EKOREEF

Report 5: Platform reef management

By
Rogaland Research
&
Dames & Moore
for
Phillips Petroleum Co. Norway

EKOREEF - Report 5: Platform reef management

Report RF-98/013 - D&M 37363.001/4

Our reference:	Author(s):	Version No. / date:
771/65 44 63	**Cripps, S.J.[1], Forsberg, O.I.[1] and Aabel, J.P.[2]**	**Vers. 2 / 20-10-1998**
No. of pages:	Project Quality Assurance.	Distribution restriction:
42	**Jacobsen, T.G. and Forsberg, O.I.**	**Open**
ISBN:	Client(s):	Open from (date):
82-7220-947-0	**Licence PL018 through Phillips Petroleum Company Norway**	**01-01-2003**
Research Program:	Project title:	
EKOREEF	**Report 5: Platform reef management**	

Scope:

This *Management* report within the Ekoreef programme has the following objectives:

- to address platform reef management related issues, presenting relevant background information and placing the issue into the wider context of the complex multi-species, multi-national North Sea fishery;
- in particular, the potential use to which Ekoreef could be put, and how this may be achieved, is analysed;
- management plans for the artificial reef(s) at Ekofisk are proposed.

The findings of this report are summarised and simplified in a main summary report for the Ekoreef programme.

Key-words:

Ekofisk, artificial reef, environment, rigs to reefs, fisheries management, decommissioning, Ekoreef.

Project Manager - Rogaland Research
Dr. Simon J. Cripps

Project Manager - Dames & Moore
Jens Petter Aabel

1 ROGALAND RESEARCH

2 DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

CONTENTS

PREFACE

As the oldest exploited oil field in the North Sea, the Ekofisk field is currently approaching the end of production. Various options are being considered by the operators as part of a choice of field cessation plans required by the Norwegian government. One such option is the use of suitable, prepared, planned and located platform components as artificial fish attracting reefs: the "Ekoreef" option.

This report presents the findings of the fourth project (report 5) within the Ekoreef programme. A total of 5 main projects have been conducted, and will together assist in the planning and estimation of the potential for one or several complex artificial reefs in the Ekofisk area.

The following reports have been delivered through the Ekoreef Programme:

1. *Summary report* - The main points of the 5 projects have been collated into a concise summarising document.
2. *Present status* - Recommendations have been given as to which areas around both the Ekofisk Tank and the Greater Ekofisk field, appear most suitable for the construction of one or several artificial reefs. An overview of the decommissioned structures available and the general environmental situation, including fishing activities is presented.
3. *Configuration* - Optimal design or designs of a potential Ekoreef have been prepared. These incorporate recommendations for structures to be included in the reef, their configuration, location and the rationale used.
4. *Impacts* - Likely negative and positive impacts on the environment and associated socio-economics have been predicted. A waste management plan is proposed.
5. *Management* - A plan for the management of the Ekoreef, including an assessment of its most beneficial uses, has been prepared.
6. *Monitoring* - A plan for the future monitoring required around the Ekoreef is proposed.

GLOSSARY

Terminology and acronyms

Benthic	Pertaining to the sea floor.
CFP	Common fisheries policy.
Demersal	Living at or near the bottom of the sea.
EMG	Ekoreef Management Group.
Epifauna	The animal life inhabiting the surface of the sediment or a structure.
EU	European Union.
ITQ	Individual transferable quotas.
NGO	Non-government organisation.
Pelagic	Pertaining to the water column.
TAC	Total allowable catch.

Fish species

Cod	*Gadus morhua.*
Edible crab	*Carcinus pagurus.*
Haddock	*Melanogramus aeglefinus.*
Krill	*Euphausiacea spp.*
Lobsters	*Homarus gammarus.*
Mackerel	*Scomber scombrus.*
Mussels	*Mytilus edulis*
Norwegian lobster	*Nephrops norvegicus*
Plaice	*Pleuronectes platessa.*
Saithe	*Pollachius virens.*
Sand-eels	*Ammodytes* spp.
Spider crab	*Maia squinado.*
Whiting	*Trisopterus luscus.*

5 EKOREEF REPORT 5: PLATFORM REEF MANAGEMENT

5.1 Summary

This Ekoreef management report has three main objectives: 1. to address management issues of use, ownership, efficiency, environmental protection and fishing practice; 2. in particular, to analyse the uses to which the reef may be put and how this may best be achieved; 3. to develop management plans for the first 10 years after establishment.

Several high value commercial fish are known to occur in the Ekofisk area, though the region does not contain high numbers of these fish. Their demersal habit indicates that fishing techniques, such as bottom trawls, that can access these fish, will be of most use. The large number of eggs produced by each female cod (3 - 7 million), and hence enormous mortality rate during early life stages, indicates that a protection reef that can assist even of small proportion of these fish to survive, has much potential.

A platform reef can have many potential benefits, though not all benefits can occur at the same time on the same reef. Benefits will be dependant on: the use to which the reef is put; its efficiency as an attractor or protector; the environment in which it is placed. There are three main categories of benefit, for: **fisheries management**, by providing a tool for the controlled exploitation, manipulation and security of commercially caught species (not just fish); **fishing**, by providing enhanced fishing opportunities for commercial fishermen, potentially allowing a reduction in catch effort and an increase in catch security; **the environment**, in the form of fisheries or habitat protection, potentially providing a means to increase the number of juveniles recruiting into the fishery, stabilising the spawning stock, at least locally, and maintaining an undisturbed refuge for non-commercial species, such as the animals attached to the jacket itself. Platform reefs can then basically be used to either assist commercial fishing, or as a protection zone.

Estimates of the attractiveness of a platform reef to fish vary, though a density of 0.3 kg fish m^{-3} is commonly quoted. Using this estimate, an average 150,000 tonne steel jacket on Ekofisk would be expected to hold about 45 tonnes of fish, though not all would be commercially usable. If all structures on Ekofisk were created into reefs as planned, a total of 1,050 tonnes of fish may be attracted. It is not known how quickly these would be replenished if the reef was fished out. Over-fishing of stocks in the region is considered unlikely.

If used for commercial fishing, it would be preferable to manage fishing pressure so that economic benefits were maximised and stocks were harvested sustainably. For safety purposes, even on a fishing reef, a restricted zone for certain types of gear may be required. Use of the reef for habitat protection has much to commend it. There is precedent for such closed areas, which are strongly recommended by some fisheries managers and nature conservationists. Platform reefs may be possible to incorporate into the current review of the Common Fisheries Policy.

Various ownership options are possible ranging from open, uncontrolled access to use by a co-operative of fishermen. Petroleum operators are the least appropriate owners of a reef, fishermen

themselves are the most appropriate, with a range of options between these two. The issue of liability needs to be resolved. Legislation enforcing an exclusion zone would seem to be a suitable means to solve the problem. Ten-year management plans for fishing and for protection are presented. The fishing plan will seek to answer and improve the following: is the reef safe? If not how can this be improved? Are the fishermen obtaining a tangible benefit from the reef? How can this benefit be maximised? Are there significant negative environmental impacts? Can these be minimised, and if so would this make the impacts acceptable? The protection plan will seek to answer and improve the following: is the reef safe? If not, how can this be improved? Is there a benefit to the environment / fishery from the reef? How can this benefit be maximised? Are there significant negative environmental /social impacts? Can these be minimised, and if so would this make the impacts acceptable?

An Ekoreef Management Group is proposed comprising representatives from various organisations. The authority of the Group will depend upon the use to which the reef is put and its level of ownership and access. The Group will be responsible for ensuring that monitoring and efficiency assessments are conducted.

The reefs must be given a chance to function. Sufficient time must be allotted in order for: a stabile faunal community to become established on and around the reef; for stakeholders to develop sustainable exploitation or protection strategies; and for the reef managers to develop and assess their plans. Such developments take time, so an initial trial period of not less than 10 years is recommended. Should the assessments during this time prove inconclusive, then a further trial period may be necessary.

In view of the importance of this management development and assessment strategy, for the North Sea environment, fisheries, fishermen, nature conservation, petroleum industry decommissioning and international economics, it is also recommended that no reef be established without a management and assessment framework in place prior to implementation. Conversion of offshore structures to artificial reefs (even if conducted carefully), without adequate follow-up, does no service to either the petroleum industry or stakeholders, in the long-run.

The findings of this report tend to indicate that the use of Ekoreef as a protected zone is likely to have greater benefits than its use to enhance commercial fishing.

5.2 Introduction

5.2.1 Background

The likely benefits of platform reefs to the North Sea fishery is an issue that is more complicated than may at first sight appear. It involves aspects of environmental protection, fish concentration, stock enhancement, fishing effort and fisheries management. Much has been promised from artificial reefs in the past. Exaggerated estimates of potential benefits has lead to disillusionment and distrust, particularly amongst fishing interests. These over-optimistic claims have probably resulted from a misunderstanding of the likely functioning of a reef. In particular, artificial reefs are often considered to achieve various usage goals simultaneously, even if these goals are largely mutually exclusive.

There are various ways an artificial reef can be managed, depending on the intended purpose (i.e. fish stock protection or fishing enhancement), the ownership, species present and the efficiency with which the reef functions. One specific management plan can not be recommended because there are a number of variables over which the current operator has little control (e.g. ownership decisions), or there is too little information (standing stock biomass on a complex platform reef). Of most use to the operator is the preparation of a flexible management plan for the first 10 years of operation. This would identify preferred options, but would be flexible enough to continue to function, should the preferred option be unobtainable or, for example, fishing efficiency be different to that expected.

Important issues that need to be considered include:

- *Use.* There are different potential uses of Ekoreef within the CFP. With moderate and fluctuating stocks and drastic remediation measures recommended, the proposal of the Ekoreef may come at an opportune time. The fisheries or fishermen's management tool concept can be applied.
- *Efficiency.* An estimate is needed of the <u>expected</u> quantity, species, size and value of fish to be attracted to the Ekoreef. A key parameter, that of attraction to the reef, is unknown and will need to be determined after implementation. The level of juvenile protection can only be determined from empirical data.
- *Fishing practice.* Recommendations, after consultation with fishermen's organisations, as to practical fishing methods that will be required, including safe proximity to the reef, gear, boat size, return period and season, would greatly assist a management plan.
- *Environmental protection.* Artificial reefs can, in theory, be used to assist fishermen at the reef site, or to protect stocks (see *Use* above). The consequence of protection is that stocks, either locally, or in the fishery as a whole, may be increased in the long-term. A common motivation for this policy is that more fish may then become available to catch (recruit to the fishery). There is however also an element of environmental protection, because an increased population of an otherwise over-exploited species will be, for example, at a reduced risk of collapse, as happened to the Canadian cod fishery.
- *Ownership.* Various potential scenarios can be envisaged for transferring responsibility for managing the fishing (e.g. co-operatives), or even ownership, from the original platform operators, to those who know best how to fish and are most likely to gain from the benefits

of good management: the fishermen or fisheries managers. Aspects such as current precedents, legislation, time scale, politics, the Common Fisheries Policy (CFP) of the EU and means to achieve a transfer of ownership/ management/ responsibility/ liability, are relevant.

Based on knowledge on the fish species around the artificial reef, the size and recolonisation rate, a management plan must be defined to ensure a sustainable fishery around the reef or a viable habitat protection zone. It is recommended that an Ekoreef Management Group (EMG) should be established comprising representatives from key organisations including authorities, NGOs, scientific institutes and fishermen's groups.

It is possible that a restricted fishing zone should be maintained for some years after the artificial reef has been constructed. This is partly for scientific purposes as one of the long term objectives of a monitoring programme (Report 6) would be to assess the use of the reef within a sustainable fishery. This would be difficult to assess under an open access policy.

5.2.2 Aims

This Management report has the following objectives:

- to address the above management related issues, presenting relevant background information and placing the issue into the wider context of the complex multi-species, multi-national North Sea fishery;
- in particular, the potential use to which Ekoreef could be put, and how this may be achieved, will be analysed;
- a management plan for the Ekofisk artificial reef will be proposed.

5.3 Fish biology of the main demersal species

5.3.1 Main species

The overview of the commercial fishing activity in the central North Sea, described in Report 2, *Current status* (Table 2.9, 2.10), indicates that the most valuable of the fish species in the Ekofisk region are cod, saithe (*Pollachius virens*), haddock (*Melanogramus aeglefinus*) and plaice (*Pleuronectes platessa*). These fish, at least in the study area are mainly demersal in habit. They would therefore be expected to concentrate on artificial reefs in the Ekofisk area. The results from the ROV survey around various platform structures in the Ekofisk area (Report 2, Current Status, Appendix 2.2) demonstrates that cod and saithe are found in relatively high numbers. In order to suggest a management strategy for these species, the biology and fishing methods must be understood. In this section, the biology and fishing methods for cod, saithe, haddock and plaice are briefly described.

5.3.2 Cod

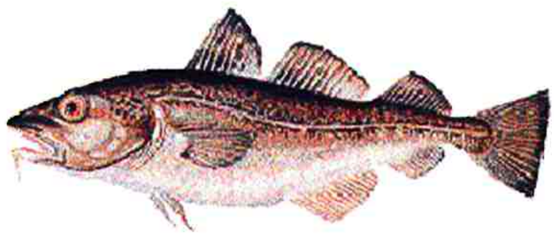


Figure 5.1*: Cod, 1995 North Sea catch: 135,000 tonnes.*

Geographical distribution and migration

There are three main, different North Sea cod stocks:

- to the south of the Dogger bank;
- to the north of Dogger bank;
- off the coast of Scotland.

There are however no clear geographical boundaries between the three stocks, and there is a strong tendency for overlapping of the stocks. Adult North Sea cod are localised, and migrate little. Experimental studies with labelled cod have demonstrated that fish restrict their wandering distance to 40 - 200 km away from the release point.

Life history

Most fish are sexually matured at 3 - 4 years, at about 50 cm length. The spawning occurs between January and April. Each female produces about 3 - 7 million eggs of about 1.4 mm diameter. The free floating eggs are carried away with the sea currents, and hatch after 2 - 3 weeks. The most important grow-out areas for larvae and fry are along the Danish coast, the German Bight and around Shetland. During the first winter, cod grow to about 15 - 30 cm. They live close to the sea bottom, and mix with other fish species such as saithe, whiting (*Trisopterus luscus*) and haddock. Adult cod attain a maximum size of 190 cm, though currently, 50 to 80 cm is more usual.

Feed web

The food they eat varies with age. Young cod consume mostly crustaceans, but older fish have diet composed mainly of fish (e.g. sand-eels *Ammodytes* spp., whiting and haddock). Cod show a strong tendency towards cannibalism, and thus may also feed on younger cod. North sea cod grow faster and become sexually mature earlier than cod in the Barents Sea.

5.3.3 Saithe

***Figure 5.2**: Saithe, 1995 North Sea catch: 100,000 tonnes*

Geographical distribution and migration

During the summer, 3+ year saithe are distributed all over the North Sea, but during winter months, they gather in the spawning grounds west of Shetland. Immature fish (0 - 3 years) however, are concentrated along the western part of the Norwegian trench and at the west coast of Norway. It is assumed the migration patterns are influenced by the distribution of krill (*Euphausiacea* spp.) which is its main diet.

Adult saithe live in deep water, often close to the sea bottom, where they search for prey organisms. Saithe migrate significantly longer distances than cod and haddock.

Life history

North Sea saithe becomes sexually mature at an age of 4 - 6 years, at a length 50 cm. Fish spawn in February-March in deep water (150 - 200 m). Eggs, larvae and fry float in the surface water, and are transported by the sea currents to the coast off western Norway. The saithe then live close to the coast the first three years, before migrating to deeper water. Saithe grow to about 20 cm the first year, and then 40 cm by the third year. The maximum size of adult saithe is 120cm, though 60 to 90 cm is currently more usual.

Feed web

Saithe feed on planktonic crustaceans during their first three years, especially copepods and krill. When saithe grow older, they feed more on other fish (sand-eels, whiting).

5.3.4 Haddock

***Figure 5.3**: Haddock, 1995 North Sea catch: 78,000 tonnes*

Geographical distribution and migration

The North Sea haddock population is composed of several separate stocks which are difficult to differentiate between. Most of haddock are distributed north of a line drawn from Egersund (Norway) to Newcastle (UK).

Life history

The North Sea haddock is sexually mature at 2 - 3 years when they are about 30 cm. Spawning occurs during spring months, and the fry settle at the sea bottom during the winter. Adult haddock usually live close to the sea bottom. The maximum size of adult haddock is 112cm, though 50 to 75 cm is more usual.

Feed web

Its diet is mainly composed of bottom-living invertebrates, such as mussels, polychaete worms and starfish. They also consume some bottom-living fish (sand-eels, whiting).

5.3.5 Plaice

***Figure 5.4**: 1995 North Sea catch: 107,000 tonnes*

Geographical distribution and migration

Plaice are widely distributed over the central and southern parts of the North Sea, and in the Skagerak / Kattegat areas. Plaice live on the sea bottom, mainly on sandy sediments, from the tide line to 250 m depth, most abundant between 10 - 50 m. The young fish usually live close to the coast, at depths shallower than 10 m.

Life history

Plaice spawn in deep water (50 - 200 m) during February-March. A female spawns 10,000 - 600,000 eggs per season. Fertilised eggs floating to the surface, and drift with the currents until they settle on the sea bottom during early summer months, when they are 12 - 17 mm length. Juvenile fish swim to shallow water and live there until autumn, when they migrate to deeper water.

Feed web

Their diet is mainly composed of sediment burrowing invertebrates, such as molluscs, polychate worms and various crustaceans.

5.4 Fishing techniques

Cod are mainly taken together with haddock and whiting in mixed roundfish fisheries using towed gears, such as demersal trawls and Danish seines. Figure 5.5 shows the fishing technique. By using different mesh sizes, only fish larger than the legal minimum size will be caught. This reduces the wastage of small undersize fish and allows some fish to reach maturity and spawn.

Saithe are mainly taken in deep water in a species-directed trawl fishery during the spawning season. North Sea plaice are mainly caught in mixed flatfish fisheries by beam trawlers. Directed fisheries are also carried out with seine and gill-nets.

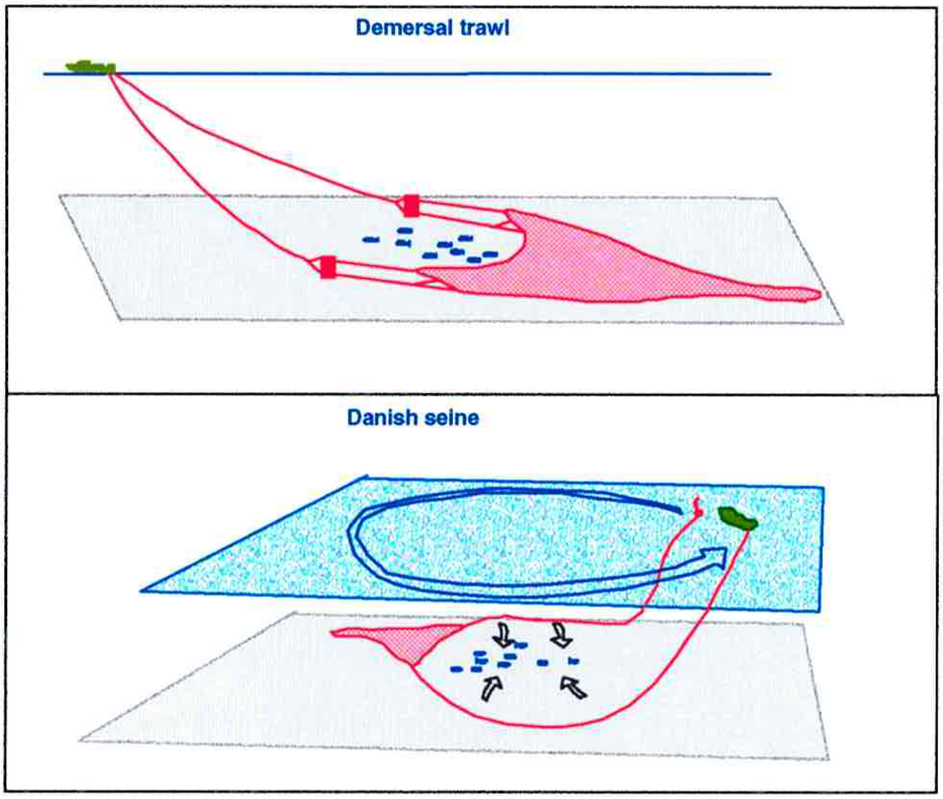


Figure 5.5: *The principles of demersal trawl and Danish seine fishing.*

5.5 The use of platform reefs

This section is mainly based on information and proposals in Cripps *et al.* (1995), Cripps (1997) and Aabel *et al.* (1997). It is important to state what uses North Sea reefs can be put to and indicate any areas of uncertainty. Thus, their implementation can be better planned, efficiency accurately monitored by permitting the correct choice of assessment parameters and the need for more information identified.

5.5.1 Potential benefits

Offshore structures do attract fish, of this there is no doubt. In addition to numerous scientific studies (e.g. by Olsen and Valdemarsen, 1977; Valdemarsen, 1979; Cripps and Aabel, 1995; and the ROV survey results presented in Report 2, *Current status*), it is well known by rig workers that platforms are good angling sites. Indeed in many instances, sports fish catches from platforms, by offshore workers are so large that their storage and subsequent transport to shore, needs to be restricted, because of transport logistic limitations.

Fish attraction alone is though an oversimplification of the situation as several aspects are associated with the creation of an artificial reef. The interaction between these aspects, e.g. biology, engineering, safety, social, management, politics, etc., is complex.

The potential benefits can be summarised as follows:

- greater density of fish;
- decreased fishing effort;
- increased catch security;
- protected juveniles - increased recruitment of young fish to a catchable size;
- protected adults - more secure stock, so population less likely to crash;
- provision of new habitat;
- restoration of damaged habitats, such as from the action of bottom trawls;
- protection of existing habitat;
- a technical conservation tool within the EU's CFP;
- a means to transfer management to the fishermen themselves.

It should be noted that not all the benefits can occur at the same time on the same reef. Actual benefits that accrue will be dependant on many factors including:

- the use to which the reef is put;
- its "efficiency" as an attractor or protector;
- the environment in which it has been placed.

5.5.2 Potential beneficiaries

From the above summary it is possible to discern 3 main categories of benefit:

1. **Fisheries management**, by providing a tool for the controlled exploitation, manipulation and security of commercially caught species (not just fish);
2. **Fishing**, by providing enhanced fishing opportunities for commercial fishermen, potentially allowing a reduction in catch effort and an increase in catch security;
3. **Environment**, in the form of fisheries or habitat protection, potentially providing a means to increase the number of juveniles recruiting into the fishery, stabilising the spawning stock, at least locally, and maintaining an undisturbed refuge for non-commercial species, such as the animals attached to the jacket itself (epifauna).

The interests of these groups are not mutually exclusive. Management seeks to maximise sustainable benefits for the fishing industry and thus will benefit both fishermen and to a lesser extent the marine environment as a whole. Concentration of fishing at a reef could be a means to reduce fishing pressure and the resulting impacts, at off-reef sites. Fisheries and habitat protection will lead to benefits for fishermen in the longer-term as described in point 3 above.

An artificial reef can be used for either fishing or protection. These uses are partially mutually exclusive, at least in the short-term. A reef with the aim of protecting habitat and fish will necessarily need to have, by virtue of its impenetrable design or regulations, a fishing exclusion zone. Whilst fishing would be conducted at the periphery of this zone, the reef would not be suitable for assisting fishermen to catch fish. The opposite will also be the case, because if fishing is permitted on the platform reef, the reef will be use for attracting and concentrating fish so that they can be more easily captured, and hence it will not be a safe protected zone. Depending on the fishing gear to be used, a fishing reef may still serve as a protected habitat for attached, non-commercial species.

5.5.3 Potential negative aspects

Not all the effects of platform reef creation are expected to be beneficial. This report, *Management* stresses the positive aspects, because it is these that a management strategy attempts to maximise. These arguments should not be taken out of context of the whole report, which attempts to give a balanced picture.

In Report 4, *Impacts*, 37 potential impacts are identified, both positive and negative. Not all are expected to be likely to occur, or occur on the same reef at the same time, however some are potentially serious. They can be grouped into the following 6 headings. For greater detail about each impact see Report 4 *Impacts*. The list should not be considered as exhaustive.

- **Exploitable stock impacts**: relating to redistribution, over-fishing or contamination of the commercially fishable stock.
- **Local biota impacts**: changes in the species present and the number of individuals for various reasons, and their contamination.
- **Sediment impacts**: changes in the characteristics of the sediment.
- Water column impacts: flow changes.

- **Socio-economic impacts**: on the fishing industry through limited access, changes in gear or loss of grounds, and the petroleum industry through negative publicity.
- **Miscellaneous impacts**: such as damage to existing infrastructure, hindrance to shipping and operator liability.

In the same way that management and good planning of a reef will seek to maximise the benefits, they will also attempt to minimise the negative impacts.

As has been stated previously, the use to which a reef is put will determine the balance of positive and negative impacts. For example, a reef managed as a protected area, may well benefit fish stocks in the area, but will negatively impact fishermen, at least in the short-term, until tangible benefits accrue sufficiently for off-reef catches to increase (if they ever do).

5.6 Platform reef efficiency

In order to estimate the best use to which a particular reef could be put, and to predict the optimal management strategy that must be implemented to achieve that goal, a knowledge of the functioning and likely efficiency of platform reefs is required.

5.6.1 Platform reef functions

Artificial reefs are tools for changing the ecosystem to achieve benefits (adapted from Stephan *et al.*, 1990). They are habitat enhancement devices placed in marine or fresh water to provide a specific habitat for target species. By increasing the carrying capacity of the natural environment their purpose is to increase the overall productivity. Artificial reefs have been used for centuries by coastal communities and have become popular fisheries management tools world-wide (De Silva, 1989; FAO, 1990).

Platform reefs could function as fishery enhancement devices because they resemble the functioning, if not the exact structure, of natural reefs. In general, they show a similar species composition and community structure to natural reefs in the same area, assuming they are subject to the same environmental conditions (Ambrose and Swarbrick, 1989; Bohnsack and Sutherland, 1985; Matthews, 1985). The depth at which a reef is situated is important, especially with respect to algal composition, because of the light available.

Fish have been shown to recruit rapidly to a reef, sometimes within hours of installation (Bohnsack and Sutherland, 1985). Some species reaching a climax (stable) population size within a few months. This recruitment may create an enhanced fishing zone up to several hundred metres from a reef, though based on the results of the ROV earlier in this study, it is thought that in the case of Ekoreef, this zone may be less than 100 m. Larger catches are however, generally limited to within 60 m (Mottet, 1981). An equilibrium community structure is usually achieved within 1 - 5 years.

Seasonal variations in the number of species and individuals present on a reef are common, as are changes in the community structure with depth. Again, this was clearly demonstrated in the results of the ROV survey within this study, which indicated changes in attached animals with increasing depth, from the surface to about 75 m, and changes in the number of fish present at different depths.

5.6.2 Fish behaviour

Several, within a range of environmental cues, are thought to play a role in attracting fish to artificial reefs, including (Bohnsack and Sutherland, 1985):

- current patterns;
- shadows;
- species interactions;
- sound;
- touch;

- pressure;
- visual cues of size, shape, colour and light.

In order for a platform reef to function as efficiently as possible in terms of the number of fish it attracts, it is important to optimise these parameters. This can be achieved through structure design, size, location and configuration with respect to other reef units. These parameters were considered in detail in Report 3, *Configuration*.

Different species exhibit different behavioural preferences throughout their life cycle. In particular, several fish species have been shown to stay near artificial structures for protection when small and vulnerable to predation (Anderson *et al.*, 1989). An artificial reef can be important for the fish stocks of a much larger area than just the reef itself, because it gives protection to the fish during their most vulnerable stages. Japanese reefs, for example, are built to improve spawning, recruitment and survival of animals during the early stages of their life histories (Mottet, 1981).

In general, it is thought that platforms make good artificial reefs because they provide;

- hard bottom habitats;
- an abundant food supply from attached and motile species (not proven);
- a visual, tactile or auditory reference point in an otherwise unstructured environment;
- structural openness permitting adequate circulation of water within the interior;
- a large surface area (compared with a plain sea-bed), which in conjunction with water circulation, encourages abundant biofouling and benthic hard-bottom species;
- physical design complexity providing shelter from strong currents and predators;
- a range of habitats throughout the water column allowing different species to remain at their most favourable depth;
- spawning and nursery grounds.

The degree of importance of each of these factors depends on the particular species and life cycle stage of the species involved (Driessen, 1985).

Operating oil platforms extend throughout the water column, providing benthic, mid-water and surface habitats. Fish studies around Gulf of Mexico platforms have revealed that fish are present at all depths, with the greatest variety in the range 30 - 70 m depth (Ditton and Falk, 1981). Ambient conditions, such as light penetration, are though very different in the Gulf of Mexico compared with the North Sea. Work conducted in the North Sea (Cripps and Aabel, 1995) does nevertheless corroborate this conclusion. Results of the Ekofisk ROV survey (Report 2, *Current status*) indicated that fish were only present within about 5 m of the bottom. The majority of fish may then use the deeper parts of a reef in the Ekofisk region, though this is by no means certain.

Once attracted to a natural or artificial structure, fish tend to assume one of three particular positions relative to the structure (Ogawa, 1986). The species found around North Sea structures may approximately be assigned to these patterns:

- upper and mid-water swimmers, such as saithe, congregate over or around structures tending to hover and remaining in the upper layers as a shoal;
- bottom layer swimmers which gather around the structure but are not sedentary, such as cod;
- sedentary fish which inhabit holes and spaces, such as ling and red fish.

Again, whilst this pattern was found by Cripps and Aabel (1995), it has not be found at Ekofisk. The pattern is though expected to develop when a platform reef at Ekofisk is established, though all the groups may not occur at the same time or in the same quantities.

Platforms do not provide all the food necessary to sustain the high densities of fish living around them. The presence of fouling on the submerged structure is not essential in attracting or retaining populations of fish. Indeed it is possible that fish do not, or only rarely feed of the sessile animals attached to the platform. The many thousands of fish found around North Sea structures must therefore continue to derive the bulk of their food from off-reef sources (Mottet, 1985; Todd and Bentley, 1991), or from other animals that may also attracted to the reef, such as krill. Studies of species around offshore platforms have focused on fish, so there is no documented evidence that commercial fish food species such as krill are actually attracted to platform reefs. The ROV survey conducted during this study provides tentative evidence that this may though be the case. though to what extent is unknown. Further, if the fish around platform reefs do grow, as is proposed, then they must be obtaining food from somewhere. The source is presently unknown.

In general, it is likely that a combination of factors gives rise to the observed distribution of fish around platforms, the species-specific aspects of behaviour being at least as important as installation-related features. The immediate platform environment is one which fish find acceptable and to which they are attracted, and one which apparently produces no adverse effects in terms of physiology, biochemistry or commercial value. A growing body of evidence indicates that offshore platforms can raise productivity levels, create new habitats and augment carrying capacities, therefore increasing the diversity, numbers, range, size and growth rates of desirable fish. By attracting juveniles, the platform reefs may allow more individuals to reach adulthood than was previously possible. It is though also possible that the presence of any juvenile fish will attract the adults of fish-eating or cannibalistic species, such as cod, that will prey on the small fish.

The structures scattered throughout the North Sea are therefore likely to be providing local reef habitats that are intermittently utilised by fish. Evidence suggests that the existing working platforms are having a small, beneficial effect on local fish populations.

5.6.3 Fish density estimates

The ecological basis behind the functioning of artificial reefs is poorly understood, despite the large investment in them by certain countries. The variety of materials used, and broad range of conditions in which reefs are deployed, has limited the conclusions that could be made. Nevertheless, at artificial reefs, high fish densities, biomass and catch rates, in addition to rapid colonisation, are well documented (Bohnsack *et al.*, 1991; Bohnsack and Sutherland, 1985).

Overall, artificial reefs are thought to aggregate existing scattered individuals and allow secondary biomass production (Bohnsack and Sutherland, 1985; FAO, 1990) by:

- increasing survival and growth of larvae and juveniles that utilise hard sub-strata by providing a settlement substratum, shelter from predation and additional food resources;
- creating new food webs through the provision of new spaces, habitats and colonisation patterns;
- protecting the sea-bed and nursery grounds;
- recycling energy by retaining a localised ecosystem.

A major uncertainty associated with a justification for the establishment of platform reefs is the degree to which they will concentrate fish, and what the effect will be on the fish stocks in the region as a whole.

Predictions of the density and quantity of fish (the standing stock) around a North Sea platform reef can be made using data from surveys of fish at operating North Sea platforms. The weight of fish per unit volume of enclosed space within the reefs created by the presence of platforms in the North Sea ranges from 0.055 kg m^{-3} to 0.62 kg m^{-3}. Other estimates from the UK sector suggest approximately 0.3 kg m^{-3}, amounting to about 70,000 pelagic fish and 9,000 demersal fish aggregating within 100 m of each installation (ICIT, 1991). The average weight of fish per unit volume of enclosed reef is then about 0.3 kg m^{-3}. A rough estimate for a reef(s) made of all jacket structures only, indicates a capacity to hold approximately 1,050 tonnes of fish in the 3.5 M m^3 of jacket volume. An average size steel jacket on Ekofisk (ca. 150,000 m^3) would then hold about 45 tonnes of fish, assuming the density value to be applicable to the special case of Ekoreef. It is unlikely that this biomass of fish will be distributed evenly throughout the reef. It is probable, for example that higher densities will be found near the sea-floor.

In general, the number of fish found around individual operating North Sea platforms, although locally high, is still small in relation to the overall stocks of fish in the North Sea. The Norwegian total allowable catch (TAC) for North Sea saithe in 1995 for example was 53,000 tonnes (ICES, 1996 in Table 2.8). The large size of a reef or series of reefs constructed using all the available platforms could though potentially hold a significant, though not large, quantity of fish amounting to about 2 % of the Norwegian saithe TAC. This quantity would be held within a small, relatively non-productive (see section 2.7, Report 2, *Present status*) area of the North Sea as a whole. That is, assuming such a large concentration of fish could be held within such an otherwise non-productive area, were it not for the presence of the reefs.

It should be noted that not all of these fish will be commercially valuable, or larger than the minimum catch size.

Depending on the effectiveness of the fishing technique employed, the reef stock would be expected to be caught in a short time, or if the stock proved difficult to catch, then small returns would be expected over a longer period. In either case, given the current level of knowledge regarding standing stocks around oil installations as reefs, the premise of the provision of increased stocks would seem inadequate on its own to motivate the establishment of such an artificial reef. Arguments based on this single premise could be open to misinterpretation, resulting in a too pessimistic assessment of the several other benefits which could be achieved.

5.6.4 Changes in fishing usage with reef decomposition

In the previous section the possible characteristics that make an artificial reef attractive to fish were listed. The main factors related to the structure and physical presence of the reefs. It is further expected that attractiveness will increase with size, i.e. larger structures will attract more fish (though it is not know yet whether the number of fish per unit volume will increase with size). Assuming this to be true, it is likely that as size decreases, in terms of usable volume, height and complexity, then the attractiveness, holding capacity and hence the number of fish on the reef will decline.

In section 4.5.6 an attempt was made to predict the likely disintegration of the reef structure, primarily as a result of corrosion after the anodes (used for corrosion protection) have been used up. Once the platform reef has collapsed, after more that 135 years, the usable volume and high, attractive profile will be reduced. The efficiency with which the remaining debris attracts fish will therefore be greatly reduced.

Conceptually, four phases of reef functioning can be envisaged, relating to the age and physical integrity of the reef structure (Table 5.1 and Figure 5.6). It must be stressed that this is just a theoretical prediction, based on structure decomposition rates and fish attraction efficiency estimates.

***Table 5.1**: Predicted long-term changes in platform reef function with age.*

Phase	Age (years after placement)	Platform	Fish and ecosystem	Function
1. Establishment	0 - 2	Newly toppled & positioned	New species attracted. Populations become more stable	Possibly restricted access or less efficient use
2. Operational	2 - 135	Corrosion protected & free phases	Relatively stable - multi-species assemblages	Most efficient exploitation or protection phase
3. Collapse	135 - 170	Structure collapses as >75% of structural members corrode	Fewer niches available - number and diversity decrease	Less efficient for exploitation - some remaining protection
4. Debris	170 - ?	Parts of the reef corrode away or are buried	Approaching ambient state	Return to pre-platform resource use

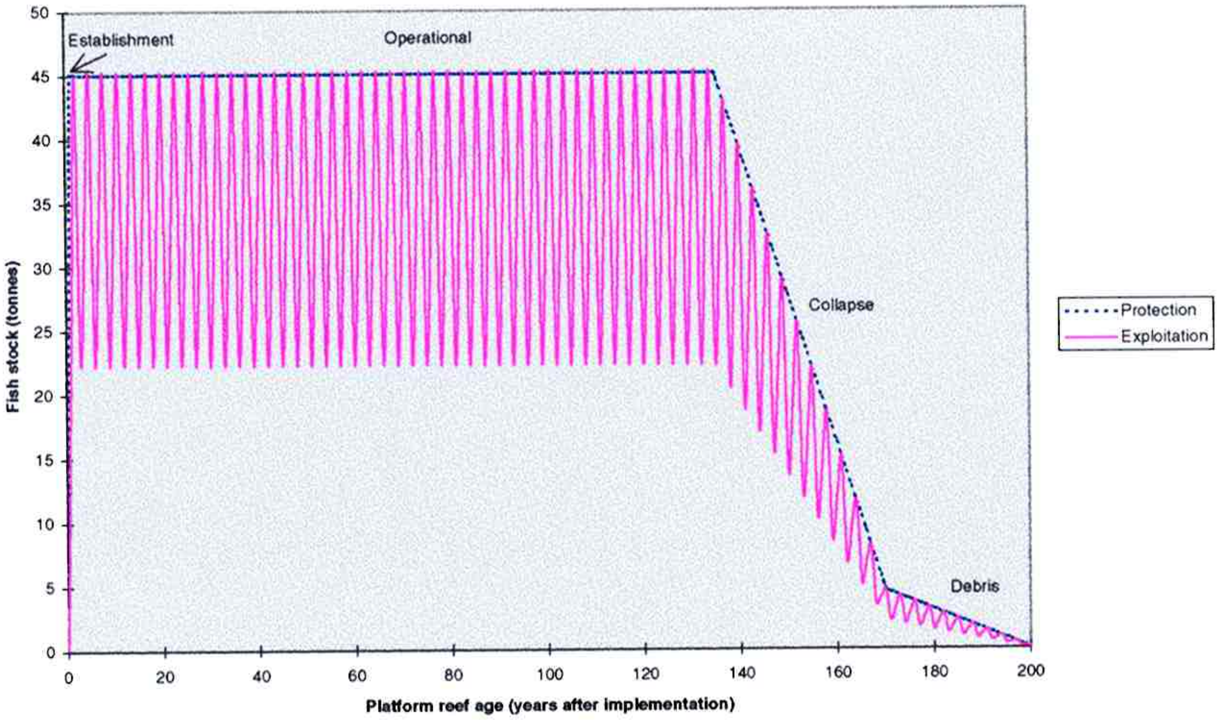


Figure 5.6: *Speculative prediction of possible long-term patterns in fish stock and catches on an artificial reef constructed using a single platform of 150,000 m*^{3} *volume.*

5.7 Using Ekoreef for fishing enhancement

5.7.1 Fishing effort reduction

Platform reefs as fish concentrating devices can make fishing easier. The quantity of fish caught around reefs can be greater for the same effort compared with fishing in open sea. This is because the reefs can increase the density of fish present, as described in the previous section.

It is in the fishermen's interest to catch the required weight of fish in as short a time as possible and by travelling as short a distance as possible. Time means staff wages and interest payments, distance means fuel costs. Catch security is also an important consideration, i.e. an increase in the probability of being able to catch the required weight of fish in a given period. The minimum catch for a boat will need to be less than the likely reef catch, for a trip to be worthwhile for a fisherman to attempt.

The limited increase in standing stock, the increase in catch security and decrease in fishing effort indicate that artificial reefs may act as fishermen's management tools, rather than the more commonly known function as fisheries management tools. This is a subtle but important distinction which summarises the likely functioning of the reefs, and is not exactly as commonly envisaged. Put simply, whilst artificial reefs in the North Sea have not yet been proved (because they have not yet been studied) to increase fish stocks (the fisheries perspective), they may make the fishermen's job easier (the fisherman's perspective) (Cripps, *et al.*, 1995).

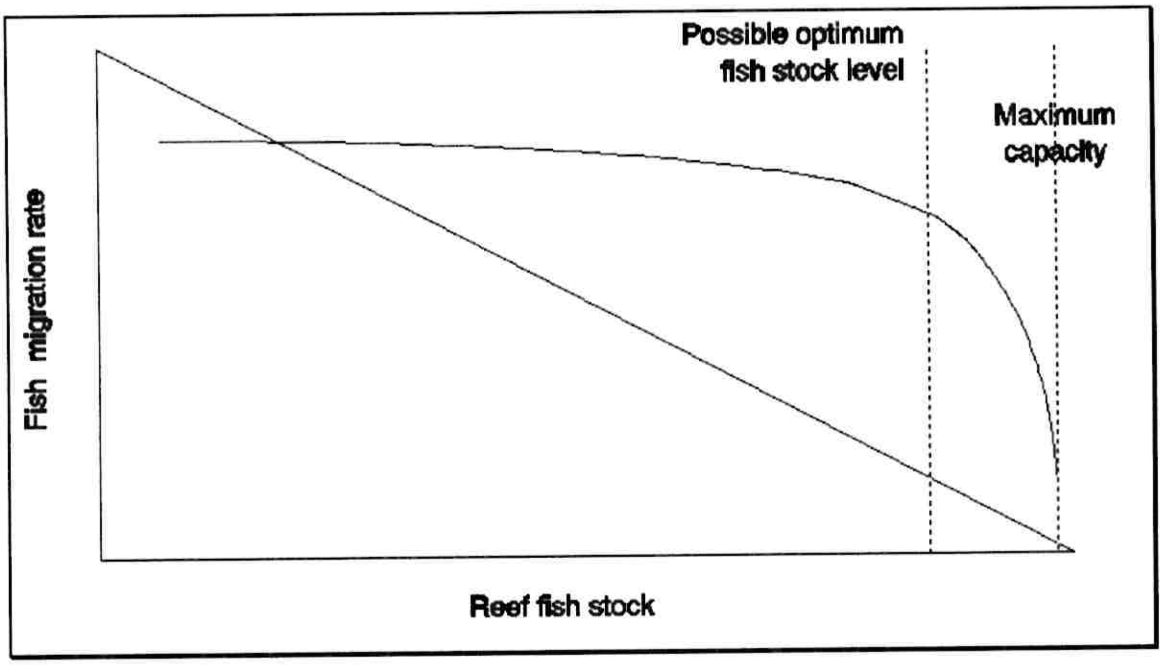
The behaviour and location of the fish around the platform reefs will be an import factor determining their susceptibility to being caught with a particular type of gear. Animals that keep close to the structure of the reef and possible remain within the reef for long periods, will be difficult to catch. Fish that swim away, at least 100 - 500 m, from the reef for some of the day, or during particular seasons, will be easier to catch.

A range of fish species may be expected to inhabit a North Sea platform reef. Not all of these will be commercially valuable species. Many of the smaller species and juveniles will use the reef as shelter from predation, but as such will tend to lie more within the structure. Some of the larger commercial species such as cod and saithe will tend to swim off but near the reef and as such will be more accessible to commercial fishermen that cannot fish too close to the reef for fear of damaging their gear. The proportion of commercial species which comprise the total standing fish stock and the location of these species in relation to the reef, are aspects influencing the commercial fishing efficiency of a reef.

5.7.2 Re-colonisation

The quantity of fish on a reef at any time is obviously an important criteria determining the usefulness, to commercial fishermen, of a reef. A further, probably more important and currently unknown factor influencing both usefulness and reef fisheries management, is the re-colonisation rate. A fast rate would enable the fish to be fished more frequently than a slow rate. For example, even if there was a very large standing stock on a reef, if after the fish were removed by fishing, numbers did not return to pre-fishing levels for a year or more, then the usefulness of the reef would be severely limited. Conversely, a reef with even a small standing stock may be worthwhile from a fishing perspective if it can be fished frequently to achieve a reliable catch quantity.

Figure 5.7: *Speculative fish migration and optimum fish stock level estimations (in Cripps et al., 1995). Fish migration rate is the net rate of change of fish biomass on the reef with time and reef fish stock is the biomass of fish already on the reef.*



The change in the re-colonisation rate as a result of changes in the stock present on the reef, would determine the optimum reef stock density that should be maintained by fishing pressure. It would, for example, be expected that as fish migrate to the reef (on average, as there will be a two-way flow), the stock on the reef increases and this in turn makes it more difficult or unattractive, for various reasons, for further fish to migrate. The rate of migration therefore declines. It may be that a considerable reduction in fishing pressure, by more infrequent fishing, would lead to only marginally increased catches (Figure 5.7). Optimal catches would then be achieved in the long term by removing fish while stocks are below maximum, therefore more frequently. It is vital to the estimation of reef fish-aggregation efficiency and to the preparation of fisheries management plans that the re-colonisation rate for oil installations in the North Sea is studied and quantified.

5.7.3 Over-fishing

There is some danger of over-fishing stocks in the region around an artificial reef. Such stocks are already under considerable pressure from multi-national fishing fleets and quotas generally above those recommended by fisheries scientists as being optimum. There may well be a need to regulate fishing in prescribed areas around the reefs, at least until sufficient data has been accumulated to estimate the possibility, if any, of over-fishing. Data from US studies indicate that the possibility of over-fishing is not great.

If current fish landing quotas are adhered to, there should be no chance of over-fishing stocks in the North Sea as a whole. The same quantity of fish will be removed as that prior to the creation of a reef, but as discussed above, the effort and time used to catch them may be reduced.

There are two main hypothetical scenarios that could influence the form and extent of any likely over-fishing pressure. The first would occur if the reef functioned efficiently as a fish attractor (Figure 5.8a). The large stock on the reef would attract fishermen who would remove a large quantity of fish, which would be replaced by a diminishing off-reef population. The second possibility is that the reef did not function as a good fish attractor (Figure 5.8b). The small stock of fish would attract only a few fishermen occasionally. They would remove a smaller quantity of fish that would be replaced only slowly from the off-reef population. The regional stocks would in this case be largely unaffected.

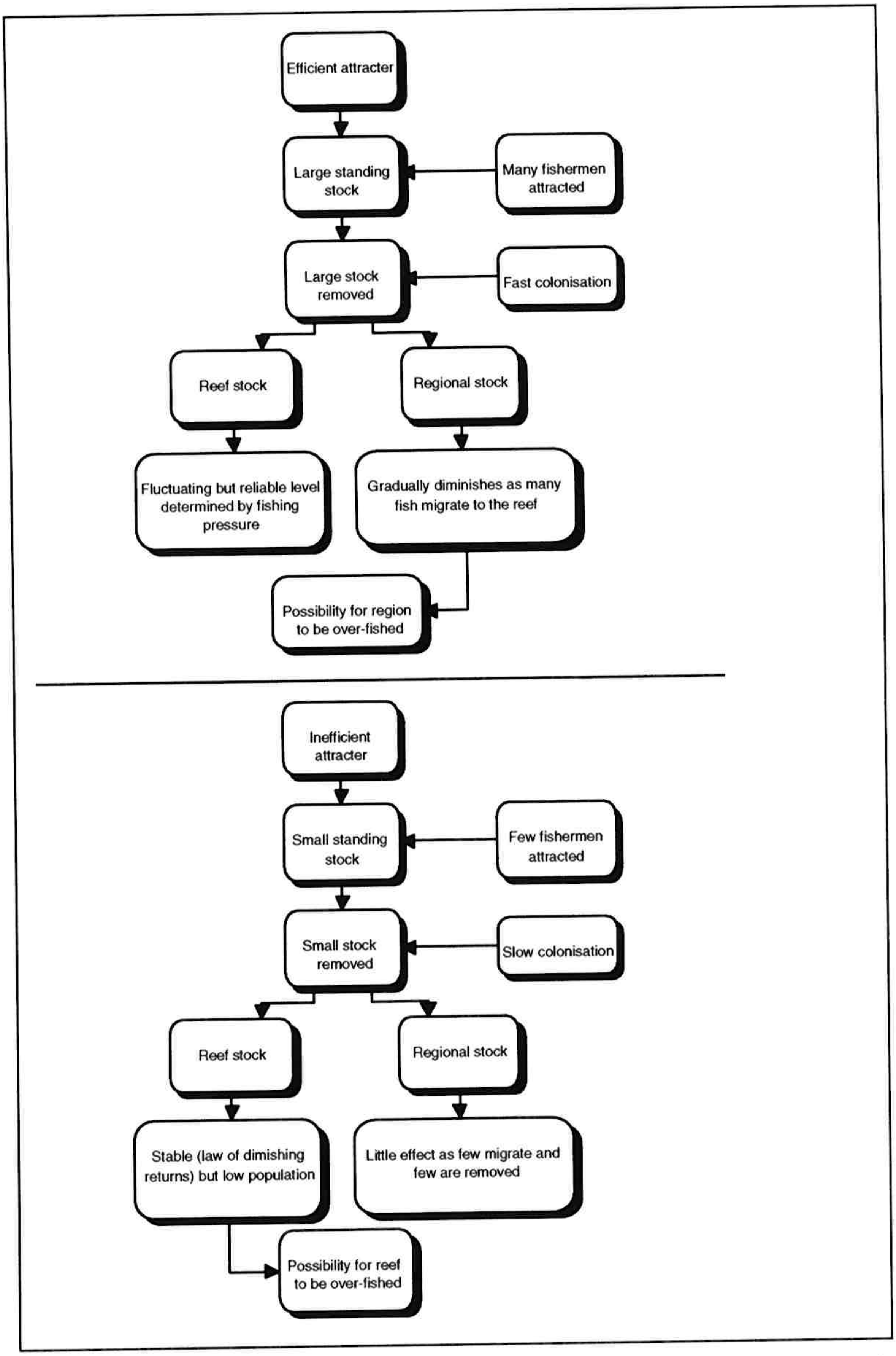


Figure 5.8: *Different scenarios for over-fishing. Top figure = 5.8a, bottom figure = 5.8b (in Cripps, et al., 1995).*

5.7.4 Fishing practice

The determination of a suitable fishing effort for a reef will be an important management parameter. When considering fisheries stock management options within a region such as the North Sea as a whole, the concept of F_{max} is commonly applied. F_{max} is the fishing effort, e.g. in terms of days fishing with a particular type of gear, that produces the maximum yield, i.e. fish caught. Figure 5.9 indicates the relationship between increasing effort and catches and is called the yield per recruit curve. If fishing is not great, then few fish are caught and these tend to be of a larger size because they have a good chance of surviving, i.e. escaping fishing mortality, from one year to the next. As the effort increases, more fish are caught, but fewer large fish survive. There then comes a point where so many fish are caught that only small fish growing from one year class to the next (recruiting) remain to be caught and a lot of effort must be expended to catch these few fish. This is similar to the law of diminishing returns.

Though only an untested theory, is possible that the assessment of F_{max} for artificial reef stocks will be a special case of the regional fisheries model explained above. Instead of fish merely recruiting into a catchable size class as a result of growth, fish will move on to the reef from the surrounding fishery. In such a case the yield per recruit curve (Figure 5.9) may be skewed to the left for reefs. Catches per unit effort may be greater on a reef, as explained above, but as the stock is small and localised it will be relatively easy to fish-out, leading to an efficient use of fishing resources and inefficient economics. The rate of decline in catches with increasing fishing effort above F_{max} will be dependant on the re-colonisation rate of the fish after fishing.

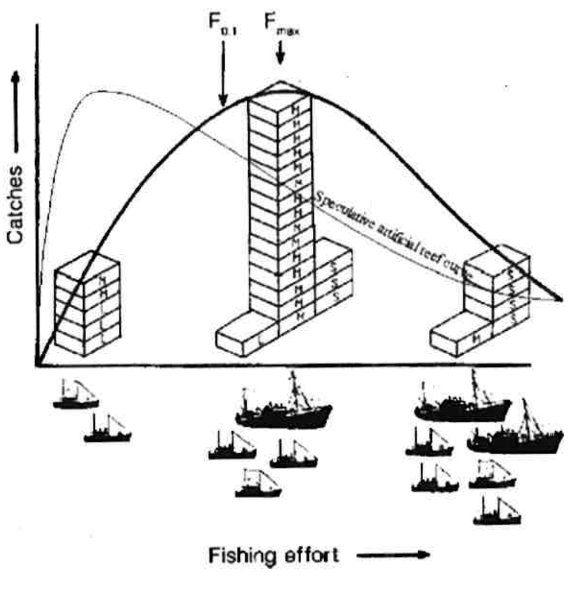


Figure 5.9: *Standard and speculative artificial reef yield per recruit curves (adapted from Holden, 1994). L, M and S on the fish boxes refer to the size of the fish. Catches should be more correctly defined as catch per unit effort.*

5.7.5 Fishing gear

A variety of fishing gear is used in and around the Ekofisk area, including gill nets, mid-water trawls, seine nets and long lines. The choice of gear to be used around an artificial reef may need to be modified. It would, for example, be both dangerous and expensive to snag a trawl on the reef. Providing the exact location of the reef is known, such as by the use of sonar, it should be possible for fishermen, who are skilled at working in various weather and current conditions, to trawl relatively close to the reef. This is with the proviso that the sea-bed will have been cleared of debris and no debris will come from the decomposition of the reef. The element of risk and therefore proximity to the reef that can be achieved will be dependant on weather, water conditions and experience. Seines and trawls may therefore be used around a reef to catch the larger near-reef fish, but will be unsuitable for use close to the reef. Long-lines may be possible to use closer to or even within the reef.

A specialist wreck fishery has developed in British coastal waters of the North Sea, in which fishermen, with skills specific to that type of fishing, exploit the denser stocks found in those locations, using suitable gear. It may then be that a specialist reef fishery will develop, without the aid of central management. This would have social implications in that specialist gear and practices, such as cruise time, may be required that are different from those that are currently traditional.

5.7.6 Restricted zones and safety

Even if a platform reef is designed and managed to be used as en enhanced fishing reef, some form of protection zone will almost certainly be required. A fishing reef (as opposed to a protection reef) will be designed to allow maximum access for fishermen. There will however be a significant risk of snagging gear, causing either damage or loss of gear, or in some cases danger to the fishermen themselves. At a recent 'Shareholders dialogue' on artificial reefs hosted by the petroleum industry's Offshore Decommissioning Communications Project, in Brussels, one of the major issues expressed by representatives from fishermen's organisations was this issue of safety.

For the safety of the fishermen and the security of the financially liable, organisation responsible for the structures, a non-fishing zone will need to be defined. The size of such a zone will need to be a balance between, the need to fish as close to the reef as possible, in order to achieve the maximum benefits of denser fish schools, and the chances of snagging gear in harsh weather conditions. A 500 m exclusion zone is currently in operation around operating platforms, and this may be applicable around platform reefs. It should be noted that 500 m is outside of the region of maximum fish stock densities.

It is unlikely that such a zone would be possible to enforce in the middle of the North Sea, even with today's satellite surveillance systems. By clearly marking and publicising the location of a reef, and by introducing legislation, it will then be the responsibility of the individual fishermen to avoid ensnarement. Under suitable weather conditions, some fishermen may be skilled enough to fish within the exclusion zone, but this will be their responsibility.

5.8 Using Ekoreef for environmental / habitat protection

5.8.1 The advantages of protection

Protection, though an emotive subject, may be a more important justification for establishing artificial reefs in the North Sea than merely stock enhancement. This would be especially so if the standing stock on the reefs proved to be small. Depending on current, often politically based, North Sea fisheries priorities, protection alone may be sufficient to justify the existence of reefs.

The principle of the protection policy is that artificial reefs can be used to preserve currently over-fished stocks. This can be achieved by preventing access to a particular area, such as where spawning or juvenile stocks are known to occur, by limiting the type of fishing gear that can be used, or by offering shelter from both fishing and natural predation. Commonly, fish mortality rates decrease with age. There are therefore an enormous number of juvenile fish produced (see section 5.3) to counteract losses. The number of fish in an age class therefore declines with age. The majority of fisheries management policies act so that mortality, through fishing, of the numerous young fish is reduced, allowing more individuals to grow to sizes in which natural mortality rates are less. Protection of breeding and juvenile fish using reefs could therefore be a means to enhance commercial stocks. A female cod, for example, sheds between 3 and 7 million eggs during each spawning. If only a small percentage of those eggs survived, then a potentially large number of juveniles could be produced.

Limiting fishing efficiency, by the presence of potentially ensnaring structures causing less efficient fishing gear to be used, may also be a means to protect damage to the benthos and improve the sustainability of a fishery.

Some types of fishing gear are more damaging to stocks and the environment in general than others. An example of a method which has a large negative impact is bottom trawling. It has been estimated in a Dutch study that every square metre of the southern part of the North Sea is trawled on average 3 times each year. In addition to physical damage, trawling has a significant by-catch of undersize individuals and non-target species.

There is already a precedent for the use of closed or restricted fishing areas for particular seasons within the current legislative framework of the EU's common fisheries policy and national governments regulations. "Several orders" giving fishing rights for a certain species to a group of fishermen, and areas such as the "mackerel box", where fishing with certain types of gear at particular times of the year was banned in order to protect juvenile mackerel (*Scomber scombrus*), are not uncommon.

5.8.2 The disadvantages of protection

There are two main potentially negative impacts associated with the use of reefs for fisheries protection. Firstly the location of reefs and recommended exclusion zones would need to be well marked on-site and on maps, for safety reasons and so that costly damage to fishing gear could be reduced. Secondly, the establishment of exclusion zones is an emotive subject with commercial fishermen, who fear a reduction in their potential fishing area. The benefits to the fishery as a whole, in terms of an increased recruitment and density would need to be emphasised, to compensate for a perceived loss in working area.

5.8.3 Protection for non-fish species

Throughout this section, the discussion has focused on fish species as it is these that will be the exclusive target of commercial fishermen in the Ekofisk region. The stocking of special high cost species, such as lobsters (*Homarus gammarus*), could however be used to increase the potential benefits of an artificial reef. The design of the reef must however suit the species stocked: for example lobsters will require burrows and caves in which to live, so an open reef for attracting pelagic fish would be unsuitable. The depth of the reef in the Ekofisk area lying in the aphotic zone at 55 - 70 m would also be unsuitable for lobsters which are commonly found to a maximum of 40 m depth. Should the installation be moved to a new shallower site, prior to establishment of a reef, then lobsters may be worth considering.

The majority of any higher price species stocked into a reef to improve the economic benefits would need to remain in the vicinity of the reef, either because of the preferential environment there, or because of some form of entrapment such as the oasis in a desert principle. Large, relatively immobile crustacean species such as the edible crab (*Carcinus pagurus*) found to 100 m, spider crab (*Maia squinado*) found to 20 m and lobster would appear to be the most suitable and possibly only realistic candidates for stocking, subject to a suitable reef design and location. Other crustaceans such as Norwegian lobster (*Nephrops norvegicus*) command a high market price, but as substrate dwellers their population is unlikely to be greatly increased by a reef.

Encrusting organisms such as mussels (*Mytilus edulis*) may be used to improve the attractiveness of a reef to fish, rather than as a harvestable stock. This is again because platform reefs are open structures, so attachable surface area is limited in relation to the overall size of the reef.

5.8.4 Platform reefs as 'nature parks'

Currently, operating platforms are acting as *de facto* artificial reefs. They represent a significant proportion of hard-bottom habitat in the central region of the North Sea. If they were to be removed, then this habitat, although artificial, would be lost. Associate attached animals and plants, some of which are known to be rare, would also be lost. There is therefore an argument for the use of platform reefs as nature reserves to increase the biodiversity of the region. Within these reserves attached animals, plants (if the reef extends into the photic zone) and fish would be protected. Their protection would come from both the exclusion zone regulations and the physical presence of the structure itself.

5.9 A discussion of reef ownership

5.9.1 The issues

Much of section 5.9 is based on discussions in Cripps *et al.* (1996), Cripps (1997) and sections 6.9 - 6.10 of Aabel, *et al.* (1997). The discussion is deliberately provocative, because artificial reefs on the scale planned in this study are new in Europe and as such need innovative ways in which to integrate them into the complex shared resource of the North Sea.

If a new artificial reef is to be created, especially if it is the size of that proposed in this report, decisions need to be made as to who, if any, are to take over the following responsibilities:

- ownership;
- liability;
- exploitation / use;
- management.

5.9.2 Ownership and management

Aabel *et al.* (1997) presented the following discussion of potential platform reef ownership, based on a proposal by Cripps *et al.* (1996).

Artificial reefs can be used for either protection or enhanced fishing purposes. If an offshore reef is to be used for enhanced fishing then a fishing plan will need to be developed and managed. Though the plan will need to take into consideration technical conservation measures, such as those used to prevent the fishing mortality of undersize fish and the small possibility of over-fishing in the surrounding region, management will, as with the fishery as a whole, be primarily aimed at socio-economic factors. To be justifiable as a fishing enhancement reef, there must be a net economic benefit accrued by the fishermen using it. The management plan will attempt to determine the conditions that will produce an economic benefit, e.g. total allowable catch limits for the reef, fishing pressure, gear and replenishment time between fishing.

The alternative to reef-specific management would be to allow the reef to be exploited as any other area in the fishery. Market forces, in the form of fishing yields, may then govern fishing on the reef, though exploitation is unlikely to be optimal, thus diminishing the potential benefits used by the petroleum industry as a motivation for this form of decommissioning.

If it is agreed that to obtain the maximum benefit from a fishing enhancement reef then some form of management is required, then the question of which group should do the management arises. The following groups may be considered:

1. national fisheries ministries;
2. the EU within the CFP;
3. a scientific reef advisory committee;
4. the original operator;
5. a contracted commercial group;
6. a fishermen's co-operative.

Groups 1 and 2 do not need to justify reef creation and as such do not have such a vested interest in optimising performance other than as what they may consider to be a small part of the overall fishery. Whilst they may join option 3 they may not prioritise an individual reef high enough to justify the expense of management. Alternatively, a small proportion of the large savings made as a result of not needing to decommission the structures on land, could fund a management and follow-up assessment programme. Option 3 may be feasible, especially if an element of R&D is involved. Option 4 is probably the least preferable alternative as petroleum companies do not have experience or the wish to be fisheries managers, irrespective of fishing industry opinion which is likely to be against such a move. Option 5 is also feasible but will represent a continuing cost for the industry.

For option 6, management and responsibility for the reef is handed back to the fishermen. This, in theory, can be done in 3 ways, through:

- national fishermen's organisations;
- specific fisherman / boat / company;
- a reef co-operative.

It is unlikely that a national organisation will consider the reef of sufficient size to warrant attention. It is extremely unlikely that an individual could legally purchase or gain access to exclusive fishing rights in what is traditionally a common resource. It would be highly controversial.

From a purely practical viewpoint, returning management of the reef to a fishing co-operative has much to commend it. The fishermen themselves, who know best how to fish, then take care of the reef and associated stocks. At present such an option is unlikely to be legally feasible, but as it is an attractive proposition it deserves further consideration at a time when the CFP is being reviewed and new radical alternatives are being sought. There have been several calls, by fisheries experts within the previous few years, for a return to a greater degree of ownership in the fisheries resource than is currently perceived by fishermen. Models to enable this, range widely from: the practice in Pacific artisanal fisheries, whereby smaller groups of fishermen are allowed exclusive rights within certain areas; to individual transferable quotas (ITQ) for each fishing boat.

The former Director of Fisheries Research for MAFF in England and Wales even suggested that a more creative interpretation of the CFP may help the current situation (Garrod, 1994). He not only suggests that fishermen should be given a greater share of ownership so that they have a vested interest in the fishery, but goes on to suggest that in the centre of basins such as the North Sea there should be a refuge for core stocks and indeed the ecosystem as a whole. Such areas would provide a pool of recruits to sustain national fisheries in coastal areas. Whilst he states that such areas would be totally closed to fishing, he details the advanced verification techniques that would be required to police such an area.

This refuge idea is exactly that proposed for artificial reefs. Reefs have the added advantage that, by their very structure, they tend to attract fish and obstruct fishermen. The main disadvantage of using reefs in such a context is that they may not be large enough to cause the necessary beneficial effects. They could however either form the core of a refuge, or a clustered reef comprised of several structures could be formed to cover a larger area.

Further work is required to examine the socio-economic and legal potential of such a transfer of management strategy and whether ownership and liability transfer would be included.

5.9.3 Liability

A discussion of the legal aspects of liability are outside of the remit of this study. The following discussion is conceptual in nature, and designed to be used as means to initiate a balanced assessment of issue.

It is most likely that the issues of ownership and liability will be connected. Should an operator be required to retain liability in perpetuity for a structure reused as and artificial reef, then this would be likely to be considered an unacceptable risk, thus limiting the likelihood of reef creation.

If the concept of platform reefs is authorised by government and generally approved by the public, then it could be argued the current operator should not continue to be responsible for structures that have passed on to other users. Excluding a short initial period after ownership of a car is transferred (to ensure the vehicle meets the criteria agreed in the sale), the previous owner of the car is not responsible or liable for it when it is used by it new owners.

The opposing argument would be that the petroleum industry has managed to save money by finding another (albeit acceptable) use for their redundant structures. These are to be left in a common resource and do potentially represent a hindrance and safety hazard to other users of the North Sea, i.e. fishermen, even though these other users may benefit from them. Until such time as they are either removed to shore, or they disintegrate, the operators should continue to be responsible.

Notionally there are six main ways that liability can be reduced to acceptable levels for the current operators:

1. transfer liability with ownership, or at least usage, to the new users;
2. government accepts full liability;
3. insure for life-time of reef;
4. set up a restricted liability fund to compensate any confirmed losses or accidents resulting from the structures;
5. obtain an agreement form government that if platform reef creation is accepted then the structures will be treated as ship-wrecks;
6. enact legislation enforcing a restricted zone around the structures, which are to be clearly marked on nautical maps, thus holding individuals that wish to break the legislation responsible for their own actions.

Acceptance of full liability by any institution (1, 2 and 3) is likely to attract misuse of the reefs, with for example, the possibility of old equipment being taken to the reefs so that claims for new can be made. Options 5 and 6 would appear, from this short discussion to be most conceivable. It is likely that if a restricted zone is accepted, then the petroleum industry must ensure that outside of that zone, the sea-floor is cleared of ensnaring structures.

5.9.4 Use within the EU

Researchers may well come to consider an artificial reef to be, at worst, of insignificant negative impact, and at best, a benefit to a fishery. In order to get to the implementation stage as a *fisheries enhancement device*, the concept must however be acceptable to either the fishing industry or the fisheries management authorities, and preferably both. Offshore reefs in the North Sea will, by virtue of their geography tend to fall within the remit of either the EU or the Norwegian government. Whilst there have been many disagreements between EU and Norwegian fisheries authorities and both groups differ in their choice of technical conservation methods, their basic political aims, in terms of maintaining as large as feasible viable national fishing fleets, are similar. To achieve this socio-economic aim, the biological principles of retaining fish stock sizes within "biological safe limits" and preferably at a maximum sustainable yield should (though are often not) be followed. A goal of "relative stability" is also sought though has not yet been achieved. It is then possible that if the use or management of an artificial reef is suitable or permissible under the EU Common Fisheries Policy (CFP) for the North Sea then it will also be a viable proposition within Norwegian fisheries limits.

Largely because of ever increasing criticism of the CFP, the EU is currently accepting suggestions and examining new ways of managing and conserving stocks that can be implemented from 2002. All new initiatives must though be legal under the current legislation. The planning of the use of redundant offshore structures as artificial reefs then comes at a particularly auspicious time. There is currently a precedent under national and EU regulations for the implementation of closed or restricted fishing zones. Further work and consultations are required to confirm that artificial reefs are a strategy that could be adopted or even prioritised by fisheries authorities.

It should be stressed that integration of artificial reefs into fisheries management policies is as much a socio-economic issue as it is a biological conservation measure, because of the practical aims of the authorities, stated above.

5.9.5 Ownership conclusions

The following points can be concluded from the above discussion of ownership, exploitation and liability:

- Various groups could take over the management of the reefs, including an expert advisory committee, the government, or the fishermen themselves.
- The reefs could be exploited by fishermen's co-operatives, openly, or not at all (protected areas).
- The issue of liability needs to be solved. Restricted access zone legislation appear the most feasible of the potential solutions.
- The use of protected zones, in the central part of the North Sea, away from busy coastal fisheries, to supply juvenile fish to the rest of the fishery, is currently being discussed by the authorities. This refuge idea is exactly that proposed for artificial reefs.
- The EU is currently considering initiatives for amendments to the Common Fisheries Policy. Artificial reefs as protection zones have a precedent under current legislation, and would appear to fit well into EU policy.

5.10 Ekoreef management plan

5.10.1 The planning process

In this section 5.10, the aims and general criteria that could comprise management plans for Ekoreef are described. Care has been taken to avoid presenting a detailed inflexible plan. Responsibility for the proposal of a detailed plan should lie with the management committee (5.10.3). The plan will incorporate their requirements and priorities, that may well turn out to be different than that predicted in this report.

There is no prior experience of the management of large reefs in the North Sea and so a flexible approach will need to be maintained. As the reef becomes established, and hopefully some of the aims for the use of the reef become fulfilled, the plan will need to be adapted to maximise the benefits and minimise the negative impacts.

5.10.2 For fishing

The following could be the main aims of a plan for the management of a reef used primarily for commercial fishing:

1. establish a management committee to oversee, monitor and assess reef exploitation;
2. ensure that the reef represents an economic benefit for the fishermen that fish there;
3. manage fishing effort so that the reef is sustainably exploited;
4. ensure that fishing is safety conducted;
5. gather adequate information in order to assess optimal fishing intensity on the reef and revise management plans accordingly;
6. enact legislation that facilitates the above aims.

As stated previously, platform reefs could be exploited by specific defined groups or individual fishermen, or they could be left open to unrestricted usage, governed only by market forces.

In the latter case, little fisheries management would be required (aims 2 and 3 above) as the means to influence exploitation would be limited. The primary aims of the management committee would be 4 - 5 above. Some research to estimate optimum exploitation levels and the efficiency of the reef at attracting fish, could be conducted, but would be difficult to control in such circumstances. Safety issues would still need to be prioritised. In the former case, where exploitation was limited in some way, the management committee would find aims 2 - 6 easier to control and accomplish.

The following stages could be incorporated into a 10 year plan for the reef:

- establishment of reef management committee;
- definition of aims for the reef and timetable for execution of those aims;
- discussion with other stakeholders in the region;
- initial proposal for an interim maximum fishing pressure estimate;

- validation of the maximum fishing pressure estimate;
- mid-term review of reef efficiency in terms of achieving previously defined aims;
- mid-term management policy review;
- final-term assessment of reef benefits;
- plan for further management, if any required.

The three keys issues that the management plan will seek to answer and maximise will be:

1. Is the reef safe? If not, how can this be improved?
2. Are the fishermen obtaining a tangible benefit from the reef? How can this benefit be maximised?
3. Are there significant negative environmental impacts? Can these be minimised, and if so would this make the impacts acceptable?

5.10.3 For protection

Whilst the level of management intervention for fishing option described in the previous section was mainly dependant on the openness of the reef to fishermen, a reef to be used for habitat protection / fisheries conservation, must, by definition, require a high level of management. The following could be the main aims of a plan for the management of a reef used primarily for commercial fishing:

1. establish a management committee to oversee, monitor and assess reef exploitation;
2. establish and mark a suitable protection / exclusion zone around the reefs;
3. ensure that the reef functions as a protected area;
4. ensure that the reef does not represent a safety hazard to other users in the region;
5. gather adequate information in order to quantify any benefits to the local environment and the surrounding fishery and revise management plans accordingly;
6. enact legislation that facilitates the above aims, especially 2 - 3.

Excluding safety, the primary aims of the management committee would be to ensure that there is no encroachment into the protected zone (aim 3) that would damage the environment being protected, and manage research to indicate if the reef is actually worked as required (aim 5).

Some research could nevertheless be conducted to estimate optimum fishing exploitation levels and the efficiency of the reef at attracting fish. An artificial reef over which access is controlled is a valuable opportunity to assess its use both as a protected zone and as a fishing enhancement reef. Data from such a reef would be most useful in the decision to implement further platform reefs.

The following stages could be incorporated into a 10 year plan for the reef:

- establishment of reef management committee;
- definition of aims for the reef and timetable for execution of those aims;
- establishment of a suitable exclusion zone;
- discussion with other stakeholders in the region;
- plan for collection of evaluation data;
- mid-term review of reef protection efficiency in terms of achieving previously defined aims;
- mid-term management policy review;
- final-term assessment of reef benefits;
- plan for further management, if any required.

The three keys issues that the management plan will seek to answer and maximise will be:

1. Is the reef safe? If not, how can this be improved?
2. Is there a benefit to the environment / fishery from the reef? How can this benefit be maximised?
3. Are there significant negative environmental /social impacts? Can these be minimised, and if so would this make the impacts acceptable?

5.10.4 Ekoreef management group

The management committee could be composed of representatives from the following groups:

- fisheries authorities;
- reef user group, i.e. fishermen;
- environmental protection authorities;
- NGO's
- joint petroleum industry group;

Additionally, the following groups may wish to become involved:

- the former petroleum industry operator;
- shipping or navigation authorities.

The degree of representation on the committee could vary according to how the issue of ownership / exploitation of the reef is decided. Should the reef be taken over by a fishing co-operative for example, then the fishermen could expected a greater degree of independence and authority, hopefully though accepting advice from the rest of the committee. On the other hand, if no specific groups takes over responsibility, then the committee itself could assume more responsibility for utilisation, or at least monitoring. In the case of the use of the reef as a protected zone, then a high level of management intervention and frequent discussion with other stakeholders would be expected.

5.10.5 Monitoring and retrieval

Irrespective of the use to which the reef is put, or its ownership, research will need to be conducted to assess whether the reef is fulfilling the aims which were defined for it. As the first reef of its kind in the North Sea, the management committee also have a responsibility to publish the results of the research so that North Sea stakeholders and the public in general can evaluate their applicability in the wider context of North Sea usage. Decisions on the establishment of other reefs may also rest on the results of these studies.

The management committee will ultimately need to develop its own plan, but an initial programme of work is described in Report 6, *Monitoring*, and hence will not be repeated here.

Many of the artificial reefs that have been constructed in Europe using 'materials of opportunity' (reused waste), for example the fly-ash reef on the south coast of Britain (Jensen, *et al.*, 1994), have been established with the proviso that, if they prove not to function or have too great negative impacts, then they can be removed. Whilst this may well prove a concern for the establisher of the reef (the original petroleum industry operator), in order to allay fears from various shareholder groups, it may well be necessary to enter into an agreement to remove the structures after a defined period if they do not 'work'. Technically, this should be possible, because the structures will need to positioned so that they retain their integrity and function efficiently as a reef.

The reefs must though be given a chance to function. Sufficient time must be allotted in order for: a stabile faunal community to become established on and around the reef; for stakeholders to develop sustainable exploitation or protection strategies; and for the reef managers to develop and assess their plans. Such developments take time, so an initial trial period of not less than 10 years is strongly recommended. Should the assessments during this time prove inconclusive, then a further trial period may be necessary.

In view of the importance of this management development and assessment strategy, for the North Sea environment, fisheries, fishermen, nature conservation, petroleum industry decommissioning and international economics, it is also strongly recommended that no reef be established without a management and assessment framework in place prior to implementation. Conversion of offshore structures to artificial reefs (even if conducted carefully), without adequate follow-up, does no service to either the petroleum industry or stakeholders, in the long-run.

5.11 References

Aabel, J.P., Cripps, S.J., Jensen, A.C. and Picken, G. (1997). Creating artificial reefs from decommissioned platforms in the North Sea: review of knowledge and proposed programme of research. Offshore Decommissioning Communications Project: London. ISBM 82-7220-837-7.

Ambrose, R. F., and Swarbrick, S. L. (1989). Comparison of fish assemblages on artificial and natural reefs off the coast of southern California. *Bull. Mar. Sci*., **44**(1), 718-733.

Anderson, T. W., De Martini, D. E., and Roberts, D. A. (1989). The relationship between habitat structure, body size and distribution of fishes at a temperate artificial reef. *Bull. Mar. Sci.*, **44**(1), 681-697.

Bohnsack, J. A., Johnson, D. L., and Ambrose, R. F. (1991). *Ecology of artificial habitats and fishes.* Academic Press Inc.

Bohnsack, J. A., and Sutherland, D.L. (1985). Artificial reef research: a review with recommendations for future priorities. *Bull. Mar. Sci.*, **37**(1), 11-39.

Cripps, S.J. (1997). Rigs to reefs - rags to riches. *Fish Farmer*, May/June 1997.

Cripps, S.J. and Aabel. (1995). DP1 - Fish survey using R.O.V. data. RF-Rogaland Research Report No. RF-95/301. 12 pp.

Cripps, S.J., Aabel, J.P. and Kjeilen, G. (1996). Using artificial reefs as fisherman's management tools. *Proceedings of the Safety and Management in Abandonment Conference, Aberdeen, UK*, Jan. 31-Feb. 1, 1996. Euroforum, London. 18 pp.

Cripps, S.J., Kjeilen, G. and Aabel, J.P. (1995). *Ekofisk Artificial Reef.* Report RF-95/205.

De Silva, M. W. R. N. (1989). Artificial reefs: A practical means to enhance living marine resources. In T. E. Chua and D. Pauley (Eds.), *Coastal area management in SE Asia: Policies, management strategies and case studies.* (pp. 173-180).

Ditton, R. B., and Falk, J. M. (1981). Obsolete petroleum platforms as artificial reef material. In *Artificial reefs: Proceedings of a Conference. Report of the Florida Sea Grant Programme.*

Driessen, P. K. (1985). Studying "Neptunes Gallery". *Sea Technol.*, **26**(9), 34, 37-38.

FAO (1990). *Shellfish culture associated with artificial reefs* No. ISBN 92-5-002981-0). FAO report.

Garrod, D. (1994). The common fisheries policy now. pp264-276. *In*: (Holden, M.) *The Common Fisheries Policy. Origin, Evaluation and Future.* Fishing News Books: Oxford. 288pp.

Holden, M. (1994). *The Common Fisheries Policy. Origin, Evaluation and Future.* Fishing News Books: Oxford. 288pp.

ICES (1996). Advance release of Tables 1-6 of ICES fisheries statistics Vol. 80, 1995. ICES C.M. 1996/Gen:5. 68 pp.

ICIT (1991). *UKOOA survey of fish distribution and contamination.* No. Report by the International Centre for Island Technology in association with Aberdeen University Research and Industrial Services Ltd. for UKOOA (90/1212), Dec. 1991. 94 pp.

Jensen, A.C., Collins, K.J., Lockwood, A.P.M., Mallinson, J.J. and Turnpenny A.H. (1994). Colonisation and fishery potential of a coal waste artificial reef in the United Kingdom. *Bulletin of Marine Science*, **55**(2), 1242-1252.

Matthews, K. R. (1985). Species similarity and movement of fish on natural and artificial reefs in Monterey Bay, California. *Bull. Mar. Sci.*, **37**(1), 252-270.

Mottet, M. G. (1981). *Enhancement of the marine environment for fisheries and aquaculture in Japan* No. Washington Dept. Fish.

Mottet, M. G. (1985). *Enhancement of the marine environment for fisheries and aquaculture in Japan.* Lewis Publishers Inc, Chelsea, Michigan.

Ogawa, Y. (1986). Fish aggregation to artificial reef. *Fishery Enhancement*, **7**, 3-21.Stephan *et al.*, 1990

Olsen, S., and Valdemarsen, J. W. (1977). Fish distribution studies around offshore installations. ICES (mimeo) C.M., **B:41**.

Stephan, C:D:, Dansby, B.G., Osburn, H.R., Matlock, G.C., Riechers, R.K. and Rayborn, R. (1990). Texas artificial reef plan. No. Fishery Management Plan Series (number 3). Texas Parks and Wildlife Department, Coastal fisheries Branch.

Todd, C. D., and Bentley, M. G. (1991). *Torness artificial reef project (1988-1991): Report for sampling years two and three and summary three year comparison.* Internal report for SOFAD, Aberdeen, May 1991.

Valdemarsen, J. W. (1979). Behaviour aspects of fish in relation to oil platforms in the North Sea. ICES (mimeo) C.M., **B: 27**.