# Artificial reefs (Runde Reef) in South Norway

## Test report for two Runde reefs, 2002-2006

**By**

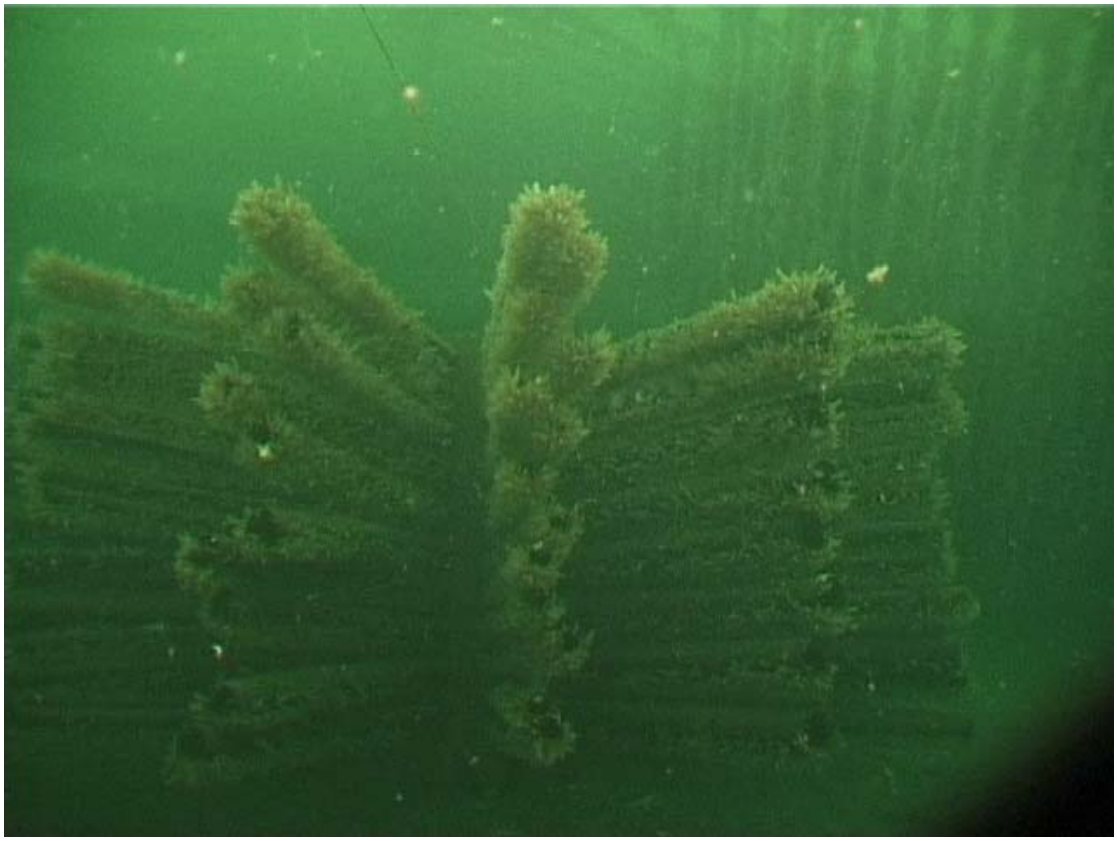
**Hartvig Christie**
**Norwegian Institute for Water Research (NIVA)**

***Summary***

**Two units of "Runde Reef" made by Reef Systems were put in place at 8 m depth in a sheltered fjord, South Norway, in July 2002. The reefs have been inspected in spring, summer and fall each year up to 2006, and fish and other associated organisms have been compared with adjacent control areas. High densities of fish established quickly (days), and attached organisms were established after a few weeks. After the first years, the reefs now support a community of macroalgae, invertebrates and fish that is clearly richer than the surrounding bottom area.**

Launching of Runde Reef from ship

Runde reef in Nordfjorden, November 2002, initially fouled by the sea squirt *Ciona intestinalis*.



## Background and aim of the project

Deployment of artificial reefs often aims to increase and enhance underwater habitats for plants (macroalgae) and animals (invertebrates and fish), and also to protect the coastline against erosion. Artificial reefs have been used to increase densities of shellfish and finfish and also to conserve biodiversity and to restore areas that have been disturbed. More details of the purposes and results of deployment of different types of artificial reefs are described in ”Jensen, Collins & Lockwood, 2000, Artificial reefs in European seas, Kluwer Academic Publishers”.

The aim of this project was to describe the effects on flora and fauna, with special focus on fish, by exposing two units of the ‘Runde Reef’ to possible immigration and colonization by local biodiversity. Fish and other organisms settled on or moving in to the reef vicinity have been recorded and compared to marine life at control sites considered to be representative for the surrounding area.

## Methods

Two units of the reef type ‘Runde Reef’ supplied by Reef Systems AS (see pictures) were located on the bottom at 8 m depth in Nordfjorden, Risør community at the Skagerrak

coast of South Norway. Each supplied reef unit consists of a central cylinder made of concrete that is 2.5 m in height and 1.4 m in diameter. The cylinder is filled with stones to increase its weight and stability. From the cylinder 14 vertical rows of 2.5 m long polyethylene ('plastic') pipes radiate horizontally outwards. The diameter of the pipes varies between 9 and 18 cm. Together, the cylinder and plastic pipes provide an external and internal surface area of 250 $m^2$, the pipes provide a total of 300 m of pipe length, and the total weight is 9 metric tonnes. The location (Norfjorden) and the number of reef units were not decided by scientific reasons, but rather due to limited economic resources and permission given by the authorities to locate the reefs in an area reserved for shellfish aquaculture.

The reefs were put in place on 11 July 2002. Four sites along a shoreline of 400 m were studied the day before (i.e. 10 July), and two of these were chosen to be the reef sites and two chosen as the control sites. The sites were monitored the day after submergence of the reefs, and then on 16 occasions up to October 2006. The recordings were based on SCUBA diver observations, counting fish (qualitative and quantitative registration) and recording of other plants and animals (qualitatively, presence) growing on or moving at the reefs, and similarly on the control sites (a bottom area of ca. 25 $m^2$). For making good estimates of fish numbers, fish were counted in each of the 14 sections between the rows of tubes (see pictures of the Runde reef), and a torch was used for inspection of the inside of the pipes. On a few occasions, replicates of 10x10 cm area were sampled from on the top and mid pipe outer-surface to determine attached organisms and small mobile animals associated with the vegetation. (NB As the control sites were flat bottom only they represent a different habitat type than the reef, but it is the only possible control sites for this study and represent the natural environment of that particular area).

As already mentioned, the circumstances allowed conducting of a limited experiment only. A future goal is to deploy more reefs, and also get an opportunity to compare the findings with reefs in more exposed waters. However, the site in Norfjorden serves as a good example for studying the effects of establishing new habitats on the seabed in situations in sheltered fjords where epibenthic and pelagic marine life is poor.

## Test results and discussion

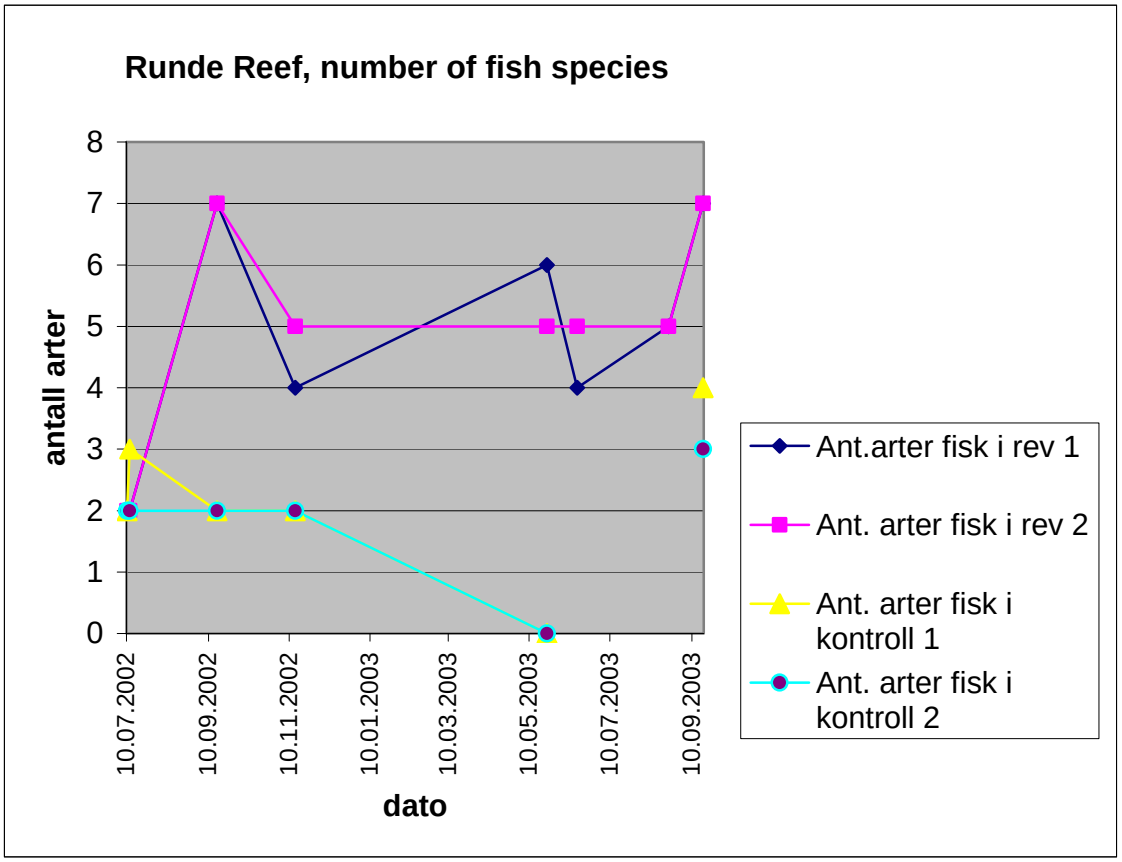
The tidal range in Norfjorden is only 20 cm; the upper ca. 1 m of the littoral zone is covered with seaweeds and mussel beds. Below the quite rich upper one metre, the bottom is composed of slowly sloping sand/mud with scarcely visible macroalgae, macrofauna or fish life. Before deployment of the reefs only a few starfish and small fish (gobies) were recorded. This situation was evident on the control sites every year with the exception of some filamentous algal vegetation in the summer of 2004 and 2005.

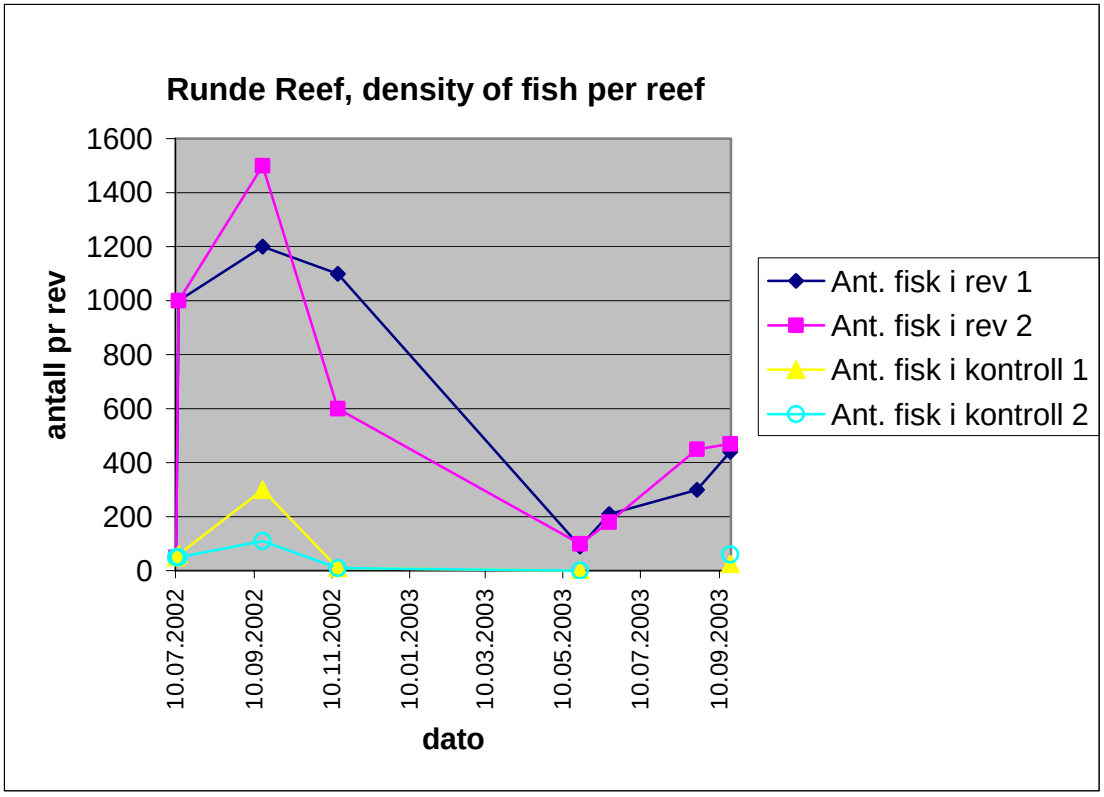
Already one day after the first deployment of the reefs, about 1 000 two-spotted gobies were attracted to each reef, probably immigrants from less favourable sites. After two months, the reefs were densely covered by sessile animals and some filamentous algae on the upper parts of the reef. Seven species of fish were observed associated with the reefs, while only 2 or 3 species were observed at the control sites. Throughout the following

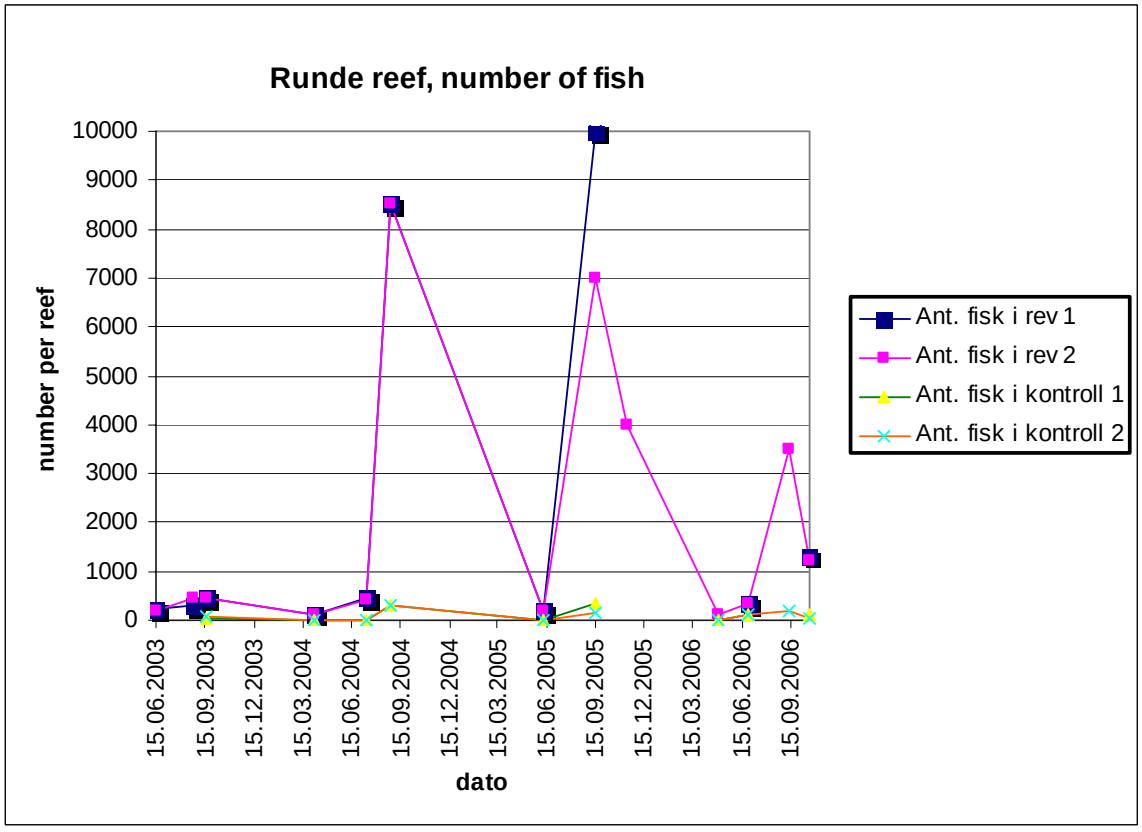
years, stationary populations of about 5 species of wrasses (most common corkwing and ballan wrasse) and gobies (3-4 species) were established. These populations exhibited high densities in summer and low densities in winter. Fish belonging to the cod family (cod, saithe, pollack, poor cod) are frequently visiting the reefs, while other species are more rarely seen.

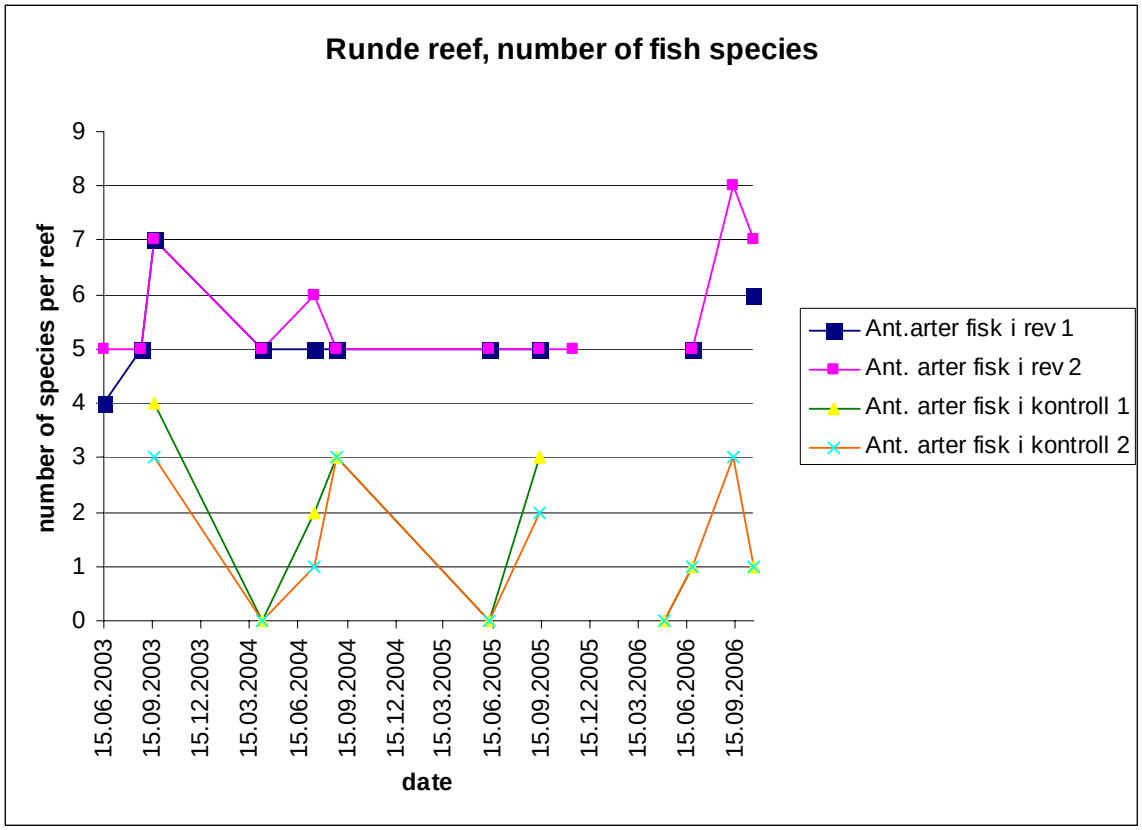
Upper part of Runde reef with attached organisms and small fish (gobids and labrids) in an early succession stage.

The figures below shows the number of fish species and total number of individuals of fish on each reef and each control site, the first two graphs show the situation during the first year, while the next two graphs show the development of fish during the rest of the study period (the graphs are divided into initial and late phase particularly due to the great differences in abundance). Both reefs developed similarly, and contrasted the control sites greatly by considerably increase in fish number and diversity. While the two-spotted goby are scarce in winter and may explode up to 10 000 individuals in summer as seen in 2004 and 2005, the wrasses maintains more stable populations by over wintering in the pipes and abundances vary between 100 and 400. The development has shown a change from initial dominance of small fish (gobies) to a more common occurrence of fish with larger size. A total of 15 fish species have been registered at the two reefs. During the last three years a few edible crabs have established at the reefs (2-4 per reef), and a large lobster has been observed once.


Runde Reef, number of fish species
antall arter
8
7
6
5
4
3
2
1
0
10.07.2002
10.09.2002
10.11.2002
10.01.2003
10.03.2003
10.05.2003
10.07.2003
10.09.2003
dato
Ant.arter fisk i rev 1
Ant. arter fisk i rev 2
Ant. arter fisk i kontroll 1
Ant. arter fisk i kontroll 2


Runde Reef, density of fish per reef
antall pr rev
1600
1400
1200
1000
800
600
400
200
0
10.07.2002
10.09.2002
10.11.2002
10.01.2003
10.03.2003
10.05.2003
10.07.2003
10.09.2003
dato
Ant. fisk i rev 1
Ant. fisk i rev 2
Ant. fisk i kontroll 1
Ant. fisk i kontroll 2


Runde reef, number of fish
number per reef
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
15.06.2003
15.09.2003
15.12.2003
15.03.2004
15.06.2004
15.09.2004
15.12.2004
15.03.2005
15.06.2005
15.09.2005
15.12.2005
15.03.2006
15.06.2006
15.09.2006
dato
Ant. fisk i rev 1
Ant. fisk i rev 2
Ant. fisk i kontroll 1
Ant. fisk i kontroll 2

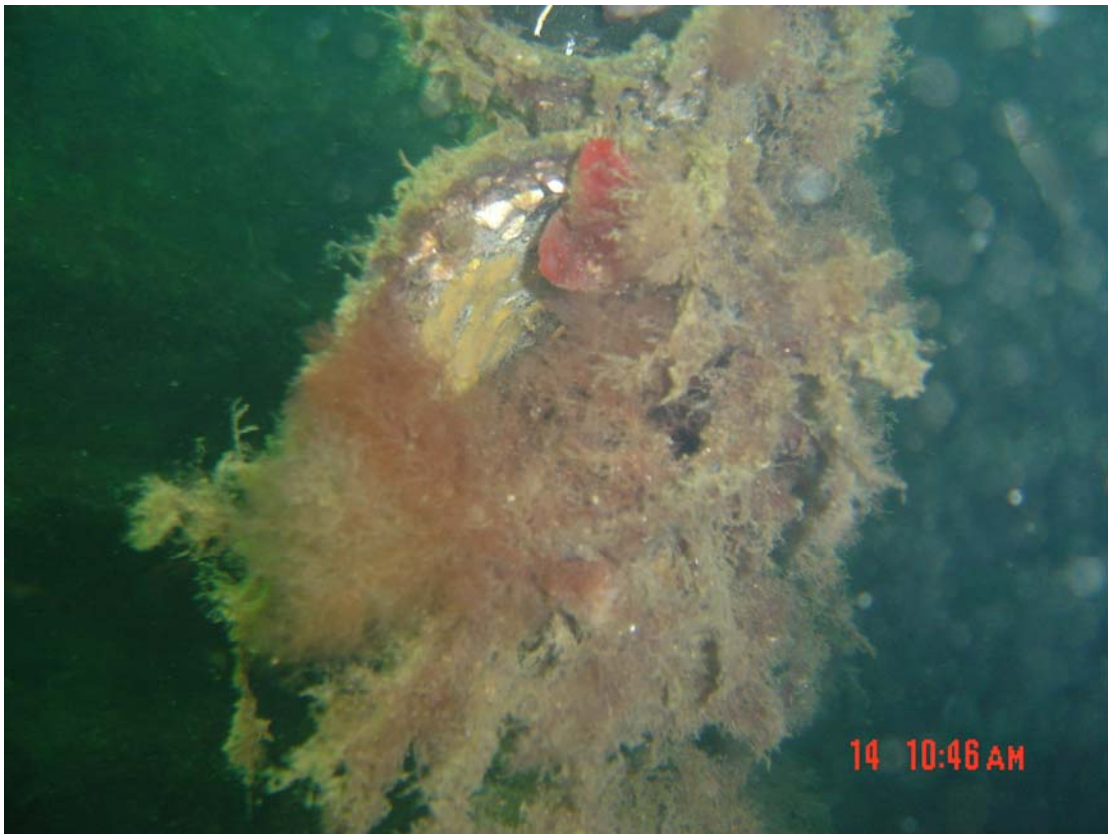



Additionally, the colonizing benthic organisms have developed during the first two years and, in spite of seasonal and annual variations, a pattern of benthic flora and fauna has emerged. Initially the sea squirt *Ciona intestinalis* dominated totally the external surfaces in densities of ca. 300 individuals per $m^2$. Later, ca. 10 species of filamentous algae dominated the top surfaces of each reef, while sessile animals dominated the rest of the external surfaces and also to some extent inside the pipes. Most common are different species of hydroids, sponges, sea squirts, sea anemones and tubeworms. Of mobile animals starfish, sea urchins, and larger crustaceans are the most spectacular, while smaller polychaete worms, snails and smaller crustaceans occur in high densities (10 000-20 000 per $m^2$) interstitially among the larger fouling plants and animals. These animals represent food for the fish, and the production of such animals is high. About 50 species of animals have been identified so far in this newly established hard-bottom community, while both more species and higher densities of these animals are expected to occur in the future although fish predation is high on the reefs.

Even if new species are found at the reefs each year, the reefs seem to have reached a phase of more stable conditions with dominating species of plants, invertebrates and fish. Most of these species' abundances fluctuate with season but peak each summer. Compared to the poor conditions of the surroundings (c.f. the control sites), the reefs represent a considerable enhancement of biodiversity including the abundance of many organisms, particularly regarding hard bottom fauna and fish. The similarity between the two reefs indicates that the results can be considered as basically representative.

However, uses of more than two reef units are needed for drawing statistically valid conclusions about the change in biodiversity and abundances.

A future goal will be to compare more reefs located over a larger area and type of seabed, and to compare reefs in a sheltered fjord with reefs in environments that are more exposed to wave action and current where macroalgae (e.g. kelp and seaweeds) are more commonly growing and the fauna (including fish) are more diverse than at the currently studied site. An interesting aspect is also to test reefs with different shapes or architectures.



The outer part of a pipe with filamentous red algae at the tip, and sea squirts, sponges and tubeworms at the internal surface.


An edible crab situated between two pipes. The surface is covered with old remains of filamentous algae and hydroids. A starfish, sea squirts and some small two-spotted gobies are seen.

It is also noteworthy that two Runde Reef units were deployed on the seabed at 10 m depth near the artificial island construction called the ‘Palm Jumeirah’ in Dubai. The establishment of sessile animals and fish occurred quickly at these reefs, and the development was essentially similar there and in the Norwegian experiment with respect to increases in biodiversity and productivity, although obviously with different species involved. Most external surfaces were covered encrusted by sessile organisms and more than 100 fish belonging to about 10 species was recorded at each reef in Dubai. The surrounding bottom was flat sand with no visible plants or animals present. More details on the Dubai project are provided in Hopkins C.C.E. 2007 (Editor) Dubai pilot project: Test report for ‘Reef Systems’at the Palm Jumeirah.

Runde Reef in Dubai, ca 7 months after deployment. The reef has turned over due to strong currents.

The studies are funded by the research grants TEFT, and by Reef Systems.

Oslo 5.02-2007

Hartvig Christie
Research Scientist NIVA (Norwegian Institute for Water Research)