.* from the benthos. Advective processes, including turbulence, are often several orders of magnitude less and care must be taken during filling to prevent the enclosed water columns from being too divergent or from being dominated by a single or few large carnivores. Such circumstances can drive the course of an experiment away from reality. Where multiple units are used, care must also be taken to ensure consistency throughout the enclosed natural ecosystems.

To ensure realistic results it is advisable to make direct comparisons between the enclosed and surrounding natural ecosystems throughout the course of the experiment.

2.2 Pelagic oceanic

The advantages of pelagic mesocosm research in the open sea are: (i) the ability to directly compare the drifting enclosed ecosystem with the surrounding environment and (ii) that the enclosed ecosystems are not affected by any coastal influence, such as high nutrient concentrations or high numbers of larval stages of benthic organisms. The application of free floating mesocosms in the open ocean is generally limited by wind (waves) and current action. Up to now only a few enclosure experiments have been performed off-shore, but the development of submersible systems, together with automated sampling techniques, may give rise to more of these in the near future. These experiments require a research ship to support and co-ordinate the work.

In some circumstances, in the vicinity of steep, rocky coastlines close to the open sea, water with oceanic characteristics can enter bights and fjords, especially after upwelling events. In such situations, enclosures (bags) can be launched either directly at the experimental site, or filled offshore and transported to sheltered positions. The opportunity is presented for comparative studies on processes within different water masses, for instance by enclosing different components of a coastal current.

Measurements taken in open water in the vicinity of enclosures will tell how closely enclosure processes parallel the natural system. As well they allow for inferences on the time course of development within naturally advective systems.

2.3 Pelagic plus benthic

Bentho-pelagic mesocosms have an advantage over pelagic mesocosms in that biological and physical exchanges between the benthos and the plankton community can be monitored. These columns can only be placed *in situ* where there is a very small change in tidal height. A bentho-pelagic mesocosm was used successfully in the Baltic where diel tidal height differences are very small. Alternatively, bentho-pelagic water columns can be built as rigid structures (*e.g.* fibreglass columns) on land near the seashore. In such columns the sediment is generally introduced in a tray from the top, followed by water from the shoreline which is kept in circulation by various pumping and mixing procedures.

2.4 Estuarine

An evaluation of transfer and transformation processes in estuaries is very important for understanding the fate of discharged substances in coastal water. Due to tidal fluctuations and other changes in both marine and freshwater hydrodynamics, many estuarine processes are not very well known and are still subject to controversy. To date the use of mesocosms in estuarine research has been restricted mainly to land-based sediment and water systems (see 2.3 above). In tidally mixed estuaries with high current velocities and frequent fluctuations of salinity, *in situ* mesocosms are very difficult to handle.

Some experiments with small (3 m^3) plastic bags have been performed in sheltered places. This type of mesocosm, although restricted to enclosing parts of the water column, may give realistic data on conversion processes within salinity gradients or turbidity zones which are very important sites for transfer and transformation processes in estuaries. Natural conditions, including high turbidity, can be maintained for short periods by stirring devices when using these small mesocosms.

Chemical and biotic processes within estuarine and shallow coastal waters are significantly influenced by sediment/water phase interactions, particularly those involving suspended materials. The frequent transient sedimentation and resuspension of particulate material during tidal action induces an additional sediment response. For this reason, mesocosms are required which allow the study of interaction between sediment and water under tidal conditions with frequent changes of suspended material and variation of salinity.

These systems are not yet available for tidally mixed estuaries, but mobile systems are under construction which will allow estuarine sediment-water studies at sheltered localities. Note that soft bottom systems, like coastal littoral systems (see 2.5, p. 8), have to be preconditioned for weeks or months. By using selected sediments and organisms such systems will enable investigations of local effects caused by dredging and pollution as well as effects of specific local benthic communities. Natural changes caused by wind or variations in discharge can be simulated by filling enclosures from different water bodies.

2.5 Littoral

Softbottom

Littoral mesocosms, mimicking soft-bottom ecosystems (intertidal mud-flats, sea grass communities) are generally housed in onshore solid structures in the open air. The sediment compartment of littoral mesocosms can be composed either of undisturbed bottom sections carefully extracted from the natural environment, or of an introduced homogeneous sediment layer which is later stocked with adult specimens of long-lived macrofauna elements and a mixture of the smaller opportunistic species to serve as a mother stock. A 0 - 5 m high layer of water over the benthic compartments completes the system.

In either case mechanical devices are required to provide realistic tidal sequences, turbulence, flow-through and adjustment of environmental conditions. In one instance an attempt has been made to sink and moor floating caissons *in situ* to enclose parts of natural mud-flats.

In general, enclosed ecosystems in littoral mesocosms are robust and realistic behaviour can last for years. As such they can provide ready access for all sorts of detailed and statistically meaningful sampling programmes. They offer cost-effective opportunities for ecotoxicological experimentation. Both short and long-term effects of perturbations on the structure and functioning of littoral ecosystems may be studied, where, for ethical reasons, pollution studies would not be justified.

Hard bottom

Rocky shores are among the most accessible of all marine communities and are particularly suitable for direct field experimentation. Yet there are situations where it is necessary to create isolated, self-maintaining sections of such communities for experimental purposes. This is particularly pertinent for the control and regulation of ambient conditions (such as water movements and addition of substances), or when several replicate communities with specific substrate topography and population structure are needed. Experimental rocky shore communities have so far only been established in land-based basins with high water turnover rates and technical devices to produce currents, waves and tide fluctuation. *In situ* enclosures have not been reported, but the idea of enclosing sections of natural rocky shorelines should be pursued.

2.6 Sublittoral

Soft bottom

So far, existing sublittoral mesocosm facilities are land-based. In general, they require rather large and complicated indoor structures and an abundance of technical support in order to maintain a stable community, since sublittoral ecosystems are often complex. The sediment compartment of sublittoral ecosystems is composed of undisturbed bottom sections, carefully extracted with a large boxcorer from selected sites. For collection and transfer of the bottom sections an adequate research ship and collecting equipment are needed. Best conditions for collection occur when the difference between the bottom-water temperature (at the sediment-water interface) and air temperature is small. Sediment sections in their own containers are either placed apart in the mesocosm or can be assembled to create larger bottom areas after removal of the liners.

The overlying water column in a sublittoral mesocosm is *in situ*-collected bottom water which is transferred to a storage basin annex (preferably subterranean) of the mesocosm facility. In cases where the mesocosm is located in the direct vicinity of a rocky coastline, water can be pumped directly from deep open water. There is no obvious need to keep sublittoral communities covered by an equivalent deep water layer to simulate the *in situ* observed hydrostatic pressure; a 1 - 2 m high layer of water is usually sufficient. Sublittoral mesocosms are generally kept in the dark. However, it should be possible to simulate depth by coloured perspex covers to avoid any errors introduced by keeping the system in total darkness.

Properly established and maintained sublittoral systems have a considerably long life (>1 year) during which satisfactory ecosystem reality is shown. Sublittoral mesocosms facilitate research in ecosystems where an experimental approach was not possible before. Moreover, as sampling in mesocosms in time and space is done on a scale never seen before in subtidal benthic ecosystem research, a completely new dimension is added to the temporal and spatial fine structure of these systems.

Boxcosms

Boxcosms present a mobile sublittoral mesocosm facility, in which the dimensions and costs have been scaled down to a minimum level. They contain several boxcore sections and may be maintained for extended periods (> 6 months) at *in situ* conditions. They have been used in various ecosystem experiments in the laboratory or in bio-assay studies on board research vessels.

Hard bottom

In situ enclosure experiments on sublittoral hard bottoms have only been performed sporadically. Since all handling and maintenance has to be done by SCUBA divers and since it is difficult to maintain satisfactory water exchange across the community, such approaches cannot generally be recommended.

Sublittoral hard bottom experimental ecosystems have not been reported in the literature, but recently an indoor system with eight community units has been established in Norway. Transplanted boulders with epibiota constitute the basic community which has been further supplied with populations of key species of macroalgae and animals. The communities receive reduced normal daylight, and a low, continuous exchange of water. Alternating tidal current generators are installed. This system has been running for six months, and although the experience so far is positive, it is too early to conclude whether the communities are really self-maintained or not.

3. BASIS OF CHOICE

Mesocosms represent a stage in the continuum between laboratory experiments in beakers and field measurements in bays. The systems used in the past have ranged in size over several orders of magnitude, so a major question facing the new user concerns the complexity of the system to be deployed. The advantages and disadvantages of the various systems are illustrated in a "wedge diagram" (Fig. 1 p. 13) and in Fig. 2 (p. 14).

Fig. 1: Size classes of experimental ecosystems

micro	meso	macro
Replication	-	Longevity
Controllability	-	Trophic complexity
Homogeneity	-	Reality
Unit cost	-	Dispersive capacity
		Buffering

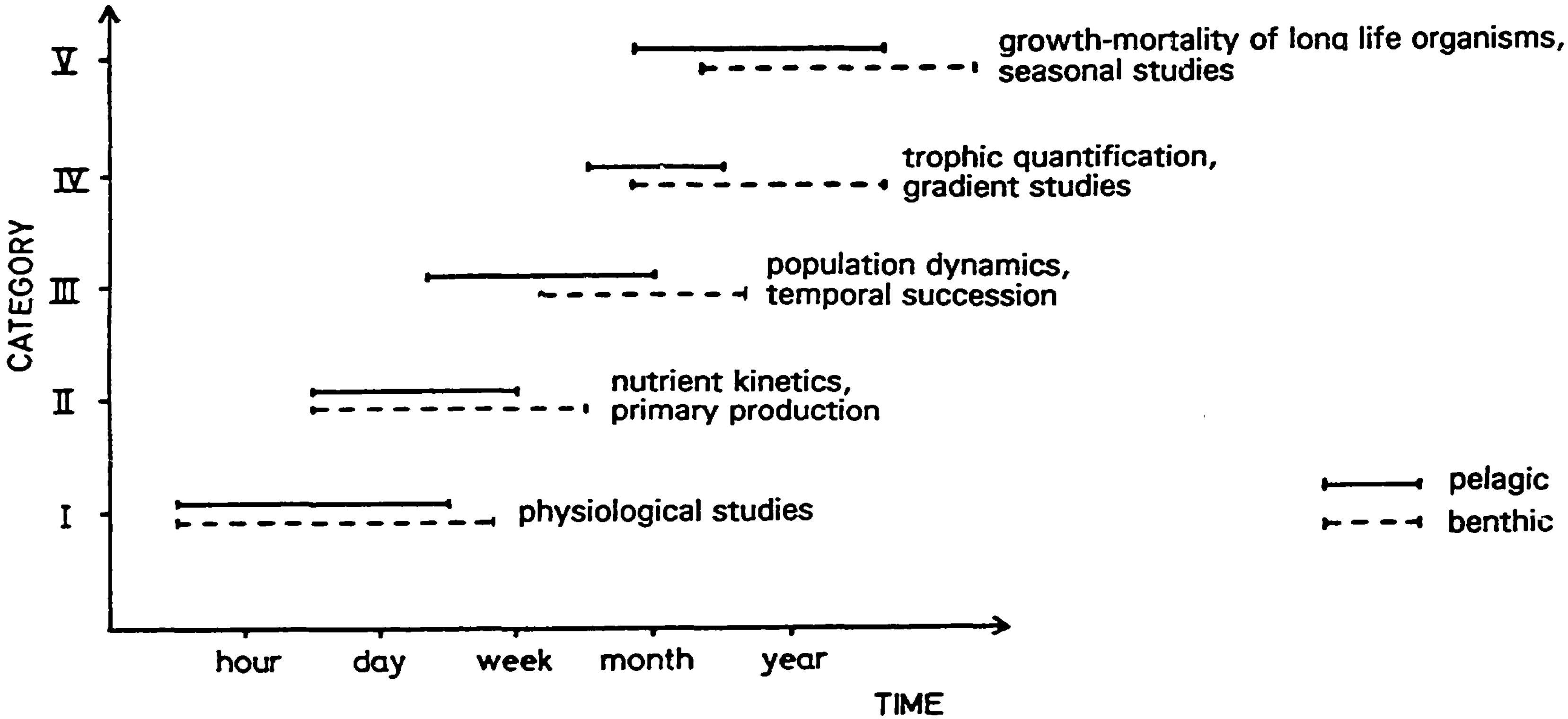
Size classes	I	II	III	IV	V

I-II Smallest systems, 1-10 m^3 or 0.25-1 m^2 Useful for short-term multi-unit experiments. Most suitable for rigorous quantitative hypothesis-testing using parametric statistics. Best operated for process studies at the heterotrophic level and also for experiments with isotopes.

II-III 10-100 m^3 or 1-5 m^2 Multi-unit <10, can be used for quantitative hypothesis testing, but also suitable for longer term, time-dependent observations. Moderate term, days-weeks. Ideal for process studies on autotrophs *e.g.* nutrient kinetics, primary production estimates, succession, population dynamics.

III-IV 100-1000 m^3 or >5 m^2. Several units >5; moderate-long term; weeks-months. Ideal for following multitrophic interactions including tertiary trophic level. Difficult to carry out quantitative hypothesis testing, ideal for "gradient" studies and trophic quantification.

IV-V 1000 m^3< Single unit. Very long term, weeks - year. Seasonal option possible. Ideal for growth-mortality studies of larger, less-abundant organisms. Data lend themselves to time-series analysis.


growth-mortality of lonq life organisms,
seasonal studies
trophic quantification,
gradient studies
population dynamics,
temporal succession
nutrient kinetics,
primary production
physiological studies
pelagic
benthic
CATEGORY
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I
hour
day
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month
year
TIME

4. NOTES ON DESIGN, SELECTION AND MAINTENANCE

The following sections describe the important details about particular systems, but much of this information is also valid for the other systems (*e.g.* in 4.2.1 p. 28) an example of an interdisciplinary measuring programme is given).

4.1 Pelagic mesocosms

4.1.1 *In situ* plastic water columns

Design

The size of the experimental ecosystem is largely decided by the purpose of the researcher's experiments. Having made this initial decision from information discussed in Section 3, a number of decisions still remain which have to be made in order to select the most appropriate design among the many experimental ecosystems illustrated in Section 6. When the research area of interest is an estuary, for example, it must be kept in mind that it is very difficult to moor large plastic bags where there is a high flushing rate. It would be better in such a case to select an on-shore facility such as that used in MERL (p. 127). Open ocean mesocosm experiments are equally difficult *in situ* because wave action tends to break the plastic water column away from the float. Shipboard microcosms have been successfully employed for different steps in the food web - *e.g.* photosynthetic studies, grazing experiments, etc.

When a two layered mesocosm (*i.e.* with a pycnocline) is required, mixing of the water column is not necessary. However, a simulation of tidal flushing over a sediment surface (*i.e.* bentho-pelagic mesocosm) requires some form of mixing within the mesocosm. It should be kept in mind that heating by the sun can cause changes in the pycnocline.

Installation of *in situ* plastic water columns

These systems are usually comprised of free-floating, multiple units, independently moored or coupled together. A supporting service barge or raft fitted with ship-board laboratory facilities and an electrical power source is desirable for long-term and intensive (*e.g.* continuous diel sampling) experiments. To prevent changes in the pycnocline due to heating by the sun, location of *in situ* plastic enclosures so they are not continually shaded by one another or the service barge is an important consideration in the mooring configuration.

Large enclosures (of more than 1 m diameter) should be held vertically in the water column within a flexible cage of weighted shroud lines or they should be ballasted by some other means. This prevents the entire enclosure from being forced toward the surface by tidal or other flows. 40 kg weights on 8 shroud lines (down lines) were adequate for 20 m deep, 300 m^3 units at Loch Ewe, Scotland (Section 6.3 p. 101). Spacing between the lines is maintained by attachment to the underside of the surface flotation ring and by a sub-surface spacer frame immediately above the weights. Plastic enclosures are best attached to the shroud lines at intervals by elastic cords. Enclosures of about 1 m diameter can be directly weighted at the bottom using about 10 - 20 kg (Section 6.3 p. 113).

The flotation system should not only support the enclosure, but should also provide adequate freeboard to prevent incursion of water during moderate weather conditions and may, for the large systems, serve as a stable platform upon which to mount equipment for sampling or for emptying the enclosure. A bridge over the mouth of the enclosure is most useful. Polystyrene foam (styrofoam) blocks mounted in a wooden or box-section steel framework have proved to be both an effective and inexpensive means of flotation. Alternatively, steel doughnut shaped floats coated in epoxy are more expensive but longer lasting. For small bags three commercial plastic buoys, each fixed in a frame, may give enough buoyancy and allow free access by an inflatable boat for sampling.

Filling

It is good practice, particularly when using plastics such as PVC, to leach most of the excess plasticizer from new enclosures by soaking *in situ* for 4-7 days before filling. This is not necessary, however, for laminated sheeting with polyethylene on the inside.

The installation of the large *in situ* enclosures usually requires SCUBA divers. Standard safety precautions must be carefully observed when divers and small boats are working in the same area.

Enclosures can be filled either by pumping or by lifting from depth with the mouth of the enclosure held open. Large volume pumps (*e.g.* diaphragm, piston or "flex-in-liner") should be used since high pressure, impellor-types can damage planktonic organisms. Pumps have been used when the mouth opening of the enclosure is restricted (*e.g.* semi-submerged bottle shaped systems for operating in exposed water) or where the enclosure water has to be prefiltered through a mesh (*e.g.* to exclude larger predatory zooplankton). However an air lift system could be considered. The depth of the water intake should be varied during filling so as to obtain the best possible sample of the water column. This is particularly important when operating in highly stratified water.

Filling by lifting is preferred since this method ensures the best possible sample of the water column, causes least trauma to the captured organisms and is very rapid. In the case of mesocosms of 100 to 1000 m^3 it is the preferred method since pumping usually takes too long. The enclosure should be collapsed and taken to a depth 2-3 m greater than its total length (ideally onto netting stretched across the sub-surface spacer frame). Then the mouth may be raised to the surface either by means of a rope fixed centrally to the frame which keeps the mouth of a small enclosure open or by means of several ropes attached at points around the mouth of a large enclosure or with air bags. In the last two instances, the mouth should be held open by clips attached to the vertical shroud lines. Two consecutive lifts are usually necessary. The first lift unfolds and aligns the material. A 90-95% fill can be achieved after collapsing and lifting again. The fill is completed by pumping. Four 300 m^3 units can be filled within 3-4 hr thus greatly improving the chances of replicating the individual enclosed systems.

It is important during filling to exclude predators, particularly fish, from enclosures containing experimental populations of fish larvae and other similarly sized target organisms. The safest way of achieving this is to pump through a 1-2 mm mesh plankton net although a 10-20 mm mesh screen fitted across the open mouth of an enclosure while lifting will successfully exclude large jellyfish. When using large meshes during filling note that fish eggs and larvae of predators captured in the water column may develop into significant populations of predators during the course of long-term mesocosm experiments.

Sampling

In general, most conventional sampling procedures can be adapted for use in the confined space of an enclosure. Most of the restrictions will be obvious to the operator, however, some of the most important features are discussed below.

Management of enclosure experiments is an exercise in compromise between a satisfactory sampling scheme and the finite quantity of material available for sampling. Removal of significant quantities of water from an enclosure will result in loss of turgidity in the flexible bag and could cause damage due to folding and flexing of the material. Plastic films can disintegrate very rapidly in cold water if allowed to crease and flex in a specific place. Such flexing often occurs at the air/water interface where constant checks should be made. The only satisfactory solution to this problem is to keep a slight head of pressure in the enclosure at all times. This can be done either by adding a small quantity of water or, if this is unacceptable, by lifting the enclosure out of the water, thus reducing its volume.

Water bottles or specially adapted samplers can be used within enclosures, but it is often easier to sample through a hose using a low pressure pump since small (<2 ℓ) water samples are usually used for the determination of hydrographic, chemical and microbiological (bacteria and phytoplankton) parameters.

Larger volumes of water can be sampled for larger organisms (*e.g.* mesozooplankton) using circulation systems fitted with appropriately sized filters. However, such systems tend to stir up the contents of the enclosure and disrupt the vertical structure of the water column. Large-volume traps (>50 ℓ), are often the only alternative means available for determining distribution patterns of zooplankton. Nets are used mostly for less abundant and fast moving organisms, *e.g.* zooplankton and fish larvae. Small plankton nets are convenient, but they integrate-out patchiness of the organisms. When used repeatedly it is important to ensure that the nets are hauled consistently. In columnar enclosures a counterweight system works well although a 1 m diameter net requires about 100 kg to pull it adequately. Avoidance of the net is a problem when sampling perceptive, fast-moving organisms such as fish larvae; sampling at night can be a useful option. Plankton nets are usually hauled up the centre of a columnar enclosure, but operators should verify that the organisms concerned are distributed evenly and not concentrated at the walls. Juvenile fish are exceptionally difficult to catch, but specifically tailored seine nets have been used with some success within the largest enclosures such as the CEPEX (1,300 m^3) water columns.

Columnar enclosures produce considerable quantities of sedimented material particularly just after filling and during the decline of an enclosed phytoplankton bloom. Sedimentation rates can be estimated using suspended traps but, to prevent anoxic build up, sediment should be pumped out from the base of the system as frequently as possible. This can cause a reduction in enclosure volume and has the effect of removing potentially recyclable inorganic nutrients. Some zooplankton can aggregate at the base of the enclosure and can be removed with the sediment. Where possible, these should be replaced or at least accounted for. If quantification of the sedimented material is required by this method it is advisable to calibrate using a known, identifiable particulate input, *e.g.* coloured or fluorescent glass ballotini.

Maintenance

Free floating enclosure systems in the euphotic zone have limited nutrient recycling capacity and inorganic nutrients are rapidly depleted. When the maintenance of nutrient levels is a necessary requirement, appropriate nutrient mixtures should be added throughout the experiment. 10:10:1 molar proportions of sufficient KNO_3; $Na_2SiO_3 \cdot 5H_2O$; KH_2PO_4 are added to simulate the levels in the surrounding water. Continual monitoring of nutrient levels throughout the experiment is desirable to prevent eutrophic conditions from occurring. It is recommended that the nutrients be evenly distributed throughout the water column with a hose. In large enclosures the relatively insoluble silicate is best distributed as a partially dissolved slurry over the surface of the enclosure.

Fouling becomes a problem in long term experiments. In general fouling is limited on the inside wall of the enclosure, but can be extensive on the outside. Cleaning is tedious and can only be done effectively by SCUBA divers. It should only be carried out if it is causing light limitation. Algae are the most important fouling organisms and "fouling skirts" to control them can be fitted around the top 2-3 metres of the inner walls of larger enclosures. These skirts are made of an easily cleaned material and are lifted and washed down at intervals during the experiment.

Experiments

The frequency with which test substances, *e.g.* pollutants, are added will depend on the objectives of the experiment. As with nutrients, some pollutant solutions are better distributed throughout the water column with a diffuser and hose rather than poured onto the surface. This gives an even concentration throughout, which can be further ensured by mixing with a submersible pump or other mechanical device. Crude oil or other such blanketing pollutants may be spread over the surface of an enclosed water column. However, such polluted systems are exceptionally difficult to sample without contaminating equipment. Extra care is therefore needed when sampling. Clean controls and "clean" points of entry, such as a short, semi-submerged pipe, should be considered.

Enclosures are ideal for tracer studies. The standard procedural precautions should be carried out and obviously great care must be taken to avoid gross contamination by immersion in radioactively labelled enclosures. Note that although the concentrations of isotope used are often very low, large quantities would be needed initially.

Dismantling

It is possible to empty the entire contents of a plastic enclosure through a plankton mesh, thereby making a complete collection of the larger organisms. Such a procedure is invaluable when working with larval fish. Usually meshes smaller than 200 µm clog, which limits the minimum size of the organisms in the final collection.

When emptying large enclosures (100-300 m^3) pumps are used to evacuate about 80% of the contents initially (the intake is covered with an appropriate mesh). At this stage in the procedure the bottom cone of the enclosure can be raised to the surface and a suitably-sized plankton net fitted in its place. The remaining contents are then drained out through the net by lifting the enclosure out of the water. An "A"-frame arrangement can be erected to provide a clearance of about 5 m above the water surface for using a block and tackle. Smaller enclosures (15 m^3) can be drained directly through a mesh bag, but note that the rate of drainage is limited by the cross-sectional area of the drain; the larger the better.

If the final contents are not required, enclosures can be drained rapidly by detaching at the surface, inverting and removing. Plastic bags are generally discarded after use in order to avoid contaminating a subsequent experiment. It is possible however to clean enclosures for re-use.

Evaluation

Data processing follows normal scientific procedures appropriate to the experiment.

Parallel measurements made in the water column outside the enclosures are useful firstly as a means of testing for leakage (*e.g.* by comparing salinity profiles) and secondly as means of verification of the realism of the enclosed systems (*e.g.* by examining component ratios).

Enclosure data are also particularly useful for evaluating ecological models.

4.1.2 Pelagic-benthic ecosystems

Many of the points listed above regarding installation and maintenance of *in situ* plastic enclosures also apply to the operation of fixed, on-shore systems (Sec. 6.3, 6.4). There are however, a number of marked differences.

Bentho-pelagic experiments

On-shore water columns can be made with flat bottoms so that a tray of sediment can be placed in the base of the container. This introduces an additional community to the experimental ecosystem which can now be regarded as bentho-pelagic rather than solely pelagic. Sediment is best obtained using box corers in an undisturbed state as possible. Sediment can be sampled from the surface with corers or by SCUBA divers inside the column.

It is extremely important to manage enclosures including sediment most carefully so as to ensure that the oxygen demand of the sediment does not turn the system anoxic. This may be avoided by generating water movement using mixing devices such as plungers or wave generators and/or by means of a constantly metered water exchange.

Lighting and heating

Free standing, on-shore water columns usually have opaque walls. Thus, unlike transparent *in situ* plastic bags, no light enters laterally through the walls. However, much of the light entering from the surface can be reflected within the container back into the water column. While this provides sufficient light for photosynthesis, it can create a minor heating problem which may have to be remedied by use of cooling probes inserted from the surface.

The rigid structure of free-standing land based systems offers much more scope for control over physical conditions within the container than free-floating enclosures. For instance a combination of differential heating and mixing can be used to generate persistent and predictable thermal stratification within an enclosed water column.

Sampling ports and observation windows

In some fixed on-shore water columns observation windows and sampling ports have been introduced at different depths. These give some advantages to the researcher, but their installation is expensive and they are generally difficult to keep clean after the initiation of an experiment.

Cleaning

Since the fixed on-shore column is a reusable container, it becomes particularly important to cleanse the sides of any fouling organisms or pollutants used in previous experiments. If the walls are coated with epoxy resin, cleaning can be relatively easy, but occasionally some pollutants may be absorbed into the resin and this may be remedied only by recoating the containers.

4.2 Benthic mesocosms

Benthic mesocosms are generally rigid structures (fibre-glass, concrete, brick), outdoors, near research stations or within the laboratory. They consist of a benthic compartment with overlying water. Water circulation, sometimes utilizing the contents of large storage basins; a supply of new water; the generation of turbulence and flow and the control of the main ambient factors are all needed to provide realistic mesocosm facilities.

4.2.1 Soft bottom, littoral

Benthic mesocosms mimicking intertidal mud flat environments are among the most successful and manageable experimental ecosystems. Natural mudflats, commonly characterized by large variations in ambient factors, represent highly dynamic ecosystems with biotic assemblages mainly consisting of hardy species, well-adapted to various types of stress. Mudflat mesocosms are equally able to cope with stress, including stress related to the imperfections of most mesocosm designs and insufficient management. Robust and generally predictable long term behaviour contributes to making mudflat mesocosms important research tools for the study of acute and chronic effects of pollutants and other perturbations on the structure and functioning of these very vulnerable natural ecosystems. Mudflat mesocosms are preferably established in the close vicinity of natural mudflat environments.

Design

Basins with a surface area of about 20 m^2 and an overall depth of 1.2 m have proved to be most appropriate (6.3, 6.4). On one side a narrow tidal channel may house the water inlets and outlets. This channel may also serve as a refuge for pelagic organisms, when the enclosed mudflat becomes exposed. The remaining part of the basin, separated by a shallow barrier from the channel, is filled with a 0.5 m deep layer of sediment. Pumps, preferably membrane-driven types, are controlled by time switches to provide a tidal water exchange. Each basin can be individually connected to a storage tank of sufficient volume to receive the water during ebb tide. A practical solution however, is to couple two such "model tidal flats" (see p.157) together and pump the overlying water back and forth between the two basins, so that low tide in one of the units coincides with high tide in the other. However such linked systems cannot be considered to be statistically independent.

Filling

Sediment is transferred from a nearby natural mudflat area to the mesocosm facility. If box cores are considered inappropriate for filling such large systems, the sediment is weathered outside for about two weeks in a thin layer on a concrete slab. Regular turning over during this procedure kills most of the higher mudflat organisms. These types of mesocosms are best set up in late winter, some weeks prior to the onset of the spring bloom and reproductive period of most of the fauna.

Once the sediment has been introduced into the basins, the benthic compartments are flooded and the tidal cycling started. Slowly oscillating "wave-boards" mounted at one end of the mesocosm generate sufficient turbulence. A continuous flow-through of new water taken from a natural tidal inlet or channel is maintained throughout the tidal periods. The rate of water supply is adjusted to establish a realistic residence time of the water in each basin. Careful construction and consistency of the water supply system (*e.g.* inlet pieces, diameter and length of pipe sections) are particularly important to ensure control of the through-put of new water.

The benthic ecosystem is established by stocking the pre-treated sediment with a selection of adult specimens of long-lived mudflat organisms (bivalves, lugworms etc.)

shortly after the introduction of sediment to the basins and the start of the tidal cycling. The size structure and stocking densities of the introduced populations should be determined by the field densities. Each species is introduced separately. Specimens are evenly distributed over the surface, burrowing behaviour is watched and damaged/disabled animals are discarded and replaced. Subdivision of the surface area of the benthic compartment into equal squares of 0.25 m^2 each using coordinate markers painted on the inside walls of the basins is most useful during this procedure.

The proper development of the meiofaunal populations and of the smaller opportunistic species is ensured simply by the introduction of some freshly collected clods of sediment into the basins. In addition, batches of mussels can be placed in plastic mesh "salad baskets" and suspended from the walls while known numbers of periwinkles may be released in order to control epibiota on the walls.

Experimental management

The experimental ecosystems are ready for experimentation after a few weeks of undisturbed development. By then the mudflats appear very natural in terms of sediment topography, vertical gradients in the sediment (O_2, sulphide, nutrient profiles) and primary productivity. As a rule, one or two of the systems are used as controls. The others are available for a wide variety of both applied and fundamental research options such as simulation of oil spills, introduction of chemical compounds, practice of oil spill combat techniques (dispersal, mechanical removal, burning), dumping of harbour sludge, industrial waste etc. In all cases the short and long-term effects of such treatments and perturbations on the structure and functioning of the whole benthic ecosystem including its overlying water is studied. Results obtained from the control basins not only serve as a reference for the effects occurring in the treated mesocosms, but in themselves frequently provide a valuable insight into the functioning of natural mudflats (this attribute of control enclosures is germane to all systems).

Measuring and sampling

A multidisciplinary approach is usually needed in a mesocosm sampling programme. As with conventional field programmes, the frequency of measuring and sampling is dependent on the specific parameter in question, the season, the time of application of the treatment, and the limitations on meaningful sampling in the relatively small mesocosms.

Generally, experiments are completed within one year and it is advisable to decide upon a sampling strategy which relates to the relative abundance of the target organisms, *i.e.* A few large samples should be taken of larger species which are few in number, while larger numbers of small samples may be taken of smaller, more numerous organisms. After the sediment has been stocked with adult animals, abiotic factors, plankton, phyto- and meiobenthos can be sampled once a week. Shortly before a treatment (such as a dosage of oil) small macrobenthos would also be sampled. Immediately after the treatment samples should be taken quite frequently. After the system stabilizes somewhat, the frequency of sampling can be gradually decreased. Because of the relatively small size of the mesocosms, large macrofauna can be sampled only a few times during a particular experiment.

A standard measuring programme relevant to oil pollution experiments in intertidal mud flat mesocosms can include at least a selection of the following parameters:

Abiotic factors:

- sediment characteristics (silt content, particle size distribution)
- temperature, pH, O_2 content and nutrient concentrations (phosphate, nitrate, nitrite, ammonium and silicate) of the water
- some vertical profiles (O_2, Redox, ETS, C/N ratio) of the sediment

Primary producers:

phytoplankton:

- species composition or composition of main algal groups
- phytopigments (qualitative and quantitative)
- primary production

phytobenthos:

- species (or group) composition
- phytopigments (qualitative and quantitative, and vertical distribution in the sediment)
- benthic primary production

macroalgae:

- estimate of biomass and percentage of sediment coverage

Secondary producers:

zooplankton:

- species composition, density

meiofauna:

- species (or major group) composition

macrofauna:

- numerical density, biomass and growth of major species including opportunistic "summer annuals"
- observation and counting of crawling tracks, lug-worm casts etc.
- census of dead animals (*e.g.* bivalves) and mass mortalities
- observation of selected predators (crabs, shrimp, fishes)
- gonad development and spawning of selected species
- larval settlement
- inter- and intraspecific relationships

Microorganisms:

bacteria and protozoans:

- total numbers and distribution in water and sediment

Activity:

- community metabolism (O_2 uptake in bell jars, ETS measurements)

Bioaccumulation:

- oil concentration in tissues of selected species

Sampling

For sampling procedures see Section 4.2.2.

Pollution experiments

Various types of crude oil, oil derivatives, weathered oil or oil pretreated with dispersing agents, or other selected chemical compounds are generally dosed in a worst case situation *i.e.* just before exposure of the mudflat environment at low tide. At this point a large part of the pollutants are stranded on top of the substratum. Due to the burrowing activities of many mudflat organisms a considerable proportion of the chemicals often becomes buried in the sediment. The remainder is again floated off the substratum with the next flood tide and so on. Coating of the walls of the basins by the pollutants appears to be relatively unimportant.

In order to simulate the expected behaviour of a natural oil spill (*e.g.* dimensions of the spill, hydrographic and weather conditions), decisions can be made to skim off the overlying water after one or more periods of remaining oil. Stranded oil can be raked so as to simulate the effects of mechanical removal of oil from the sediment and the application of an ignition agent to get rid of stranded oil can be carried out during low tide.

Mesocosms have been used in a modified configuration to tackle the problems inherent in harbour sludge dumping in offshore areas and its subsequent effect on nearby mudflat environments. In such experiments, the complementary storage basins next to each mesocosm containing the benthic compartment are transformed into model dump sites, into which a realistic layer of sludge is introduced. The sludge in the "dumpsite" is never allowed to become exposed and there is no sludge flow-through with supply water from outside. Harmful compounds released from the sludge into the water only enter the benthic mesocosm by the tidal ebb and flow. Enhanced release of pollutants from the sludge due to wave action during storms can be simulated by controlled raking of the sludge in the "dumpsite". Note that in this type of experiment the toxicological effects on the ecosystem sometimes will be completely overshadowed by effects of eutrophication, caused by the release of nutrients from the same type of sludge. This problem has been solved by getting rid of at least part of the nitrate from the sludge by exposing the sludge alternately to aerobic and anaerobic conditions prior to its introduction into the model dump site. This treatment induces the microbial breakdown of nitrates to gaseous nitrogen.

Evaluation

The particular strength of controlled mesocosm experiments is the relative ease with which synoptic and precise observations and measurements can be made over extended periods, largely independently of the weather conditions. This facilitates an optimal comparison of the results from which causes and effects can easily be deduced. However, for budgetary, logistic, space or other limitations, the number of true replicate mesocosms is often so small that it may compromise or frustrate a proper statistical interpretation of the results. However, a set of initial identical individual systems with increasing pollutant concentrations can reveal significant trends of effects in complex ecosystems. Mesocosm experiments for ecotoxicological testing frequently lead to the recognition of indicator species for which consequential effects can be predicted in a reliable way. Unexpected interactions between different species and faunal groups have also been described from mesocosm experiments. Further, the well defined data sets from mesocosm research lend themselves to modelling and some convincing models underline this view.

4.2.2 Soft bottom, sublittoral

Sublittoral mesocosms consist of large, swimming pool-like structures, supplied with seawater, into which undisturbed sections of the sea bed from shelf sea areas, fjords etc., can be transplanted. Proper establishment and maintenance of a subtidal mesocosm depends on "feeling" and experience and, in most cases, takes much time and effort. However, these systems facilitate rigorous experimentation on hitherto inaccessible parts of the marine environment.

Design

Sublittoral mesocosm facilities are generally housed in large halls, aquarium buildings or marine laboratories. The basins in which the sediment sections are kept are made of concrete or brick and coated with a non-toxic epoxy resin. Prefabricated tanks of armoured plastics or fibre glass can be a good alternative (pp 115, 127 etc.). The surface area of existing tanks ranges between 20 and 100 m^2, with a water depth between 1 and 2 m.

Filling

Collection of sediment in bulk for mesocosm purposes, for example with a grab sampler, is not advised, as the fine sediment and community structure is destroyed and its restoration, if it occurs at all, takes a great deal of time. Sediment sections for use in the mesocosms are carefully extracted from the sea bed with a large (0.25 m^2)

boxcorer. The undisturbed cores are placed immediately in flow-through containers on board the research vessel for eventual transfer to the mesocosm. The best time for transplantation is when water and air temperature differences are minimal.

Sediment sections must never be left in the mesocosm in their stainless steel housings as stainless steel is not an inert material. Therefore, before coring, internal liners of PVC are fitted into the corer. After the sediment section is placed in the mesocosm, the stainless steel housing can be removed. When (cylindrical) corers of "fibrocast" or some other electrolytically inert material are deployed, the sediment is retained within this housing. Removal of the bottom plates beneath the sections is always a difficult and tedious job.

Depending on the aim of the research, individual bottom sections can be installed separately in the mesocosms or can be grouped into larger entities covering several square meters. In the latter case, the sections in their housings are arranged closely together in blocks enclosed in a larger container, and the interstices are filled in with extra sediment after the removal of the housings.

Mesocosms near deep, open water can be supplied with water directly from the sea. In other cases bottom water from the open sea is collected with a ship, transferred to the mesocosm and stored in underground or otherwise isolated tanks. Technical provisions (aeration, filtration, circulation, cooling) may be needed to prevent the water from rapidly deteriorating. Since the reduced hydrostatic pressure appears to have no distinct effects on the benthic communities, there is no need to simulate realistic water depths.

Water flows into the mesocosm basins through horizontal pipe sections mounted on a side wall just above water level. These pipes are pierced with small holes along one side, so that the incoming water strikes the water surface at a narrow angle. A horizontal gutter is mounted on the opposite wall of the basin at about the same height and is connected either to the storage tank or to a drain. This combination of inflow pipe and "skimmer" provides a more or less homogeneous flow of water from one end of the basin to the other. Dosed nutrients or food particles are evenly distributed in this way, and floating particles are removed from the surface. The water level in the basins is lowered to simplify access during sediment sampling and measuring programmes.

Sampling

Many of the common sampling techniques applied in benthic studies can also be used in mesocosms. Because these benthic systems have a restricted surface area it is important that sampling and measurement rely on non-destructive methods such as direct observation of animal behaviour and tracks; analysis of stereo photographs; time lapse photography; insertion of microsensors and probes; use of microcorers for sediment, micro- and meiofauna; and deployment of bell jars and programmed water samplers. *A priori* differentiation of sampling volumes and sampling frequency according to envisaged needs will increase the longevity of the mesocosm. Empty core holes should be filled in either with the analysed sediment or with empty core tubes. A feature of research in subtidal mesocosms is the extraordinarily fine spatial scale on which observations are made and samples are collected. In contrast to research in the natural sub-littoral situation where sampling occurs almost at random, or at best in scales of metres, mesocosm research permits positioning on centimetre or even millimetre scales.

Evaluation

It must be emphasized that research in mesocosms should never be regarded as a substitute for field research. In fact, mesocosm studies fill in a rather confined niche, *e.g.* where experiments are needed to investigate and verify the short and long-term effects of perturbations (pollutants, eutrophication, changes in ambient factors etc.) on the structure and functioning of the ecosystem. Access to the bottom community permitting observation and sampling in great detail contributes much to the advantages of this type of research. Possible further research options for such a system are self evident.

So far studies have been carried out in mesocosms on pore-water chemistry; flux rates of nutrients; metals and organic pollutants and their mediation by bioturbation; impact of pollutants, organic enrichment and dredge materials on bottom systems; partitioning of energy over major faunal groups; spatial distribution of bottom organisms and evaluation of microbial loops. All methods are open to new approaches and improvements, dependent on the skill and expertise of the researchers.

4.2.3 Hard bottom, littoral

Design

So far, rocky bottom communities have only been established in land-based basins in the vicinity of research stations with the necessary infrastructure for maintenance and analysis. The technical management of such systems takes considerable effort. As hard bottom ecosystems in general are characterized by rigorous water movements, the systems are supplied with some type of water movement generators for producing waves or currents.

The substrates in use are concrete, clean rock, natural boulders with epigrowth, macro algae and a variety of artificial materials such as wood, glass and plastic. It is recommended that the dominant solid surface is rock or concrete. Note that a carefully constructed substrate (area size, slope, etc.) may facilitate the use of observation techniques (*e.g.* fixed site photography, video recording, bell jars). For long-term experiments incorporating natural recruitment to the communities, it is important to ensure that replicate basins have as similar surfaces (material, texture) as possible.

It should be emphasized that although all systems hitherto reported are of the basin design, there should be good opportunities to establish *in situ* hard bottom enclosures elsewhere, especially in the littoral zone.

Installation

Experimental communities can be established either by transplantation of natural rocks with epigrowth or by recruitment through water borne larvae and spores. In general community establishment solely by recruitment will be too slow to conform with most experimental time-tables. Short-term experiments (weeks to months) must rely on stocking with organisms in proper proportions. Long-term experiments can utilize a combination of transplantation and gradual recruitment, and in several of the experiments conducted the recruitment pattern itself has been a major element of the research.

The establishment of sublittoral communities by transplantation will require SCUBA divers for careful handling of the transplant units. The procedure is best carried out in stable temperatures, preferably in late autumn.

No current experimental hard bottom system has included natural populations of top predators such as fish. In general the occurrence of fish in the hard bottom designs is sporadic. Exclusion of top predators poses no practical problems in systems established by transplantation, and the introduction of predators by recruitment is easily controlled by visual inspection and removal if necessary.

Measurement strategies

In general the measuring and monitoring procedures used in hard bottom mesocosms have been derived from methods applied in the field. The methods applied in studies of community structure are both nondestructive (*e.g.* by repetitive surveys of designated areas of the substrate), and destructive (*e.g.* by sampling whole rocks with epigrowth and motile forms which then are preserved for definite identification).

Fixed site recording is performed both by direct annotation of algae and animals within defined areas of the substrate, and by photography and subsequent image analysis. SCUBA diving is used extensively to avoid damage by observers walking on the bottom.

Community recruitment can be studied by introducing settlement panels of various materials. Since the systems are easily controlled and observations may be nondestructive, they are ideal for studies on settlement response to changing conditions (*e.g.* waves, predation, grazing, shading, texture, depth).

Total community metabolism, production and respiration can be estimated from diurnal change in pH and oxygen of the water phase of the system. By use of bell jars the metabolism of smaller sections of the community may be studied (*e.g.* single, macroalgal individuals with epigrowth, primary communities on rock tiles). When the water exchange rate is high, it may be necessary to stop the water supply for a period in order to produce a measurable response in the total water chemistry.

Hard bottom experimental ecosystems are ideal for studies of populations and individuals under natural conditions. Because organisms occur only on the surface they are easier to control than those in soft-bottom systems. This configuration enables good control of population size and individual performance. Individuals may be withdrawn for physiological and other measurements and returned undamaged. By using labels and making repeat measurements of individual organisms it is possible to follow them throughout a long-term experiment and thus build up a historical record of performance.

Maintenance

In a land-based system maintenance is a matter of installing adequate technical surveillance equipment, such as alarm systems, on pumps and water movement generators. In some circumstances the danger of overheating or freezing must be counteracted by high water turnover or by insulation of basin walls and pipelines.

It has proven necessary to clean the inlet pipelines at frequent intervals not only to ensure an adequate water supply, but also to prevent the establishment of an assemblage of filter feeders in pipes and header tanks which may seriously reduce the supply of recruits and food particles to the basin communities.

Subtidal benthic communities rely on the input of organic matter from the water column. Ideally input water should be taken from a source providing sufficient food, because artificial addition of adequate particulate matter is difficult to achieve in long-term experiments.

Manipulations and perturbations

Exposure of these communities to chemical agents, such as nutrients and pollutants, is normally achieved by adding the agents to the water supply system. In general, the water movement within the basins is sufficient for a homogeneous distribution of the agent throughout the community. The experiments performed are in general long-term. Various devices to produce a chronic input of these agents can be constructed. Hard bottom communities are easy to manipulate experimentally. Fundamental community relationships can be studied easily in mesocosms by altering the two dimensional structure of a dominantly sessile population.

Evaluation

The performance of hard bottom systems should be evaluated against appropriate natural systems with similar physical characteristics. Evaluation can include comparison of hydrographic conditions, inputs of particulate organic matter, settling patterns and intensities. This is easily done by using data from settling panels in the water entering the basins and in the sea near the water intake. Performance by enclosed organisms should be compared with those of natural populations in quantitative programs dealing with growth, physiology, biochemistry etc.

4.2.4 Hard bottom, sublittoral

Experience with experimental subtidal hard bottoms is limited. The rocky shore mesocosms at Karlskrona, Sweden; Solbergstrand, Norway; and the Smithsonian coral reef system, Washington, D.C. all have a subtidal component to them. These have been treated in section 4.2.3., p137,141. It would seem that there is only one strictly subtidal system currently in use, with communities from 5 - 10 m depth established in indoor basins of 15 m^3 volume. These communities have been established at Solbergstrand, Norway, and have been running since January, 1989. These recommendations are based on the experience gleaned from this experiment.

In general most of the recommendations listed for the hard bottom littoral zone mesocosms (section 4.2.3) are relevant for the establishment and maintenance of subtidal hard bottom systems as well. The present section will therefore constitute a supplement to section 4.2.3, dealing with aspects specifically pertinent to subtidal mesocosms.

Design

As with intertidal hard bottom ecosystems, the initial prime concern is the establishment of realistic substrates, water regimes and communities. In addition, an appropriate light regime must be devised in order to simulate the light at the water depth in question.

A truly realistic light regime can only be simulated by a water column of the appropriate depth and turbidity above the communities. A structure to hold this amount of water would, in most cases, be prohibitively expensive. An alternative is to keep the mesocosms under a semitransparent roof to permit a specific amount of light to enter the basins. If necessary coloured plates can be used to simulate the selective spectral absorption of light through the water column. At Solbergstrand the diurnal light cycle is followed, and light intensity at the bottom of the mesocosm basins is reduced to 1.5 - 2% of sea surface light (*i.e.* about 10 m depth) by use of a roof made of transparent fiberglass and opaque metal roofing panels.

It is important to generate a proper advective regime in the system. In nature the existence of subtidal hard bottoms is either due to an extremely steep sea floor or vigorous water movements. In artificial systems, currents may be created mechanically by directional water inlet nozzles, propellers or paddles. At Solbergstrand where the mesocosm basins are cylindrical (1.2 m deep, 4 m diameter), the most cost-effective way to generate tidal currents was found to be by horizontally rotating paddles. These create a fairly strong current of about 35 cm/s at the outer circumference of the basins, but there is virtually no current in the center where soft bottom units and the main water outflows are situated. The current direction is reversed every seven hours. Eight current generators are driven by a single 0.37 kW electric motor.

Installation

In basins, installation is accomplished by a combination of transplantation and natural recruitment. In the Solbergstrand system about 6 m^2 of the bottom is covered by boulders with epigrowth. These were transplanted from a vigorous current site at 4 to 10m depth. The boulders lie on a bed of commercial gravel which forms a stable substratum, as well as a refuge for newly established juveniles. In addition, populations of selected animal and algal species have been introduced to the basins as a source of materials for various subprojects. Canopy-forming macroalgae have been fastened to the walls of the basin by rubber bands, with no apparent abrasive damage to the stipes even at high current velocities and strong wave action. Natural recruitment occurs in long-term experiments with flow-through seawater systems. Seawater pumps may damage fragile planktonic larvae, but to a lesser extent than previously thought. The loss of recruits to filter feeding organisms (*e.g.* mussels) in the pipelines is a more serious loss, and one should ensure frequent mechanical cleaning to prevent establishment of a fouling community in the water supply system.

As with littoral systems, excessive adjustment of population densities should be avoided, but removal of top predators may be necessary. At Solbergstrand predators like starfish and crabs and strong grazers like sea urchins and isopods have already established populations in the mesocosms through external recruitment. Their density is monitored, and to some extent adjusted. The use of cages and supports on the basin walls, or in the water, has reduced the loss of vulnerable species or associations without excessive removal of the predators and grazers in the system.

Addition of test substances

In general, addition via the water inflow is the practical means of dosing pollutants and other chemical agents under study, and the means by which most such agents are introduced to a subtidal community in nature. Dosing may be continuous or intermittent. Surface bound pollutants (*e.g.* oil) are less relevant for subtidal communities, unless mixed into the water. Excessive sedimentation of particulate matter can be simulated either by adding the particles to the water inflow, or if settling in the pipelines is a danger, the material can easily be discharged directly onto the water surface of the basins. Ideally the current generators should ensure even distribution of the material in the water, but with the present Solbergstrand design, settling material will tend to aggregate in the center of the basins where the current speed is least. In some respects this may be utilized for studies cn gradients in sedimentation.

<u>Evaluation</u>

Subtidal hard bottom mesocosms are simplifications of the field communities, and in most experiments a link to the field should be established to see how well they perform. Preferably one should compare the seasonal change in structure of the mesocosm communities with that of the mother community, which can be achieved by tagging undisturbed rocks and boulders in situ and analysing them for epigrowth by use of SCUBA divers in the same way as with the transplanted rocks. In this respect one should concentrate on changes in densities and degree of cover of the species which are present in the mesocosms to see how well these perform in "captivity". The mesocosm communities are mainly a product of the transplantation, although some later recruitment may occur, and hence must be expected to have reduced diversity from the start compared to the mother community. An indication of how suitable they are for a specific long-term experiment is whether, compared to the field, they show a dynamic stability of their own or a gradual diminution with time.

It is recommended that studies of performance of the individual species of the mesocosm should include a natural population of the same species, preferably from the "mother" community. Sub-experiments on feeding rates, growth, behaviour etc. should include samples from this population.

The present experiments with subtidal hard bottom mesocosms are indeed exploratory. They are expected to generate questions about performance of subunits and processes which lend themselves to further laboratory experimentation. The move from mesocosm observations to laboratory testing of hypotheses and detailed scrutiny of processes is procedurally sound, and the results should again be used to improve the mesocosm design and conditions for later experiments. This process is not specific to the subtidal mesocosm approach alone, but to all exploratory research on experimental ecosystems.

A link to mathematical modelling has not been established in the present systems, but ought to be encouraged at a later stage if the mesocosm approach proves to be successful over the longer term. Since the present mesocosms are products of transplantation of community sections and single populations, the value of trying to generate a model simulating the mesocosm dynamics is doubtful. On the other hand, results from the mesocosms, associated with laboratory experiments, ought to provide valuable inputs to models of natural hard bottom communities in the sublittoral.

4.3 Macrocosms

Construction

These systems are either artificial or natural systems on land, or dammed ponds at sea level with a natural bottom. Systems on land might also have a variety of bottom substrates such as gravel, sand, mud or rock.

Application

The tabular rather than columnar aspect of macrocosms with large surface-area : volume ratios favours work on pelagic organisms with horizontal dispersion and swimming preferences.

Almost all macrocosms will have a resident benthic population with molluscs, crabs, amphipods and polychaetes as significant components. Most of these benthic organisms produce pelagic larvae, but their contribution to the pelagic biomass is normally modest. Resting eggs of calanoid copepods, on the other hand, are normally numerous.

Most macrocosm studies have been concerned with the larval and early juvenile stages of fish. Such studies beyond larval metamorphosis demand large volumes: the larvae need a rapidly increasing amount of food; when these larvae metamorphose their density should be 1-5 m^{-3}; to allow for a reasonable sample sizes of the population over a 40-100 day period, the starting population should consist of 10-100,000 larvae or more.

The macrocosm is ideal for studying variations in growth rate within a population of larval fish. A very accurate description can be given for age-specific growth rate distribution in a given cohort and by use of back-calculated growth from otolith studies, the growth characteristics of a surviving as well as a dying sub-population can be given.

In addition to single cohort studies, macrocosms make repeated release studies possible. Thus the same species can be studied at other temperature and food level conditions. Finally interaction can be studied as, at some stage, the first cohort might feed on younger, succeeding, cohorts. Each cohort can be identified and, by back-calculated growth trajectories from otoliths of each larva it is possible to identify the growth characteristic of the surviving portion of the population (the subpopulation concept).

Interaction between different species can be studied beyond metamorphosis with different strategies:

- simultaneous release; often resulting in high survival of all species;

- staggered release; often resulting in low or no survival of the species released later although high initial growth rate and survival can be observed.

It is recommended that isolated control groups of subsequently released species be set up simultaneously in small mesocosms (*e.g.* floating plastic bags), ideally deployed within the macrocosm.

As yet macrocosms have not been used for pollution studies. However, as they can be run for long periods with no water renewal (propeller only), they should be well suited for some types of study (food-web-accumulation; sublethal effects; degradation/transformation, etc.).

Filling, exchange rate and drainage

Systems on land have to be filled and renewed by pumping. The water inflow can be filtered to prevent introduction of specific size groups of organisms. Normal exchange rates have been 1-5 % per day. In dammed ponds the rate can be increased during studies of the juvenile stage of fishes simply by fixing a grid in the dam to allow tidal water exchange.

Most macrocosms are treated with a poison such as Rotenone to eliminate predatory fish. This should be done well before the start of experiment to permit the plankton to recover. Careful filtration of incoming water is needed to prevent introduction of new predators, including fish eggs.

Sampling

A standard sampling program includes:

- water samples in distinct depths at one or two stations by a Ruttner water sampler for salinity, oxygen, temperature, quantitative and qualitative phytoplankton determination and nutrient salts.
- Pump sampling at distinct depths at one or two stations for microzooplankton.
- Horizontal net hauls at distinct depths across the macrocosm for macrozooplankton and fish larvae.

Frequency of sampling depends on the expected rate of change and desired accuracy. From time to time 24h sampling should be performed. Fish larvae studies also demand repeated sampling on the same day (0900 and 2100 or even more frequently, (*e.g.* every 3 hours) to establish feeding pattern and food preferences. Schooling or swarming organisms could need alternative monitoring devices such as echo sounder with integrator, underwater cameras and video equipment.

Land-based systems can be drained completely and surviving organisms collected. Juvenile fish can either be caught by net or collected if the system is drained. In pond systems, Rotenone treatment at the end of an experiment provides an estimate of ultimate survival.

Maintenance

Normally there is no need for removal of sediments or wall cleaning as the wall effect will be insignificant in macrocosms. Water should enter the macrocosm as close to the bottom as possible to ensure good water quality.

Due to the large surface area, macrocosms are relatively turbulent systems. However, turbulence has frequently been enhanced by propellors. Nutrients can be introduced into the water behind the propeller, but have also been introduced in the steady water supply at the bottom to ensure an appropriate level throughout the water column. As macrocosms are often shallow, photosynthesis may take place throughout the whole water column and result in almost total incorporation of nutrients.

Evaluation

Most macrocosm studies will lack replicates for economic and logistic reasons. By sampling and monitoring, the significance of some specific processes can be examined within the enclosed water volume. The observer is able to control some of the conditions such as timing of larval release, density of larvae and predators.

Some macrocosm studies have been combined with mesocosm studies permitting study of the same species, but with different larval densities and/or food densities.

Accurate and realistic models can be elaborated from macrocosm studies. These models should be able to quantify the impact from predation and cannibalism when compared with observations made on natural populations of the same species.

The expected and observed survival rates,taken from the known circumstances of the macrocosm, should be used in the process of evaluating the significance of predation and other causes of larval mortality in natural populations.

5. FUTURE CONSIDERATIONS

The applications of experimental marine systems in the future will of course depend on the nature of the questions being asked. It is likely that solutions to foreseeable ecological and environmental problems, such as climatic effects of marine processes, will use information gathered from mesocosm studies including interdisciplinary aspects such as:

- quantification of exchange rates between air/sea bottom/sea, and coastline/sea interfaces including estuarine systems,

- estimation of fluxes of materials in ecosystems, including mass balances and the exchange of biomass elements between the different compartments (*e.g.* the sources, production, conversion and fate of dissolved organic substances).

Other, more specific, questions might be:

- ecological causes and effects of harmful plankton blooms, and strategies for avoiding, limiting or detecting blooms,
- effects and accumulation of pollutants in ecosystems,in particular their conversion and fate,
- processes and effects of eutrophication especially in relation to mariculture and agricultural runoff,
- release and effects of natural and artificial tracers in ecosystems,
- succession and competition at low level nutrient and food concentrations, including trace metals and vitamins,
- experimental investigation of structured water columns particularly in relation to biological activity at ergoclines,
- investigation of the survival, growth and population dynamics of sparsely distributed planktonic organisms, particularly fish larvae.

The contained nature of experimental ecosystems makes them ideal for studying short-term rapid processes, especially diurnal turnover rates of CO_2, O_2 or SO_2 associated with primary production. Such data are vitally useful for climatic change models. It is the lack of lateral advection of the enclosed system and the consequent certainty of meaningful repetitive sampling which makes mesocosms ideal for such purposes as the investigation of the turnover of dissolved organic carbon and nitrogen pools. Not only can these pools be sampled on a very intensive basis and the results obtained related to parallel changes in the enclosed water column components, but turnover rates can be estimated by the addition of isotopes. Various experimental treatments can also be tested.

The analysis of eutrophication and pollutant effects on complex ecosystems using mesocosms is well established. Much more needs to be done, however, particularly concerning eutrophic effects of terrestrial runoff and localized mariculture. Mesocosms should assist in the investigation of the effects of enhanced nutrient levels on phytoplankton succession and bloom formation including the evaluation of conditions leading to harmful blooms. However, other pollutants should not be excluded since mesocosms provide a unique opportunity to study complex, long-term effects together with patterns of degradation and subsequent recovery.

Mesocosms have also made a significant contribution to our understanding of the ecology of marine fish larvae and have great potential in mariculture. Their large volumes clearly allow larvae, used to a relatively uncrowded and boundless environment, to develop under more favourable circumstances than in a laboratory tank. Many groups are adopting mesocosms for larval fish research, but much more work needs to be done on other planktonic organisms, and on the interactions between predators and prey which seem to be so significant in determining community structure.

Modern instrumentation and our appreciation of the complex, diverse nature of the pelagic environment have led to a great concentration of work on processes associated with discontinuities such as fronts, pycnoclines and physical interfaces. It has already proved possible to simulate thermal stratification in land-based mesocosms so the potential exists for careful experimental characterization of other, similar oceanic features. Mesocosms usually incorporate air/sea or sea/bottom interfaces and therefore can be further adapted for studying exchange processes across these boundaries.

Technical Developments

Combined Systems

The great complexity of natural ecosystems, especially at coastal sites, together with the interaction between pelagic and benthic processes, requires the combination of different types of experimental ecosystems. Such ensembles have already been established at several coastal institutes and allow the subdivision of pelagic and benthic dominated systems or complex natural systems into compartments or subsystems. Such combined systems (benthic, bentho-pelagic and pelagic), enable a realistic study of complex effects of pollutants on the different ecosystem components, including the transformation and degradation of the pollutants themselves. Artificially composed systems in combination with separated natural experimental ecosystems facilitate the investigation of single species or individual trophic level components. For instance, pelagic mono-cultures of phytoplankton, inoculated into filtered seawater, can be subjected to the same physical environmental conditions as enclosed natural systems running in parallel. In benthic systems different sediments with selected organisms might be added to abiotic substrata.

Design

To date the technology is lacking to deploy suitable mesocosms in tidal estuaries and the open ocean. The deployment of experimental ecosystems in estuaries is complicated by changing salinities and high current speeds which restrict the suitability of flexible enclosures (plastic bags) and make it more difficult to simulate natural conditions with high turbidity and increasing salinities. It is likely that such conditions can be simulated more effectively by large-scale land-based systems rather than by *in situ* units.

The performance of enclosure experiments in the open sea will mainly be limited by wave action and wind drift. Further difficulties are the predominantly low levels of nutrients and standing plankton crops which require very sensitive measurements to detect processes within the steady state systems. Thus for long-term studies of pelagic oceanic systems new mesocosm designs will have to be developed. These could either be submersible systems with attendant difficulties of sampling and maintenance, or robust drifting devices, resistant to wave and wind action, which could be tethered to research vessels.

Other new developments include mobile coastal systems which can be used at different sites to investigate local effects such as oil pollution, eutrophication or causes and consequences of harmful plankton blooms. Future new marine experimental ecosystems also need to be developed for the study of processes at interfaces. These boundaries are very sensitive to manipulations and appropriate *in situ* studies will probably be limited to short time scales.

Research Strategies

As has been frequently stated, it is often useful to combine work in experimental ecosystems first with field investigations, in order to evaluate the realism of enclosed systems, and secondly with laboratory experiments, in order to quantify isolated processes under comparable conditions. These can then be related to similar processes observed in enclosed complex natural ecosystems.

In the future, mesocosms must be used more extensively by interdisciplinary research groups in order to develop the meaningful numerical models, including ecosystem components, necessary for critical system analysis. Further data from experimental enclosures offers a unique opportunity for defining the limits of model predictability. It would be most desirable to see experimental ecosystem programmes being included in large international marine research projects such like JGOFS (Joint Global Ocean Flux Study), IGBP (International Geosphere/Biosphere Program) and international climate programmes like GLOBEC.

6. DESCRIPTION OF EXPERIMENTAL ECOSYSTEM SYSTEMS

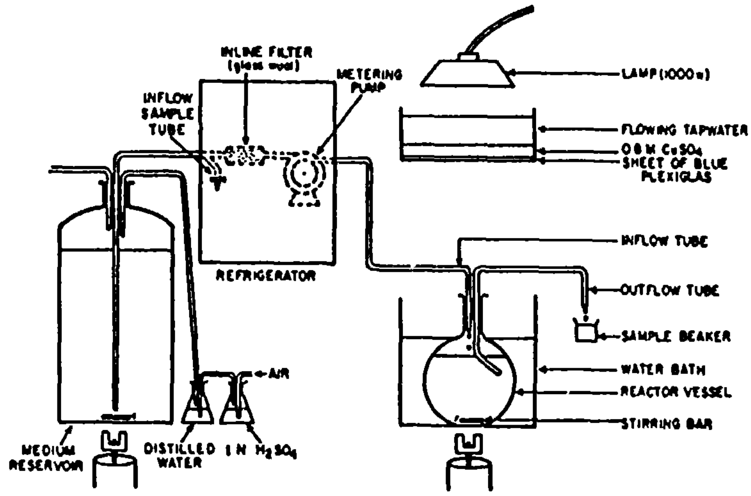
6.1 Introduction

In the following section a brief description is given of various micro-, meso-, and macrocosms which have been used by marine scientists for different experiments. The size interpretation of micro, meso, and macro has been fairly loosely applied so that containers which are only slightly larger or smaller than the respective grouping (see p.2) have been included in the most appropriate group. For convenience in locating system descriptions within each size group, they have been arranged so that pelagic systems appear first, bentho-pelagic second and benthic third. Descriptions of equipment have been taken from published literature reports, and information supplied by researchers. SCOR WG 85 is grateful to all these persons for supplying details of their work. An index to this section is supplied so that use of different sized containers can be cross-referenced with other useful categories, such as benthic/pelagic/pollution experiments, larval fish etc.

6.2 Microcosms

Pelagic (less than 1 m^3 volume)

Benthic (less than 0.1 m^2)



DESCRIPTION OF EQUIPMENT

Specific Name: Chemostat

Size:

Volume: Usually 20 ml to several litres.

Material: Non-toxic, all glass or perspex construction.

Purpose: Physiological growth parameters of bacteria and phytoplankton.

Application: Widely used by physiologists for measurement of nutrient uptake and light response of phytoplankton.

Location:

Contact Address: Commercially available chemostats :

1)New Brunswick Scientific Co. Inc.
1130 Somerset St.,
New Brunswick, NJ 08903, USA

2)Kontes Glass Co., Vineland, NJ 08360

Filling: Media and equipment autoclaved for axenic culture experiments.

Sampling: From discharge tube.

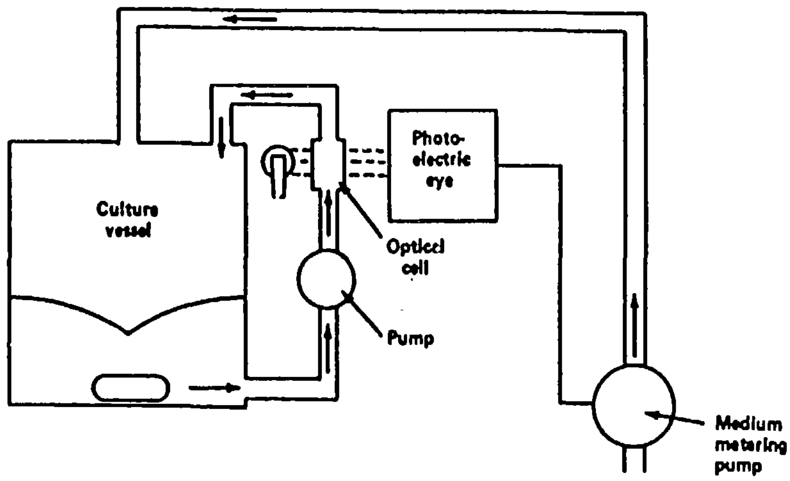
Key References:

Calcott, P.H. 1981. *In* Continuous Cultures of Cells Vol I. CRC Press Inc., Boca Raton, Florida, 191 pp.

Davis, C.O., P.J. Harrison and R.C. Dugdale. 1976. J. Phycol. *9*: 175-180.

Conway, H.L., P.J. Harrison and C.O. Davis. 1976. Mar. Biol. *35*: 187-199.

Comments: Kinetics of chemostat behaviour are discussed in the references given above.



Schematic additions necessary to convert chemostat to turbidostat.

DESCRIPTION OF EQUIPMENT

Specific Name: Turbidostat. (see chemostat)

Size:
Volume: Usually 20 ml to several litres.

Material: Non-toxic glass or perspex.

Purpose: Constant cell density cultivation determined by light absorption of culture.

Application: Feeding experiments where a constant quantity of plankton is required.

<u>Location</u>:

<u>Contact Address</u>: Turbidostats are made commercially by (1) Lab-Line Instruments, 15th and Bloomingdale Ave, Melrose Park, Illinois, 60160 USA. (2) L.Eschmeiler Co., Kiel, Germany (FRG)

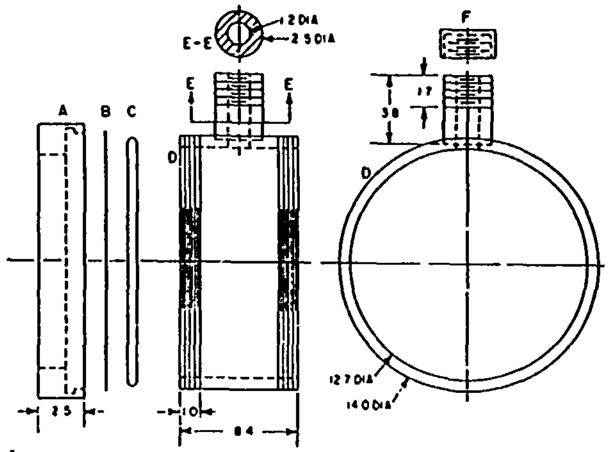
<u>Filling</u>: Autoclaved equipment and medium to assure axenic culture.

<u>Sampling</u>: From discharge tube.

<u>Key References</u>:

Calcott, P.H. <u>In</u> Continuous Cultures of Cells. 1981. Vol.I. CRC Press Inc., Boca Raton, Fl. 191 pp.

<u>Comments</u>: See operation of chemostats for more details.



Schematic diagram of an *in situ* diffusion chamber. Nuclepore membranes (B) and Teflon O rings (C) are held in place by screw-on outer flanges (A). Main body (D) has capped opening (E) for filling and emptying. Main body is constructed of Plexiglas round stock while outer flanges are machined from flat stock. All dimensions are in cm

DESCRIPTION OF EQUIPMENT

Specific Name: *In situ* diffusion chamber.

Size:
- Depth: 8.4 cm
- Diameter: 12.7 cm
- Volume: *ca* 800 ml

Material: Plexiglass.

Purpose: Growth dynamics of phytoplankton.

Application: Used to investigate the microbial plankton community including phytoplankton, bacterial and phagotrophic microflagellate dynamics.

Location: Kaneohe Bay, Hawaii.

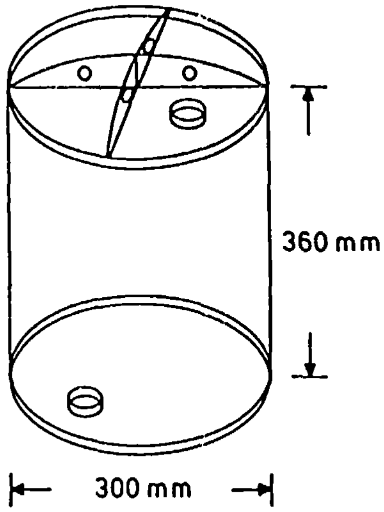
Contact Address:

Filling: From 10 litre cubitainer samples collected locally by snorkel-divers.

Sampling: Total volume subsampled for various analyses.

Key References:
Landry, M.R., L.W. Haas and V.L. Fagerness 1984. Mar. Ecol. Prog. Ser. *16*: 127-133.

Comments: Equipment is an example of a number of *in situ* growth chambers used to examine dynamics of plankton populations.



DESCRIPTION OF EQUIPMENT

Specific Name: OKEX (OKologische EXperimente, Ecological experiments)

Size: (cylindrical)
Depth: 360 mm
Diameter: 300 mm
Volume: 25.4 ℓ

Material: top and bottom cover - plexiglass, mantle cover - polyethylene foil

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Purpose: Ecophysiological responses of phytoplankton on environmental changes

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Application: Coastal ecosystem research; ecosystem approaches in the open Baltic Sea and upwelling regions off NW Africa.

Location: Open Baltic Sea, upwelling areas off NW Africa

Contact Address: Institute of Marine Research, Academy of Sciences of the GDR, Rostock-Warnemunde DDR-2530

Filling:

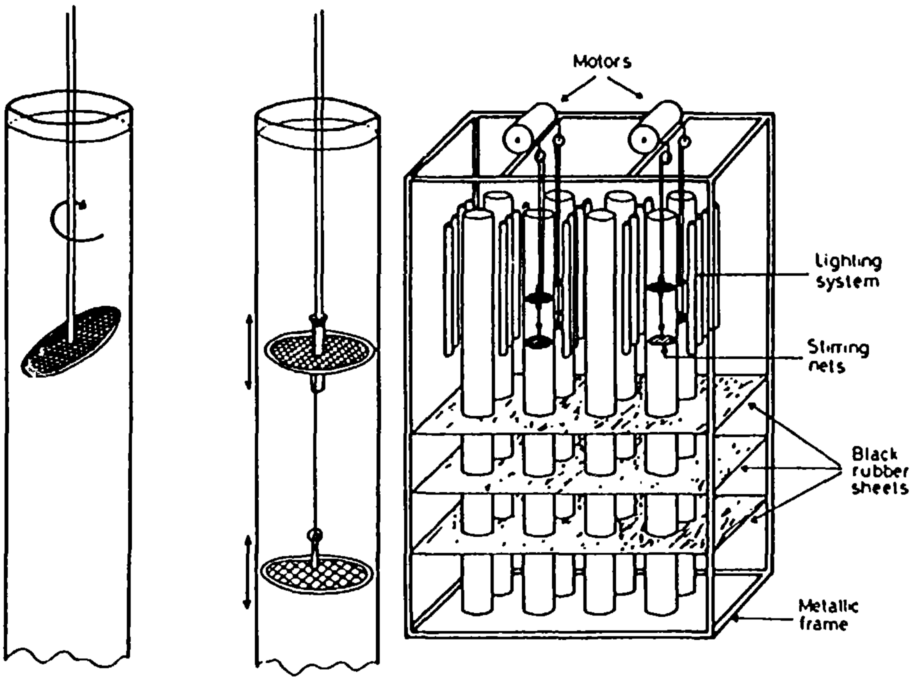
Sampling: Because of the comparatively small size of the enclosures every container has to be considered a single sample. Therefore an experiment of *x* days consists of *x* containers, one sample being taken every day.

Key References:

Schulz, S. *et al* 1985. *Geod. Geoph.* Veröff. RIV,41, 66pp.

Schulz, S. *et al* (in press) Kiel. Meeresforsch.

Comments: This method is used for short term processes. To date 10 papers have been published about the results



DESCRIPTION OF EQUIPMENT

Specific Name: Microcosm (tubes)

Size:

Depth: 200 cm

Diameter: 15 cm

Volume: 30 ℓ

Eight, 30 ℓ tubes installed in constant temperature chamber.

Material: Perspex tubes; stirrers made of netlon netting 6 mm mesh size. Four 20 W, 60 cm fluorescent lamps provide lighting for each tube.

Purpose: To examine phytoplankton growth during turbulence.

Application: Different levels of turbulence applied to natural phytoplankton populations.

Location: Masnou (20 km north of Barcelona, Spain)

Contact Address: Institut de Ciences del Mar, P. Nacional, s/n, 08003 Barcelona, Spain.

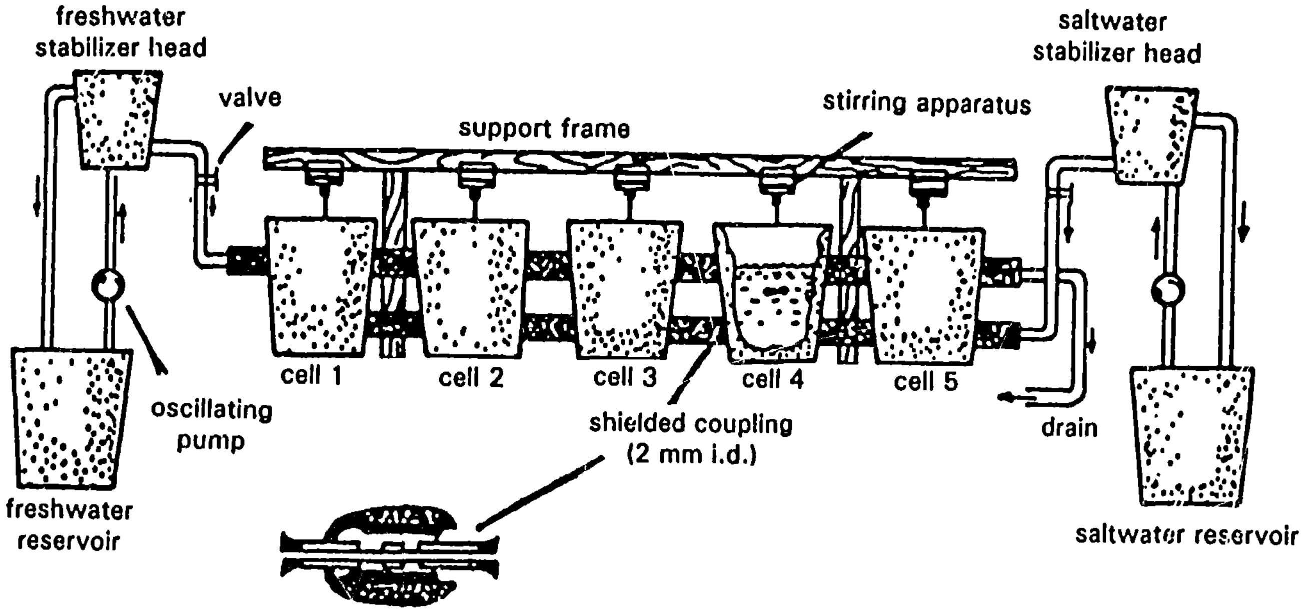
Filling: Filtered (150 μm mesh) sea water from Masnou Harbour (20 km north of Barcelona)

Sampling: Samples collected from 40 and 145 cm depth in each tube.

Key References:

Estrada, M., Alcaraz, M. and C. Marrase. 1987. Mar. Ecol. Prog. Ser. *38*: 267-281.

Comments: Experiments have been carried out for up to 50 days duration.



DESCRIPTION OF EQUIPMENT

Specific Name: Estuarine microecosystem

Size:

Volume: Each cell consists of a *ca* 45 litre canister.

Material: Polyethylene canisters; polyvinylchloride tubing.

Purpose: Simulation of hydrological conditions in estuarine regions.

Application: Primary and secondary production studies under conditions of changing salinity. Pollution studies using kraft mill effluent.

Location: Simulation of Trinity river estuary, Galveston Bay, Texas.

Contact Address: University of Texas, Marine Science Institute, Port Aransas, Texas.

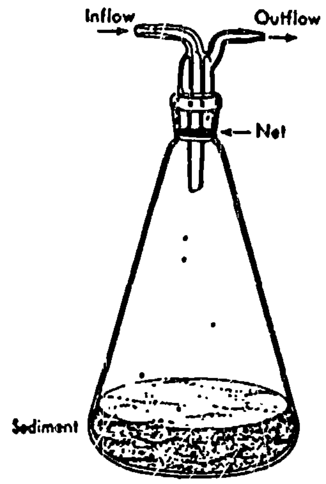
Filling: Fresh water from Trinity river, salt water from Gulf of Mexico; sediments from Trinity Bay.

Sampling: Directly from each canister.

Key References:

Cooper, D.C. and B. J. Copeland. 1973. Ecol. Monographs, *43*: 213-236.

Comments: Organismal composition of the microecosystems were qualitatively similar but quantitatively dissimilar to that of Trinity Bay.



DESCRIPTION OF EQUIPMENT

Specific Name: Laboratory soft-bottom microcosm.

Size:	2 litre Erlenmeyer flask with a water flow of 2.2 litres/hr.
Material:	Glass and PVC tubing.
Purpose:	Study of natural populations of meio and macrofauna.
Application:	Effect of cadmium exposure over a period of up to 400 days.

Location: Hallsfjänden (Northern Baltic).

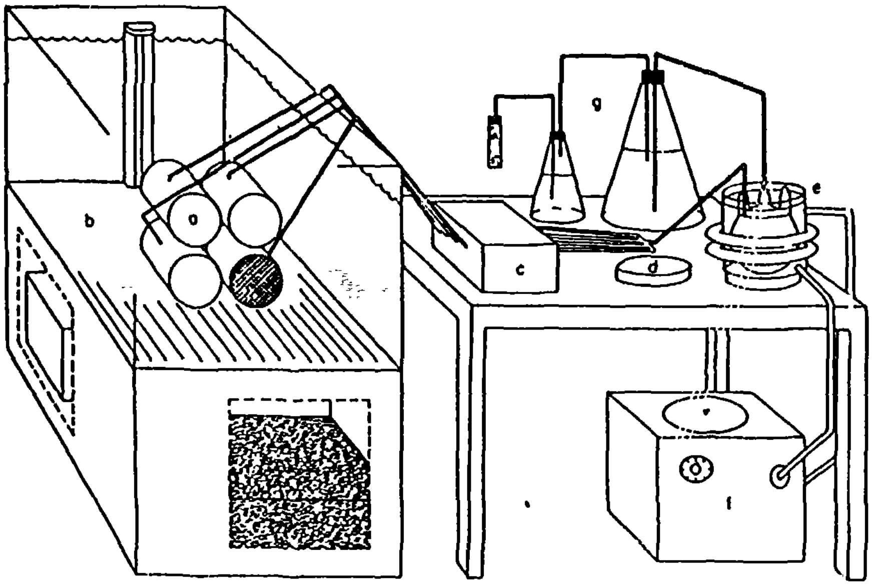
Contact Address: Brackish Water Toxicology Laboratory, Swedish Environmental Protection Board, 5-61182 Nykoping, Sweden.

Filling: Sediments obtained from 40 m using an Ockelman dredge. (Mesh size 450 μm)

Sampling: Removal of sediment and sieving to separate animals.

Key References: Sundelin, B. 1983. Mar. Biol. *74*: 203-212.

Comments: Equipment is an example of a very simple system such as has been used in a variety of toxicological studies.



Apparatus for the continuous culture of a bentho-pelagic amphipod a, Amphipod chambers; b, Aquarium; c, Proportionating pump; d, Magnetic stirrer to vibrate junction and prevent clogging; e, Phytoplankton culture; f, Temperature controlled bath; g, Nutrient medium for phytoplankton.

DESCRIPTION OF EQUIPMENT

Specific Name: Amphipod growth chambers.

Size:
Volume: Each chamber, 2.25 litres

Material: Plexiglass with Nitex screening

Purpose: Study of the food requirements of small bentho-pelagic organisms.

Application: Study of amphipod food requirements over a generation.

Location: Department of Oceanography, University of British Columbia.

Contact Address:	Department of Oceanography, University of British Columbia, Vancouver, B.C. V6T 1W5 Canada.
Filling:	Natural seawater supply to the laboratory
Sampling:	See reference.
Key References:	Parsons, T.R. and C.A. Bawden 1979. Estuarine and Coastal Mar. Sci. 8: 547-553
Comments:	Advantage over batch feeding experiments is the continual availability of prey. Disadvantages include difficulties of continuous operation, clogging pipes, malfunction of pumps, etc.

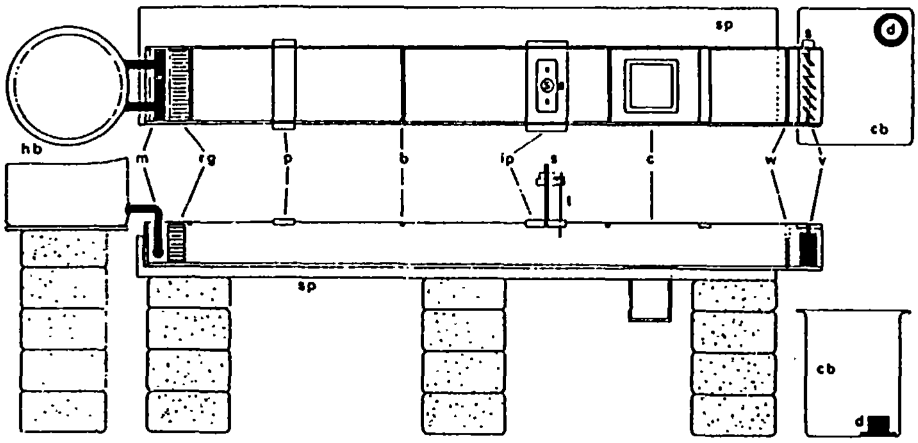


Fig. 1. Plan and side views of the Dalhousie flume, showing the headbox (hb), manifold (m), rectifier grid (rg), moveable platform (p), channel brace (b), instrument platform (ip), with profiling stepping motor (s) and thermistor probe (t). This platform is also moveable, but is generally used in the working section of the channel. The corewell and corebox (c) are located 75 cm upstream of the sharp-edged weir plate (w) and stepping motor (s) controlled weir vanes (v). Also shown are the flume support (sp), catch basin (cb) and drain (d). Not shown are the flow control valves on the manifold and the constant head overflow pipe between the headbox and catch basin. The total channel length is 325 cm

DESCRIPTION OF EQUIPMENT

Specific Name: Dalhousie Flume Channel

Size:

Depth:	20 cm
Width:	35 cm
Length:	3 m

Material: Plexiglass with polyethylene head tank

Purpose: Simulation of unidirectional boundary flows

Application: Benthic-pelagic coupling; bed-load transport of organic matter; microbial adhesion of sediments; critical erosion thresholds of sediment; suspension-feeder behaviour.

Location: Aquatron Seawater Laboratory
Department of Oceanography
Dalhousie University
Halifax, Nova Scotia, Canada. B3H 4J1

Contact Address: as above (Dr. Jon Grant)

Filling: Flow through of natural seawater. Test section accepts 3" diameter sediment cores, box core microcosms, or custom applications.

Sampling: Friction velocity (U^*)
Free-stream velocity
Temperature
Suspended sediments
Bedload trap

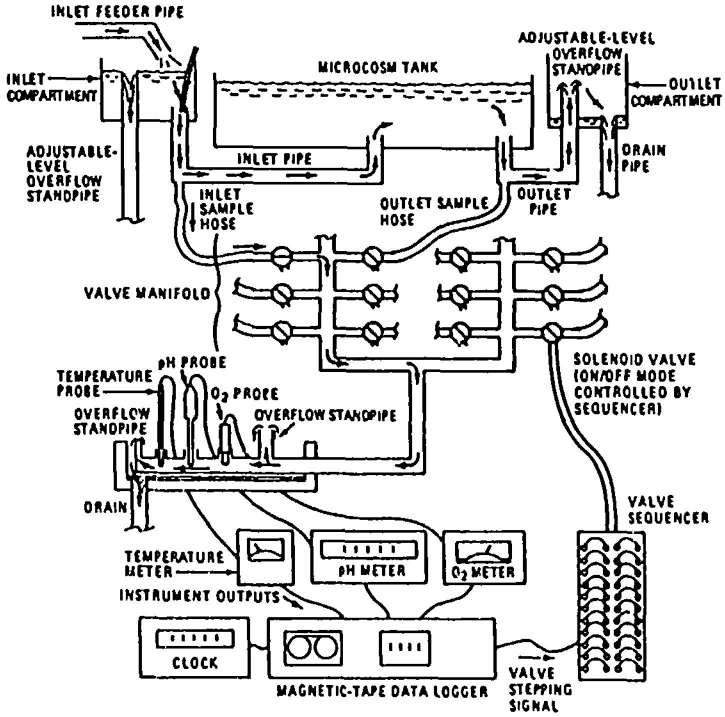
Key References:

Muschenheim, D.K., J. Grant, E.L. Mills. 1986. Mar. Ecol. Prog. Ser. *28*: 185-195.

Grant, J., U.V. Bathmann. 1987. Science *236*: 1472-1474.

Comments:

Generates free-stream velocity in excess of 60cm sec^{-1}. Flow characteristics are computer-logged. Intended for shorter-term experiments due to large volumes of seawater used. Natural seawater holding tanks are adjacent. Smaller re-circulating flume is also in use.



DESCRIPTION OF EQUIPMENT

Specific Name: Flow-through microcosm.

Size:
Volume: 500 litres each, 12 replicate tanks.

Material: Fibreglass.

Purpose: Nutrient enrichment in oligotrophic waters.

Application: Study of nitrogen and phosphorous enrichment of benthic communities.

Location: (1) Mokapu peninsula (Hawaii) near to coral reef, (2) Kaneohe Bay near sewage outfall.

Contact Address: Naval Ocean System Center, Kailua, Hawaii.
or Hawaii Inst. Marine Biology, Kaneohe, Hawaii.

Filling: Pumped, using glass fiber/vinyl casing impeller pumps. Water taken from surge pool near shore.

Sampling: Automated probes and direct sampling of benthic organisms from tanks. Tanks made up to contain different benthic habitats including sand, limestone and settling panels.

Key References:

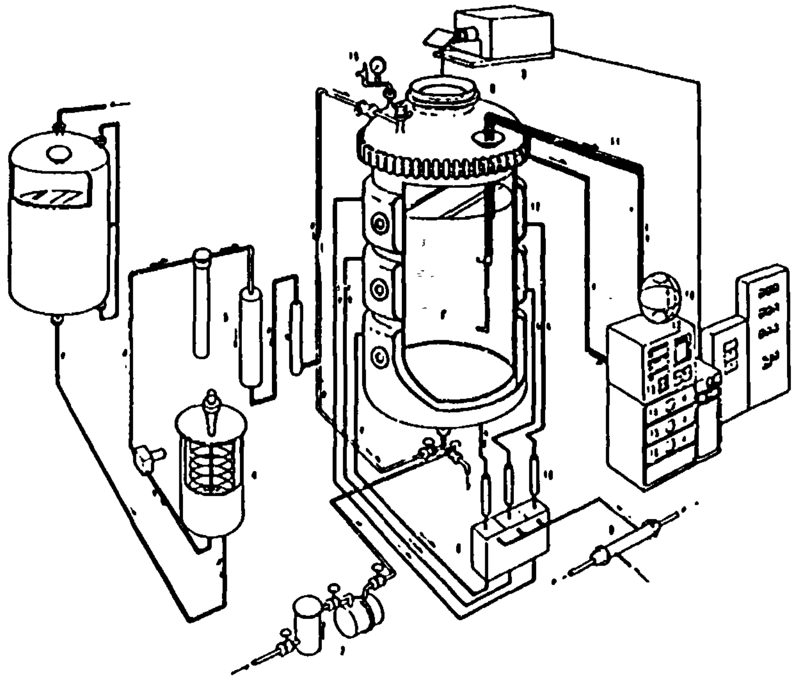
Henderson, R.S. and S.V. Smith. 1980. *In* Microcosms in Ecological Research *Publ*. Technical Information Center, U.S. Dept. Energy, Springfield VA 22161

Comments: Two microcosm facilities were set up to compare benthic growth in oligotrophic and eutrophic (sewage polluted) environments.

6.3 Mesocosms

Pelagic (1 m^3 to 10^3 m^3)

Benthic (.1 m^2 to 10^3 m^2)



Schematic diagram of the NIES tank: (1) cultivating tank (1 m^3); (2) storage tank (10 m^3); (3) Xe lamp house; (4) mixing tank (0.2 m^3), (5) filters for medium; (6) thermoregulating baths; (7) filter for air; (8) concave lens; (9) cooler; (10) sampling equipment; (11) sampling tubes; (12) thermometer; (13) salinometer; (14) pH meter; (15) turbidimeter; (16) fluorometer; (17) jackets; (18) heaters; (19) pressure gauge.

DESCRIPTION OF EQUIPMENT

Specific Name: NIES tank

Size:

Depth: 1.5 m
Diameter: 1.0 m
Volume: 1 m^3

Material: Steel with glass lining

Purpose: Mass cultivation of phytoplankton

Application: Vertical migration experiments and biochemical reactions associated with carbon, nitrogen and phosphorous metabolism in algae.

__Location__: National Institute of Environmental Studies, Tsukuba, Japan.

__Contact Address__: Laboratory of Marine Environment, The National Institute for Environmental studies, Yatabe-machi, Tsukuba, Ibaraki 305, Japan.

__Filling__: Seawater from off Hachijo Island pumped through 0.22μm filters.

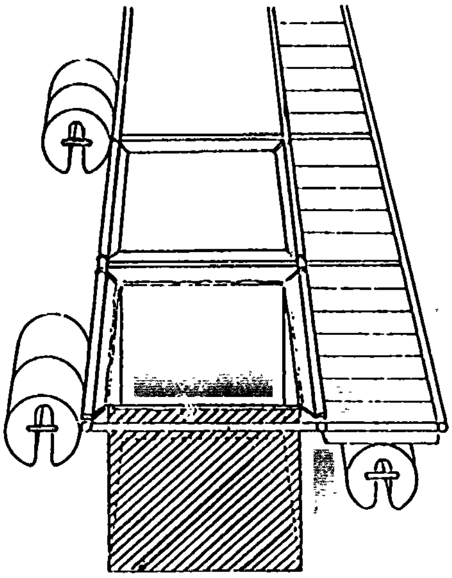
__Sampling__: Culture sampled at 5 levels through Teflon tubes.

__Key References__:

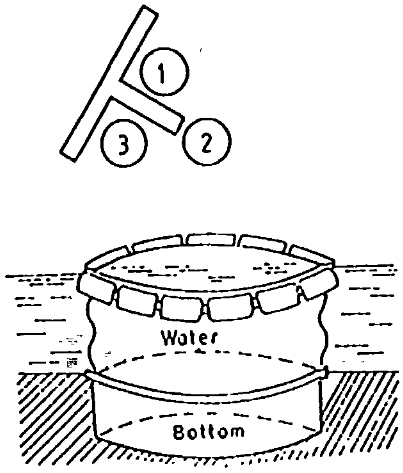
Kohata, K. and M. Watanabe. 1986. J. Exp. Mar. Biol. Ecol. *100*: 209 - 224.

Kohata, K. and M. Watanabe. 1989. J. Phycol. *25*: 377-385.

__Comments__:



A.



B.

DESCRIPTION OF EQUIPMENT

Specific Name: A. Pekom B. Flak

Size:	A.		B.
Depth:	100 cm	Depth	90 cm
Height:	100 cm	Diameter	200 cm
Width	100 cm		
Volume:	1 m^3	Volume	1.5 - 2.4 m^3

Material: A) Polyethylene B.)Polyethylene attached to a metal ring.

Purpose: A) Trophodynamics in microbial food webs, Phytoplankton growth and periodicity.
B) Influences of nutrients.

Application: Shallow coastal ecosystems of the Baltic sea. A.) Pelagic communities. B.) Shallow water communities.

Location: Darss-Zingster Boddencette. Estuary of the southern Baltic Sea, German Democratic Republic.

Contact Address: Biology section, Department of Experimental Ecology, Wilhelm-Pieck University, Rostock, Friligrathstr.7/8, Rostock, DDR-2500

Filling:

Sampling:

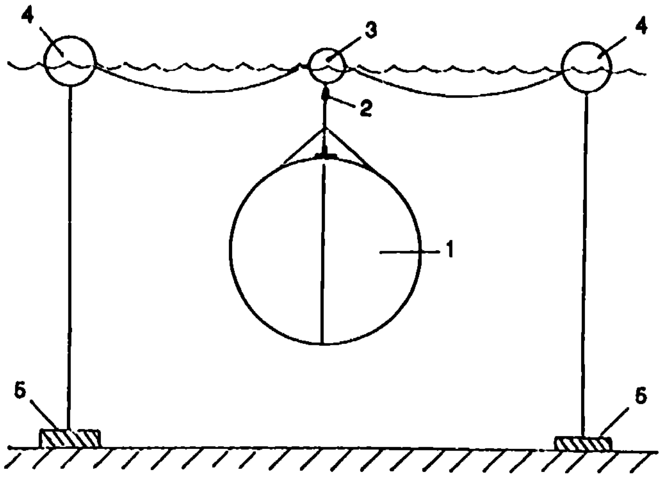
Key References:

Schiewer, U. *et al.* 1986. Limnologica (Berlin) *17*: 7-28.

Schiewer, U. *et al.* Carbon flux dynamics in a shallow eutrophic estuary. Limnologica (Berlin) (in press).

Schiewer, U. *et al.* Kieler Meeresforschungen, Sonderheft 6. (in press).

Comments: A) 4 enclosures, 8 or 28 days June/July 1981-83. B. 3 enclosures 2 or 2.5 months June/August 1985-87.



1. IES
2. swivel
3. marker bouy
4. buoys
5. moorings

DESCRIPTION OF EQUIPMENT

Specific Name: Isolated Ecological System (IES)

Size: Spherical shape

Diameter: 100cm

Volume: 1.3m^3

Material: Polyvinylchloride

Purpose: To study the impact of heavy metals on the pelagic system.

Application: Coastal ecosystem research; pollution response.

<u>Location</u>: NE coast of the Gulf of Riga / USSR among the Estonian islands.

<u>Contact Address</u>: Institute of Biology, Academy of Sciences of Latvian SSR, Mierea Str. 3, Salaspils 229021, Latvian SSR, USSR.

<u>Filling</u>:

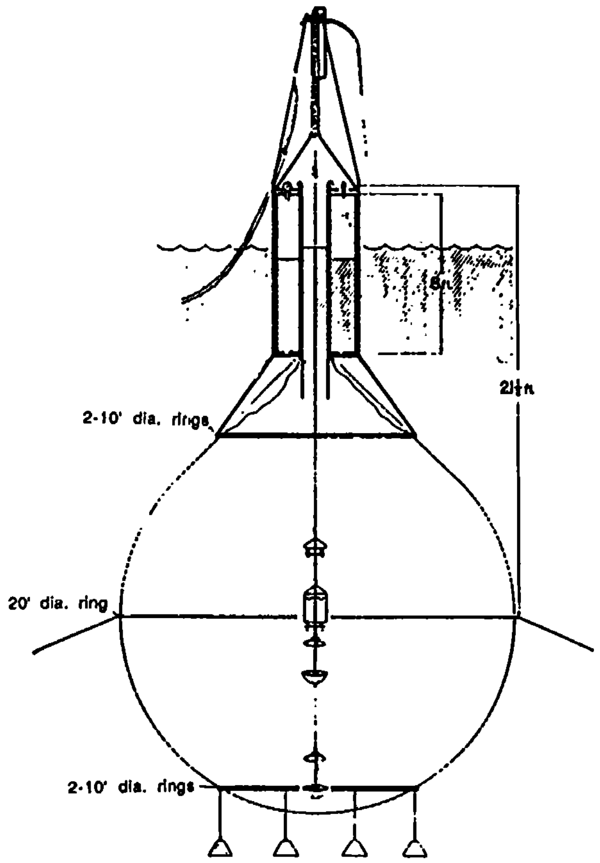
<u>Sampling</u>:

<u>Key References</u>:

Andrushaitis, A., *et al.* 1984. Hydrobiol. J. 20/1, 76-81.(in Russian.)

Seisuma, S. *et al.* 1986. Impact of heavy metals on plankton in experimental ecosystems. Riga, Sinatne, 256pp (in Russian).

<u>Comments</u>: According to the authors the system has been used quite successfully in the above mentioned area. At the moment no further experiments of this type are planned. It is however intended that the microcosms be used in forthcoming trophodynamic experiments.



DESCRIPTION OF EQUIPMENT

Specific Name: Departure Bay Plastic Bag Mesocosm

Size:
- Depth: *ca* 10 m
- Diameter: *ca* 7 m
- Volume: *ca* 130 m^3

Material: Polyvinyl chloride

Purpose: Phytoplankton dynamics.

Application: Growth and decay of a phytoplankton bloom over a period of 3 weeks.

Location: Departure Bay, British Columbia, Canada.

Contact Address: Experiments ended in the 1960s

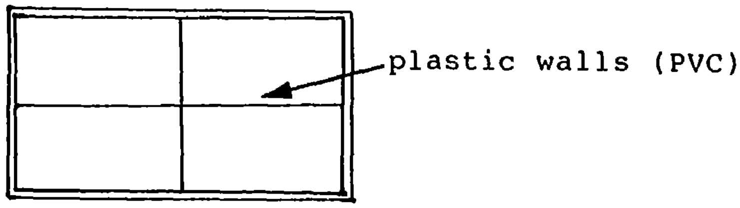
Filling: Seawater is pumped through a diatomaceous earth filter and then "inoculated" with a small volume of natural seawater.

Sampling: Water bottles (Nansen or Van Dorn)

Key References:

Strickland, J.D.H. and Terhune, L.D.B. 1961. Limnol. Oceanogr. *6*: 93-96.

Comments: One of the earliest mesocosms used for phytoplankton / nutrient studies. (e.g. McAllister, C.D. et al 1961. Limnol. Oceanogr. *6*: 237-258).



DESCRIPTION OF EQUIPMENT

Specific Name: 92 m^3 tank

Size:

Length: 8 m
Width: 4 m
Volume: 92 m^3 (*i.e.* 4 x 23 m^3)

Material: Concrete with removable plastic walls (PVC).

Purpose: Comparative mesocosm investigations.

Application: Plankton food chain investigations, Plankton production, rearing of turbot and other fish larvae, predation experiments.

Location: North Sea Centre, DK-9850 Hirtshals, Denmark.

Contact Address: Danish Institute for Fisheries and Marine Research, P.O. Box 101, DK-9850 Hirtshals, Denmark.

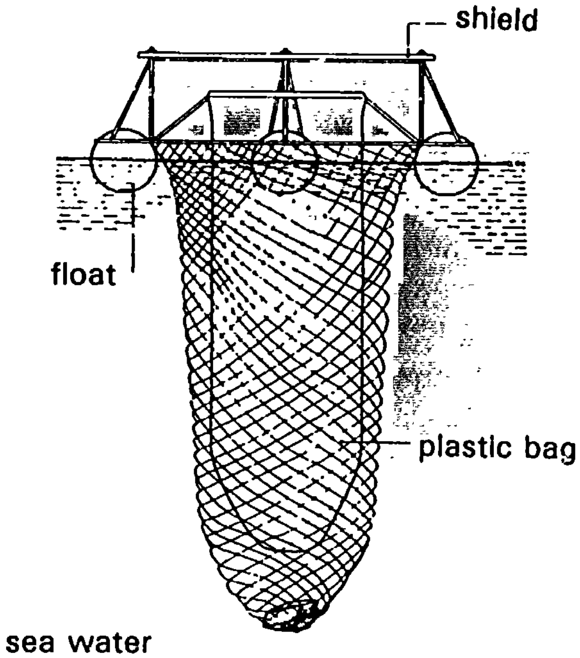
Filling:

Sampling:

Key References:

N. De Pauw et al (Eds.) 1989. Aquaculture - A Biotechnology in Progress. European Aquaculture Society, Bredene, Belgium.

Comments: Herring and cod larvae have shown remarkably high survival and growth rates when grown with low natural food concentrations in these predator-free tanks.



DESCRIPTION OF EQUIPMENT

Specific Name: Plastic Bag

Size:

Depth: *ca* 20 m.

Diameter: 0.75 m

Volume: 14 m^3

Material: Laminated plastic, inner bag polyethylene and outer polyamide. Protective netting outside.

Purpose: Study of plankton.

Application: Evaluation of low levels of pollutants.

Location: Den Helder, Netherlands.

Contact Address: Central Laboratory TNO Dept. Marine Ecology, Den Helder, Netherlands.

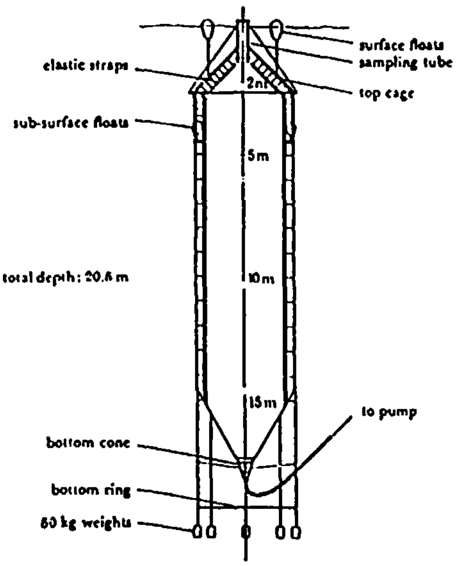
Filling: Pumped seawater.

Sampling: Non-metallic water bottles and pumped samples for zooplankton.

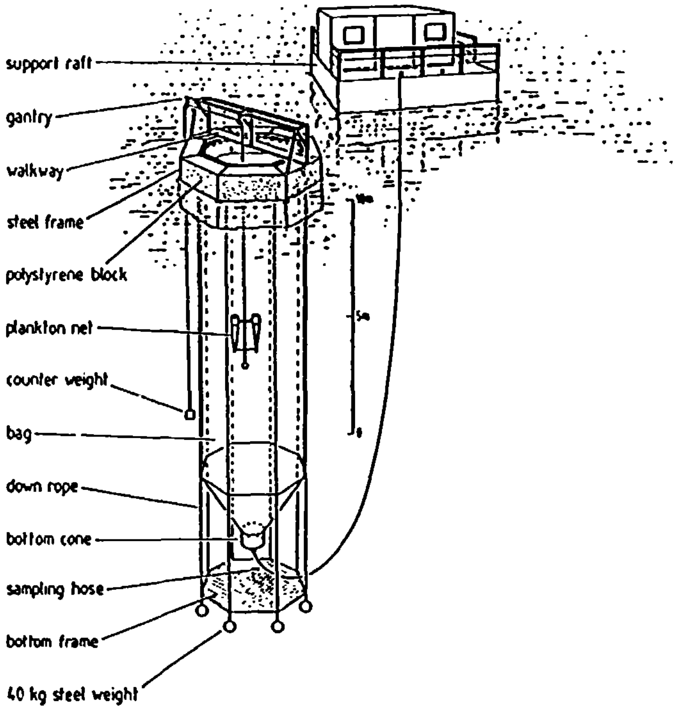
Key References:

Kuiper, J. 1977 Mar. Biol. *44*: 97-107.

Comments: Good replication of biological events achieved in 4 bags over a period of *ca* 40 days.



(a)



(b)

DESCRIPTION OF EQUIPMENT

Specific Name: Loch Ewe Enclosures

	(a)	(b)	(c) (not illustrated, as b.)
Size:			
Depth:	17 m	20 m	20 m
Diameter:	3 m	4.75 m	2.75 m
Volume:	100 m^3	300 m^3	100 m^3
No. Units:	4	4	2

Material: Translucent nylon-reinforced PVC.

Purpose: Trophodynamics of the pelagic community.

Application: Coastal ecosystem research, pollution research; heavy metals, oil derivatives, sewage sludge, aquacultural pesticides, larval fish research.

Location: Loch Ewe, Scotland, UK.

Contact Address: Marine Laboratory, P.O. Box 101 Victoria Road, Aberdeen, Scotland, AB98DB.

Filling: (a) Diaphragm pump. (b) Lifting to the surface with ropes attached to the circumference of the enclosure. Raised from approximately 22m and then topped off with diaphragm pump. The mouth of the enclosure may be screened during filling with 1cm mesh net.

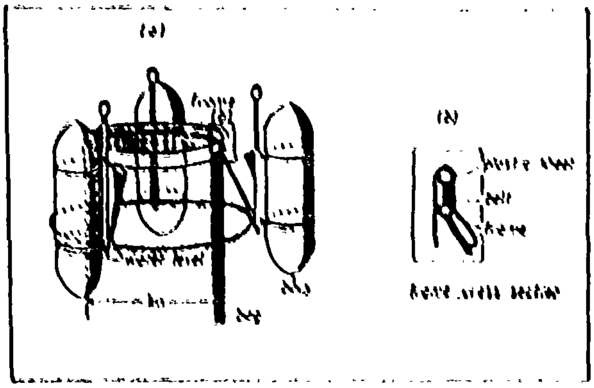
Sampling: "Archimedes screw" pump for nutrients, phytoplankton, suspended particulates through *in situ* hose at selected depths. Nets and *in situ* recycling pumps for zooplankton and larval fish. Settled material extracted from basal cone by pump through hose. Can be drained entirely by pumping and lifting out of the water.

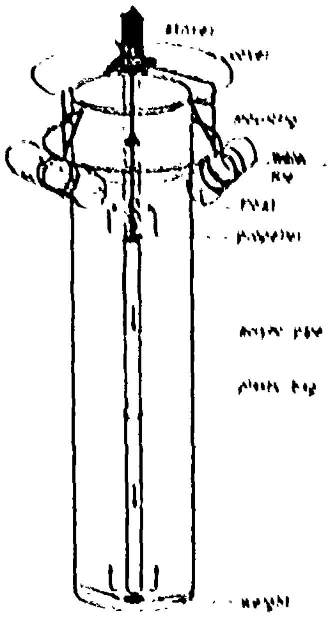
Key References:

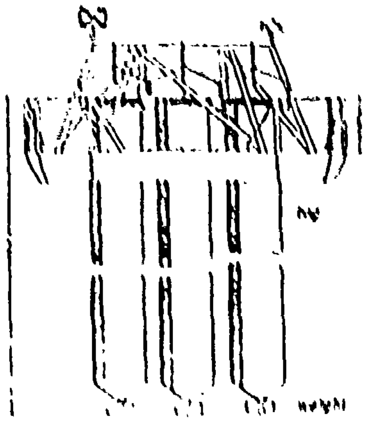
Davies, J.M. and Gamble, J.C. (1979) Phil Trans. Roy. Soc. Lond. B. *286*: 523-544.

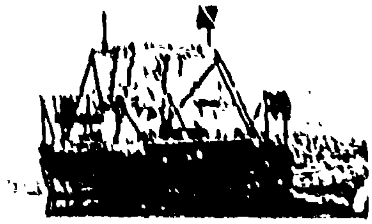
Gamble, J.C. *et al.*, (1981), Rapp P:v. Reun. Cons. Int. Explor. Mer. *178*: 121-134.

Comments: Over 20 papers have been published on data obtained from these enclosures. Note that the system consists of multiple units connected to a service raft fitted out as a field laboratory. 7 Kw of power available for pumps, instruments etc.









DESCRIPTION OF EQUIPMENT

Specific Name: Hamburg Enclosures

Size:

Depth:	3 - 35 m
Diameter:	1 m
Volume:	2.3 - 27 m^3

Material: Seamless tubes of colourless combination foil (polyamid/polyethylene 30/100 µm). The one-layer material is flexible, translucent (90%), physiologically inert and impermeable to gases and dissolved substances. By use of freshly produced rolled-up tubes no cleaning or preconditioning necessary.

Purpose: Dynamics of planktonic ecosystems (natural systems, phytoplankton monocultures, eco-toxicology).

Application: Marine, coastal and estuarine ecosystem research, pollutant effects. Experiments lasting approximately 1 month.

Location: North Sea: open water (weather-limited drift experiments). Heligoland Harbour (F.R.G.), Rosfjord (South Norway) Elbe Estuary (Brunsbüttel-Lock, F.R.G)

Contact Address: Institute for Biogeochemistry and Marine Chemistry, University Hamburg, Martin-Luther-King Platz 6, D-2000 Hamburg 13, F.R.G.

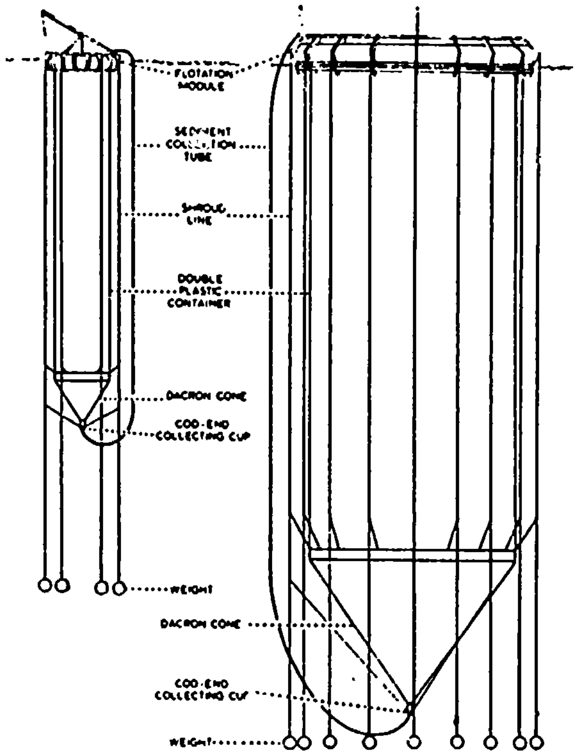
Filling: Bags are filled by pumping (flex-i-liner pump) (time depends on pumping capacity), horizontal or vertical traction through the water (10' for 10 m deep bags.)

Sampling: Ball samplers (Brockmann and Hentzschel 1983. Mar. Ecol. Progr. Ser. *14*: 107-109) or silicon tubes (vacuum).

Key References:

Brockmann *et al*. 1974. Mar. Biol. *24*: 163-166.
Brockmann *et al*. 1977. Helgol. wiss. Meeresunter. *30*: 201-216.
Brockmann *et al*. 1983. Mar. Ecol. Prog. Ser. *14*: 1-8.
Kuiper *et al*. 1983. Mar. Ecol. Prog. Ser. *14*: 9-17.

Comments: Up to now about 30 papers have been published. The system is still in use and has also been introduced to Dutch and Norwegian scientists. The general advantages are (i)quick and easy launching; (ii) smooth, physiologically inert, impermeable, flexible and translucent bag material; (iii) different depths depending on location. Some disadvantages (i) subject to wave action and changes in salinity (ii) size limitation.



DESCRIPTION OF EQUIPMENT

Specific Name: Controlled Ecosystem Enclosure (CEE)

Size:	Small	Large
Depth:	16.0 m	29.0 m
Diameter:	2.5 m	10.0 m
Volume:	64.0 m^3	1300.0 m^3

Material: Polyethylene reinforced with nylon thread.

Purpose: Trophodynamics of the pelagic community

Application: Coastal ecosystem research; pollutant response; larval and juvenile fish growth dynamics. Experiments run for 15 to 90 days.

Location: Saanich Inlet, British Columbia, Canada.

Contact Address: Department of Oceanography, University of British Columbia, Vancouver, B.C. V6T 1W5

Filling: From the bottom, using an air filled flotation collar to raise the bag walls to the surface. Final volume added with pumps to assure turgidity of columns.

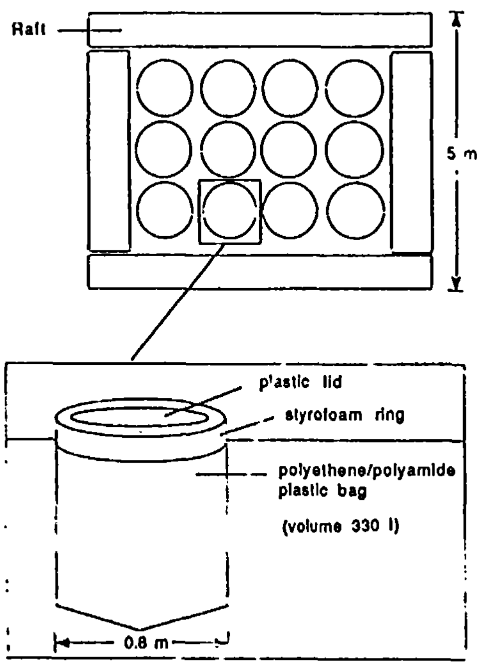
Sampling: Peristaltic pump for nutrients. Diaphragm (compressed air) pump for phytoplankton and zooplankton.

Key References:

Menzel, D.W. and Case J. 1977. Bull. Mar. Sci. *27*: 1-7.

Case, J. 1978. Rapp. P.V. Reun. cons int. Explor. Mer.*173*: 49-58.

Comments: Over 50 papers have been published on scientific results using the equipment described above. Most of these occurred as part of the Controlled Ecosystem Pollution Experiment Program (CEPEX) sponsored largely by the National Science Foundation (U.S.A.). Unit cost of small and large CEEs including mooring system, $30,000 and $100,000, respectively, in 1975.



DESCRIPTION OF EQUIPMENT

Specific Name: Phytoplankton Ecology Mesocosm (PEM)

Size:	Cylindrical plastic sacks
Depth:	Varies with the individual experiments
Diameter:	0.8 m
Volume:	Varies with length
Material:	Two-layer plastic. (polyethene/polyamide)
Purpose:	Trophodynamic studies in the pelagic system.
Application:	Coastal ecosystem approaches, response of the system to nutrient additions and changes in the grazing pressure by meso- and macro-zooplankton.

<u>Location</u>: Gullmar Fjord on the Swedish west coast.

<u>Contact Address</u>: Department of Marine Ecology. University of Lund. Box 124, S-221 00 Lund, Sweden.

<u>Filling</u>:

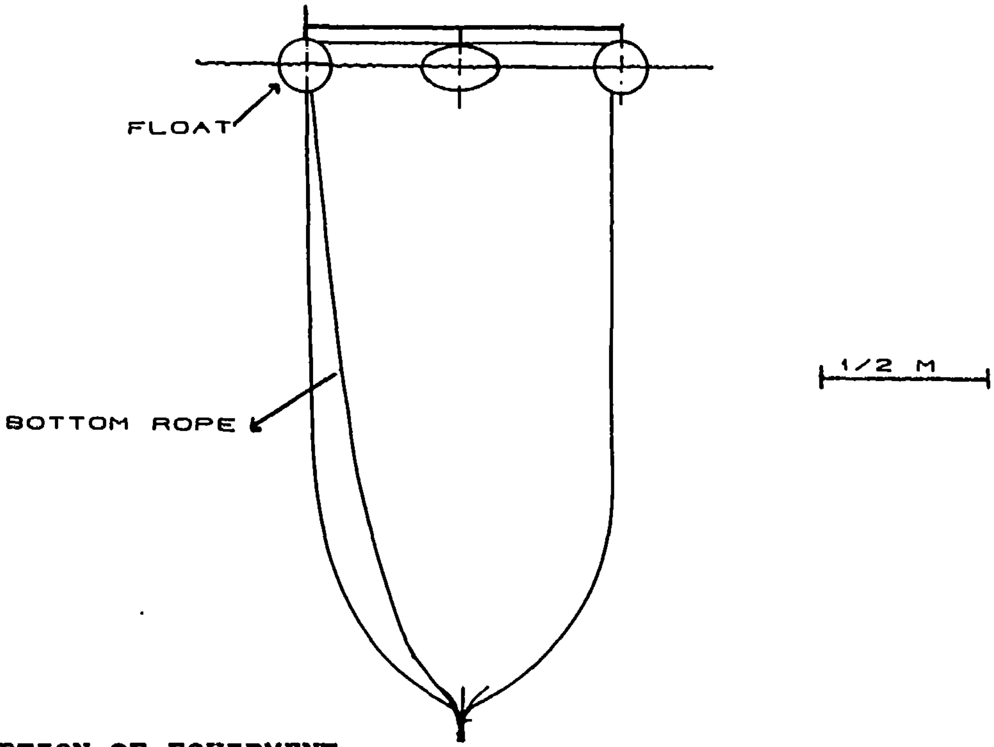
<u>Sampling</u>:

<u>Key References</u>:

Olssen, P. *et al.* Mesocosm studies of zooplankton grazing on a natural phytoplankton community on the Swedish west coast. (in press)

Graneli, E. *et al.* *In* A novel phytoplankton bloom - causes and impacts of recurrent brown tides. Ed. M Cosper. Springer - Verlag. (in Press)

<u>Comments</u>: The described mesocosm system has been used successfully several times. Besides phytoplankton-zooplankton relationships, the influence of a small commercial fish (*Sprattus sprattus*)was also studied in some of the experiments.



DESCRIPTION OF EQUIPMENT

Specific Name: Plastic Bag

Size:

Diameter:	0.95 m	1.25 m
Volume:	2 m^3	4 m^3

Material: Black Polyethylene

Purpose: Fish larvae studies

Application: Parallel groups of larvae to the one in the large macrocosms (see pages 167-168 and 104-105) were run in plastic bags. In these bags three food levels were established, all being purposely below the one in the macrocosm. Typical larval densities were from 0.1-0.2 larvae/litre. Complete bag termination within each food level gave survival and growth rates within time intervals, normally 10-15 days. Final termination was normally 30-50 days after larval transfer. Such parallel studies were carried out with larvae of herring, capelin and turbot.

Location: Flodevigen Biological Station, activity from 1977 to 1980

Contact Address: Institute of Marine Research
Box 1870,
N-5024 Bergen, Norway

Filling: Bags were filled with filtered seawater (through a 350μm mesh net) from the macrocosm.

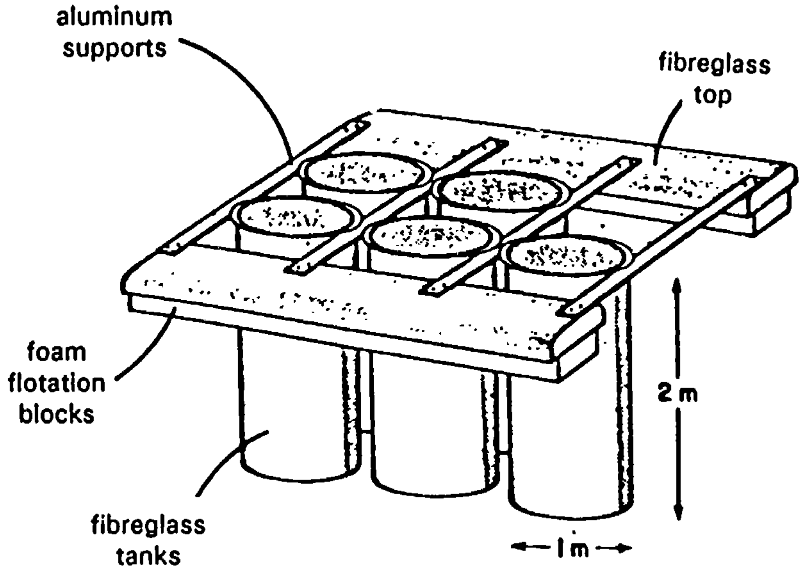
Sampling: At each food level three bags were initiated and the bags were terminated at 10 to 15 day intervals by sieving all the water through a 350μm mesh net by inverting the bags. Zooplankton was sampled in between terminations by tube and pump sampling.

Key References:

Oeiestad, V. and E. Moksness, 1981. Study of growth and survival of herring larvae *(Clupea harengus L.)* using plastic bag and concrete enclosure methods combined. Rapp. P.-v. Reun. Cons. Perm. int. explor. mer. *178*: 144-149.

Comments: In some bag experiments the food level was maintained by adding natural zooplankton while in others no further supply took place. Plastic bag studies were also carried out with larvae of cod, turbot and halibut.

The use of plastic bags has increased sharply in Norway in the late eighties both for scientific purposes and for large-scale production of juvenile marine fish species with the activity concentrated on cod, turbot and halibut.



DESCRIPTION OF EQUIPMENT

Specific Name: Portable Marine Enclosure (PME)

Size:
Depth: 2.0 m
Diameter: 1.0 m
Volume: 1.5 m^3

Material: Fiberglass tanks, optionally lined with polyethylene (4 mil) bags.

Purpose: Fate and pathways of marine pollutants, using a ship-portable enclosure to reach remote sites.

Application: Release of metals from Alice Arm (AMAX) mine tailings; release of metals from False Creek sediments in high and low light, oxic and anoxic conditions; degradation of crude oil in low light environments.

<u>Location</u>: Patricia Bay, B.C. Canada. One remote experiment in Alice Arm, B.C., Canada.

<u>Contact Address</u>: Ocean Chemistry, Institute of Ocean Science, P.O. Box 6000, Sidney, B.C. V8L 4B2

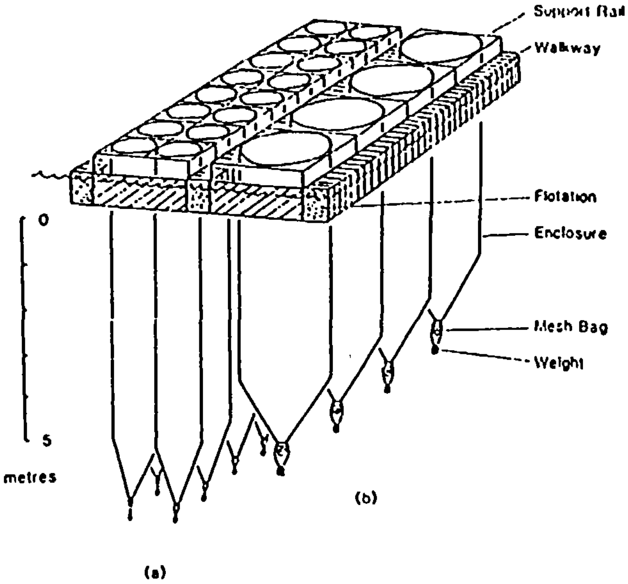
<u>Filling</u>: By pump. In Alice Arm, a clean pumping system, (teflon and polyethylene only in contact with sea water) filled 2 tanks with water from 50 m depth. Depths to 300 m are possible.

<u>Sampling</u>: By pump.

<u>Key References</u>:

Wong, C.S., F.A. Whitney, , W.K. Johnson and W.J. Cretney, in prep. Application of experimental enclosures for the study of pathways and fate of chemical pollutants. <u>In</u>: Proceedings of the International Marine Ecosystem Enclosure Experiments at Beijing, China, May 10 - 14, 1987. Ed.: C.S. Wong and P.J. Harrison. Publ. International Development Research Council, Ottawa, Canada.

<u>Comments</u>: Small volume restricts biological observations to bacteria and phytoplankton. Opaque walls allow simple light limitation with black covers.



DESCRIPTION OF EQUIPMENT

Specific Name: Loch Ewe Mini-bag System

Size:	(a)	(b)
Length:	8 m	6.5 m
Diameter:	1 m	2 m
Volume:	5 m^3	15 m^3
No. Units:	16	8

Material: (a) Translucent Nylon-reinforced PVC
(b) Opaque (black) Nylon-reinforced PVC

Purpose: Trophodynamics of the pelagic community, Pollution Chemistry.

Application: Coastal ecosystem research, pollution research-sewage sludge, Radioisotope studies in food chain dynamics, predator-prey experiments with fish larvae.

Location: Loch Ewe, Scotland, U.K.

Contact Address: Marine Laboratory, P.O. Box 101, Victoria Road, Aberdeen, Scotland, U.K. AB9 8DB.

Filling: May be filled either by lifting or with a pump.

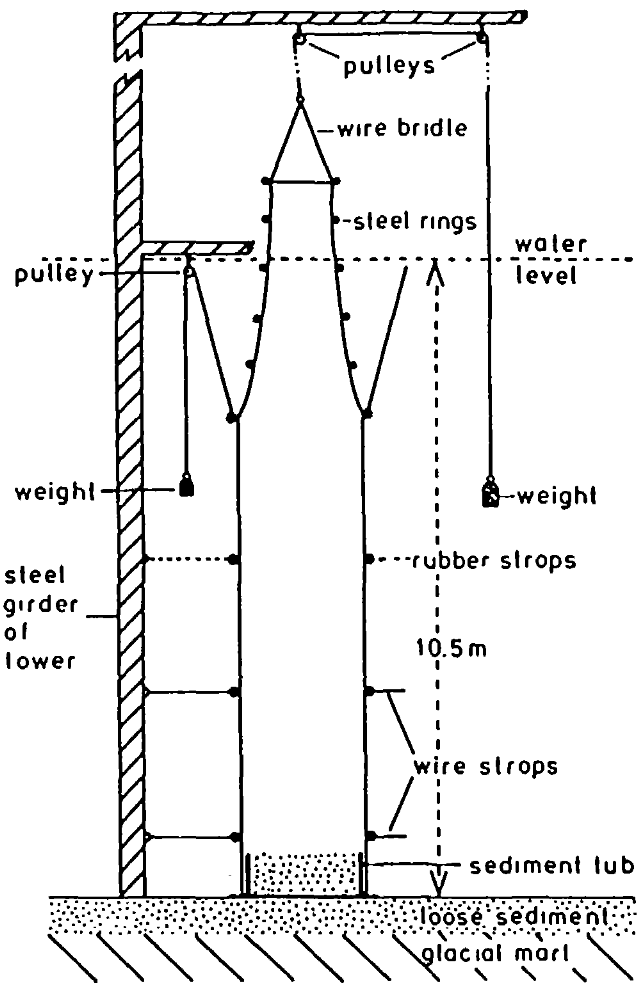
Sampling:

Key References:

Gamble, J.C. and L.A. Fuiman. 1987. J. Exp. Mar. Biol. Ecol. *113*: 91-103

Fuiman, L.A. and Gamble, J.C. 1988. Mar. Ecol. Prog. Ser. *44*: 1-6.

Comments: This is a self-contained system which can be linked to a service raft for pumping facilities etc. It is ideal for shorter-term experiments with replication. Sampling hoses can be fitted instead of mesh bags, when bags are fitted the enclosure is sealed with a removable plug. Contents can be drained through the mesh bag by lifting the enclosure out of water.



DESCRIPTION OF EQUIPMENT

Specific Name: Kiel Plankton Tower.

Size:

Depth: 11 m

Diameter: 2 m

Volume: 30 m^3

Material: Nylon mesh coated with polyethylene.

Purpose: Study of water column/sediment interaction.

Application: Production, grazing and sedimentation in water column; oxygen uptake, nutrient release from sediments; Seasonality of processes.

Location: Kielbight, Boknis Eck.

Contact Address: Alfred-Wegener-Institut für Polar Und Meeresforschung, Columbusstraße, D-2850 Bremerhaven, FRG.
and
Institut für Meereskunde, Düsternbrooker Weg 20, D2300 Kiel, FRG

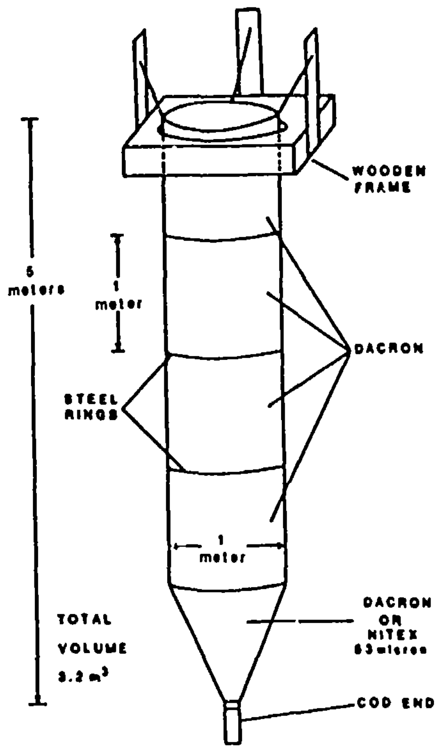
Filling:

Sampling:

Key References:

Smetacek et al. The Plankton Tower. IV. Interactions between water column and sediment in enclosure experiments in Kiel Bight. In: Marine Mesocosms. G.D. Grice and M.R. Reeve (Eds.) 205-216. Springer Verlag.

Comments: The bags were suspended in a steel frame (16.5 m tall x 10 m x 10 m) standing on the sea bottom.
Cannot be used in areas with large tides.



DESCRIPTION OF EQUIPMENT

Specific Name: Larval fish Enclosure.

Size:
Depth: 5 m
Diameter: 1 m
Volume: 3.2 m^3

Material: Dacron sail cloth for cylindrical section; Nitex or Dacron conical selection.

Purpose: Studies of the growth and feeding of larval fish.

Application: Applied to the study of larval capelin (Mallotus villosus) feeding with respect to prey size; appropriate for additional studies on larval growth and predation.

Location: Bryant's Cove, Newfoundland; Conception Bay, Newfoundland

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Contact Address: Fisheries and Oceans Canada,
Institut Maurice Lamontagne
B.P. 1000,
Mont-Joli, Quebec. G5H 3Z4, Canada.

Filling: Diffusion of water through the walls requiring 1.5h for full Dacron construction and less than 5 min for the Nitex cone construction.

Sampling: *In situ* probes and diaphragm pumps (3 litres per minute) for nutrients; plankton and larvae sampled with Jabsco submersible pump (37 litres per minute).

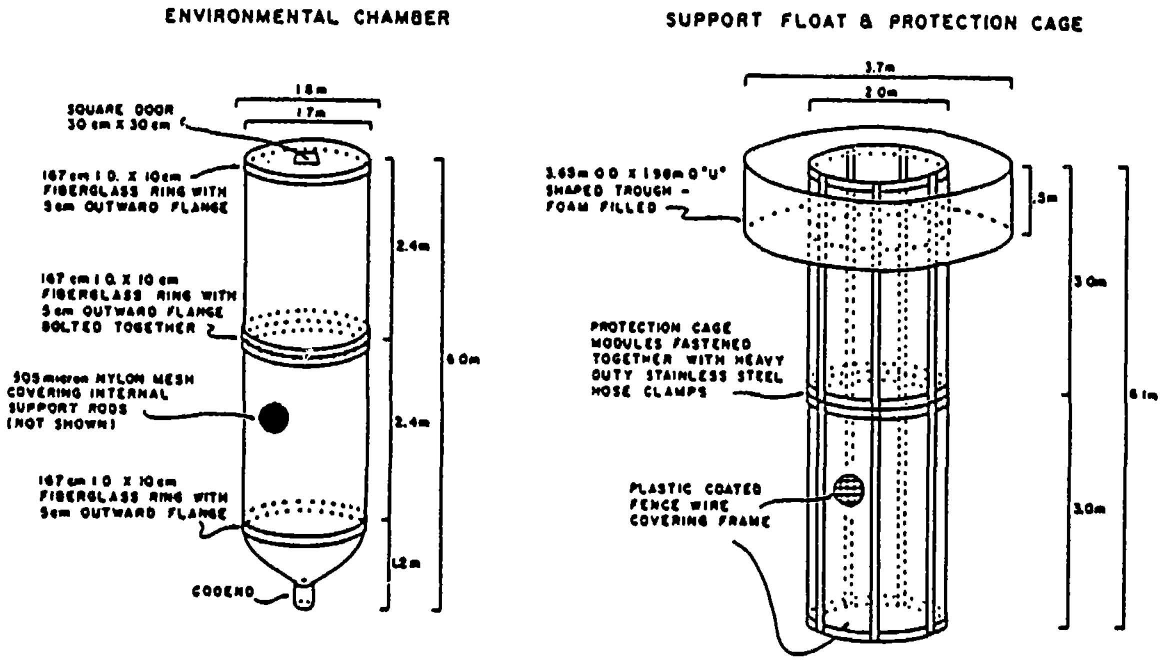
Key References:

Y. de Lafontaine and W.C. Leggett. 1987. Can. J. Fish Aquat. Sci. *44*: 54-65.

Y. de Lafontaine and W.C. Leggett. 1987. Can. J. Fish Aquat. Sci. *44*: 1534-1543.

Y. de Lafontaine and W.C. Leggett. 1988. Can. J. Fish Aquat. Sci. *45*: 1173-1190.

Comments: Semiporous (Dacron *ca* 25μm; Nitex 53μm pore size, respectively) materials allowed for accurate reproducibility of the physico-chemical conditions within the containers compared with external environment. Initial experiments of up to one week but probably suitable for 4 week experiments. The advantage of semiporous materials for the simulation of natural conditions may be disadvantageous for experiments on the effects of soluble pollutants on larval survival. Cost in 1987 US $1200.



DESCRIPTION OF EQUIPMENT

Specific Name: Environmental Chamber for larval fish.

Size:

Depth: 6 m

Diameter: 1.8 m

Volume: 11.5 m^3

Material: Environmental Chamber: 505μm nylon mesh. Protection cage: plastic coated fence wire.

Purpose: Monitor growth and survival of larval fish.

Application: Study of winter flounder larval survival over a period of 2 weeks.

Location: Lower basin of the Pettaquamscutt River, Rhode Island U.S.A.

Contact Address: United States National Marine Fisheries Service, Northeast Fisheries Center, Narraganset, R.I. 02882 USA.

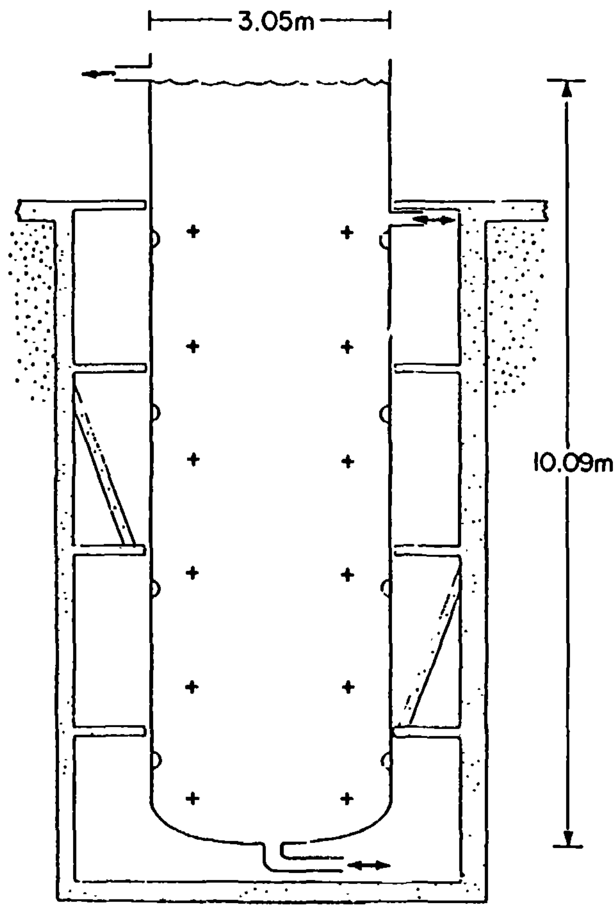
Filling: Larval fish environmental chamber was filled as it was lowered into the protection cage. 505μm mesh allowed retention of larval fish but eliminated easy passage of zooplankton from surrounding water.

Sampling: Zooplankton and seawater samples collected with a Niskin bottle; fish larvae collected at the end of the 2 week experiment by raising the environmental chamber and capturing larvae in the cod end.

Key References:

Laurence, G.C., T.A. Halvik, B.R, Burns and A.S. Smigielski. 1979. Trans. Amer. Fish. Soc. *108*: 197-203.

Comments: Survival rate of larvae after 2 weeks was 77%; growth rates were *ca* 11%/day dry weight. Properties of seawater, including zooplankton were the same inside and outside the environmental containers.



DESCRIPTION OF EQUIPMENT

Specific Name: Tower Tank.

Size:

Depth:	10.09 m
Diameter:	3.05 m
Volume:	73.0 m^3

Material: 6.45 mm hot rolled steel with an inner lining of a matte finished black plastic (laminar x 500). Insulated outside with polyurethane.

Purpose: Plankton dynamics; observations on vertical distributions.

Location: La Jolla, California.

Contact Address: Hydraulic Laboratory, Scripps Institute of Oceanography, University of California, La Jolla, California 92093, U.S.A.

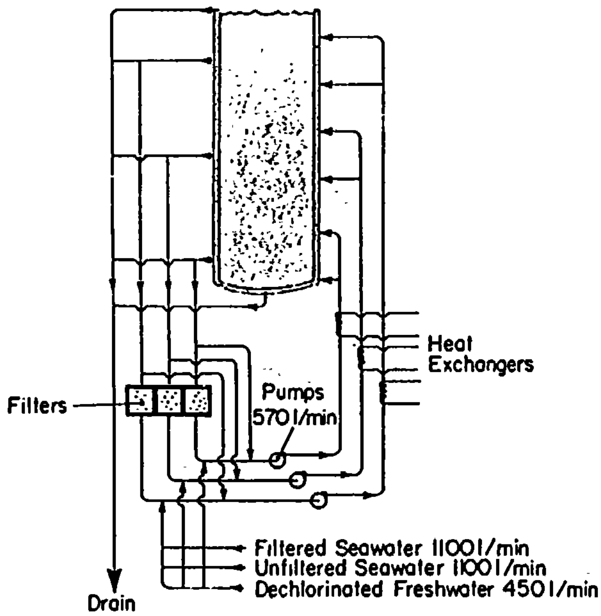
Filling: Pumped seawater. Can be chilled or filtered. Artificial lighting provided as overhead metal halide lamps.

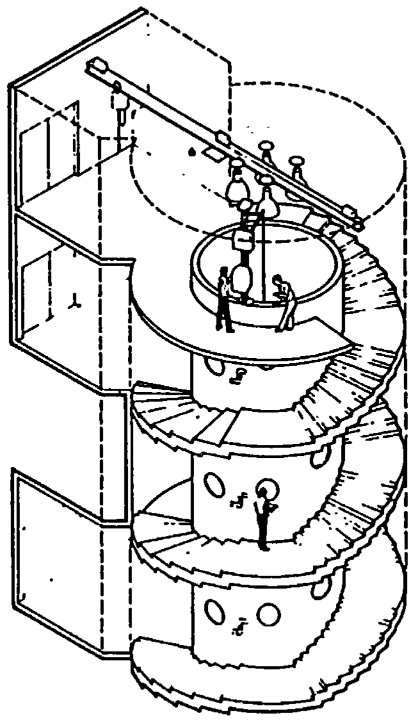
Sampling: Sampling ports located on the side of the tower; nets or bottles as required, from overhead scaffolding.

Key References:

Strickland, J.D.H., O. Holm-Hansen, R.W. Eppley and R.J. Linn. 1969. Limnol. Oceanogr. *14*: 23-34.

Comments: Good habitat control for plankton populations up to *ca* 100 days; disadvantage is a lack of replication.





<u>Specific Name</u>: Aquatron Tower Tank

<u>Size</u>:

Depth:	10.46 m
Diameter:	3.66 m
Volume:	108.00 m^3

<u>Material</u>: Concrete lined with polyvinyl chloride. Insulated. Helical stairway to access 26 viewing ports (plate glass) and 10 sampling ports. 6 overhead metal halide lamps, chain hoist and hydro winch. Removable vertical divider.

<u>Purpose</u>: Provides mesocosm-scale, controlled-environment marine tank for biological research and equipment development/testing.

<u>Application</u>: Plankton dynamics and vertical swimming behaviour; diving physiology of birds, cephalopods and fish; aquaculture physiology; larval fish growth and mortality; spawning and visual acuity of squid; temporal variations in trace metal concentrations during phytoplankton bloom; copepod population dynamics; behaviour of the red crab, <u>Pleurocodes</u>; rearing of larval fish; swimming and feeding behaviour of pteropods; photodecomposition of organic matter; mass culture of plankton for biochemical analysis.

<u>Location</u>: Dalhousie University Campus.

<u>Contact Address</u>: Aquatron Laboratory,
Life Sciences Centre
Dalhousie University, Halifax, Nova Scotia, Canada, B3H 4J1

<u>Filling</u>: Pumped, filtered seawater (1 micron filters), with temperature and/or salinity manipulation in static or flow-through modes, with or without stratification.

<u>Sampling</u>: Bottles, pumps or nets deployed from the surface; or from wall-penetrating sample ports at 1m depth intervals. Non-destructive observations with underwater camera or via viewing ports. Removable vertical divider permits replication.

<u>Key Reference</u>:

Balch, M., C. Boyd and M. Mullin. 1978. Rapp. P.v. Cons int. Explor Mer, *173*: 13-21.

<u>Comments</u>: Equipment has the advantage of allowing direct visual observations. Disadvantages include cost of a single unit and the lack of replicate containers. Artificial lights give good radiation control but raise problems of surface heating.

(see next page)

DESCRIPTION OF EQUIPMENT

Specific Name: Aquatron Pool Tank

Size:
- Depth: 3.54 - 3.91 m
- Diameter: 15.24 m
- Volume: 984 m^3

Material: Concrete lined with PVC. 22 under-water viewing windows. Axially suspended rotating bridge spans tank. 20 overhead mercury lamps. Small connecting isolation tank.

Purpose: Provides mesocosm-scale, controlled-environment marine tank for biological research and equipment development/testing.

Application: Chemotherapy of seals to control codworm; finfish and shellfish tainting by hydrocarbons; lobster social behaviour; squid physiology, swimming energetics and early life history; aquaculture physiology; testing of fishing gear, plankton nets, ROV, etc.; genetics of salmon maturation; acoustic target strengths of fish.

Location: Dalhousie University Campus

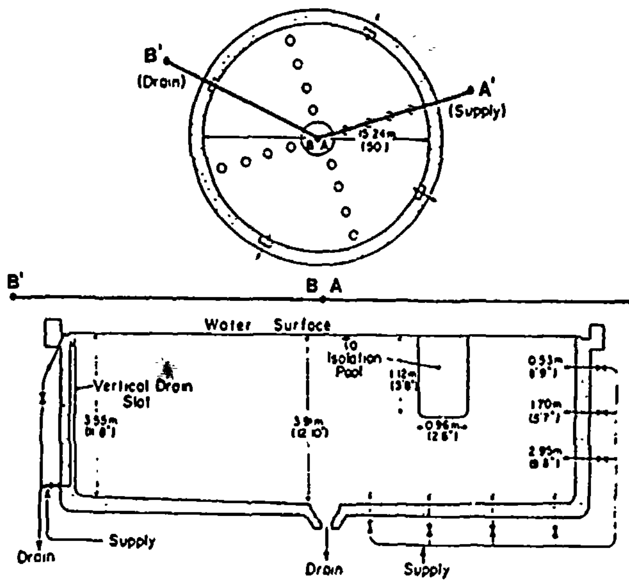
Contact Address: Aquatron Laboratory, Life Sciences Centre, Dalhousie University, Halifax, Nova Scotia, Canada. B3H 4J1

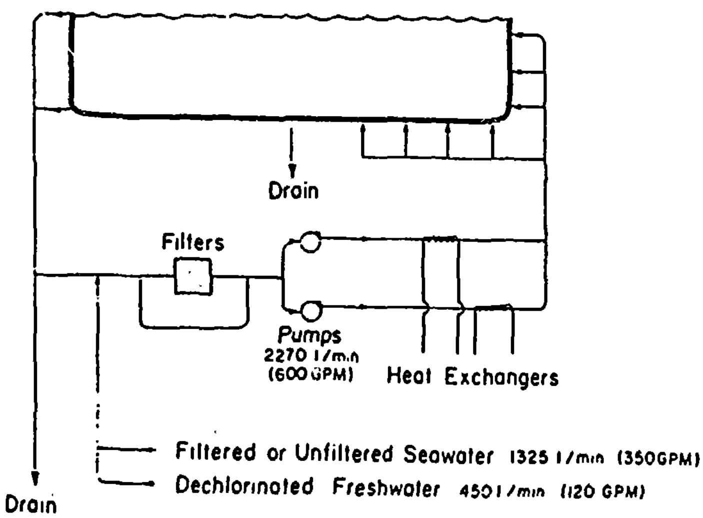
Filling: Pumped, filtered seawater, with temperature and/or salinity manipulation in static or flow-through modes.

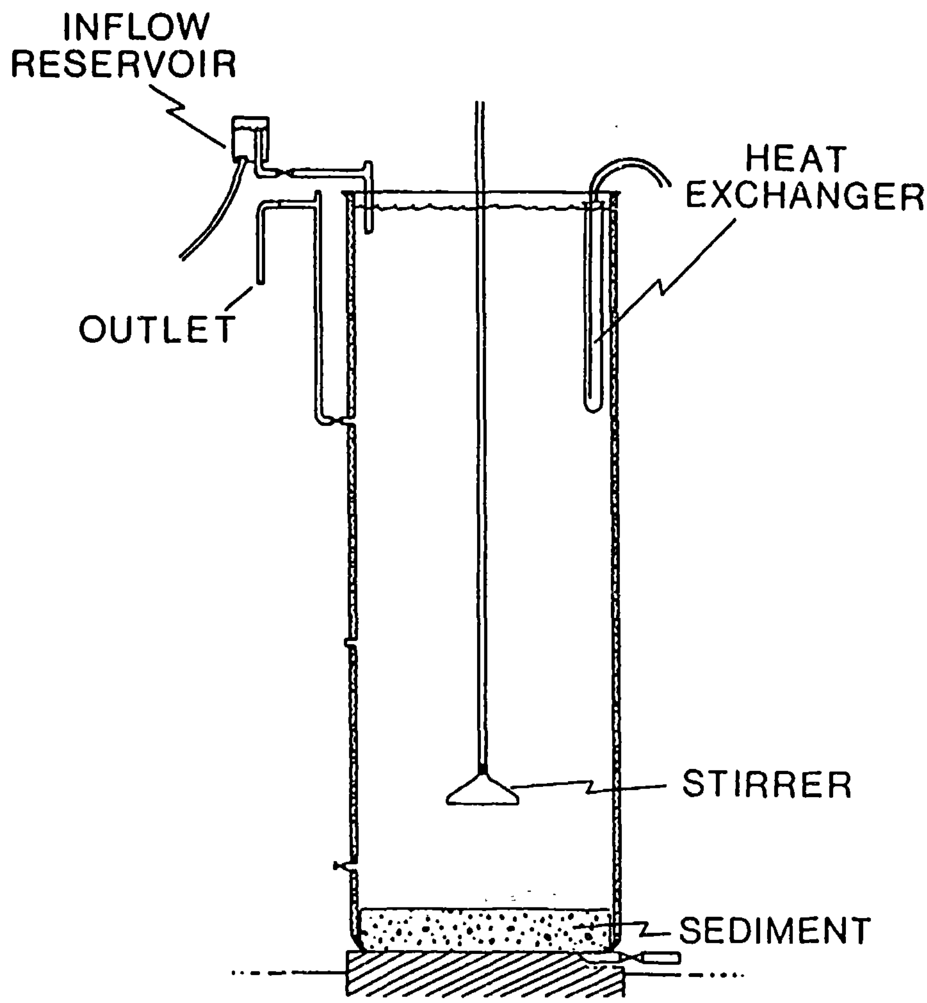
<u>Sampling</u>: Bottles, pumps or nets deployed from surface; Non-destructive observations with underwater camera or via viewing windows.

<u>Key References</u>:
O'Dor, R.K., R.D. Durward, and N. Balch. 1977. Biol. Bull., *153*: 322-335.

<u>Comments</u>: Tank volume has allowed maintenance of oceanic squid, not possible in smaller tanks.







DESCRIPTION OF EQUIPMENT

Specific Name: Marine Ecosystem Research Laboratory (MERL) Tank

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Size:

Depth:	5.4 m
Diameter:	1.8 m
Volume:	13 m^3

Material: Fibreglass, land based. Insulated walls and heat exchanger maintain temperature ± $2^{o}C$.

Purpose: Perturbation of ecosystems by pollutants including both pelagic and benthic habitats.

Application: Used in the study of heavy metal and oil pollution; computer model studies; natural environmental change; eutrophication.

Location: Narraganset Bay, Rhode Island, U.S.A.

Contact Address: Marine Ecosystem Research Laboratory, Graduate School of Oceanography, University of Rhode Island, Rhode Island, 02281, U.S.A.

Filling: Pumped seawater from bay. Sediment added prior to the experiment.

Sampling: Water column is mixed with a plunger (2h on, 4h off) so that uniform samples can be obtained.

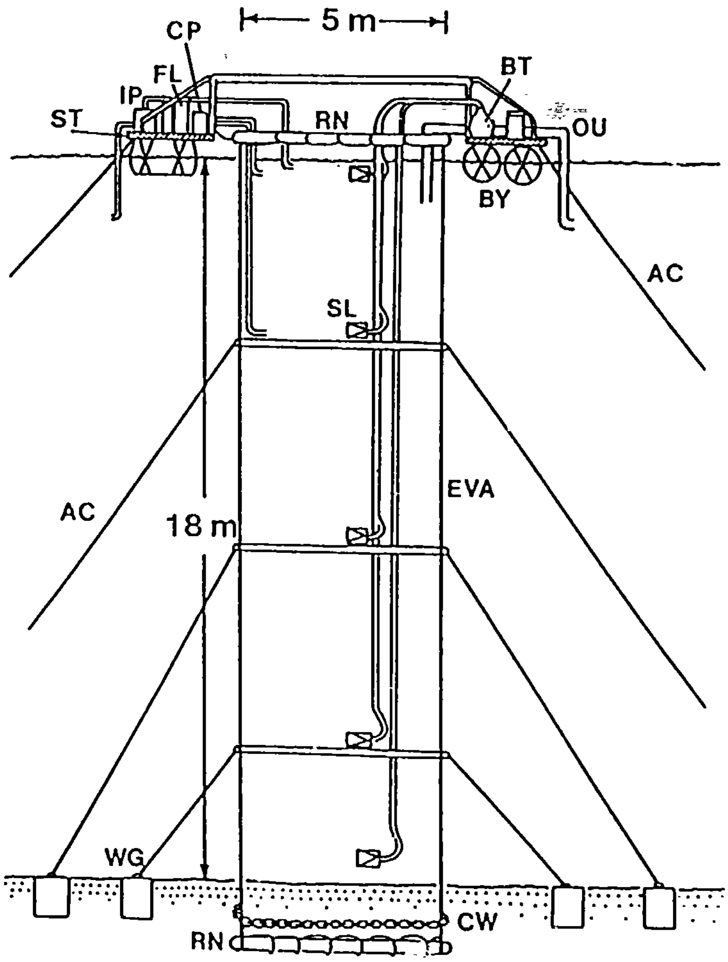
Key References:

Oviatt, C.A. *et al.* 1980. Mar. Ecol. Prog. Ser. *2*: 179-191.

Oviatt, C.A. *et al.* 1989. J. Plankton. Res. *11*: 1223-1244.

Comments: Various experiments indicate that this shore based facility is an acceptable analog of the Narraganset Bay ecosystem. Continuous flow through into replicate tanks together with tidal mixing (plunger) provides an experimental simulation of near shore ecology. Up to nine replicates can be run simultaneously.

Mesocosm enclosure open in contact with the sediment.
AC- anchor rope; BT- 5 litre sampling bottle; BY- buoy; CP- circulation pump; CW- chain weight; EVA- ethylenevinylacetate sheet; FL- filter for inflow seawater; IP- pump for inflow seawater; OU- outflow; RN- supporting steel ring; SL- sampling; ST- loading stage; WG- weight.



DESCRIPTION OF EQUIPMENT

Specific Name: NIES Mesocosm

Size:

Depth: 18 m
Diameter: 5 m
Volume: 350 m^3

Material: Ethylene vinylacetate reinforced by polyester grids.

Purpose: Perturbation of ecosystems by eutrophication (N and P enrichment)

Application: Used to study simulated red tide bloom.

Location: Harima Nada, Seto Inland Sea, Japan.

Contact Address: Laboratory of Marine Environment, The National Institute for Environmental studies, Yatabe-machi, Tsukuba, Ibaraki 305, Japan.

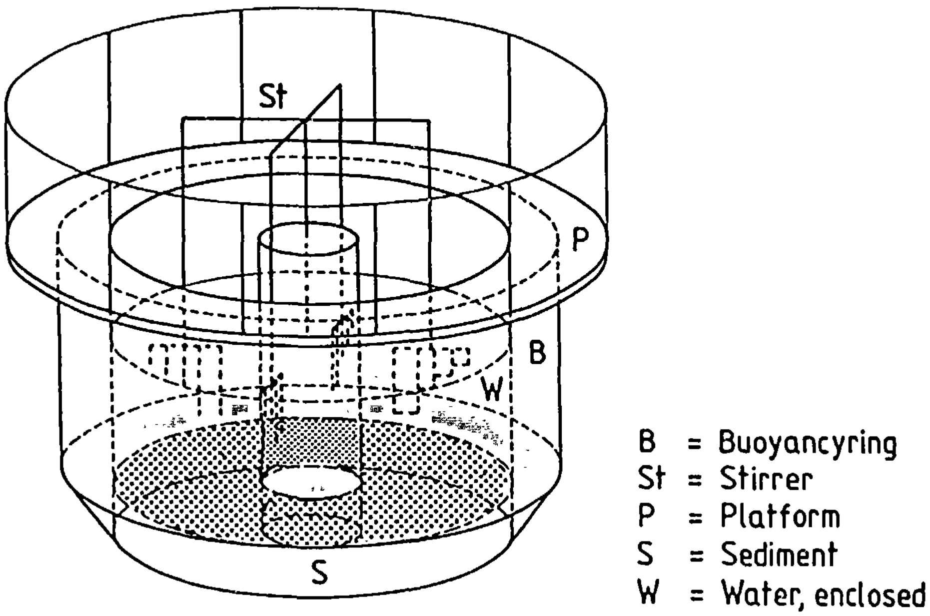
Filling: Natural seawater enclosed with sediment.

Sampling: Water sampled at 5 levels (0, 5, 10, 15, and 18 m) through silicon aspirator tubes.

Key References:

Kohata, K. and M. Watanabe. 1989. J. Exp. Mar. Biol. Ecol. (submitted)

Comments: Cannot be used in areas with large tides.



DESCRIPTION OF EQUIPMENT

Specific Name: Combined Estuarine Tidal Enclosures (CETE)

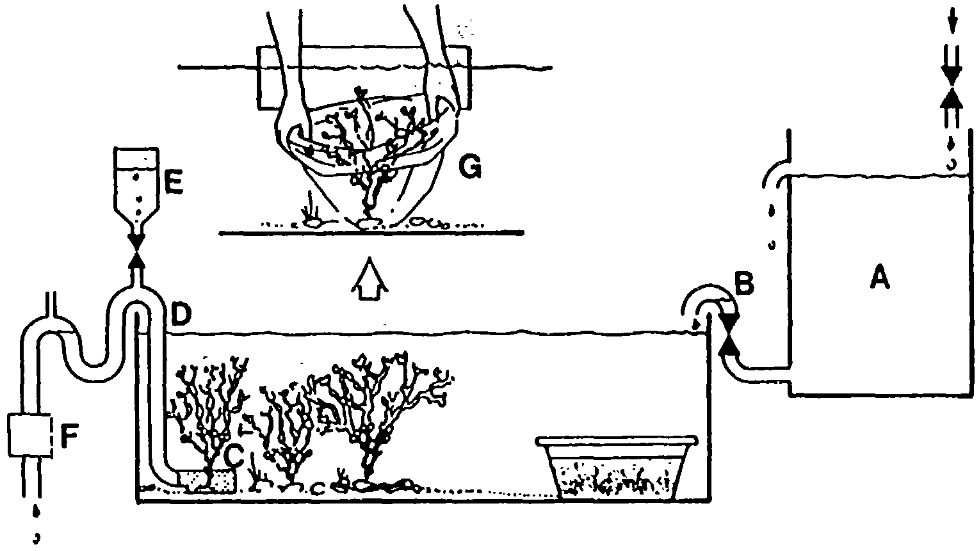
Size:
Depth: 2 m
Diameter: 4 m
Volume: 20 m^3

Material: Glass fibre plastic

Purpose: Pelagic-benthic process studies of tidal estuaries

Application: Estuarine and coastal ecosystem research, transfer and transformation of chemicals including pollutants, tidal dynamics of suspended matter, effects of turbidity maxima. Experiments planned for 30-90 days.

Location:	Lower estuary of river Elbe.
Contact Address:	Institut for Biogeochemistry and Marine Chemistry, University of Hamburg, Martin-Luther-King-Platz 6, D-2000 Hamburg 13, FRG
Filling:	Sediments will be filled in once a year. After preconditioning of the sediment, the system will be pumped full of water. Then water will be exchanged with the intermediate and counterpart enclosed systems to simulate the tidal effects of changing salinity. Tidal currents will be imitated by stirring.
Sampling:	Sediment cores (replacement), ball sampler, tube systems.
Key References:	Under construction. SFB 327, Hamburg, Grant proposal.
Comments:	Mobile estuarine pelagic-benthic mesocosms are under construction and will be located at sheltered places within the Elbe estuary.



A. Water reservoir. B. Valve restricting flow. C. Strainer. D. Siphon. E. Gas trap. F. Flow meter. G. Collection in plastic bags.

DESCRIPTION OF EQUIPMENT

Specific Name: Littoral ecosystem

Size:

Depth: 0.75 m

Diameter: 1.5 m

Volume: 4.2 m^3

Material: Polyethylene liner for PVC "swimming pool".

Purpose: Simulation of intertidal environments.

Application: Assessment of pollutant stress; studies on the natural ecology of nearshore ecosystems including verification of mathematical models.

Location: Studsvik (70 km south of Stockholm); 200 m from the sea shore.

Contact Address: Swedish Water and Air Pollution Research Laboratory, Stockholm, Sweden.

Filling: Water taken 100 m offshore at a depth of 100m. Pumped water with no metal parts coming in contact with water.

Sampling: Plastic bags for large flora, see diagram, G; also water samples siphoned from container.

Key References:

Notini, M., B. Nagell, A. Hagstrom and O. Grahn. 1977. Oikos, *28*: 2-9.

Comments: Flow through system at 2.5 litres / min. Good quantitative and qualitative agreement between the character of the mesocosm and natural littoral ecosystems.

DESCRIPTION OF EQUIPMENT: see next page

Specific Name: Bremerhaven Caissons

Size:

Depth: 2m (intertidal)

Volume: 13 m^3

Area: (benthic area : 13 m^3)

Material: Aluminum walls, polycarbonate windows.

Purpose: Intertidal field studies

Application: Bioaccumulation studies of lead, chromium and cadmium. Biological fate of oil and oil dispersants.

Location: German Bight, FRG.

Contact Address: Institut fur Meeresforschung,
Bremerhaven, Am Handelshafer 2,
D-2850 Bremerhaven,
Federal Republic of Germany.

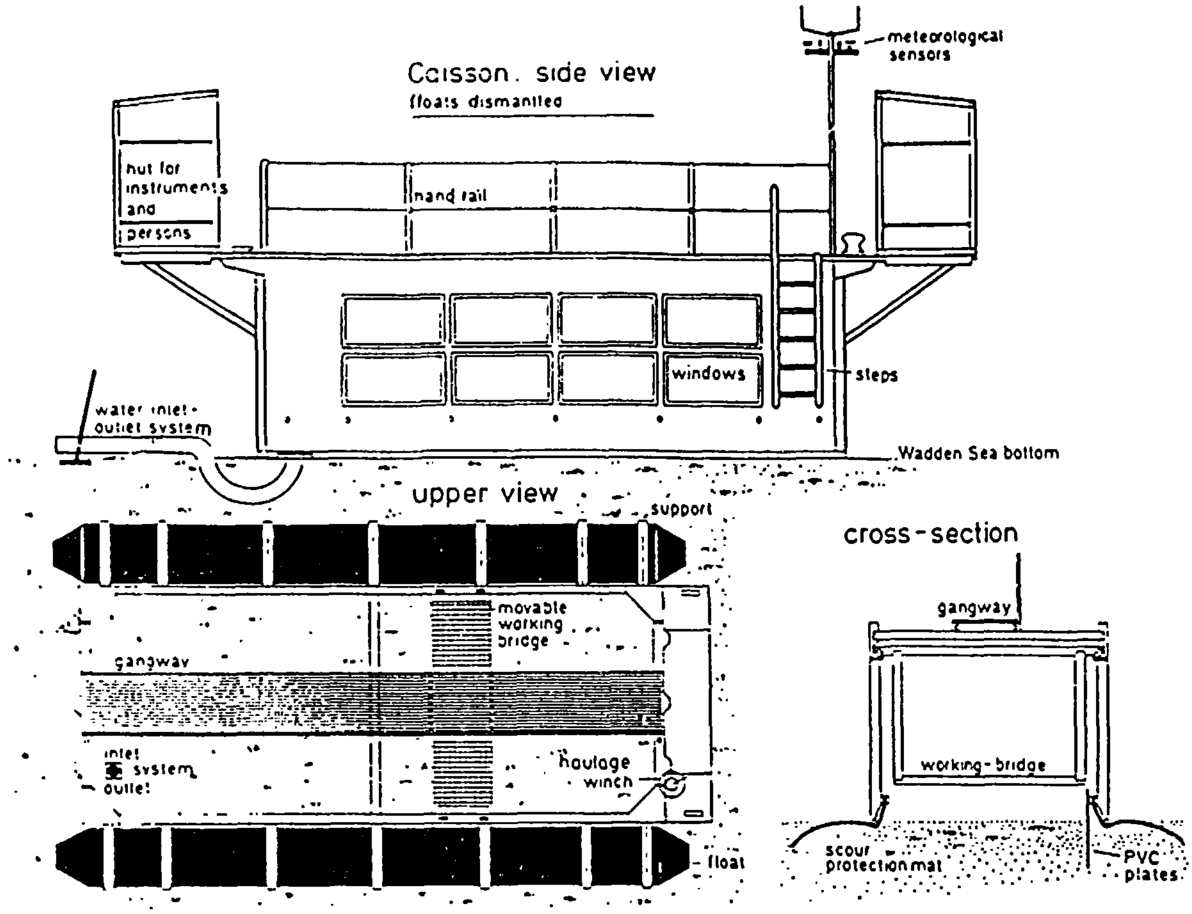
Filling: Filled tidally twice a day through inlet tube.

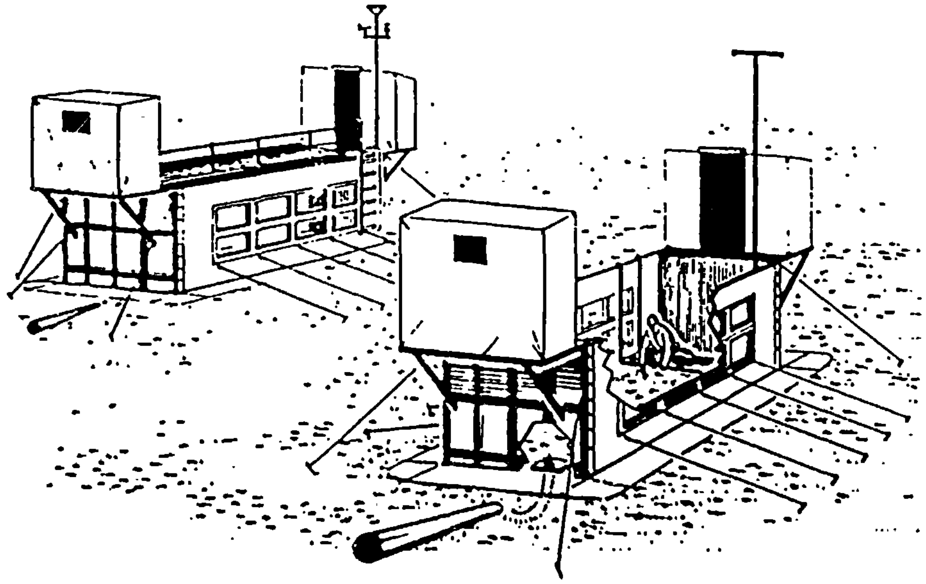
Sampling: Some automated collection of environmental data. Conventional sampling of biota.

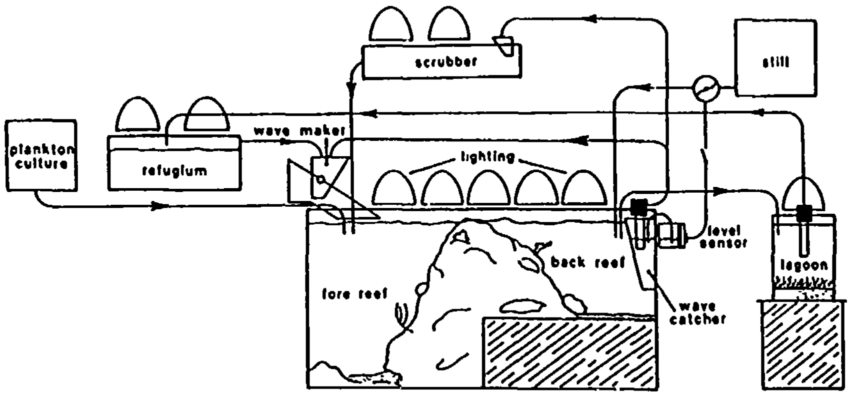
Key References:

Farke, H., M. Schulz-Baldes, K. Ohm and S.A. Gerlach. 1984. Mar. Ecol. Prog. Ser. *16*: 193-197.

Comments: Used for relatively short term experiments lasting *ca* 4 weeks. Equipment is easily assembled and can be transported to different sites.


Caisson. side view
floats dismantled
meteorological sensors
hut for instruments and persons
hand rail
windows
steps
water inlet-outlet system
Wadden Sea bottom
upper view
support
movable working bridge
gangway
inlet system outlet
haulage winch
float
cross-section
gangway
working-bridge
scour protection mat
PVC plates





DESCRIPTION OF EQUIPMENT

Specific Name: Coral Reef Microcosm

Size:

Depth:	18 m
Diameter:	1.2 m wide; 3.7 m deep
Volume:	7 m^3

Material: glass/calcium carbonate substrate.

Purpose: Exhibition/education; research.

Application: Maintenance of diversity in an artificial system; animal behaviour; algal nutrient response.

Location: Smithsonian Institution, Washington DC USA.

Contact Address: Marine Systems Laboratory, Smithsonian Institution, Washington D.C. 20560.

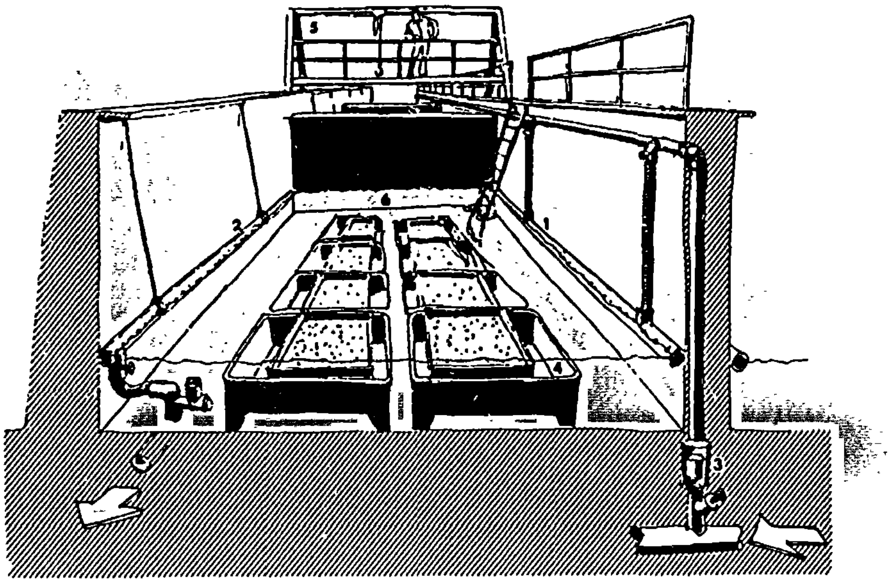
Filling: Initially artificial seawater gradually replaced with coarse filtered outer coastal water.

Sampling: Non-destructive - bottle samples, probes etc.

Key References:

Adey W.H. 1983. Coral Reefs *1*: 193-201.

Comments: Experimental ecosystem has separate components for plankton culture, refugia and lagoon organisms as indicated in the illustration above. Cost of materials in 1982, $10,000 - $20,000. Maintenance - needs attention approximately every second day.



Schematic drawing of one of the two basins in the mesocosm. The second basin is indicated on the right hand side of the figure. 1: perforated tube for inflow of water; 2: perforated tube for outflow; 3: flowmeter; 4: box containing liner with sediment; 5: movable bridge; 6: partition dividing each basin into three compartments.

DESCRIPTION OF EQUIPMENT

Specific Name: Solbergstrand Soft bottom Sublittoral mesocosm.

Size: six units each:

Depth: from 0 to 1.7 m

Bottom: 28 - 39 m^2

Volume: 30 m^3

Material: Concrete basins coated with epoxy resin. Box core samples transferred in PVC liners. Overhead lighting with incandescent lamps.

Purpose: Dynamics and structure of sediment communities.

Application: Benthic boundary fluxes, porewater chemistry, bacterial production, soft bottom dynamics, long term pollutant effects and recovery, treatment of contaminated residues. Experiments of up to 1 year duration can be run depending on treatments desired.

Location: NIVA Marine Research Station Solbergstrand (Near Drobak, Oslofjord, Norway).

Contact Address: Norwegian Institute for Marine Research P.O. Box 333, Blindern, N-0313, Oslo 3, Norway.

Filling: Seawater from 42m supplied with an impeller pump. Maximum flow 12 m^3h^{-1} or 4 m^3h^{-1} into each compartment. Compartments filled with samples taken by a box corer fitted with an internal PVC liner. The liner will constitute the outer wall of the sediment sections when in position. Groups of cores may be kept in a common water body or have separate water supplies.

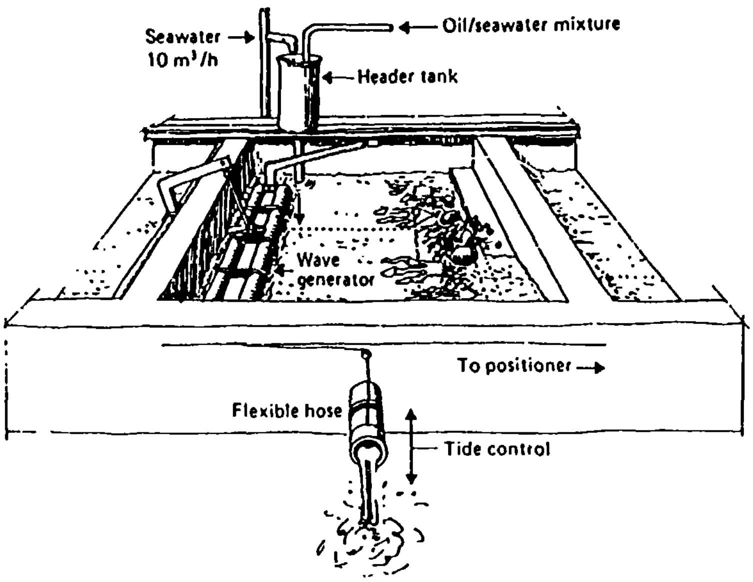
Sampling:

- Hand held double corers: after sampling the outer tube remains in the sediment in order to prevent sediment collapse.
- Complete seal-off for studies of fluxes from the sediment.
- Time lapse photography of animal behaviour.

Key References:

Berge, J. A. *et al*. 1986. A soft bottom sublittoral mesocosm by the Oslofjord: Description, performance and examples of application. Ophelia *26*: 37-54.

Comments: Generally a high degree of replication of natural events was achieved with some minor effects due to compaction of the surface layer, reduced diffusion and reduced supply of organic material to the sediment surface.



DESCRIPTION OF EQUIPMENT

Specific Name: Solbergstrand Rocky Shore Basin

Size:

Depth:	0.6 m
Bottom area:	40 m^2
Volume:	25 m^3

Material: Concrete

Purpose: Dynamics and pollutant effects on littoral organisms.

Application: Long term pollutant response, littoral community succession and dynamics.

<u>Location</u>: NIVA Marine Research Station Solbergstrand, Oslofjord, Norway.

<u>Contact Address</u>: Norwegian Institute for Water Research
P.O. Box 33 Blindern
N-0313 Oslo 3 Norway.

<u>Filling</u>: Transplantation of boulders with epigrowth. Subsequent long term recruitment.

<u>Sampling</u>: Primarily non-destructive. Fixed area species enumeration; photographic registration; settlement panels; studies of tagged individuals; whole system production and respiration.

<u>Key References</u>:

Bakke, T., 1986. Experimental long term oil pollution in a boreal rocky shore environment. Proceedings 9th AMOP Technical Seminar, Canada 1986. ISBN 0-662-14812-6

Gray, J.S., 1986. Oil pollution studies of the Solbergstrand mesocosms. In Cadogan, J.I.G., Clark, R.B. and J.P. Hartley (Eds.) <u>Environmental Effects of North Sea Oil and Gas Developments</u>, Proceedings from the Royal Society, London, Chapter 13.

<u>Comments</u>: About 20 papers published or in preparation on scientific results from use of the equipment above, mostly from a shoreline pollution project sponsored by BP Petroleum Development (Norway).

(See next page)

DESCRIPTION OF EQUIPMENT

Specific Name: Chesapeake Bay Mesocosms

Size:
- Depth: 1.5 m
- Volume: 60 m^3

Material: Fibreglass

Purpose: Study of near-shore environment (e.g. salt marsh).

Application: Display and research on marine, estuarine and tidal marshes; sandy and muddy shallow and deepwater bottoms; oyster bars.

Location: Smithsonian Institution, Washington, D.C.

Contact Address: Marine systems Laboratory, Smithsonian Institution, Washington, D.C. USA

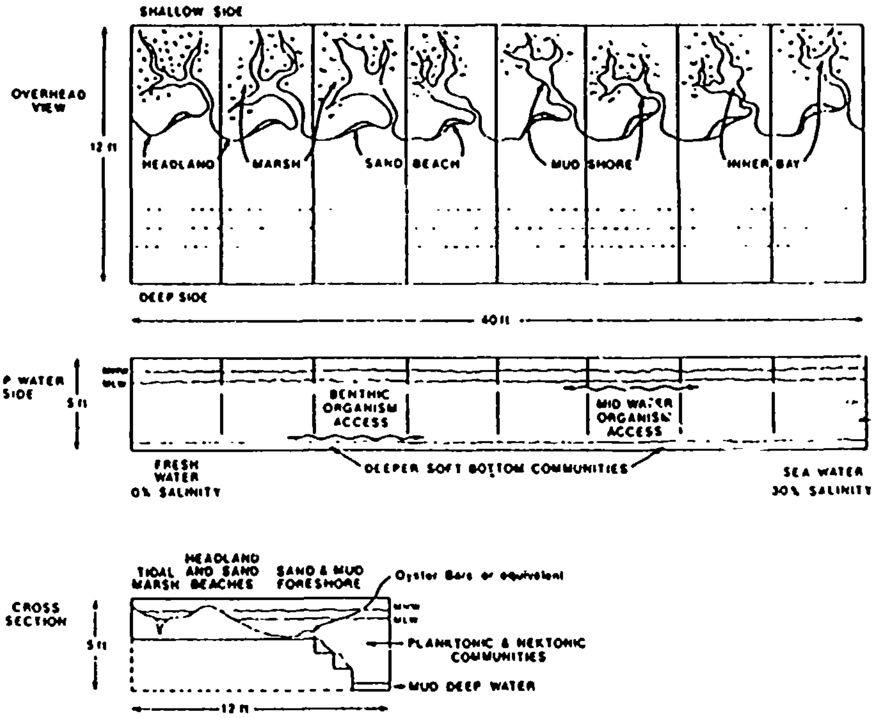
Filling: Pumped fresh and saltwater to maintain a salinity gradient; recycled water under artificial lighting; tidal simulation.

Sampling: Non destructive - probes, small water and soil samples etc. as required.

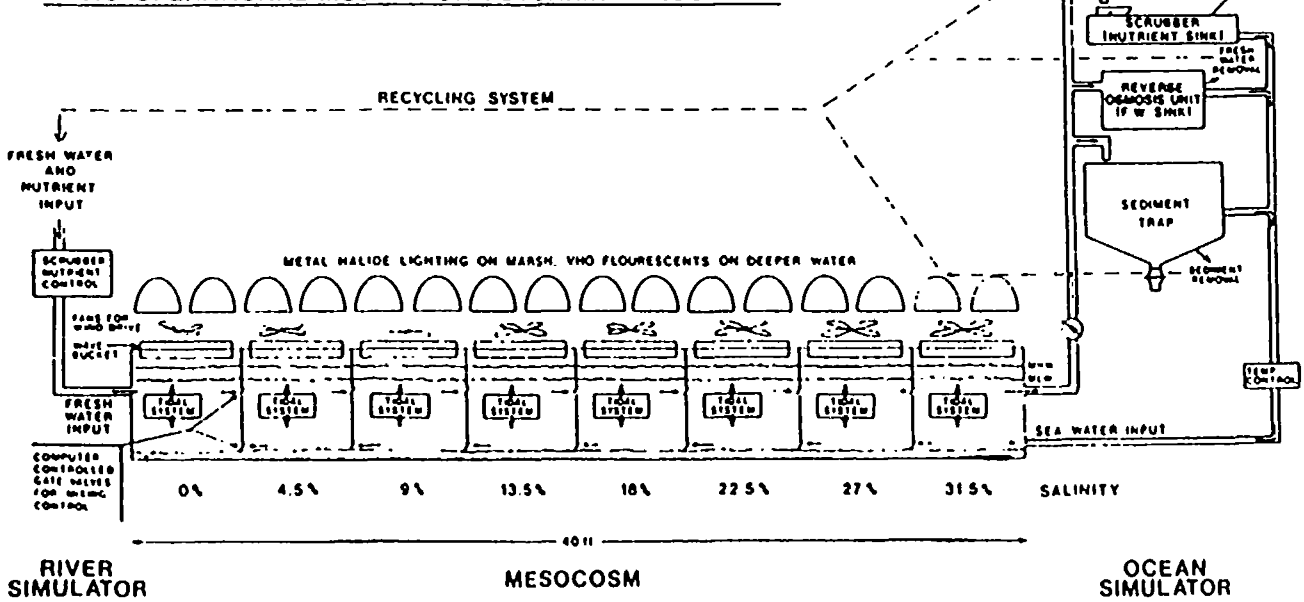
Key References:

Comments: Maintained for two years with simulated seasonal cycle, tidal cycle and wave action.

BASIC ECOLOGICAL MODEL FOR ESTUARINE MESOCOSM



BASIC OPERATIONAL MODEL FOR ESTUARINE MESOCOSM



(See next page)

DESCRIPTION OF EQUIPMENT

Specific Name: Florida Everglades Mesocosm

Size:
Volume: 88 m^3
Area: 150 m^2

Material: Concrete block coated with butyl rubber.

Purpose: Simulation of marine estuarine and fresh water units.

Application: Display and ecological research potential

Location: Smithsonian Institution, Washington D.C.

Contact Address: Marine systems Laboratory, Smithsonian Institution, Washington, D.C. USA.

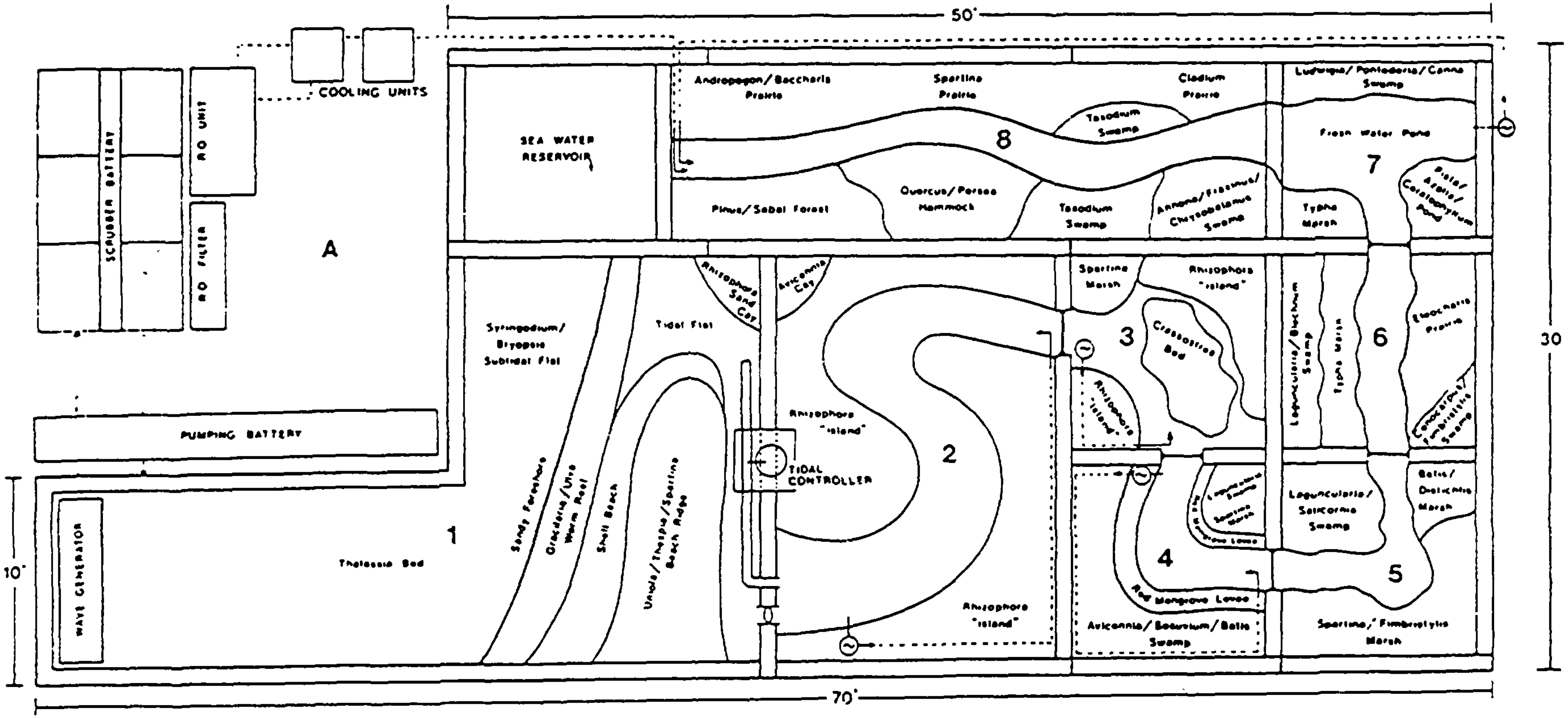
Filling: Freshwater and saltwater (28-35$^o/_{oo}$) mixture maintained with seasonal temperature change; some artificial lighting, tidal and wave action.

Sampling: Non-destructive - probes, small amounts of water and soil etc.

Key References: None

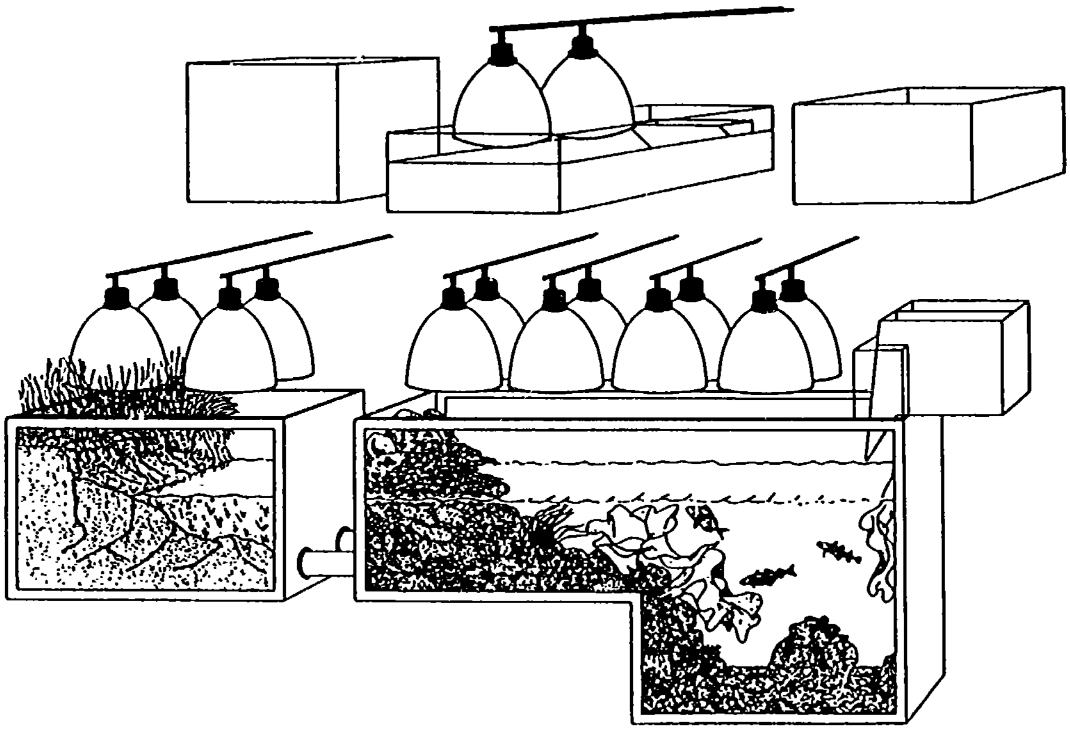
Comments: Wide diversity of species in different ecosystems maintained annually.

EVERGLADES MESOCOSM [Greenhouse, Washington, D.C.]



COMMUNITIES

A Gulf of Mexico simulator
1 Everglades Coast
2 Red Mangrove
3 Oyster Bay
4 Black Mangrove
5 Salt Marsh
6 Oligohaline Marsh
7 Fresh Water Pond
8 Fresh Water Stream with Prairie and Hammock Communities



DESCRIPTION OF EQUIPMENT

Specific Name: Atlantic Subarctic Microcosm

Size:

Depth: Approximate depth 1.5 m

Volume: 10.9 m^3; consisting of rocky shore (9.1 m^3) and marshland mudflat

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Material: Fibreglass.

Purpose: Simulation of Maine rocky shore.

Application: Display and research on primary productivity under simulated environmental parameters.

Location: Smithsonian Institution, Washington D.C.

Contact Address: Marine Systems Laboratory, Smithsonian Institution, Washington, D.C. USA.

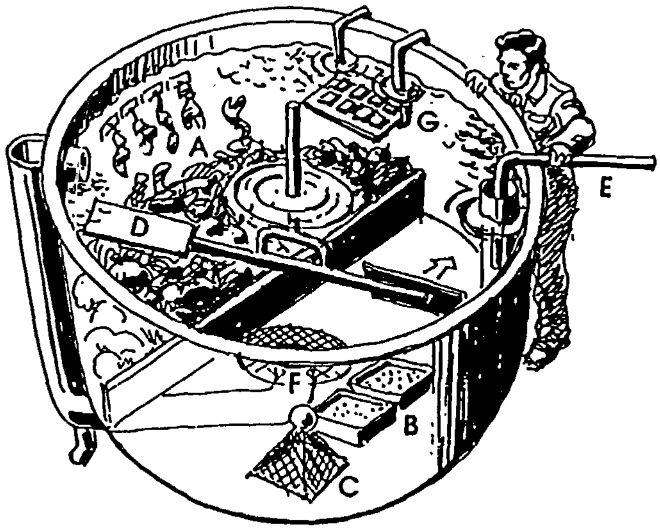
Filling: Pumped seawater (31-34%). Wave action and current; artificial lighting with metal halide lamps.

Sampling: Non-destructive - probes, small amounts of water and soil etc.

Key References:

Brittsen, J.M. 1989. Regulation of kelp *(Laminaria longicrusis)* growth in a subarctic marine microcosm and the rocky coast of Maine U.S.A. M.S. Thesis. University of Maryland.

Comments: Four years of continuous operation maintaining good organism diversity.



A Main hard bottom community on gravel bed

B Soft bottom communities in trays

C Caged animals

D Tidal current generator

E Water inlet

F Outlet to overflow

G Settling panels

DESCRIPTION OF EQUIPMENT

Specific Name: Solbergstrand Subtidal Mixed Bottom Mesocosm.

Size: 8 Units Each

Depth: 1.2 m

Diameter: 4 m

Volume: 15 m^3

Material: Indoor fiberglass tanks.

Purpose: Maintenance of transplanted hard bottom communities.

Application: At present applied to experiments on thermal effluents after use of the cooling water in fish farming.

<u>Location</u>: NIVA Marine Research Station Solbergstrand Oslofjord, Norway.

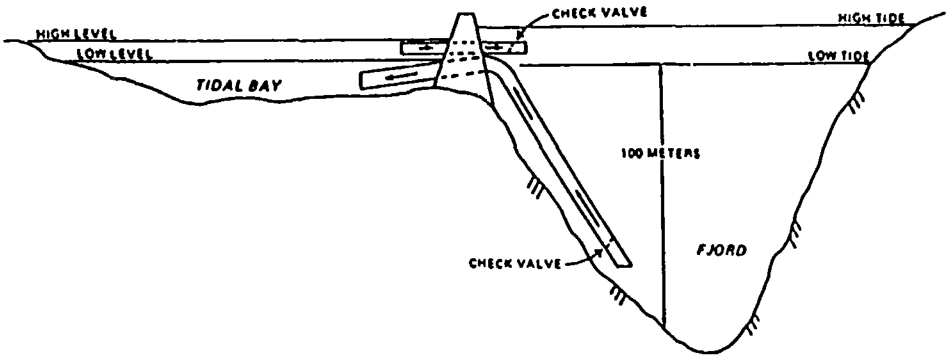
<u>Contact Address</u>: Norwegian Institute for Water Research
P.O. Box 33 Blindern
N-0313 Oslo 3, Norway.

<u>Filling</u>: Communities are established by transplantation of rocks covered with key populations of algae and animals. Gradual recruitment is subsequently allowed through the inflowing water.

<u>Sampling</u>: Primarily non-destructive. Fixed area species enumeration, photographic catalogue, studies of tagged individuals, settlement plates.

<u>Key References</u>: None yet. The system has been running for only 6 months.

<u>Comments</u>: The system is designed for long term experiments. The present project is expected to run for 2.5 years.



DESCRIPTION OF EQUIPMENT

Specific Name: Artificial Impoundment

Size:
- Depth: 3.5 m
- Diameter: *ca* 20 m
- Volume: 852 m^3

Material: Inert rubber membrane liner (Sure-Seal, Carslisle Corp., Carslisle, Pa.)

Purpose: Enhancement of primary productivity for aquaculture.

Application: Studies on the growth of *Mytilus edulis* and juvenile chum salmon in impoundments.

Location: Seward, Alaska.

Contact Address: Institute of Marine Science,
University of Alaska
Fairbanks, Alaska 99701 USA

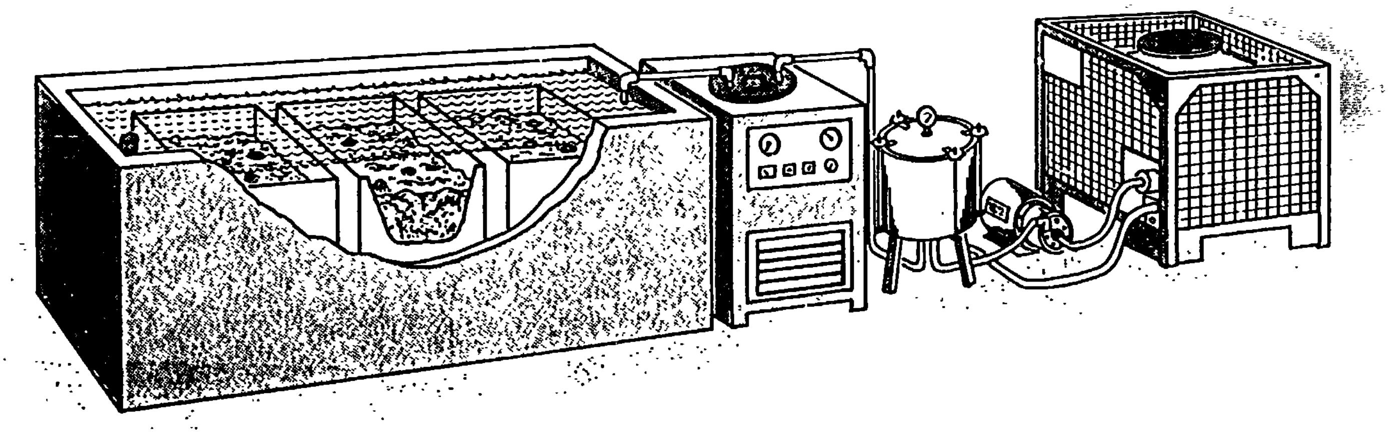
Filling: Tidal upwelling from below the thermocline.

Sampling: Conventional Van Dorn bottles for phytoplankton and nutrients; nets for larger organisms.

Key References:

Neve R.A., R.C. Clasby,J.J. Goering and D.W. Hood. 1976. Mar. Sci. Comm. *2*: 109-124.
Paul, A.J., J.M. Paul and R.A. Neve. 1978. J. Cons. int Explor. Mer, *38*: 100-104

Comments: Flushing rates from 2 to 35% per day. Increased phytoplankton production is proportional to the amount of water exchanged.



DESCRIPTION OF EQUIPMENT

Specific Name: NIOS Boxcosm

Size:

Depth:	0.8 m
Length:	1.8 m
Width:	0.65 m
Volume:	1.5 m^3

Material: Insulated reinforced plastic container with cover plate, cooler, membrane pump, biological filter unit and accessory water storage.

Purpose: Low cost mobile benthic mesocosm for ecotoxicological studies.

Application: Testing facility for effects of pollutants on benthic ecosystems. Eutrophication experiments; bioperturbation studies, pore water chemistry. Tropho-dynamics of benthic associations. Growth experiments in macrofaunal organisms.

Location: NIOS, Netherlands Institute for Oceanic Sciences, Texel, The Netherlands.

Contact Address: NIOS, P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands
Tel.: 31-2220-19541
Fax.: 31-2220-19674

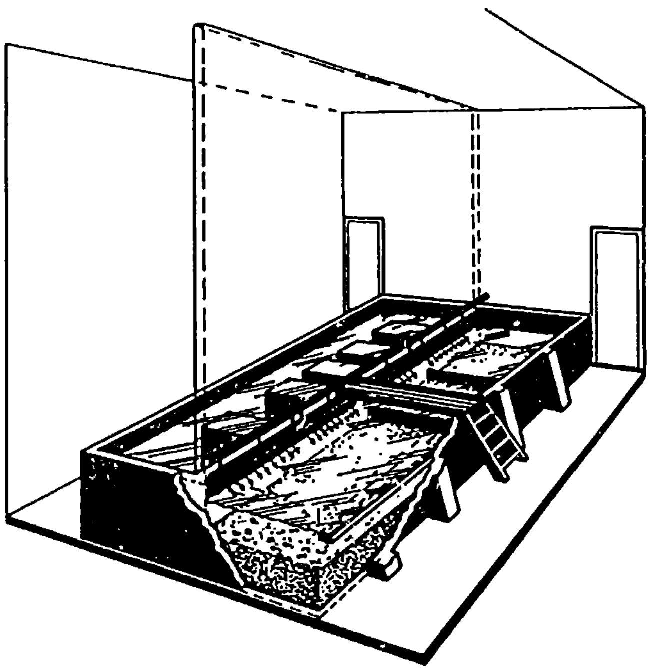
Filling: NIOS boxcosms can hold a maximum of 3 large (0.25 m^2) box core samples in coated stainless steel or other non-corrosive boxes. 1.5 m^3 of water, collected in the open North Sea, is recirculated through the system.

Sampling: Small hand cores, non-destructive observations, measurements with micro-electrodes, bell jar techniques etc.

Key References:

In Euromar Subproject proposals (1988), Edited by Euromar General Secretary, Alfred Wegener Institute, Bremerhaven, F.R.G.:1-255.

Comments: Boxcosms provide benthic mesocosm facilities at minimum dimensions and costs. Undisturbed *Amphiura* communities have been kept in good condition in a prototype of the boxcosm for a period of 6 months.



DESCRIPTION OF EQUIPMENT

Specific Name :Sublittoral soft bottom North Sea Mesocosm

Size:

Depth: Sediment layer covered by 0.5 m water column
Surface area of benthic community:
Uninterrupted areas of up to 25 m^2, but generally in smaller sections or in separate box cores of .25 m^2··Water storage annex to mesocosms 2 x 60 m^2

Material: Concrete basins with an inside covering of fiber-glass installed within a large thermo-insulated room. Temperature of seawater thermostatically controlled by means of a heat exchanger. System is held in the dark. Membrane-driven pump provides flow through the system by a perforated inflow pipe at one side of the basins and a skimming gutter at the other side.

Purpose: Research and experimentation of sublittoral benthic shelf sea ecosystems.

Application: Measurements and observations dealing with almost all aspects of benthic ecosystem research: boundary layer chemistry, microbial loop studies, distribution and growth of macrofaunal organisms, effects of eutrophication and pollutants on benthic systems.

Location: NIOS, Netherlands Institute for Oceanic Sciences, Texel, The Netherlands.

Contact Address: NIOS, P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands
Tel.: 31-2220-19541
Fax.: 31-2220-19674

Filling: **Sediment:** Transfer of undisturbed bottom sections, collected with a large 0.25 m^2 box corer; larger bottom areas in the mesocosm carefully composed from separate 60 x core samples.
Water: Transfer of water from the open North Sea in 1000 ℓ cube containers on board R.V. Aurelia. Storage of water at the institute in 2 large subterranean 60 m^3 storage basins annexed to the mesocosms.

Sampling: By handcorers from gantry placed over basins. Long-term observations and measurements preferably by means of non-destructive methods; video, still camera deployment of bell jars, micro electrodes etc.

Key References: Not yet available.

Comments: Recently built and improved mesocosm facility, largely following the concept of the Solberg system in Norway (see pages 74-77). The system aims at bringing off-shore benthic communities in reach of detailed laboratory research. Pilot studies have already showed the success of this approach, indicated by the healthy condition of benthic communities from the open North Sea kept in the mesocosm over periods of 6 months.

DESCRIPTION OF EQUIPMENT: For figure see next page

Specific Name: MOdel TIdal Flat (MOTIF)

Size: Dimensions: l x w x h = 6 x 3.5 x 1.2 m; 18 m^2 tidal flat; 3 m^2 tidal channel. Water depth at high tide 0.5 m above surface of 0.45 thick sediment layer. MOTIFs are grouped in pairs.

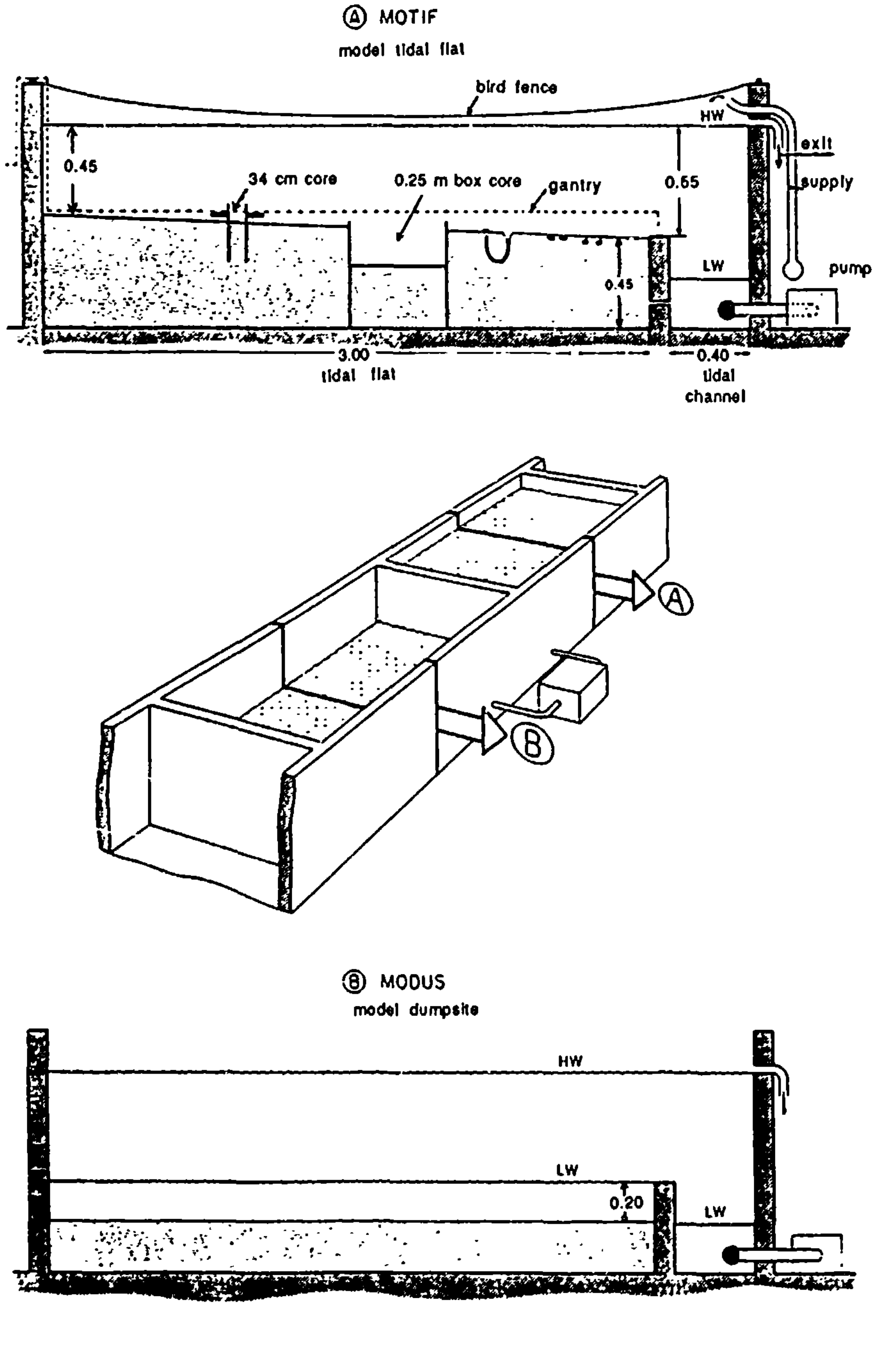
Material: Concrete and brick painted with Colturit. Tidal cycle simulated by pumping the water back and forth between 2 MOTIFs. Wave boards produce water turbulence.

Purpose: Applied research into the acute and long-term effects of oil spills and oil spill combatting techniques (*i.e.* dispersal, mechanical removal, burning) on intertidal mud flat ecosystems.

Application: Holistic ecosystem research comprising variations in abiotic environmental factors, concentration and composition of oil in water and sediment, production, species composition and biomass of plankton organisms, meiobenthos and macrobenthos, densities of bacteria, and bioaccumulation of oil and oil derivatives in tissues of selected bivalves.

Location : Research Institute for Nature Management (RIN), Texel, The Netherlands.

Contact Address: Mt-TNO, Department of Biology, Laboratory for Applied Marine Research, P.O. Box 57, 1780 AB Den Helder, The Netherlands
Tel. 31-2230-32924


Ⓐ MOTIF
model tidal flat
bird fence
HW
exit
supply
0.45
34 cm core
0.25 m box core
gantry
0.65
LW
pump
0.45
3.00
tidal flat
0.40
tidal
channel
Ⓐ
Ⓑ
Ⓑ MODUS
model dumpsite
HW
LW
0.20
LW

Filling: Sediment compartment filled with semi-sterilized, natural mud flat sediment. Stocked with adult specimens of common long-living macrobenthic species and a mother stock of smaller opportunistic species. Mussels are suspended in cages from the walls. Intake and flow-through of seawater from the nearby tidal channel.

Sampling: From a gantry lowered over exposed model flats with various types of small samplers and hand corers and sometimes with a large 0.25 m^2 box corer, to be emptied with a spade.

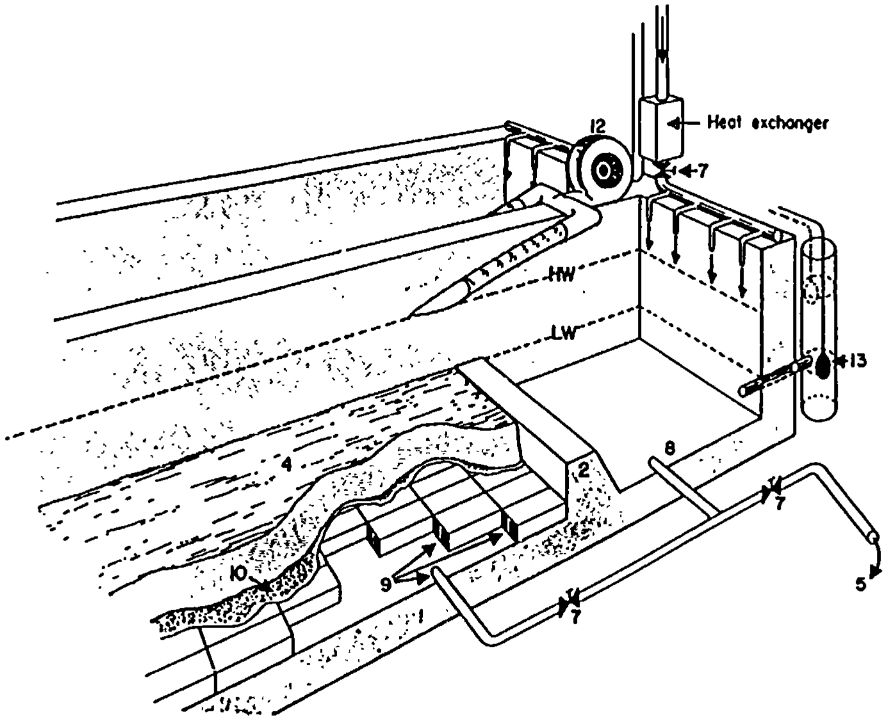
Key References:

Kuiper, J. *et al.*, 1986. The influence of dispersants on the fate and effects of oil in model tidal flat ecosystems. Final Report Oil Pollution experiments with special reference to the use of FINASOL osr 5 (OPEX), 1984-86). TNO-MT Report R86/182, Delft, The Netherlands: 1-94.

Scholten, J. *et al.*, 1987. Effects of two selected oil combat methods in experimental tidal flat ecosystems. Final Report Oil Pollution Experiments (OPEX) 1986. TNO-MT Report R87/348, Delft, The Netherlands: 1-78.

Comments: MOTIFs have been used successfully for 6 years in oil pollution studies. Besides direct applicable results, they have contributed to a better insight of the structure and evolution of mud flat ecosystems. Testing indicated a satisfactory degree of system reality and replicability.

After 1986, the existing set-up of the MOTIFs was changed, such that one of each pair of MOTIFs was converted into a MOdel DUmp Site into which harbour sludge was introduced. Possible effects of chronic pollutants and eutrophication on the mud flat ecosystem are studied in the paired MOTIF.



Schematic drawing of the tidal mud-flat basin, showing: *1* concrete basin, *2* bar, *3* tidal channel, *4* mud-flat, *5* storage basin, *6* level tank, *7* magnetic valves, *8* drain, *9* cistern, *10* nylon wool layer, *11* lamps, *12* ventilators, *13* level-gauge containing censors, *14* time switches

DESCRIPTION OF EQUIPMENT

Specific Name: Indoor tidal mudflat ecosystems

Size:

dimension of containers: 10 x 2.5 x 1 m
surface area of mudflat: 20 m^2
surface area of tidal channel: 5 m^2
water depth at high tide 0.5 m above 0.4 m deep sediment

Material: Concrete coated with epoxy resin. Tidal cycles established by centrifugal pumps connected to time switches. Overhead lighting with high pressure Philips SON/T, 400 W discharge lamps. Water temperature thermostatically controlled by means of a graphite heat exchanger.

Purpose: Fundamental research into the structure and functioning of mudflat ecosystems.

Application: Long-term evolution of community structure in polychaetes, bioperturbation activity of lugworms, pore water chemistry, vertical sediment profiles, and energy budget studies.

Location: NIOS, Netherlands Institute for Oceanic Sciences, Texel, The Netherlands.

Contact Address: NIOS, P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands
Tel.: 31-2220-19541
Fax.: 31-2220-19674

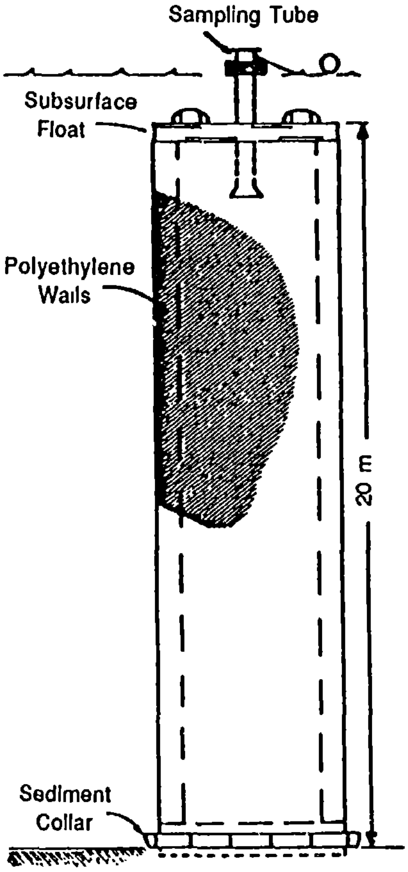
Filling: Sediment compartment filled with semi-sterilized natural mudflat sediment and stocked with adult specimens of long lived macrobenthos species and a mother stock of various opportunistic fauna elements.
Intake of seawater from a nearby tidal inlet and in a 60 m^3 storage tank from which it is recirculated.

Sampling: From gantry lowered over exposed mudflat with various types of handcorers; core holes filled with sieved sediment. *In situ* measurement of sediment parameters with microprobes and sensors, measurement of community respiration with bell-jar techniques.

Key References:

Wilde, P.A.W.J. de and B.R. Kuipers. 1977. A large indoor tidal mudflat ecosystem. Helgolander wiss. Meeresunters. 30: 334-342.

Comments: In one of the two experimental mudflats the development of a single ecosystem could be followed over a period of almost 10 years.



DESCRIPTION OF EQUIPMENT

Specific Name: Sediment-Seawater Enclosure (SSE)

Size:

Depth: 20 m

Diameter: 5.0 m

Volume: 390 m^3

Material: Steel (epoxy-coated) sediment collar
Fabrene (DuPont, woven polyethylene) walls
Fibreglass subsurface float and sampling tube.

Purpose: Sediment-Seawater interactions, nutrient fluxes from sediments.

Application: 2 test experiments with this enclosure demonstrated severe leakage problems through either the sediment or the sub-surface float. The system will likely not be used again.

Location: Patricia Bay, B.C. Canada. Bottom depth of 20 m at low tide.

Contact Address: Ocean Chemistry, Institute of Ocean Sciences, P.O. Box 6000, Sydney, B.C., Canada. V8L 4B2

Filling: Dropping a polyethylene sleeve over an essentially undisturbed water column and sediment bed.

Sampling: Through a retrievable sampling tube (300 mm I.D.), using small diameter nets, CTD and light meter, and by pumping sea water.

Key References:

Wong, C.S., F.A. Whitney, W.K. Johnson, and W.J, Cretney, in prep. Application of Experiment Enclosures for the study of pathways and fate of Chemical pollutants. In: Proceedings of the International Marine Ecosystem Enclosure Experiments at Beijing, China, May 10-14, 1987. Ed.: C.S. Wong and P.J. Harrison. Publisher, International Development Research Center, Ottawa, Canada.

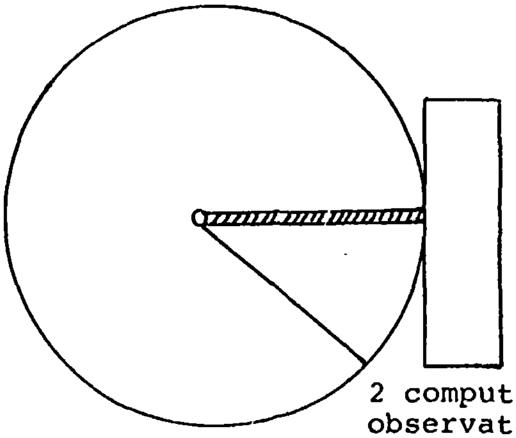
Comments: An attempt was made with this system to enclose an undisturbed sediment bed, in an area that has a 3 m tidal range. A major problem with the design is that there is no way to restrict water flow through the sediment bed, so that any density decrease in surrounding waters leads to the rapid collapse of the enclosure.

6.3. Macrocosms

Pelagic (>10^3 m^3)

Benthic (>100 m^3)

(Large tank)



DESCRIPTION OF EQUIPMENT

Specific Name: 2200 m^3 tank

Size

Depth: 5.5 m

Diameter: 23 m

Volume: 2200 m^3

Material: Concrete and PVC liner

Purpose: Mesocosm investigations of larval fish. Ecological experiments with larger fish (predator-prey relations)

Application: Extensive rearing of turbot larvae. Feeding behaviour in cod.

<u>Location</u>: North Sea Centre. DK - 9850 Hirtshals. Denmark

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<u>Contact Address</u>: Danish Institute for Fisheries and Marine Research, P.O. Box 101, DK 9850 Hirtshals, Denmark.

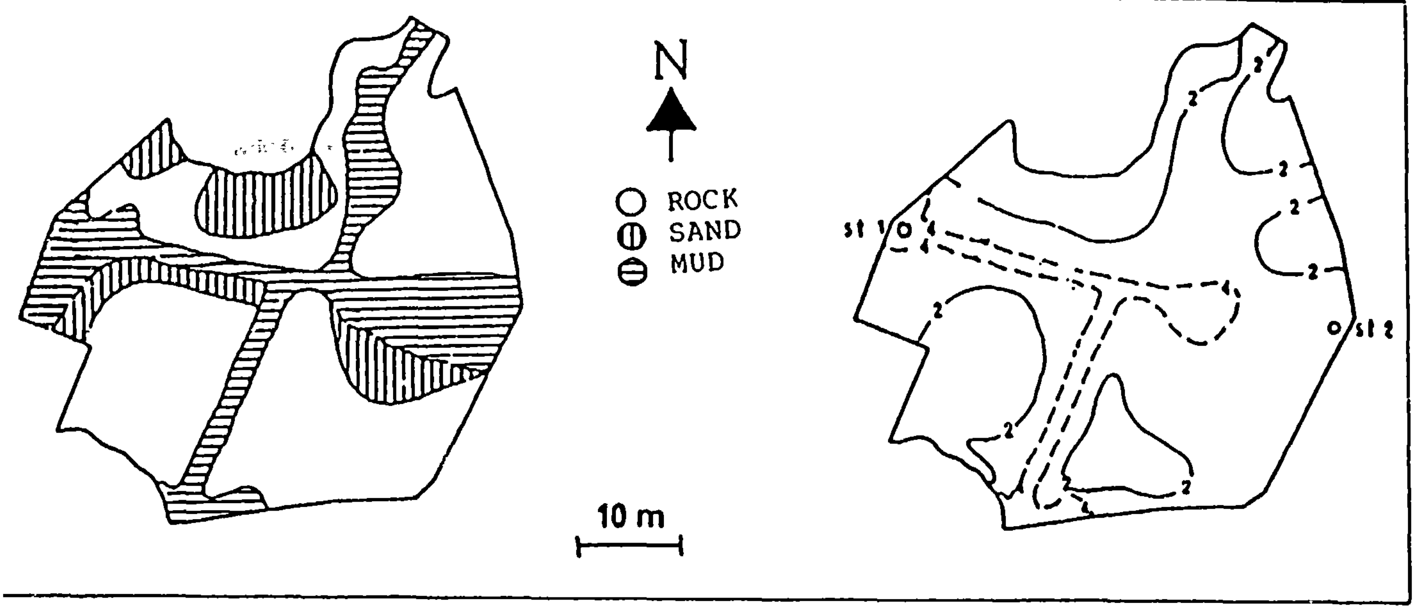
<u>Filling</u>:

<u>Sampling</u>:

<u>Key References</u>:

Beyer, J.E., E.B. Christensen, V. Christensen, T. Kiorboe, P. Munk, H. Paulsen and K. Richardson. 1985. Int. Council. Explor. Sea, C.M. 1985/Mini.Symp) No. 7.

<u>Comments</u>: Most successful experiments gave 62% survival of turbot larvae after 32 days.



DESCRIPTION OF EQUIPMENT

Specific Name : Upper Basin at the Biological Station Flodevigen.

Size:

Depth:	4 m maximum; 2.5 m mean depth.
Diameter:	approx. 50 m
Volume:	4,400 m^3
Area:	1,700 m^2

Material: Natural depression on land (rock and walls of concrete; bottom partly rock, gravel, sand and mud).

Purpose: Originally constructed in 1937 for imitation of the production conditions in oyster ponds.

Application: Since 1975 used to study the early life history and growth rates of fish and shellfish beyond metamorphosis with special emphasis on the effect of food densities and presence/absence of predators on survival.

<u>Location</u>: Biological Station Flodevigen, outside Arendal in South-East Norway; belonging to the Institute of Marine Research in Bergen (governmental).

<u>Contact Address</u>: Lagoon Management and Construction A/S
Arken Kontorhotell
5095 Ulset
Norway

<u>Filling</u>: Enclosures drained and filled with seawater from 75m depth. Overwintering population develops with 2% water exchange per day from outside the enclosure.

<u>Sampling</u>: Net hauls for larval fish

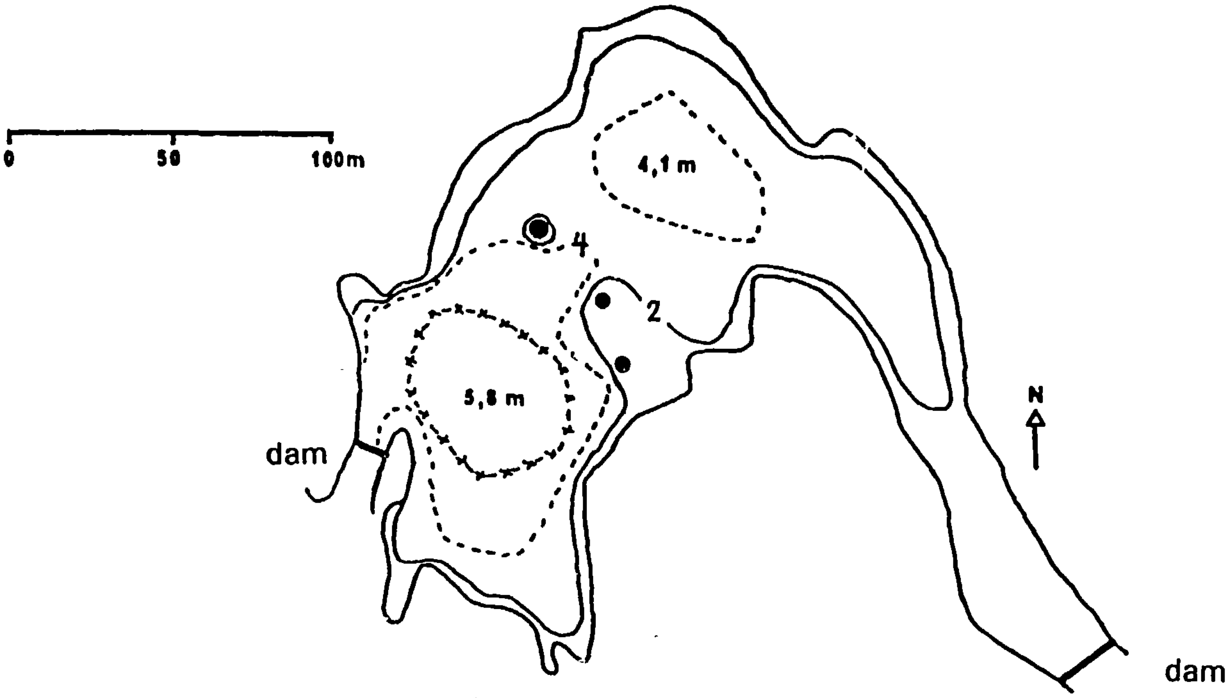
<u>Key References</u>:

Ellertsen, B., *et al* 1981. Growth and survival of cod larvae in an enclosure. Experiments and a mathematical model. ICES Rapp. Proc. -Verb.,178:45-57.

Öiestad, V., *et al.* 1976. Rearing of different species of marine fish fry in a constructed basin. Proc. 10th Eur. Mar. Biol. Symp., Vol.1.

Öiestad, V. and Moksness, E. 1981. Study of growth and survival of herring larvae (C.h) using plastic bag and concrete enclosure combined. ECES Rapp. Proc.-Verb. 178.

<u>Comments</u>: The study has included the following species from yolksac to beyond metamorphosis: herring; cod; plaice; flounder and the hybrid; turbot; sole; halibut in bags; capelin (not to metamorphosis); lobster and oyster. About 10 publications include material from these experiments.



DESCRIPTION OF EQUIPMENT

Specific Name: Hyltropollen

Size:

Depth: 6 m maximum, 3.0 m mean depth.

Diameter: approx. 100 m

Volume: 60,000 m^3

Area: 20,000 m^2

Material: Seawater pond. Bottom is mud, sand and gravel; rock on the rim; two dams, one permanently closed.

Purpose: To study the early life history of cod from yolksac stage to juvenile fish (>10cm) in an almost natural system.

Application: Every year from 1980-1987, large populations of cod larvae have been released into the pond and their development in conjunction with zooplankton (food and predators) has been studied in detail as has the zooplankton and phytoplankton; almost 400,000 juvenile cod have been collected alive for other studies.

Location: A few km west of the Aquaculture Station Austevoll in a small island community 1 h south of Bergen; part of the Institute of Marine Research in Bergen.

Contact Address: Lagoon Management and Construction A/S
Arken Kontorhotell
5095 Ulset
Norway

Filling:

Sampling:

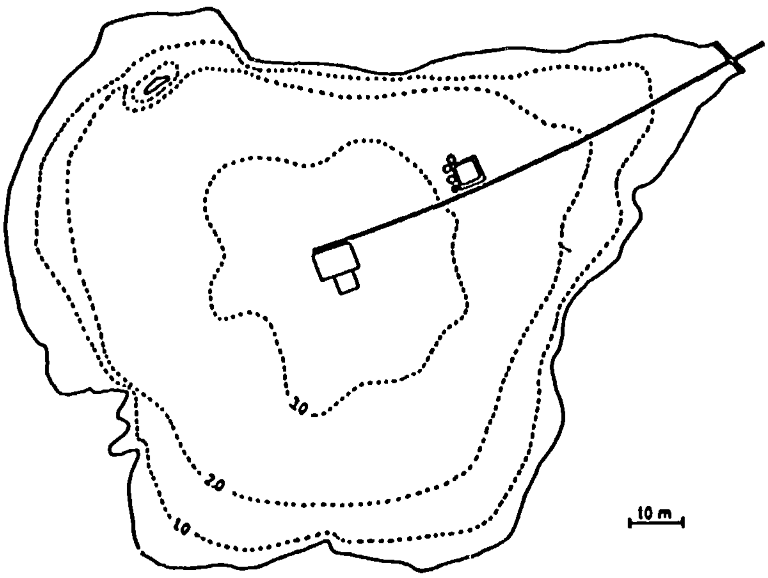
Key References:

Öiestad, V., *et al.* 1985. Trans. Am. Fish. Soc. *114*: 590-595.

Öiestad, V., 1985. NAFO Sci. Coun. Studies., *8*: 25-32.

Öiestad, V., 1984. In: E.Dahl. *et al* (Eds.), Flodev. RappSer., *1*: 213-229.

Comments: Results from these studies are included in another ten reports and new publications are planned about zooplankton and food densities (for now only in Norwegian) and on "green gut" in first feeding cod.



DESCRIPTION OF EQUIPMENT

Specific Name: Svartatjonn.

Size:

Depth: 4 m maximum, 2.4 m mean depth.

Diameter: 100 m

Volume: 22,000 m^3

Area : 9,000 m^2

Material: Originally a freshwater pond 3 m above sea level; most of the bottom is mud, with some rock and gravel around the rim.

Purpose: Early life history study of marine fish and shellfish and of manipulation of phytoplankton and zooplankton dynamics.

Application: Switched over to seawater during early 1984, cod larvae studies during the spring in 1984-86. Turbot, sole, and lobster studied most summers 1984-88; different types of manipulations have been tested (turbulence by propeller, fertilizers, different exchange rates).

Location: A few km north of Aquaculture Station Austevoll, a small island community 1 h south of Bergen; part of the Institute of Marine Research.

Contact Address: Lagoon Management and Construction A/S
Arken Kontorhotell
5095 Ulset
Norway

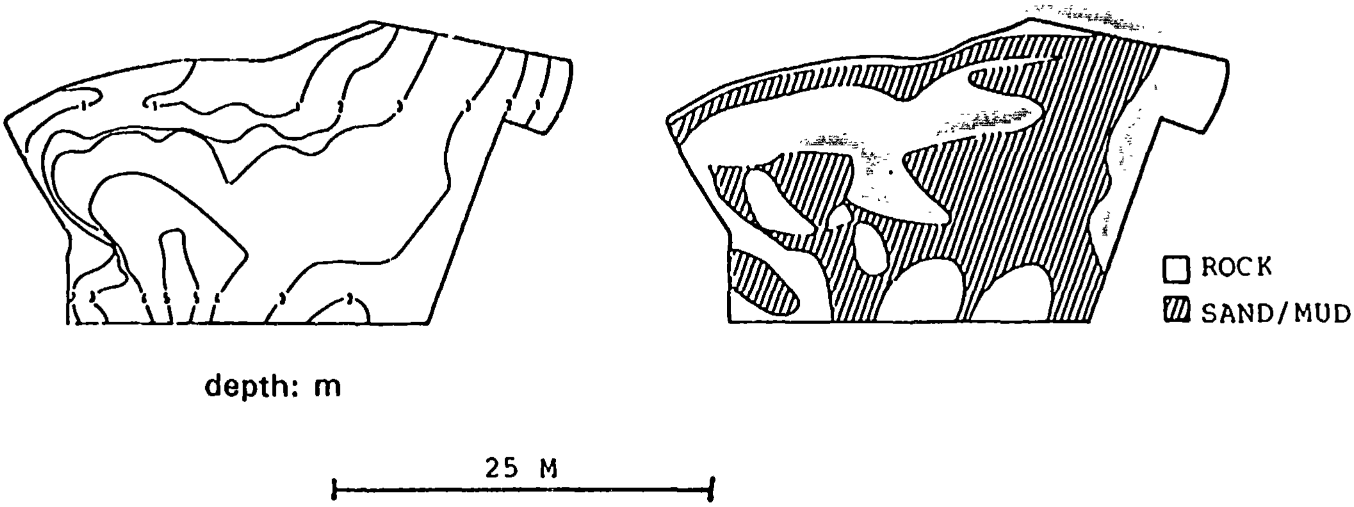
Filling:

Sampling:

Key References:

Naas, K., Aksnes, A. and Meeren, T.V. 1989. Phytoplankton and zooplankton responses to fertilization and other types of manipulations in a fish pond in Austevoll, Norway. Manus.

Comments: A number of publications are under preparation mainly on fish larvae studies in plastic bags in the basin (turbot and cod) and on oysters, as well as on species succession and a model for fish larvae ponds (cod).



DESCRIPTION OF EQUIPMENT

Specific Name: Lower Basin at the Biological Station Flodevigen

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Size:

Depth: 5 m maximum, 3.3 m mean depth.

Diameter: approx. 25 m

Volume: 2,000 m^3

Area : 600 m^2

Material: Natural depression on land (rock) and walls of concrete; bottom partly of rock, gravel, sand and mud.

Purpose: Originally constructed in 1885 to test the viability of cod larvae released in Norwegian coastal waters

Application: Since 1977 used to study the early life history of fish in parallel with the upper basin. As it is also used to supply water to the laboratory, the use of this basin has been far more restricted than the upper basin some of the time; also used for plastic bag studies.

Location: Biological station Flodevigen, outside Arendal in Southeastern Norway; belongs to the Institute of Marine Research in Bergen.

Contact Address: Lagoon Management and Construction A/S
Arken Kontorhotell
5095 Ulset
Norway

Filling:

Sampling:

Key References:

Moksness, E. 1982. Fisk. Dir. Skr. Ser. Hav. Unders.,*17*: 267-287

Moksness, E. and Öiestad, V. 1987. J. Cons. int. Explor. Mer. *44*: 32-42.

Rognerud, C. 1887. Bull. U.S. Fish. Commn. *8*: 113-119

Comments: A turbot study carried out in 1980 and only published in Norwegian, is about to be published in English.

7. INDEX

UNESCO TECHNICAL PAPERS IN MARINE SCIENCE

Titles of numbers which are out of stock

No.		Year	SCOR WG
	Incorporated with Nos. 4, 8 and 14 in No. 27	1965	WG 10
	Report of the first meeting of the joint group of experts on photosynthetic radiant energy held at Moscow, 5-9 October 1964. Sponsored by UNESCO, SCOR and IAPO	1965	WG 15
	Report on the intercalibration measurements in Copenhagen, 9-13 June 1965. Organized by ICES	1966	—
	Incorporated with Nos. 1,8 and 14 in No. 27	1966	WG 10
	Report of the second meeting of the joint group of experts on photosynthetic radiant energy held at Kauizawa, 15-19 August 1966. Sponsored by UNESCO, SCOR, IAPO	1966	WG 15
	Report of a meeting of the joint group of experts on radiocarbon estimation of primary production held at Copenhagen, 24-26 October 1966. Sponsored by UNESCO, SCOR, ICES	1967	WG 20
	Report of the second meeting of the Committee for the Check-List of the Fishes of the North Eastern Atlantic and on the Mediterranean, London, 20-22 April 1967	1968	—
	Incorporated with Nos. 1, 4 and 14 in No. 27	1968	WG 10
	Report on intercalibration measurements, Leningrad, 24-28 May 1966 and Copenhagen, September 1966; organized by ICES	1969	—
	Guide to the Indian Ocean Biological Centre (IOBC), Cochin (India), by the UNESCO Curator 1967-1969 (Dr. J. Tranter)	1969	—
	An intercomparison of some current meters, report on an experiment at WHOI Mooring Site "D", 16-24 July 1967 by the Working Group on Continuous Current Velocity Measurements. Sponsored by SCOR, LIAPSO and UNESCO	1969	WG 21
	Check-List of the Fishes of the North-Eastern Atlantic and of the Mediterranean (report of the third meeting of the Committee, Hamburg, April 1969)	1969	—
	Technical report of sea trials conducted by the working group on photosynthetic radiant energy, Gulf of California, May 1968; sponsored by SCOR, IAPSO, UNESCO	1969	WG 15
	Incorporated with Nos. 1, 4 and 8 in No. 27	1970	WG 10
	Monitoring life in the ocean, sponsored by SCOR, ACMRR, UNESCO, IBP/PM	1973	WG 29
	Sixth report of the joint panel on oceanographic tables and standards, Kiel, 24-26 January 1973; sponsored by UNESCO, ICES, SCOR, IAPSO	1974	WG 10
	An intercomparison of some current meters, report on an experiment of Research Vessel Akademic Kurchatov, March-April 1970, by the Working Group on Current Velocity Measurements; sponsored by SCOR, IAPSO, UNESCO	1974	WG 21
18	A review of methods used for quantitative phytoplankton studies; sponsored by SCOR, UNESCO	1974	WG 33
19	Marine Science Teaching at the University Level. Report of the UNESCO Workshop on University Curricula-*Available in Spanish and Arabic*	1974	—
20	Ichthyoplankton. Report of the CICAR Ichthyoplankton Workshop-*Also published in Spanish*	1975	—
21	An intercomparison of open sea tidal pressure sensors. Report of SCOR Working Group 27: "Tides of the open sea"	1975	WG 27
22	European sub-regional co-operation in oceanography. Report of Working Group sponsored by the UNESCO Scientific Co-operation Bureau for Europe and the Division of Marine Sciences	1975	—
23	An intercomparison of some currents meters, III. Report on an experiment carried out from the Research Vessel Atlantis II, August-September 1972, by the Working Group on Continuous Velocity Measurements: sponsored by SCOR, IAPSO and UNESCO	1975	WG 21
24	Seventh report of the joint panel on oceanographic tables and standards, Grenoble, 2-5 September 1975; sponsored by UNESCO, ICES, SCOR, IAPSO	1976	WG 10
25	Marine science programme for the Red Sea: Recommendations of the workshop held in Bremerhaven, FRG, 22-23 October 1974; sponsored by the Deutsche Forschungsgemeinschaft and UNESCO	1976	—
26	Marine science in the Gulf area-Report of a consultative meeting, Paris, 11-14 November 1975	1976	—
27	Collected reports of the joint panel on oceanographic tables and standards, 1964-1969	1976	WG 10
28	Eighth report of the joint panel on oceanographic tables and standards, Woods Hole, U.S.A., sponsored by UNESCO, ICES, SCOR, IAPSO	1978	WG 10
29	Committee for the preparation of CLOFETA. Report of the first meeting, Paris, 16-18 January 1978	1979	—
30	Ninth report of the joint panel on oceanographic tables and standards, UNESCO, Paris, 11-13 September 1978	1979	—
32	Coastal lagoon research, present and future. Report and guidelines of a seminar, Duke University Marine Laboratory, Beaufort, NC, U.S.A. August 1978 (UNESCO, IABO).	1981	—
37	Background papers and supporting data on the Practical Salinity Scale 1978.	1981	WG 10
50	Progress on oceanographic tables and standards 1983-1986: Work and recommendations of the UNESCO/SCOR/ICES/IAPSO Joint Panel	1987	—