Evaluation and improvement of shellfish dredge design and fishing effort in relation to technical conservation measures and environmental impact:

ECODREDGE CT98-4465
FINAL REPORT

May 2003

To the

Commission of the European Communities

By

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This study has been carried out with the financial assistance of the European Commission.

Authorship, Acknowledgements, Abstract, Executive Summary, Introduction, and Objectives

This report to be referred to as

Lart, W. et al. 2003

Evaluation and improvement of shellfish dredge design and fishing effort in relation to technical conservation measures and environmental impact: [ECODREDGE FAIR CT98-4465]
FINAL REPORT Volume 1:Review of Dredge Fisheries

Volume 2: Ecodredge Investigations, Volume 3: Bibloigraphy

Seafish Report CR 198-200
ISBN 0 903941 46 5

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Acknowledgements

The participants would like to thank the Commission of the European Communities who financed this project under the FAIR (Fisheries Agriculture and Industrial Research) programme.

Sea Fish Industry Authority

We would like to thank the owners, skippers and crews of the following vessels:

FV Augsust Rose; owner Jim Smith and crew, FV Seafalke; owner Keith Schofield, Skipper David Guy and crew, FV Star of Annan; owner John MacAlister skippers, Ian Fletcher, Spike Williams, and crew, FV De Bounty; owner and skipper Ian Skelly and crew Richard Georgeson, FV Alena owners Ian and Bill Bickerstaff, skipper Richard Bickerstaff and crew.

We would like to thank Martyn Melhuish for his support particularly during the early stages of this project. We would like to thank Jack Ingram and colleagues at Katon Ingram Ltd who built the scallop dredge instrumentation and instrumented scallop described in Invest. Section 3.1.1.1.1 and who patiently maintained and modified it as required. David Palmer of CEFAS Lowestoft provided advice and information through the whole project; we are grateful for his help.

IFREMER

We would like to thank the skipper Jean Michel Debarre and crew of the RV Gwen-Drez and also the skipper Jean-Yves Le Goff and crew of the FV Jeancani. Thanks are due to the IFEREMER dive team and technicans.

Port Erin Marine Laboratory, University of Liverpool

The work was carried out at the Port Erin Marine Laboratory Isle of Man. Thanks are due to the skipper and crew of the RVs Roagan and Sula and to technicians, divers, and other support staff at the laboratory. Thanks are also due to the owner and skipper of FV De Bounty, Ian Skelly and his crew.

Portuguese partners; IPIMAR and Faculty of Marine Science and Aquaculture, Universidade Do Algave

We would like to thank the skippers and crews of the vessels RV Donax and FV Narciso Sérgio. Thanks are due to the following personnel for technical assistance during fieldwork and sample processing, Luz Abreu, António Laranjo and José Sofia Augusto Pombal, Laurinda Paiva, Nelson Almeida, Paulo Castro, Rolando Machado, Tibério Simões and Vitor Bettencourt. Teresa Drago carried out analysis of sediment samples and the sedimentology work (data of sediment grain size). We also would like to thank the staff of the Centro Regional de Investigação Pesqueira do Centro who contributed in many ways to the success of our work.

ABSTRACT

This project systematically examines the bivalve dredging process and its physiological and ecological consequences. The literature on ecology and population dynamics of the target species, dredge design and fisheries and the environmental effects of dredging and selectivity of dredging is reviewed. A programme of experimental work, both laboratory and field studies is described in scallop and clam dredge fisheries in European waters; scallop species (UK, France) *Pecten maximus*, *Aequipecten opercularis*, clam species (Italy; N. Adriatic) *Chamelea gallina*, clam species (Portugal) *Spisula solida*, *Donax trunculus*, *Callista chione*. Selectivity measures and dredge design are examined for their consequences in terms of environmental effects. Studies included physical, chemical and biological effects both at individual and community level, and selectivity of dredging. These studies include the use of instrumentation and modelling to describe physical effects and behavioural observations, stress and damage indices, both acute and chronic, to describe environmental effects.

In the discussion measurement of environmental effects and selectivity are discussed along with the environmental effects of selectivity parameters, dredge designs and responses to fishing effort. The results are discussed in the context of dredge fishery management.

EXECUTIVE SUMMARY

Introduction

As stress on the marine environment increases, so does the attention received by particular fisheries. Many dredge fisheries are lightly regulated and take place in coastal waters, which are being managed increasingly as multiple resources. This means that non-fishing interests are becoming increasingly influential on management priorities, and that the size and species selectivity of dredges and their impacts on the seabed are becoming important issues. Within this sector issues raised include the capture of undersized animals, seabed modification and non-catch mortality. In addressing these issues the fishing industry needs to be closely involved with research to ensure that the approach taken is realistic and representative.

This project aims to study the interactions between shellfish dredges, affected species and the marine environment. The work will be oriented towards the goals of improving selectivity, understanding and reducing incidental mortality and undesirable environmental effects. Ultimately, the intention is to develop dredge designs and management strategies with reduced environmental impacts.

Two main species groupings are studied: scallop (*Pecten maximus* and *Aequipecten opercularis*) fisheries in Northern Europe, and clam fisheries on the Adriatic and Iberian Peninsula. Hydraulic ('turbo soffianti') dredging for *Chamelea gallina* pursued by fisheries in the Adriatic, and towed dredge fisheries for *Spisula solida*, *Callista chione*, *Donax trunculus* and on the Portuguese coast.

This summary consists of an outline of the work undertaken and a summary of the discussion. The discussion section of the Investigations (Volume 2, Section 4) should be referred to for a full account with references to this report and the literature.

Objectives

1. To review dredge fisheries and their operating conditions in all the nations considered.
2. To develop techniques appropriate to each fishery to study the selectivity and environmental effects of dredging.
3. To examine and quantify the role of dredge components in the selectivity of *Aequipecten opercularis* and *Pecten maximus* and to consider possible technical measures to improve selectivity.
4. To study the selectivity of dredges used on Portuguese clams.
5. To examine the mode of action of dredging on affected species and the seabed, and to develop means to reduce physical impacts.
6. To study the incidental mortality, biological stress, ecological, physical and chemical environmental effects of dredging on a seasonal basis.
7. To study the role of selectivity components and dredge design on the environmental effects of dredging.

Review: Volume 1

Volume 1 is a review of both the scientific and technical literature as well as industry and government sources. This is updated where relevant in Volume 2: Investigations to the end of 2002 (mostly in the Discussion Section 4).

The review contains the following topics:

The ecology and population dynamics of king scallop (*Pecten maximus*), queen scallop (*Aequipecten opercularis*), and clam species *Chamelea gallina, Spisula solida, Ensis siliqua, Donax trunculus* in the waters covered by the study. There are outlines descriptions of the biology of *Chlamys varia Venerupes rhomboides, Glycymeris glycymeris* and also *Mytilus edulis*. These are all target species for dredge fishing in one or more of the participant's Nations. These reviews cover habitat, growth, reproduction and population dynamics.

A catalogue of 36 dredge designs ranging from simple hand rakes to hydraulic dredges both those used in Europe and elsewhere.

The operating practices and management regimes of the fisheries that these dredges are used in described. Topics covered include target species and bycatch, fishing areas and ports, seasonal patterns of fishing effort and catch, catch per effort, fleet profile variation in catchability with vessel size, interactions with other interests markets and trends and comments. Management regimes for each species are tabulated in terms of input and output controls.

The literature on environmental effects of dredging (and where appropriate other gear types) are reviewed. The subjects covered are the physical, chemical, biological and ecological effects of dredging.

Selectivity is discussed in terms of species selectivity and behaviour in king and queen scallops (*Pecten maximus* and *Aequipecten opercularis*) and size selection in king scallops (*Pecten maximus*) and Portuguese clams.

Volume 2: Investigations

This Volume contains 31 papers describing results of the study. Each of these describes work on a given topic. These are divided into three subject areas:

Environmental effects

This divides into physical, chemical and biological effects. These studies are orientated towards examining the capture process and its impact on the environment. Physical effects were described using instrumentation and modelled using models of sediment mechanics. There are also descriptions of capture mechanisms observed by video in scallop and Portuguese clam dredges. Chemical effects were studied in Portuguese clam dredges and hydraulic (turbo soffianti) dredges where nutrient and chlorphyll fluxes were studied post dredging. The biological effects are further divided into behavioural and physiological effects and damage studies concerning individual organisms' responses to dredge impact and studies of the effects on biological communities.

Selectivity

In this subject area species selectivity is investigated in relation to behaviour in queen an king scallop fisheries (*Pecten maximus* and *Aequipecten opercularis*) and size selection is studied in Portuguese clam fisheries (*Callista chione*, *Donax trunculus* and *Spisula solida*) and spring tooth dredge fisheries for scallops (*Pecten maximus*). Size selection is discussed in relation to wear on scallop dredges.

Dredge design and environmental effects

Components of dredge design were examined in relation to their utility in reducing the environmental effects of dredging. These investigations are centred around modifying or replacing the teeth on scallop dredges. Means examined were; Magnus effect' dredges which utilise two contra rotating cylinders creating a water flow rising from the seabed in order to lift the scallops off the seabed, the utility of using effects generated by a foil in close proximity to the seabed and the use of hydraulic or water jet dredges to catch scallops. Also tooth and skid queen scallop dredges were compared. Finally innovative clam dredges from Portugal and hydraulic scallop dredges from France were compared with normal dredges in terms of the stress levels and damage rates in the target species' catch and benthic impacts in the Portuguese dredging.

Results and Discussion

The results from the review and the investigations are reviewed together with relevant currently available literature in the discussion.

Measurement of environmental effects

This is divided into physical, chemical and biological effects.

Physical effects

Amongst the most predominant environmental effects were the physical, mostly mechanical, effects both on the organisms encountered and on the substrate. This study developed techniques for monitoring and modelling physical effects, and simulating biological effects on the organisms and substrate. These methods enabled the study of critical aspects of dredge design and operation, and could be used as a basis for research into future dredge designs or modes of operation designed to reduce physical effects. It was found difficult to model the effect of spring toothed scallop dredges in the seabed but feasible to model the effects of hydraulic dredges for clams using models derived from sediment mechanical principles. For spring toothed scallop dredges it was possible to observe the mechanism of capture by video and a working hypothesis for this mechanism was derived. Scallops were observed to be rotated out of the seabed by the downward force of the teeth. The studies of damage rates in organisms encountering the gear indicate that most of the damage occurs at this point first of contact with the teeth. It was also found that for most species only a fraction of the animals of all species encountering the dredges were actually retained by the gear. Thus by catch studies alone do not give an adequate picture of the impact of scallop dredging. It is suggested that the damage to scallops could be related to the dredge bouncing on the seabed when its equilibrium is perturbed. This effect would be expected to occur most frequently with changes in substrate and further work might take the form of means to damp the springs and hence avoid resonance or in

very specific targeting using ground discrimination equipment. It may be feasible to use the instrumentation technology developed during this project to improve understanding of the factors that lead to resonance.

Chemical effects

Chemical effects were studied in two fisheries, Portuguese clam dredging and turbo soffianti dredging for *Chamellia gallina* using divers to sample the identifiable dredge tracks. The chemical effects were found to be small and of short duration. If large areas were frequently disturbed there could be a change in the Nitrogen: Phosphorus ratio because of differential re-adsorption of these elements. However it was considered that unless effort was very intense, chemical effects were likely to be minimal particularly in areas where there was high energy input into the seabed from other sources such as tidal currents and wave energy.

Biological effects

Time series data on the growth of scallops on grounds off west Brittany suggests that heavy exploitation over the period since 1979 has affected their growth. Also reviewed are observations of efficiency and non catch mortality. These studies suggest that there is a need to investigate the fate of both damaged and undamaged organisms encountering the dredges. Three approaches were taken to the study of biological effects:

Acute stress, damage and predation

These studies examine stress and damage levels during and immediately post dredging and the consequences in terms of predation post post-dredging. In most cases it was possible to set up adequate experiments using a combination of simulated dredging and *in situ* experiments using video cameras. In these experiments it was found that shell damage not stress was the most important factor determining the likelihood or otherwise of predation post dredging. However, since these experiments were done *in situ* the community of predators occurring naturally in the environment would have had and important influence on the fate of the scallops. The absence of the starfish (*Asterias rubens*) on the site used (where it had been present in previous years) may mean that these results underestimate the effects of stress on vulnerability to predation.

Chronic effects

It was found less easy to carry out observations of the chronic effects of dredging on physiological indices because of the difficulty in obtaining control sites where there was an absence of fishing. However observations were made on seasonal and spatial basis and in relation to the different conditions of fishing (low and high pressure use or otherwise of mechanical sorter (riddle)) in the turbo soffianti fishery for clams in the Adriatic.

Community effects

Several techniques were examined for short and long term community effects. Short term observations were used to examine the fate of organisms immediately post dredging both in terms of their spatial distribution and vulnerability to predation and yielded valuable information. Longer-term effects proved more difficult to examine

because of the difficulty in obtaining valid control sites. Historical data on faunal assemblages in the area of the Adriatic where turbo soffianti dredging is practised, collected prior to commencement of the dredge fishery, was investigated with a view to estimating changes due to the fishery. It was clear that in this case sampling and identification differences precluded adequate interpretation of the differences observed. A review of the literature revealed that a number of studies had succeeded in this approach and that in circumstances where there is an absence of good quality time series data and experiments this is the only possible way to determine long term change and can yield valuable results.

Measurement of Dredge selectivity

Species and size selectivity was studied in scallop dredges for queen scallop (*Aequipecten opercularis*) and king or great scallops (*Pecten maxinus*) and size selectivity in Portuguese clam dredges. The approach taken was to examine the effects of components considered likely to affect dredge selectivity and then to quantify the effects of these components both using new and worn components where appropriate. The results obtained are described as follows:

Queen scallop species selectivity

Seasonal variations in catchability could be related to behaviour. Over the course of 13 months observations were conducted using a 'top net' set to catch queen scallops swimming over the top of the normal toothed dredges. During the period June to mid or late autumn queen scallops were found in the 'top net', indicating that they were swimming in advance of the arrival of the gear and so avoiding capture. The changes in behaviour were related to laboratory observations of the reaction time of the scallop; during these months the scallops reacted more quickly and so avoided the dredge, but there was no difference in the scallops' ability to perform adductions.

Direct comparison between toothed dredges with those equipped with skids and tickler chains (both set up for targeting queen scallops) showed that, at least during the summer months, the catch per unit effort of queen scallop in skid dredges was equal to or exceeded that for toothed dredges. King scallops were caught as a by catch in toothed queenie dredges but in much smaller quantities in skid dredges. This was related to the habitat of the two scallop species; queen scallops live on the surface of the sediment compared with king scallops that recess into the surface layer. However there may be some element of active swimming, which may improve the efficiency of skid dredges during the summer months; to fully examine the year round comparative viability of skid and toothed dredges seasonal trials would have to be carried out.

King scallop selectivity

This aspect of the work investigated selectivity mechanisms of spring toothed scallop dredge components; those components that were shown to be selective were then examined more quantitatively. A literature review indicated that absolute efficiency of these dredges (that is comparing catches with those animals left on the seabed) varies by length, both for small and large sizes of scallops, with efficiency peaking at a particular length. The studies carried out in this project describe relative efficiencies between gear components of differing dimensions.

The results obtained and cited in this study showed that only tooth spacing and ring size of the dredge bellies affected their selectivity. Selectivity could not be detected due to the mesh and/or chain mail backs. Tooth spacing was less reliable than belly ring size as a selective device. Estimates for L_{50} s obtained for belly ring size of spring toothed dredges, were similar to literature values obtained for dive plate dredges in French waters for new bellies of 10mm diameter wire. However, differences in selectivity were found with different ring wire diameters and also due to wear on the belly matrix. Bellies become more selective as they wear but the larger ring sizes allow marketable scallops to escape before the smaller ring sizes. Changes in the design of the bellies; thicker wire and variations in the thickness of the washers can have an effect on the pattern of change of selectivity with wear.

Portuguese clam dredge selectivity

Mesh size and tooth spacing were compared for their effect on selectivity and it was found that only mesh size had any effect. It was found possible to quantify mesh size selectivity for *Spisula solida* (Northern fishery) *Callista chione* and *Donax trunculus* (Southern fishery). Although tooth spacing had no effect on size selection, it is clear that tooth length is likely to have an effect on species selectivity.

Dredge design and environmental effects

Studies to investigate the effects of alternatives to teeth on scallop dredges were undertaken. Three devices for lifting king scallops from the seabed were examined;

- the Magnus effect in which two contra rotating cylinders were used to create an upward current from the seabed,
- the use of a foil to create an upward current of water intended to lift the scallops off the seabed
- and the use of a water-jet or hydraulic dredge.

The hydraulic dredge was considered the most viable and one was designed to capture king scallops and tested in comparison with a classical French dredge. Also the skid and toothed queen scallop dredges were compared. For clams, two Portuguese dredge designs (one targeting *Spisula solida* and the other *Callista chione*) which used metal cages instead of net bags to contain the catch were compared with their classical counterparts.

Comparisons were made using a selection of techniques described in this project; selectivity comparisons, stress levels, damage levels of catch and bycatch, and relative efficiencies. In all cases there was some improvement in at least one aspect of the dredges' environmental impact. Of the four innovative dredges, hydraulic king scallop dredge, skid queen scallop dredge, and two Portuguese clam dredges tested, three are in use in commercial fisheries, the exception being the hydraulic scallop dredge. This dredge which would be limited to use in shallow water would also require significant development to improve efficiency if it were to be a viable option. These results show that it is possible to alter the environmental impact of dredges, and define and monitor these impacts using the types of indices developed in this project.

In the most successful cases these improvements have been achieved through the modification of existing designs.

Selectivity and environmental effects

The results from this study enabled the examination of the benefits that would accrue from selecting bivalves at the seabed as opposed to on deck.

Scallop dredges

The results indicated that selecting scallops at the seabed resulted in a 75% [1]reduction in stress as compared with sorting the animals on deck. The results of the damage studies indicate that most of the damage is done to scallops at point of first contact with the dredge, and studies of predator interactions found that damage rather than stress, was the most important factor which made the scallops vulnerable to predation. However, a caveat must be added to the above results since there were very few starfish (*Asterias rubins*) present in the habitat when these observations were made.

Of the two mechanisms of selection (tooth spacing and belly ring size) described it would be advantageous to select at the teeth because of the short contact time with the dredge. Selection at the belly rings is more reliable than tooth selection; so the best approach would be to optimise both parameters.

Portuguese clam dredging

The cumulative stress which occurs due to the mechanical action of the dredge and aerial exposure affected the stress levels in undersized *Spisula solida* in ways that potentially reduced their survival. Improvements in dredge design (see above) have resulted in reduced damage rates (both for target and non target organisms) and more rapid selection. These results therefore indicate the benefits which accrue from using this design, and from improved selection using larger meshes on the traditional dredge designs.

Fishing effort and environmental effects

The distribution of fishing effort is related to bivalve availability, seasonal condition and marketability and management controls. These can be highly variable thus making experimentation on the environmental effects of effort levels very difficult, as was found when control areas were sought in the N. Adriatic. However, some of the results of the project have been orientated towards description of the temporal and spatial effects of fishing effort.

Seasonal effects

Seasonal changes were observed in both the acute and chronic stress indictor responses in clams. These could be related to other aspects of the animal's reproductive and growth physiology and to seasonal conditions such as temperature.

For scallops the stress effects could be related to the annual seasonal breeding cycle of the animal. During the spring when the animals reserves were being utilised for the development of the gonads in preparation for spawning the acute stress effect of

[1] In terms of Adenyle Energy Charge (AEC)

dredging was highest. In the autumn there was a reduced stress effect due to dredging, because of the higher level of reserves in the muscle tissue. In the behavioural studies only one parameter was observed to vary between seasons, the number of adductions which the animals made on first stimulation with the starfish leg, which was lower in the spring than in the autumn; also possibly reflecting the immediate energy available to the scallops' adductor muscles.

Clams (*Chamellae gallina*) in the N.Adriatic exhibit changes seasonal changes in several indices such as scope for growth and survival in air. However, because of the natural endogenous stress levels due to breeding condition and the natural variation in environmental conditions it would be difficult to separate out the period when the highest change in these parameters may be produced by fishing. An adequate control population would improve the resolution of this problem.

Recovery time and cumulative effects

Scallops

Acute stress and recovery in scallops was investigated in relation to speed and duration of tow and the cumulative effect of repeated daily stress. It was found that recovery rates were related to the speed of dredging (as defined by the speed of the simulator). At levels of acceleration approximately corresponding to normal dredging scallops will recover within 6 hours levels of dredging. Lower levels of acceleration (corresponding to approximately half normal dredging speed) results in a more rapid recovery with normal levels of AEC reached in 2 hours.

Simulated tow lengths of 15 and 30 minutes did not result in significant increased stress but tow duration of less than this resulted in reduced stress. Repeated dredging on a daily basis for 3 days at both high intensity of simulation and low intensity did not affect the level of stress found the following day. Recovery time was similar (2 hours) for low intensity simulation (not tested in higher intensity simulation).

This suggests that the undamaged scallops can recover from repeated dredging. However, in order to recover there would be a load on the metabolism and each time the animals are stressed they may be vulnerable to predation. The behavioural studies suggested that vulnerability may have persisted for up to at least 24 hours.

Chemical and Community effects

These results indicate that in the dredge fisheries studied, effort would have to be over a large area to result in a change in the Nitrogen: Phosphorus ratio as discussed above. Other chemical changes were of limited duration.

One location was subjected to intense effort in the Portuguese clam fishery and the recovery in benthic organisms was then monitored. Recovery took place more rapidly in meiofauna (8 days) than in macrofauna (2months). The rate of recovery is likely to be affected by season; examples are given from the literature. Both the short-term chemical and benthic effects described above are likely to be attenuated by storms occurring post dredging.

Investigations of longer term changes in community structure were hampered by finding suitable control sites. Two sites one of which had not been fished for 4 years

prior to the sampling and the other which had been dredged continuously had different community structures. The fished site had a higher proportion of faster growing species and scavengers whilst slower growing species and deposit feeders were found in the unfished area.

Consideration of management measures

This section discusses the possible implications of these results for management of dredge fisheries. It is not intended to be prescriptive, only to illustrate some of the possible uses of the results in dredge fishery management.

Dredge design, efficiency and fishing effort

It is clear that dredge design affects on both environmental effects and efficiency and that it is possible to assess these effects using the techniques described in this study. Four innovative dredge designs were compared with traditional or classical designs in terms of environmental effects (see above). Of these three showed equal or improved efficiency and reduced environmental effects, three of these were in commercial use in dredge fisheries. The 4th design was a prototype hydraulic scallop dredge that had reduced environmental effects in terms of stress and damage on the scallops but much reduced efficiency when compared with the classical dredge. Thus the impact per catch of scallops may not have been an improvement; with development this aspect could perhaps have been improved.

Stock management considerations may require the avoidance of increased catch in fully exploited bivalve fisheries. The evolution of dredge design to minimise environmental impact must therefore take into account changes that improve efficiency. The management of the Portuguese clam fisheries where reduced impact and improved efficiency has been observed, have taken steps to avoid increased catches through the introduction of these selective, reduced impact dredges, by limiting catches to a daily quota. This way the impact per catch of clams is reduced and the overall impact of the fishery is reduced. Similar assessments should be made when considering means for improved targeting of fishing effort; there may be improved efficiency that should be taken into account when implementing such schemes.

There may also a need to define the operational characteristics of a given dredge type in terms of its environmental effects. One example from the review is the Thames cockle (*Cerastoderma edule*) fishery which operates a system of type approval for the dredges used which stipulate a maximum rate of damage to the target species achieved by the dredge.

Selectivity

Species

The ability to design fishing gear which specifically targets a given species is clearly a benefit for fisheries management since it enables the avoidance of by catch. Two dredge features investigated in this study were found to influence species selectivity; the use of skids and tickler chains instead of teeth in queen scallop dredges and tooth length in Portuguese clam dredges.

Queen scallop dredges are used in the Irish Sea (ICES division VIIa) where there is a closed season for landing king scallops during the summer months (June-October). Thus avoiding the use of toothed dredges at this time of year may be considered as a management option. There would also be a reduction in the by catch of king scallops at other times of year if these dredges were used. Since smaller ring sizes are used on queen scallop dredges than on king scallop dredges this would result in a reduction in the stress levels in small king scallops. Another feature of the skid dredge catches was the reduced proportion of stones in the catch which might be advantageous in that wear and tear on the bellies would be reduced and there is a potential fuel saving from a reduction in the weight of the catch.

However, it must be recognised that the vessels using the toothed gear to target queen scallops are designed to use this type of dredge. The teeth are used as a pivot point against the gunwale of the vessel about which the dredges are tipped when the catch is discharged onto the deck. The teeth would also be expected to act as shock absorbers on areas of stony substrate; vessels using skid dredges and tickler chains overcome this by adding a weak link to the tickler chains. Although this study compared skid with toothed dredges on several grounds the full spatial extent of the fishery was not covered and comparison was only made during the summer months.

Thus further work on the engineering and operational aspects as well as the investigation the spatial and temporal viability would be required if the skid dredges were to be considered a viable option for the queen scallop fishery as a whole.

Size

As discussed above size selectivity in dredges is a measure that would reduce stress in bivalves. The evidence from this study is that it would not reduce damage levels since most damage appears to occur at the point of contact with the teeth. Investigations suggest that predation is more likely to occur on scallops which are damaged rather than those which were only stressed. Thus the main reason for implementing such a measure would be to reduce the metabolic load on the bivalves of being subjected to being dredged, sorted on deck and returned to the sea.

Currently there are no universal regulations governing tooth spacing and ring sizes used in dredge bellies in the UK king scallop fisheries. In most areas vessels use tooth spacing and ring sizes that suit local conditions but 9teeth/bar and 75mm id ring size has been adopted in local regulations in some areas. In French fisheries minimum ring sizes vary between fisheries, the smallest being 72mm and the largest 92mm with the majority at 85mm. These sizes are based on the growth of scallops; the minimum legal landing size also varies between fisheries.

The results on tooth spacing suggest that selection at the teeth does not always occur and varies with tooth designs tooth length and conditions. Where teeth do function as selective devices 9teeth/700mm bar and 8teeth/700mm bar correspond to optimum for 100 and 110mm MLLS [2] respectively.

Belly ring sizes vary with a number of vessels using 75mm id rings but other vessels using larger 85mm rings. This study found that, when new belly ring sizes of 85mm

[2] Minimum Legal Landing Size

internal diameter would be optimal for areas where the MLLS is 100mm. Larger ring sizes (88 and 92mm) were investigated for the MLLS of 110mm but it was difficult to achieve full efficiency on the marketable scallops for these ring sizes. However, the characteristics of the ring selectivity changed with time and they started to loose small scallops as the dredge bellies wore. In some circumstances the rings proved not to be robust enough for the fishery. It might be possible to develop sufficiently hard enough rigs to counter this tendency but the smaller rings would still have improved tensile strength by virtue of their shape if made out of the same material. For whole rings the tensile strength of all sizes tested was probably adequate when new but the effect of wear is likely to be the concentration of stress at the locations where wear occurs. Therefore the effect of wear on the ring strength has to be taken into account when deciding a suitable ring size for selection of scallops. The results in this study show that it may be possible to develop more selective, larger, harder rings but that development is required to fulfil this requirement.

Two lines of development would be pursued;

1. Improving the hardness of the rings and washers making up the dredge bellies. There are at least two dredge belly manufacturers who are developing specialised steels and hardening processes that could perhaps be used to achieve more selective gear.

2. Altering the geometry of the rings and washers so that as to reduce the effects of wear on the strength of the belly rings.

This would require research and commercial testing of the belly designs. Until viable bellies are designed then it would be difficult to implement management measures compelling ring sizes of greater than 75mm internal diameter.

Clam size selectivity

The study of Portuguese clam size selectivity in the NW *Spisula solida* fishery has resulted in legislation in this fishery raising the minimum mesh size from 25 to 40mm.

Seasonal and rotational closures

Many of the fisheries in this study have seasonal closures as management measures and the studies of fishing strategy suggest that vessels move from one area to another in response to bivalve abundance. The stress response of bivalves to fishing varies on a seasonal basis and the ecosystems recover on the scale of days, weeks or years post fishing.

This suggests that studies of stress responses both at individual and ecosystem level might help to elucidate optimum harvesting strategies. For example it might be considered important to conserve the growth of the stock and this would indicate closure during periods of most growth. Alternatively it might be considered necessary to conserve the animals at times of year when the short term stress response is greatest. However an important difficulty would be obtaining adequate controls particularly for the chronic and ecosystem responses.

Many areas have short-term closures for public health reasons because of harmful algal blooms. Currently this is a major factor affecting short term patterns of fishing which leads in effect to spatial and temporal closure although these closures are not necessarily connected to the condition or stress response of the scallops.

Rotational closures designed to manage the effects of dredging on ecosystems could take two forms. For short-term effects the systems appear to recover in time periods of days or weeks. If left longer for periods in the order of years these results indicate that succession into a different state would be expected with longer-lived species becoming more important. Literature sources show that closure of scallop fishing grounds for periods of several years can have dramatic effects on the exploitable biomass of scallops and rotational closures are now being considered as management tools in several scallop fisheries.

INTRODUCTION TO ECODREDGE

Dredge fisheries face stock and environmental management pressures. Size and species selectivity and non-catch (incidental) mortality are important issues concerned with technical measures. Environmental issues are likely to become of increasing influence, particularly as many dredge fisheries take place in coastal waters which are increasingly managed in terms of multiple resource use.

This project aims to study the interactions between shellfish dredges, affected species and the marine environment. The work will be oriented towards the goals of improving selectivity, understanding and reducing incidental mortality and undesirable environmental effects. Ultimately, the intention is to develop dredge designs and management strategies with reduced environmental impacts.

Two main species groupings are studied: scallop (*Pecten maximus* and *Aequipecten opercularis*) fisheries in Northern Europe, and clam fisheries on the Adriatic and Iberian Peninsula. Hydraulic ('turbo soffianti') dredging for *Chamelea gallina* pursued by fisheries in the Adriatic, and towed dredge fisheries for *Spisula solida*, *Venus striatula*, *Donax trunculus* and *Ensis siliqua* on the Iberian Peninsula.

Selectivity

In UK, French and Irish scallop fisheries the role of the main components of the dredges, tooth spacing, mesh size and ring size, which could affect selectivity is not fully understood. There are some French data available, and some work has begun in Scottish scallop fisheries (Lart et al. 1997), but a common approach is required as some of these fisheries are common resources. Information is required on size selectivity for both species and the implications of increasing selectivity on the durability of the gear. The relationship between the fisheries for *Aequipecten opercularis* and *Pecten maximus* requires further understanding, and possible technical measures to improve species selectivity considered.

In some fisheries the current mesh size of the dredges results in the capture of a high proportion of juveniles of less than the minimum legal landing size. There is a requirement to investigate the selectivity of the dredge in order to have a rational basis for a minimum mesh size and tooth spacing.

Incidental or non-catch mortality

As non-quota species, scallop stocks are vulnerable to transfer of effort from quota species. A number of studies (Gruffydd 1972; Chapman et al. 1977; Allison 1993) have shown incidental mortality in *P. maximus* dredge fisheries ranging from 2 - 60% (per passage of the dredge). The implementation of scallop re-laying programmes using dredges will require that shellfish undergo minimum stress when dredged. Increased effort may have a deleterious effect on stocks as the frequency of encounters with the gear increases. Populations of *Chamelea gallina* in the Adriatic have suffered repeated mortalities in recent years that may be related to dredge fisheries.

This mortality may be a result of direct contact with the dredge itself, dehydration due to aerial exposure whilst on deck, or indirectly on the seabed as a result of increased predator aggregation (Hill et al. 1996; Veale et al. 2000). Other issues may be of importance, such as disruption of the habitat of the target species that may lead to a loss of condition. Thus understanding the cause of non-catch mortality requires not only knowledge of the physical interaction between the dredge and the target species, but also an understanding of the ecological and physiological effects of dredging.

This project seeks to address the issues surrounding technical measures and non-catch mortality by systematically examining the dredging process and its physiological and ecological consequences. Innovations in terms of technical measures and dredge design will be examined for their consequences in terms of environmental effects.

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OBJECTIVES OF ECODREDGE

1) To review dredge fisheries and their operating conditions in all the nations considered.

2) To develop techniques appropriate to each fishery to study the selectivity and environmental effects of dredging.

3) To examine and quantify the role of dredge components in the selectivity of *Aequipecten opercularis* and *Pecten maximus* and to consider possible technical measures to improve selectivity.

4) To study the selectivity of dredges used on Portuguese clams.

5) To examine the mode of action of dredging on affected species and the seabed, and to develop means to reduce physical impacts.

6) To study the incidental mortality, biological stress, ecological, physical and chemical environmental effects of dredging on a seasonal basis.

7) To study the role of selectivity components and dredge design on the environmental effects of dredging.