SPECIFIC COMMUNITY PROGRAMME FOR RESEARCH, TECHNOLOGICAL DEVELOPMENT AND DEMONSTRATION IN THE FIELD OF AGRICULTURE AND AGRO-INDUSTRY, INCLUSIVE FISHERIES

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CONCERTED ACTION ON SCALLOP SEABED CULTIVATION IN EUROPE (1993-1996)

FINAL REPORT (1997)

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SHORT ABSTRACT

ENGLISH

Faced with the decline of scallop (*Pecten maximus*) fisheries and high costs of ongrowing in suspension, scallop seabed cultivation appeared to be the most suitable technique for European conditions. A three-year European Concerted Action supported by European Union and Norway (associated country) joined together four teams involved in scallop seedings :

- IFREMER Brest / laboratory Molluscs, in Brittany (France), a national institute of ocean research (co-ordinator of the Concerted Action) ;
- Connemara Shellfish Co-op, in Connemara, County of Galway (Ireland), a fishermen's co-operative ;
- Seafish Ardtoe, in Scotland (United Kingdom), an institute provided by the fishing industry ;
- Institute of Marine Research, in Bergen (Norway), a national institute of research.

Underwater observations were made possible by the **important diving team** (8 to 10 people) set up by the group, and its **video equipment** (up to 4 underwater remote video cameras including one in a submarine robot). Three common field works with divers and video, could be carried out. They first required the setting up of a common diving code of practice including the different national regulations. They also enabled the comparison of various underwater sampling methods. These common field works studied :

- the **recessing behaviour and vitality** of juvenile scallops at seeding in Autumn, according to three sizes of juveniles (Brest, France, 1993) ; which pointed out the need of recovery for re-seeded scallops ;
- the impact of placing **crab traps** around the perimeter of plots seeded with juvenile scallops, on the survival of the scallops (Connemara, Ireland, 1994) ; which gave significant effect results with the smaller scallops (30-35 mm) ;
- the effect of placing **an alternative prey (mussels)** together in the seeding area of juvenile scallops, on the survival of the scallops (Ardtoe, Scotland, 1995) ; which gave some preliminary results with weak mussels only (after aerial exposure in the sun).

Concurrently, four table meetings were planned for preparation of the field works, as far as for active discussions about the know-how and bottlenecks in seabed cultivation. These meetings facilitated the gathering of up-to-date informations about scallop culture in Europe and in the most important producing countries (Japan, Canada, New-Zealand).

In France, scallop seedings now provide one-third to one-half of the local scallop fishery in Brest Bay (90 boats). In Ireland, seedings to enhance the natural scallop fisheries are continuing in two areas and a private company harvested 8 tonnes of bottom cultured scallops in 1996. In the United Kingdom, the granting of the first commercial Several Fishery

Orders in February 1993 (giving a legal ownership of the natural or seeded stock of a defined seabed area) increased the interest of scallop farms to turn from suspending techniques to bottom cultivation. In Norway, a governmental report, on the long term strategy of the Norwegian aquaculture, proposed the scallop *Pecten maximus,* along with the Atlantic halibut as main species for aquaculture development.

The Concerted Action identified and analysed 3 factors to improve scallop seabed cultivation :

- the fitness of the **seeding sites** (biological and socio-economical factors) ;
- the fitness of **juvenile scallops** (size and vitality) ;
- the fitness of **practices**, especially in order to avoid predation.

- Sites :

Scallop seabed cultivation is an extensive aquaculture (sea ranching) requiring **broad coastal areas.** Criteria of choice for seeding sites, either biological and socio-economical, could be listed and ranked. The abundance of predators, especially crabs, is an important criteria in the choice of a seeding site. In addition, **rights to access and to exploit** such coastal areas appeared different within European countries, all regulations being unsuited to vast areas under coastal management by professional groups.

- Juveniles :

Fitness of the juvenile scallops comprises two elements, their **size** and their **vitality.** Convenient size could range from 20 to 60 mm and was determined in each area according to local constraints in sites and in spat supply. The vitality of animals was identified as an important factor, but was marginally studied in the Concerted Action (some biochemistry in the French field work, 1993), failing to have a satisfactory diagnostic tool. The perfecting of a simple test could enable profitable comparisons in future works.

- Practices :

At present, seeding practices in sea ranching concern only the choice of the seeding season, of the seeding size of animals and of the seeding density ; in future, they would benefit from regarding also the **animal acclimatization** in order to restore or improve their vitality and the **site preparation** aiming to decrease the predator density (potting) or activity upon scallops (alternative prey).

Faced with **increasing numbers of aquaculture S.M.E. or fishery professional organisations involved in scallop seabed cultivation in Europe**, the national Research and Development authorities have more or less involved themselves in scallop studies and coastal management. However this needs **long term programmes**, demanding basic research (physiology), experiments in the wild (diving observations), in an environment which remains poorly known (need of ecology) and poorly regulated (need of law).

FRANCAIS

Face au déclin des pêcheries de coquille Saint-Jacques (*Pecten maximus*) et au fort coût de l'élevage en suspension, les semis de coquille Saint-Jacques sur le fond semblent être la technique de production la plus appropriée en Europe. Une Action Concertée européenne de 3 ans, financée par l'Union Européenne et la Norvège (pays associé) a réuni quatre équipes engagées dans les semis de coquille Saint-Jacques :

- IFREMER Brest / laboratoire Mollusque, en Bretagne (France), un institut national de recherche océanologique (coordinateur de l'Action Concertée) ;
- la Connemara Shellfish Co-op, au Connemara, Comté de Galway (Irlande), une coopérative de pêcheurs ;
- Seafish Ardtoe, en Écosse (Royaume-Uni), un institut financé par le secteur de la pêche ;
- Institute of Marine Research, à Bergen (Norvège), un institut national de recherche.

Des observations sous-marines ont pu être pratiquées compte tenu de l'**importante équipe de plongeurs** (8 à 10 personnes) générée par le groupe, et par son **équipement vidéo** (jusqu'à 4 caméras sous-marines dont une à bord d'un robot submersible). Trois études de terrain communes, avec plongeurs et vidéo, ont pu être réalisées. Elles ont d'abord nécessité d'établir un code commun de pratique de la plongée incluant les diverses réglementations nationales. Elles ont aussi été l'occasion de comparer différentes méthodes d'échantillonnage sous-marin. Ces études de terrain ont étudié :

- **l'enfouissement et la vitalité** des juvéniles de coquille Saint-Jacques lors d'un semis d'automne, selon trois tailles de juvéniles (Brest, France, 1993) ; ce qui a mis en évidence le besoin des animaux d'une récupération de vitalité après semis ;
- l'impact sur la survie des coquilles, de **casiers à crabes** placés autour des zones de semis (Connemara, Irlande, 1994) ; ce qui a donné des résultats significatifs pour le lot des plus petites coquilles (30-35 mm) ;
- l'effet de **semer une deuxième proie (moules)** en même temps que les coquilles (Ardtoe, Ecosse, 1995) ; ce qui n'a semblé intéressant qu'avec des moules préalablement affaiblies (par exondation au soleil).

Parallèlement, quatre réunions annuelles ont été organisées pour la préparation des études de terrain, ainsi que pour d'actives discussions sur le savoir-faire et les points de blocage de l'élevage des coquilles sur le fond. Ces réunions ont permis de réunir et de mettre à jour les informations sur l'élevage de la coquille Saint-Jacques en Europe et dans les principaux pays producteurs de coquilles (Japon, Canada, Nouvelle-Zélande).

En France, les semis de coquilles fournissent maintenant un tiers à la moitié des captures en rade de Brest (90 bateaux). En Irlande, les semis de coquilles pour compléter les pêches de gisements naturels sont poursuivis sur deux sites ; de plus une société privée a récolté 8 tonnes de coquilles de semis en 1996. Au Royaume-Uni, l'attribution en 1993 du premier Several Fishery Orders à usage commercial (conférant un droit de propriété sur le stock d'une espèce et d'un site donné) a relancé l'intérêt des éleveurs de coquilles en suspendu pour réaliser des semis sur le fond. En Norvège, un rapport gouvernemental sur la stratégie à long terme de l'aquaculture norvégienne préconise la coquille Saint-Jacques (*Pecten maximus*), avec le flétan, comme espèce pilote pour un développement aquacole.

L'Action Concertée a identifié et analysé trois points clefs pour améliorer les semis de coquille Saint-Jacques :

- l'aptitude des **sites** de semis (facteurs biologiques et socio-économiques) ;
- l'aptitude des **jeunes coquilles** (taille et vitalité) ;
- des **pratiques adaptées**, notamment dans la lutte contre la prédation.

- Sites :

L'élevage de coquille Saint-Jacques sur le fond est une aquaculture extensive (sea ranching) qui **demande de vastes zones côtières**. Les critères de choix pour les sites de semis, tant biologiques que socio-économiques, ont été listés et hiérarchisés. L'abondance de prédateurs, notamment de crabes, est un facteur de choix important. En outre, les **droits d'accès et d'exploitation** de telles surfaces sont très variables d'un pays à l'autre de l'Union Européenne, toutes les réglementations paraissant mal adaptées à la gestion de vastes zones côtières par les groupes professionnels locaux.

- Juvéniles :

La qualité des juvéniles comprend deux aspects, leur **taille au semis** et leur **vitalité**. La taille adéquate peut varier de 20 à 60 mm et est déterminée dans chaque secteur au vu des contraintes dues aux sites et des possibilités d'approvisionnement en naissain. La vitalité des animaux a été identifiée comme un élément prépondérant, mais n'a été étudiée que marginalement dans l'Action Concertée (aspects biochimiques dans l'étude de terrain réalisée en France en 1993), faute d'un outil de diagnostic satisfaisant. La mise au point d'un test simple serait très utile pour la suite des études sur ce sujet.

- Pratiques :

Actuellement, les pratiques de semis de coquille Saint-Jacques concernent seulement le choix de la saison, de la taille des animaux et de la densité de semis ; A l'avenir, elles devraient inclure aussi l'**acclimatation des juvéniles** pour restaurer ou améliorer leur vitalité, et la **préparation du site** en vue de réduire le nombre de prédateurs (par pêche) ou leur activité sur les coquilles (attraction vers une autre proie).

Face à l'**augmentation du nombre de P.M.E. ou d'organisations professionnelles engagées dans les semis de coquille Saint-Jacques en Europe**, les organismes de Recherche et Développement se sont plus ou moins impliqués dans des études sur la coquille Saint-Jacques et la gestion de la bande côtière. Cependant ceci implique des **programmes à long terme** en recherche fondamentale (physiologie), des études dans le milieu (observations en plongée), dans un environnement qui reste mal connu (besoin d'écologie) et mal géré (besoin de réglementation).

FULL SUMMARY

Faced with the decline of scallop (*Pecten maximus*) fisheries and high costs of ongrowing in suspension, scallop seabed cultivation appeared to be the most suitable technique for European conditions. A three-year European Concerted Action supported by European Union and Norway (associated country) joined together four teams involved in scallop seedings :

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- Institute of Marine Research, in Bergen (Norway), a national institute of research.

This represents 10 to 15 people working in scallop seedings. A few other researchers (Universities) and producers, connected with the main partners, were also involved in this Concerted Action.

The Concerted Action was not a shared cost research programme, but a grant to help the teams to meet together (one table meeting per year) and to practice some common works (one one-week field work per year), especially underwater observations which were made possible by the **important diving team** (8 to 10 people) set up by the group, and its **video equipment** (up to 4 underwater remote video cameras including one in a submarine robot).

<u>Three common field works</u> with divers and video, could be carried out, which required the setting up of a common diving code of practice including the different national regulations. They also enabled the comparison of various underwater sampling methods, according especially to numbers of re-seeded scallops (from a few thousands in Scotland to about 40 000 in France and Ireland). These common field works studied :

- the **recessing behaviour and vitality** of juvenile scallops at seeding in Autumn, according to three sizes of juveniles (Brest, France, 1993) ;
- the impact of placing **crab traps** around the perimeter of plots seeded with juvenile scallops, on the survival of the scallops (Connemara, Ireland, 1994) ;
- the effect of placing **an alternative prey (mussels)** together in the seeding area of juvenile scallops, on the survival of the scallops (Ardtoe, Scotland, 1995).

The recessing monitoring by divers in the French field work showed that, in Autumn, scallop seedings may require larger animals (45 mm) than the ones which are used to be re-seeded in this area (30 mm). Biochemical analysis of the Adenylic Energetic Charge (A.E.C.) pointed out the need of recovery for re-seeded scallops : three days after the seeding none of the three size batches had recovered its initial energetic level.

In Ireland, the crab potting gave significant results with scallops of 30-35 mm and no difference with larger animals (50-55 mm) which were preyed on by less crabs. However potting increased the predator abundance.

In the last field work conducted in Scotland, live mussels as an alternative prey did not decrease the scallop mortality at seeding. On the contrary, some small video trials with weak mussels (after aerial exposure in the sun) seemed to show a clear preference of the crabs for such mussels, but this was not quantified.

Concurrently, four table meetings were planned for preparation of the field works, as far as for active discussions about the know-how and bottlenecks in seabed cultivation. They facilitated the gathering of up-to-date informations about scallop culture in Europe and in the most important producing countries (Japan, Canada, New-Zealand).

Annual table meetings .

date	*place*	*subjects*
June 1993	**Ardtoe** (Scotland)	• Review of the knowledge on scallop seabed cultivation : - in the European Union - outwith of Europe • Topics to be developed for scallop seedings • Field operations proposals
May 1994	**Bergen** (Norway)	• 1st annual progress report • The Norwegian Sea Ranching Programme (PUSH) • Common poster for Pectinid workshop Cork 1995 • Common diving code of practice • Criteria for seeding site selection • Analysis of previous field work in France • Plans for next field work in Ireland
May 1995	**Cork** (Ireland)	• Participation at 10th Pectinid workshop Cork 1995 • 2nd annual progress report • Co-operation : student and personnel exchanges • Juvenile scallop quality at seeding • Analysis of the previous field work in Ireland • Plans for next field work in Scotland
May 1996	**Brest** (France)	Final meeting : • 3rd annual progress report • Preparation of the final report • Dive monitoring of scallop seedings • Probleme of live transport of juvenile scallops

In Brest Bay, in France, the production of scallops from hatchery and intermediate culture has now reached over 5 millions juveniles. The success of seedings remains variable but generally provide recapture rates over 25 %. The result is that the part of cultivated animals reach one-third to one-half of the total production of the bay : 90 t out of 184 t in 1995. Even if the recapture rates of seedings remain variable, the difficult and expansive start-up period has been completed in Brest, the hatchery having been extended and modernized, the possibilities of seeding sites being well known and the financial participation of fishermen (90 boats) being increasing. This example draws a new interest for scallop culture from other professional groups around small scallop beds, especially in South Brittany and they ask for technical assistance for site selection, spat supply and transport, predator control and coastal management.

In Ireland, seedings of scallops to enhance the natural fisheries are continuing in 2 areas and a private company harvested 8 tonnes of bottom cultured scallops in 1996. There is no overall national Irish programme for the development of scallop aquaculture. However the Marine Institute has set up a scallop group as one of their "Innovations Committee's for Aquaculture" which provides a forum for industry and researchers to keep abreast of developments.

Scallop farming In United Kingdom is based solely in Scotland at the present time although the Welsh coast and the South coast of England may be utilised in the near future. The granting of the first commercial Several Fishery Orders in February 1993 (giving a legal ownership of the natural or seeded stock of a defined area of seabed) has opened the way to further commercial development in seabed cultivation. Two Several Fishery Orders for scallops have been granted for England and Wales and their owners are planning spat purchase. 21 applications for Several Fishery Orders are waiting in Scotland to be considered by the Secretary of State.

In Norway, scallop bottom culture has mainly concerned the relaying of undersized harvested scallops (70-100 mm shell height) by some scallop fishermen. In order to re-seed smaller scallops (40-60 mm), predation studies on brown crab (*Cancer pagurus*) are now carried out with 2 private companies. In 1996, a governmental report, on the long term strategy of the Norwegian aquaculture, proposed the scallop *Pecten maximus*, along with the Atlantic halibut as main species for aquaculture development.

With regard to slow growth of animals and high costs of manpower in suspending culture and despite some biological unknowns and unsuited regulations, bottom culture seems to be the most suitable technique for European conditions.

The Concerted Action identified and analysed 3 factors to improve scallop seabed cultivation :

- the fitness of the **seeding sites** (biological and socio-economical factors) ;
- the fitness of **juvenile scallops** (size and vitality) ;
- the fitness of **practices**, especially in order to avoid predation.

- <u>Sites</u> :

Scallop seabed cultivation is an extensive aquaculture (sea ranching) requiring **broad coastal areas**. This implies the development of novel organisational or business structures that would have access to extensive suitable scallop seabed cultivation sites.

The three field works gave the opportunity of working on three different sites : Brest Bay, France (1993), Kilkieran Bay, Ireland (1994) and Ardtoe, Scotland (1995). This enabled the visiting teams to understand the problems encountered by the host team on its own site (overall predator avoidance and collective management). But there was no specific comparison conducted between these sites. The problem of sites was mainly discussed in table meetings.

Criteria of choice for seeding sites, either biological and socio-economical, could be listed and ranked. The abundance of predators, especially crabs, is an important criteria in the choice of a seeding site, but remains difficult to avoid, particularly in regions where crustaceans are not heavily fished. In addition, **rights to access and to exploit** such coastal areas appeared different within European countries, all regulations being unsuited to vast areas under coastal management by professional groups.

- Juveniles :

Fitness of the juvenile scallops comprises two elements, their size and their vitality. **Convenient size could range from 20 to 60 mm** and was determined in each area according to local constraints in sites (hardness of sediment, shelter from currents and swell, abundance of predators) and in spat supply. From French and Irish field works it could not conclude if the animal size at seeding played a significant role on the observed mortality, but it was clear that it had an effect on animal dispersal.

The other point is the vitality that juvenile scallops require to swim in order to escape predators, to find a convenient place and to recess. This vitality varies widely according to previous rearing density in intermediate culture, and to duration and type of transportation up to the seeding site. The vitality of animals was identified as an important factor, but was marginally studied in the Concerted Action (some biochemistry in the French field work, 1993), failing to have a satisfactory diagnostic tool. **The probleme is to quantify the vitality** because no simple tool or index exists at the present time. The perfecting of a simple tool could enable profitable comparisons in future works.

- Practices :

At present, seeding practices in sea ranching concern only the choice of the seeding season, of the seeding size of animals and of the seeding density ; in future, they would benefit from regarding also the **animal acclimatization** in order to restore or improve their vitality and the **site preparation** aiming to decrease the predator density (potting) or activity upon scallops (alternative prey).

The convenient seeding seasons and scallop sizes may differ widely according to the sites. But the seeding density used to be about a few scallops per meter-square because the animals would spread away if they were too much close to each other. Therefore scallop seabed cultivation is a very extensive culture compared to oyster seabed cultivation for example (over 100 spat /m2).

Animal vitality is poorly studied (see above) and most often the aim is more to maintain the vitality (transportation) than to increase it (acclimatization).

Site preparation is rarely carried out, but could be improved to avoid ulterior predation of re-seeded scallops. Different practices could be studied :

- Dredging with cotton sweepers in order to remove starfish and seaweeds ;
- Potting crabs around and in the seeding area ;
- Placing alternative preys to predators, such as other Bivalves (weak mussels) or dead fish.

These two latest practices have been initially tested in the one-week field works of the Concerted Action but would require new experiments for further investigations.

These works have been disseminated in a number of ways : the involvement of all the key "players" in the scallop culture industry at the Concerted Action meetings, the Concerted Action intermediate reports, the holding of seminars on scallop seabed cultivation, posters and papers presented at the 10th. International Pectinid Workshop, as well as by conventional publications. The use of such a variety of methods of disseminating the gathered information ensures that the industry as well as the scientific community are aware and up to date of the state of art of this subject.

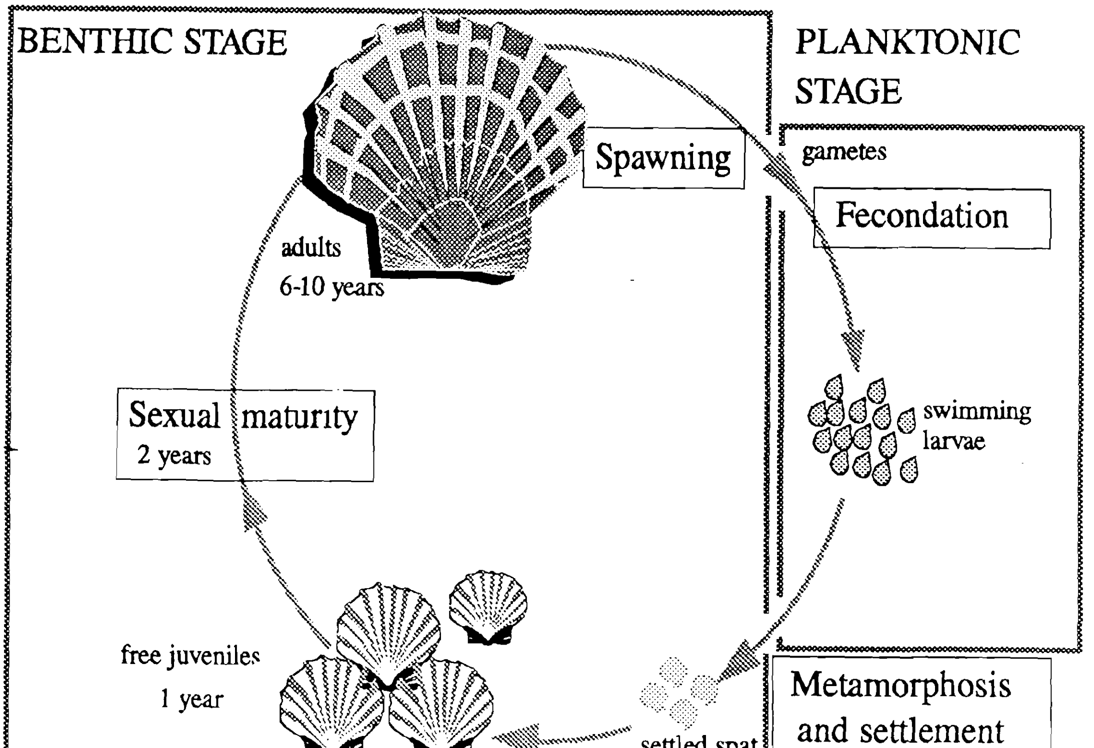
Faced with **increasing numbers of aquaculture S.M.E. or fishery professional organizations involved in scallop seabed cultivation in Europe**, the national Research and Development authorities have more or less involved themselves in scallop studies and coastal management. However this needs long term programmes, demanding basic research (physiology), experiments in the wild (diving observations), in an environment which remains poorly known (need of ecology) and poorly regulated (need of law).

1 - INTRODUCTION

After the decline of natural beds of scallops (*Pecten maximus*) in France and the United Kingdom (U.K.), questions were asked in these countries about the re-stocking or farming possibilities on these scallop beds. Actually, starting in the 1970's in Japan, aquaculture of Pectinids (scallop family) has expanded very quickly throughout the world, overall in Asia, America (Couturier 1990, Cliche *et al.* 1995) and Oceania (Bull 1994, Thompson *et al.* 1995) but remained low in Europe (Dao 1995 and 1997).

The reproductive cycle, biology and growth of the king scallop (Mason 1957, Buestel and Laurec 1976, Strand and Nylund 1991) and the ecology of its young stages (Minchin 1992) has been well described (*figure 1*). The pelagic larval stage, followed by settlement by a byssus at about 250 µm enabled to assess a spat supply for rearing. And the detachment at around 10 mm for a benthic free but sedentary life, the animal being recessed in the sediment, enabled to consider extensive seabed cultivation (sea ranching).

Figure 1 - ***The biological cycle of the scallop Pecten maximus.***

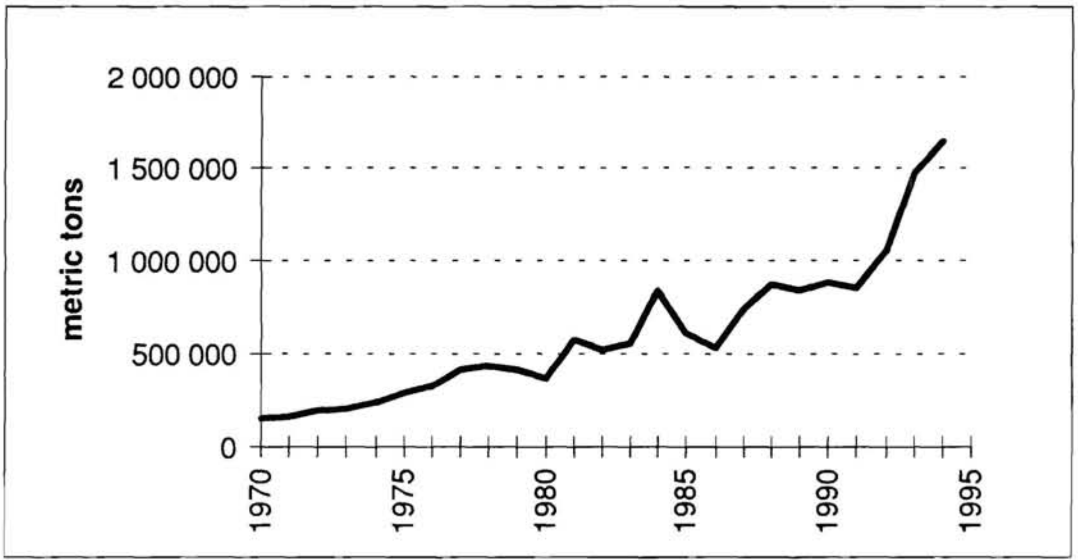


1.1. SCIENTIFIC BACKGROUND ON SCALLOP CULTIVATION..

1.1.1. World wide resources

The world production of Pectinids is over **1 600 000 metric tons** (FAO 1994 in Dao 1997) and is constantly increasing (*figure 2*). All products are named "scallop", which in fact groups together about twenty main species, produced in equivalent proportions from fishing and aquaculture (Dao 1995 and 1997).

*Figure 2 - **World production of Pectinids (data F.A.O.)***



The most significant fishing areas are the East coasts of United States and Canada, Iceland and Norway, Peru, Australia and some countries from South-East Asia. The producing countries of the E.U. are mainly the U.K., France and Ireland.

Aquaculture concerns a few pectinid species and was initiated in Japan in the 70s, after the control of mass production of natural spat of local species. Annual production then increased from a few thousand to 400 000 tons in 1990 (Ito, 1991). The aquaculture techniques have since been developed in several countries and with other species, especially in China, New-Zealand, Chile, Canada, and, to a lesser degree, in the E.U.

1.1.2. Aquaculture in the European Union.

Thanks to the techniques of spat collecting in the wild and of intermediate culture in supple structures, copied from the Japanese example, production of scallop juveniles could be carried out, especially in Scotland and Ireland (Mikolajunas 1995, Minchin 1995). In France, the lack of reliable annual results on spat collecting in the wild, turned the focus of the programme to artificial reproduction in a hatchery (Buestel *et al.* 1982) ; in addition the rarity of oceanic sheltered sites (such as fjords) turned the intermediate culture techniques to rigid structures, such as frames and cages (Dao *et al.* 1985 ; Fleury *et al.* 1995-a). More recently, Norway also has turned to hatchery production of scallop spat (Strand and Mortensen 1995).

With regard to the ongrowing, in the U.K., till early 1990's, owing to the lack of regulations about seabed leases, the production required suspending techniques, either one animal by one animal (ear-hanging) or in cages (lantern nets). This induced problems with algae fouling and subsequently results in slow growth (4 or 5 years) and in need of manpower to clean the nets. On the other hand, in France, the juveniles used to be seeded (at the size of about 30 mm) on natural beds with the aim of re-stocking (Brest Bay) or sea ranching (Saint-Brieuc Bay). The seeding density could range from 3 juveniles /m2 (Buestel and Dao 1979) to about 10 /m2 (Fleury and Dao 1992). In the U.K, a new regulation, in the early 1990's has permitted the consideration of on-bottom scallop seedings which appears to be less expensive and induces good growth in 3 years (Mikolajunas 1995). For similar reasons Ireland and Norway also have taken an interest for scallop seedings. But recapture rates have been low and unstalbe (0 to 50 %), maybe due to uncontrolable environmental conditions, lack of know-how and, generally, to the lack of basic knowledge on marine animal biology, especially Invertebrates.

In this way, in Europe in the early 1990's, the technical production process was well known (*figure 3*), but poorly controled : **spat could be produced** from collecting in the wild (Ireland and Scotland) or from hatchery (France and Norway), but ongrowing techniques remained either too much slow and expensive (suspending techniques) or not reliable enough (on-bottom seedings). No great improvement seemed possible in suspending techniques but better progress could be made in seedings. And actually, previous results in France (Dao *et al.* 1985) and in Ireland (Minchin 1985) have shown that **bottom culture seems to be the most suitable technique for European conditions.** However its application needs long term programmes, demanding basic research (physiology), experiments in the wild (diving observations), in an environment which remains poorly known (need of ecology) and poorly regulated (need of law).

1.1.3. Biological and methodological constraints.

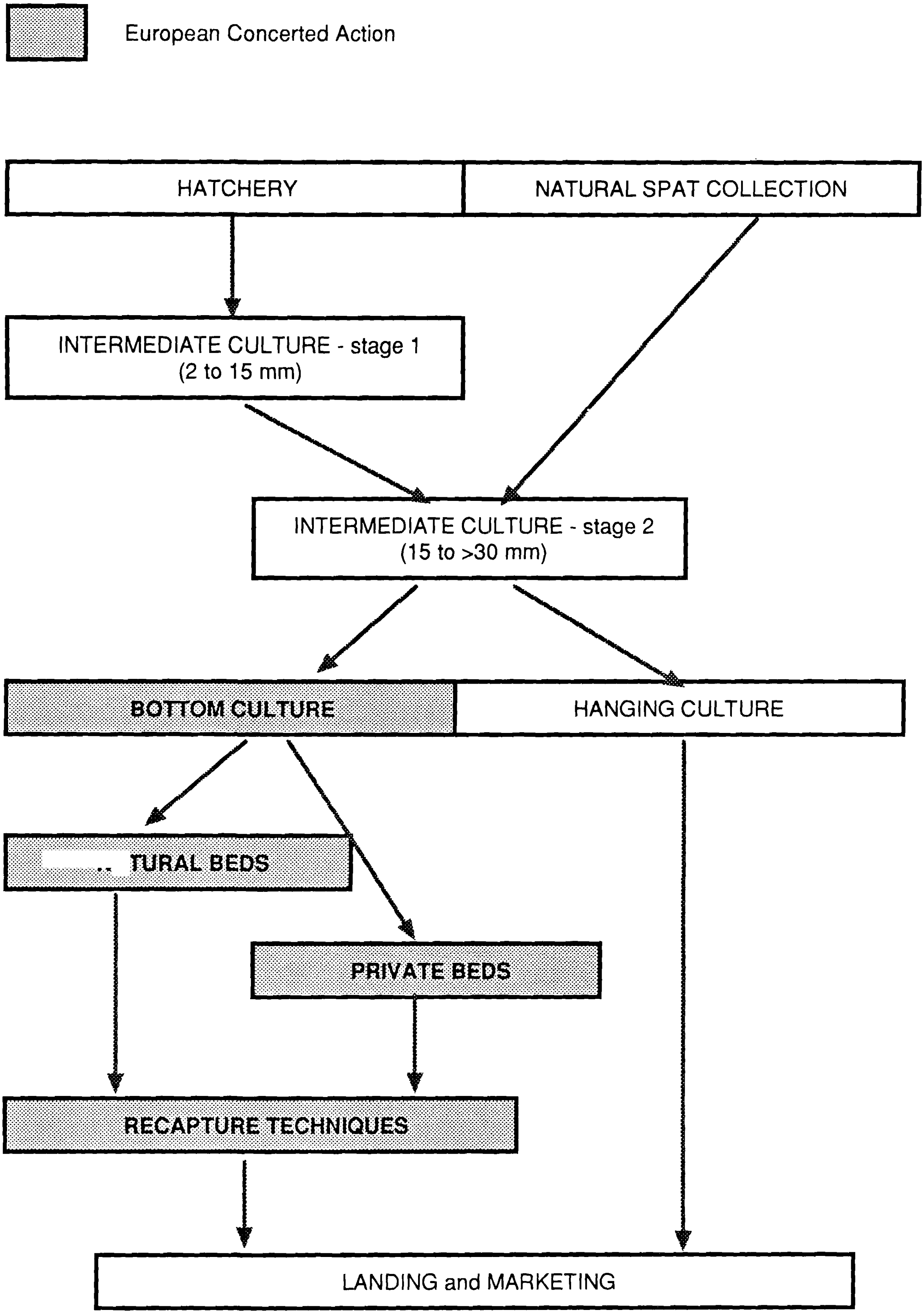
Bottom culture requires settled sea-beds with some degree of shelter, such as marine bays where ecological conditions may be poorly known. The scallop behaviour and their requirements for swimming, recessing or escaping predators are still badly known. More over, identification and impact of some predators such as starfish (*Asterias* spp., *Marthasterias glacialis*), lobster (*Homarus* spp.), crabs (*Cancer* spp., *Necora puber, Carcinus maenas, ...*) or whelks (*Buccinum undatum*) have been related and studied in different parts of the world, in Canada (Elner and Jamieson 1979, Barbeau 1994), in Scotland (Lake *et al* 1987), in Ireland (Minchin 1991) or in France (Halary *et al* 1994), but predation rates appear to be very variable and unpredictable, influenced by various biological and physical factors such as prey size and water temperature, i.e. season of the year (Barbeau and Shiebling 1994).

Most experiments last at least 2 or 3 years, with a difficult protocol due to diving which limits the number and quality of observations. A seeding experiment can be evaluated by its zootechnical performances (growth and survival rates). Growth can be easily modelized, whereas survival and spatial distribution cannot be analyzed precisely. Different methods have to be compared : diving, sub-marine videoing, experimental dredging.

Results are few and mainly unpublished, excepted oral communications to the international scallop scientific community which has its meetings every two years, that is to say in British Columbia, Canada, in 1993, and overall in Cork, Ireland, in 1995 (10th International Pectinid Workshop). This is true also for other teams in the world (Canada, Australia, New-Zealand).

Evaluation acuracy remains essential for the economic evaluation of scallop potential for industry.

Figure 3 - ***Technical pathway for scallop production.***



1.2. ECONOMICAL ENVIRONMENT.

1.2.1. Production costs.

Cost studies appear quite rarely (or unpublished) even in scallop fisheries which have been looked into for years. In aquaculture, Paquotte and Fleury (1994) investigated the importance of the recapture rate of re-seeded scallops upon the financial feasibility of a scallop project in France. For a private industry based on a global production from hatchery, intermediate culture and seabed cultivation, they estimated that 30% of average recapture rate could be the required minimum. With regard to the high level of loans in such a private project, this minimum rate should be lower with a public management.

Paquotte and Fleury (1994) also appraised the production costs at each stage :

- 2 U.S. cents per post-larva (size of 2 mm ; end of hatchery-nursery) ;
- 8 U.S. cents per juvenile taken out from cages for re-seeding (size of30 mm) ;
- 34 U.S. cents per marketable scallop (10 cm) when recapture rate is 30%, that is to say around 2.3 U.S.$ (about 2 ECUs) per kg of live animal. **Such costs could fit with the market prices from fisheries or importations.**

1.2.2. Market.

The scallop today is a high quality product with an expanding market. Natural resources have been exploited considerably and stocks are barely maintained. Aquaculture in several countries has proved to be competitive on the world market.

European consumption is mainly concentrated in France where the supply can be estimated at 45-50 thousand tons (equivalent of live animals with shells), although E.U. production has a maximum of 30 to 50 % of this value. The consumption is expanding in France, Belgium and Spain, and to a lesser degree in Italy and the U.K. A precise study of this market and consumption has still to be undertaken.

1.2.3. Coastal management.

Unlike the hanging cultures, this extensive farming (or "sea ranching") maintains the quality of the environment and it leaves surface of the sea free for other activities (tourism, navigation). Large coastal spaces are profitable in Europe. From this type of aquaculture, private running methods can be developed, following the example of the deep water cultivation of the flat oyster *Ostrea edulis* in France, as well as collective running methods in fisheries, with regulations controlling access to the resource. The fishing gear, along with dredging or diving, are very effective.

During the first step of development, the only effect is rearing itself, that is to say direct exploitation of animals introduced as juveniles. Later, it is expected that the total biomass created by shellfish farming will contribute to an increase of population of the wild spawners, reinforcing the stock of animals (Dao *et al.* 1985).

As a combination of aquaculture and fishery, large coastal management of scallops enabled good results in Japan (Ito 1991) and New-Zealand (Bull 1994), but possibilities of transfer to European conditions remains to be studied.

1.3. THE EUROPEAN CONCERTED ACTION

An European Concerted Action on scallop seabed cultivation was set up in 1993 with the financial support of the European Union (E.U.) and of Norway. It proposed to join together different teams involved in scallop seabed cultivation (*figure 4, p.19 : poster presented at the 10th International Pectinid Workshop, Cork, 1995*) :

- IFREMER Brest / Molluscs laboratory, in Brittany (France), a national institute of research (coordinator of the Concerted Action) ;
- Connemara Shellfish Co-op, in Connemara, County of Galway (Ireland), a fishermen's co-operative ;
- Seafish Ardtoe, in Scotland (U.K.), an institute provided by the fishing industry ;
- Institute of Marine Research, in Bergen (Norway), a national institute of research.

This represented 10 to 15 people working in scallop seeding, including 8 to 10 divers. A few other researchers (Universities) and producers connected with the main partners were also involved in this Concerted Action.

The Concerted Action exclusively aimed to benefit from research studies by increasing technical and scientific exchanges. Total E.U. fundings and Norwegian contribution amounted to 104 000 ECUs mostly for travel and reception of foreign teams *(table A)*. Consequently a Concerted Action is not a common research programme but a cooperation between European teams. Research and development programmes themselves remained supported by each country involved. In the same way, social and economic consequences were not of the Concerted Action behalf.

table A : ***European Union fundings and Norwegian contribution*** (*) ***in ECUs***

	FRANCE + coordination	*IRELAND*	*SCOTLAND*	*NORWAY*
travel and subsistence	25 000	15 000	15 000	18 000
Consumables	5 000	2 000	2 000	2 000
Others	5 000	9 000	4 000	2 000
TOTAL	**35 000**	**26 000**	**21 000**	**22 000**

(*) : NORWAY is a non-member state but has agreement with the Community for full association with the programme.

1.3.1. Teams involved in the Concerted Action

- *IFREMER Brest, France*

In France research results have selected bottom culture. But contrary to Ireland and Scotland, natural spat collection has remained experimental, due to the low yield per bag. Work emphasis has been on hatchery with successful production. Research and development programmes have been maintained by national and regional contributions since 1983 (1983-1988 and 1988-1993). Two techniques using bottom culture have been operated :

- Process of fishery : exploitation of an additional population together with the wild one, through spat seeding and fishing regulation such as rotation of fishing areas, added to more traditional measures, such as minimum size, type of dredges, fishing periods, ...
- Process of aquaculture : optimization of private rights on bottom grounds for scallop cultivation, possibly associated with oysters.

Research efforts have been devoted to hatchery techniques, particularly on reproduction and larval development, connected to physiology and microbiology. In scallop culture itself, the research programme of IFREMER finished in 1995 and development remains supported only by regional bodies (Brest Bay contract, 1992-1996).

- *Connemara Shellfish Co-op, Galway, Ireland*

The Connemara Shellfish Co-operative is a co-operative of 180 inshore fishermen (fulltime and part time) located in one of the E.U.'s most peripheral areas.

The co-operative manages natural oyster (*Ostrea edulis*) and scallop (*Pecten maximus*) beds. The oyster beds are now a successful extensive aquacultural management. The Co-operative goal is to use extensive aquaculture techniques to boost scallop production from the current 20 tonnes per year to 200 tonnes per year (historical levels). The Co-operative has developed a juvenile scallop rearing system tuned to local conditions and carries out experimental sowings of juvenile scallops.

The key study areas to advance the project were :

- Comparative study of hatchery versus natural scallop seed in sowings ;
- The control or avoidance of predators (crabs, starfish) ;
- Studies on mixed culture of scallops and oysters.
- The recapture of the scallops by small boats employed by the Co-operative members ;

The exchange of information with other interested parties in Ireland, and with IFREMER Brest, in the past, has considerably shortened the learning curve to date, and it is hoped that by concerted effort the remaining barriers will be overcome.

- *Seafish Ardtoe, Scotland -U.K.*

The Sea Fish Industry Authority (S.F.I.A.) has its board members appointed by national government and raises money through a production levy on the U.K. fishing industry.

Scallop cultivation research has been undertaken by Seafish Marine Farming Unit, in Ardtoe, Scotland. since the mid 1970's. Initial trials involved the feasibility of collecting spat from the wild. This was shown to be viable and allowed a research programme of suspended cultivation, using baskets and ear hanging. While such techniques have been shown to be successful, they require considerable capital investment and are vulnerable to adverse environmental and biological factors. Some of the problems associated with suspended cultivation were recognised to be overcome by placing the scallops on the seabed.

During the mid 1980's the investigation of such techniques was started, with a national programme of research. Scallop seabed cultivation studies have been limited in regard to the lack of legal safeguard. Now, right of ownership of the stock can be secured by the Secretary of State granting a **Several Fishery Order** which assures commercial interest.

Natural predation was recognised as a potential constraint to scallop seabed cultivation and trials have been undertaken to assess its overall importance. Results have indicated that the use of scallops of 6 cm (or more) for seeding, appreciably reduces both crab and starfish predation.

It has been recognised that the application to commercial production, of findings from field trials, is not a straight forward process. Scaling up problems include : seabed suitability and site selection, stock handling and transport, seeding methods, stock assessment, predator control and harvesting techniques. Funding for this research is primarily from the U.K. government and will continue until 1998.

- *I.M.R. Bergen, Norway*

Since 1985 Research and Development projects on scallop culture have been carried out at the Department of Fisheries and Marine biology (University of Bergen) and Department of Aquaculture (Institute of Marine Research). The research has covered hatchery spat production, reproduction and growth in natural stocks and spat growth in landbased nurseries, fertilized ponds and suspended cultures in the sea. Research has been also carried out on spat nutrition. The research was founded by national Councils (Norwegian Council of Fishery research and the Norwegian Council for Scientific and Industrial Research).

A pilot commercial hatchery was established in 1987. After promising results In 1990-91, the hatchery was closed in 1992 due to lack of financial support. A new research programme concerning spat production in hatchery has been accepted for funding (1993-95) by the Norwegian Council of Fishery research. This project aims to improve the spat survival after metamorphosis and transfer to open sea.

The programme on seabed cultivation started in 1993 with fundings from Department of Aquaculture (Institute of Marine Research). The objective is to provide information on seabed cultivation on the west of Norway. Two sites are considered for experiments on the seabed : Austevoll (South of Bergen) and Fosen (West of Trondheim). The work is to **cover biological studies of seeded spat, predation control, genetic aspects and harvesting techniques.**

1.3.2. Outlines

The European Concerted Action aimed to improve the exchange of information and methodology within existing funded projects. **Two levels of objectives** were identified within the Concerted Action :

- The first one was the confirmation of interest in bottom culture production by comparing results on different sites in Europe, and to set up European research team in scallop farming and management, that is to say **cooperation outcomes**, such as comparaison of different sites, comparaison of different regulations, exchanges of students and personal, ...
- In addition, the Concerted Action aimed to **improve the know-how in scallop seabed cultivation** and to study the contribution of bottom culture to the management of natural resources by a summation of European knowledge.

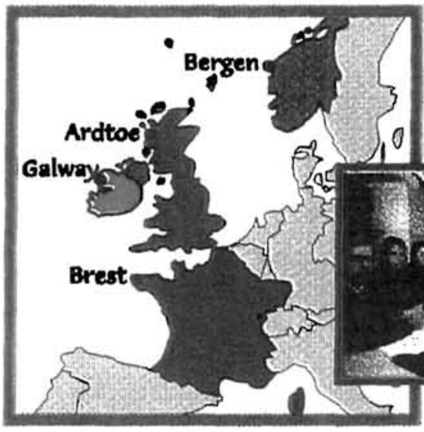
Two approaches were conducted (*table B*). The first one, which was more theoretical, was a yearly meeting (in Spring) where national or regional results were discussed. The second approach, more practical, consisted in an annual common field work (in early Autumn) to compare sampling methods, understand local constraints, and carry out specified actions permitted by the addition of divers and video equipment of the different teams, such as scallop monitoring at seeding and predation studies in the wild.

table B : ***Concerted Action agenda :***

Year	*FRANCE*	*IRELAND*	*SCOTLAND*	*NORWAY*
1993	Field work		Table meeting	
1994		Field work		Table meeting
1995	Final meeting (*in 1996 in fact*)	Table meeting + 10th International Pectinid Workshop	Field work	

*Figure 4 - **European Concerted Action (1993-96) on scallop seabed cultivation***
(poster presented at 10th International Pectinid Workshop, Cork, Ireland, May 1995)

1. MEANS



* **IFREMER Brest, FRANCE**
** SEAFISH Ardtoe, SCOTLAND - U.K.
*** MUIRIN Téo. Connemara, IRELAND.
**** INSTITUTE OF MARINE RESEARCH Bergen, NORWAY.

10-15 people including 8-10 divers

Founds for **3 years** (1993-95) : **82 000 ECUs** (+ Norway)

2. PROGRAMME

1 ROUND TABLE MEETING /YEAR : field work preparation, results, discussion

+ 1 FIELD WORK /YEAR with **research vessel supply**, **divers** and **underwater video** :

1993 - Brest :

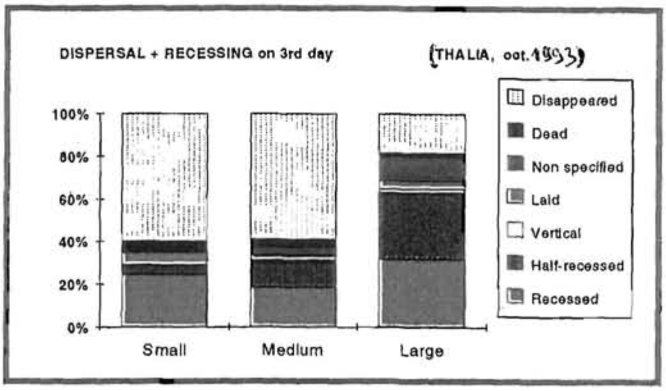
Recessing and dispersal of **3 sizes of juveniles** + biochemistry (vitality).

1994 - Connemara :

Predation by crabs according to scallop size and potting or not.

1995 - Ardtoe :

Influence of **quality of spat** *(to be discussed)*



3. EXPECTED RESULTS

Scientific results : - Criteria for a **good seeding practice** : season, size, quality, potting.
+ Set-up of a **common programme for future.**

Cooperation results :

- Comparaison of **different sites :** shelter, sediment, fauna, ...
- Comparaison of **different regulations :** fishing beds, leases, ...
- **Common diving code practice.**
- **Student cooperation** in quality of spat, predation, regulations, ...

2 - MATERIAL AND METHODS

In addition to theoretical discussions in table meetings, three large scale practical field experiments were carried out during the Concerted Action. Scientists, technicians and students from the four participating countries were involved in each of the field works.

Direct and remote underwater observations were the primary source of data, with **different materials and methods** which could be compared.

2.1. <u>MEANS AT SEA.</u>

The **experimental sites** selected for each field work were sheltered areas, with a sandy-muddy sediment interspersed with patches of mearl. The depth was as shallow as possible (between 3 to 15 m) in order to obtain maximum light for the video recording and maximum dive time for scuba sampling.

Nautical means involved **different boats** ranging from research vessels about (20 m) in France ("*Thalia*") and in Ireland ("*Lough Beltra*") to various smaller barges or dinghies. Research vessels were used as floating laboratories and hotels located close to the seeding areas, mainly for day and night supervision of the remote video equipment. Smaller boats were used for spat transportation from the sea shore to the seeding sites and for diver assistance.

The **dive team** of each participating group was rather limited (2 to 4 people) but thanks to the Concerted Action, each team in turn could take advantage of the large diving team set up by this initiative (8 to 10 divers).

The **video equipment** was mainly deployed in the second field work in Connemara, Ireland 1994, with :

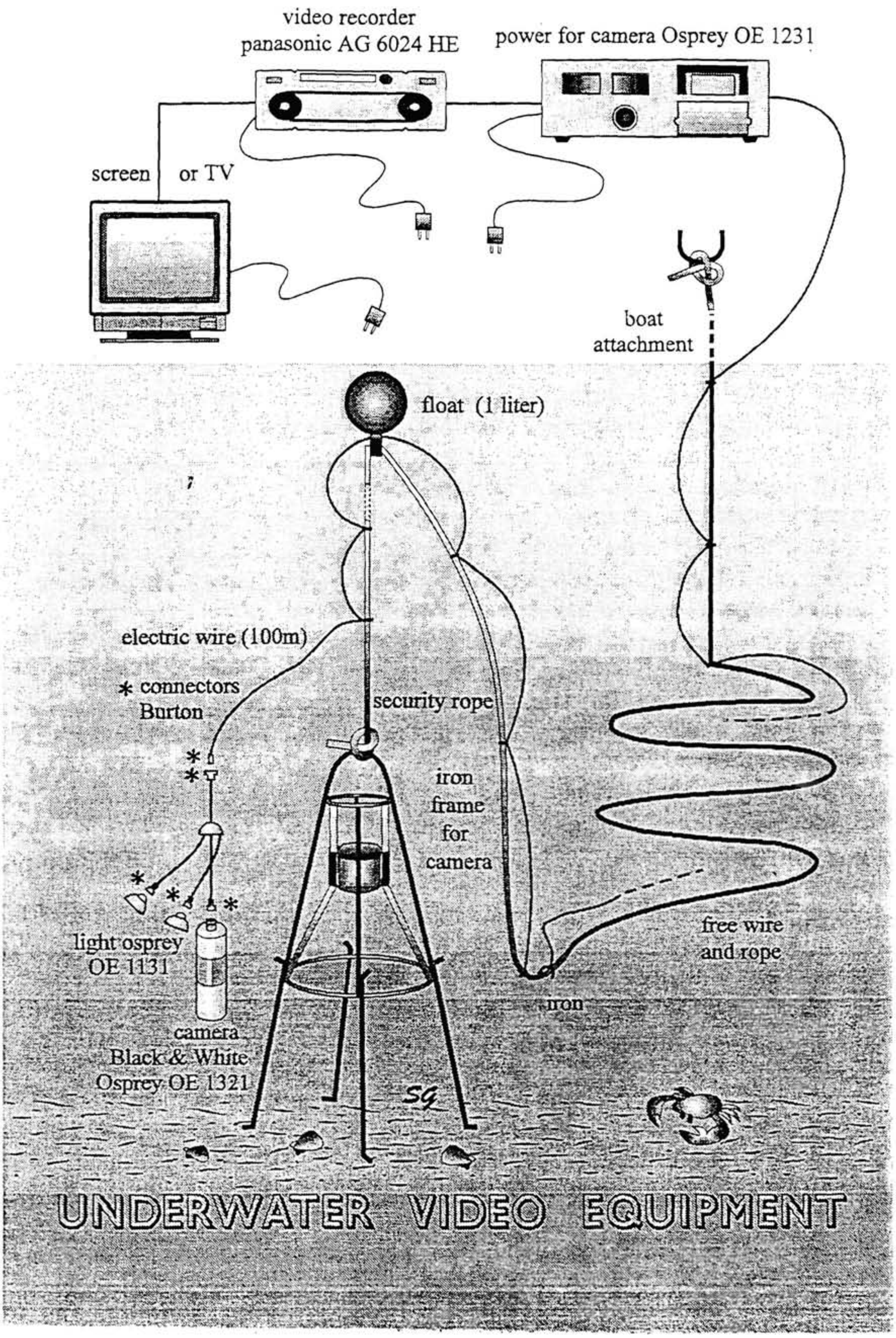
- French team : a black-and-white video camera of hight sensitivity (0.3 lux), extendable with a 100 meters wire, and a time-lapse recorder (*figure 5*). This equipment has been used on a regular basis in scallop sampling in France on a Saint-Brieuc dredge since 1985 in order to assess natural resources and to manage the fishing fleet.

- Scottish team : a similar equipment, recently rented by the group for the field work week ;

- Irish team : video equipment similar to the French one, but the time-lapse recorder was missing and was replaced by a common one. The research vessel "*Loch Beltra*" was also equiped with a small sub-marine robot with video camera. This was funded by the European Commission ;

- Norwegian team : a diver's hand video, commonly used during sampling operations, with limited recording time.

*Figure 5 - **Remote underwater video equipment.***



Juvenile scallops, issued from a commercial production, were of various sizes (15 to 55 mm) according to the aims of the field works. Numbers ranged from a few thousands (in Scotland) to 40-50 000 (in France and in Ireland).

The predator avoidance in Ireland and Scotland required fleets of **crab traps** (locally called "pots" in Ireland and "creels" in Scotland).

2.2. METHODS CARRIED OUT IN FIELD WORKS.

Field work preparation mainly consisted of placing seabed transect lines. In Ireland and Scotland, the works also included crab fishing with traps for 1 or 3 weeks prior to the experimental seedings. Data on the catch of crabs was recorded on catch composition by species, size, sex, and total catch .

If the means and site preparation performed by the different teams appeared to be quite similar, **on the contrary the sampling techniques were rather different** and could be compared during the field works and discussed at the final table meeting, in Brest, in May 1996.

2.2.1. 1st field work, in Brest, France, October 1993.

The aim of the French field work was to study the recessing behaviour of reseeded scallops in Autumn, according to three different sizes of juveniles : SMALL (15 mm), MEDIUM (30 mm) and LARGE (45 mm). The method involved **underwater observations**, using both remote video and divers, **linked with biochemical analysis** of the muscle (tonus, energy, reserves of glycogen) in order to monitor the scallop loss of vitality. The underwater observations looked at resumption of filtration (but was rapidly given up because too much uneasy in the wild), recessing, swimming and dispersion of scallops, as much as identification of predators. Two complementary methods were used :

- Observation by **remote video** from the research vessel "*Thalia*" via continuous recording (at the low rate of 4 images /second) of a defined area (less than 1m2) containing 10 scallops from each group.

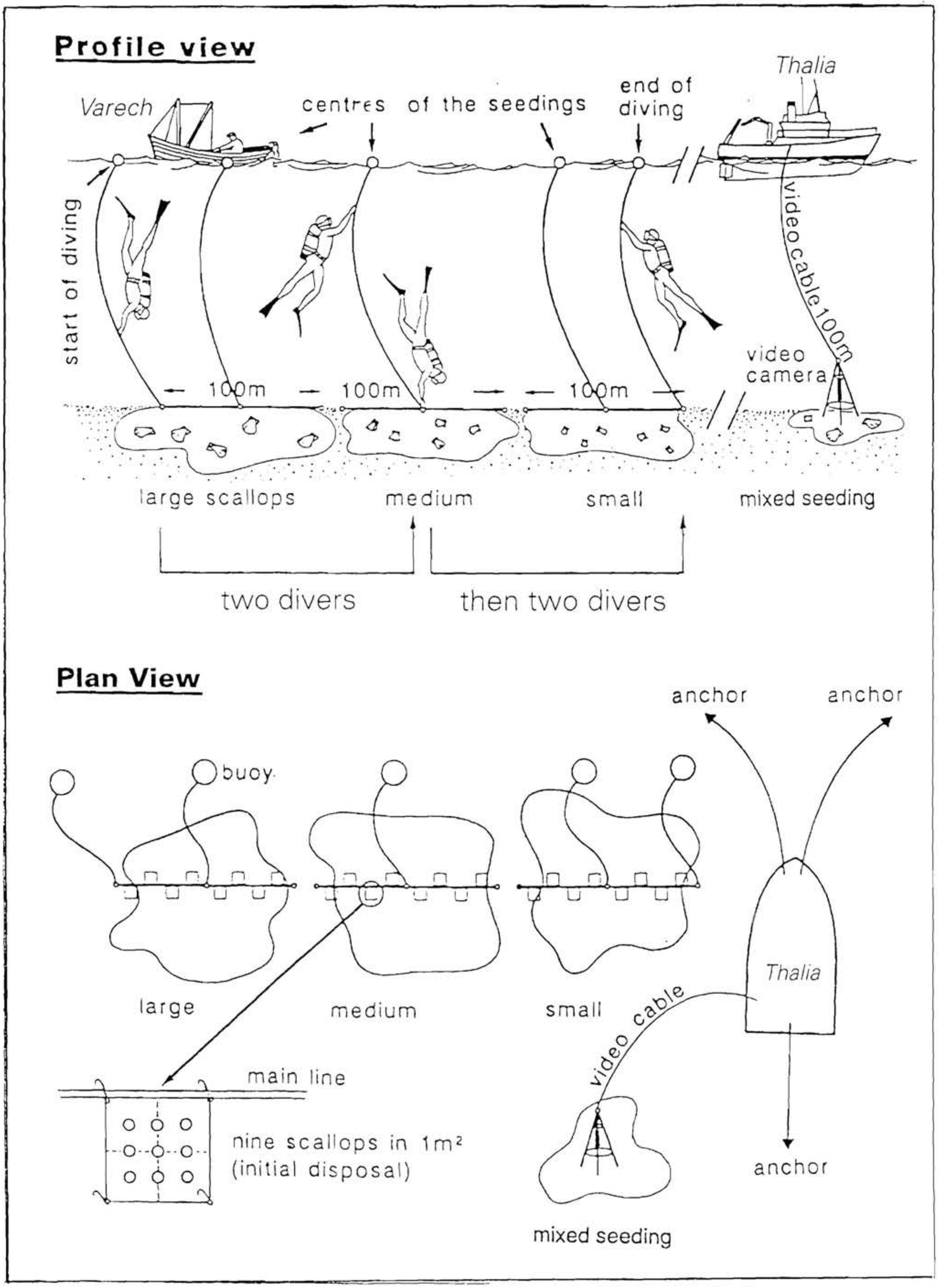
- Observation by **diving** : regular dives on 3 adjacent but separate re seeded batches, each consisting of 15-20 000 scallops (100 m bottom lines, each with 20 x 1m^2 plots positioned every 5 m) : examination of the scallop behaviour was directly noted for each scallop in the plots (1 dive after re-seeding, 1 dive on first night and then 1 dive per day). 9 scallops per plot had to be marked (from 1 to 9 with black marker) and put into their respective places in order to follow their individual behaviour and movement (*figure 6*). So the dive sampling method here was a monitoring of specified scallops in specified **experimental units**

In order to check a potential relationship between behaviour and juvenile quality (stress of aerial exposure, handlings, swimming and recessing), samples of scallops were taken before re-seeding, then daily by diving for **biochemical analysis** of the smooth part (energy release) and of the striated part of muscle (storage), that is to say :

- Adenylic energetic charge (A.E.C.) in the smooth part ;

- Dry material, glucides, lipids and proteins in the striated part of the muscle.

*Figure 6. - **French field work : experimental installations for the monitoring of re-seeded scallops.***



Analysis of energy reserves in the striated muscle were made from freeze-dried matter. Carbohydrates were measured according to Dubois's method (Dubois *et al.*, 1956), proteins were measured according to Lowry's method (Lowry *et al.*, 1951) with an automatic analyser, and lipids were measured with the gravimetric method described by Moal *et al. (1985).* Analysis of A.E.C. in the smooth muscle were performed using a "high performance liquid chromatography" (HPLC) after the samples had been stored in liquid nitrogen, according to the method described by Moal *et al.* (1989).

2.2.2. 2nd field work, in Connemara, Ireland, September 1994.

The 2nd field work was set up by the Irish team and studied the effect of placing crab traps around the perimeter of plots seeded with juvenile scallops on the survival of the seeded scallops .

The site was subdivided into four 2 500 m2 plots, separated from each other by 50 m. A premarked cross transect was laid on each plot. An anchor was set between each pair of plots and a guide rope linked this anchor to each sampling transect. A perimeter of crab traps were laid around two of the plots. A plot with traps and a plot without traps were seeded with 24 000 small juvenile scallops (mean shell height 37 mm), and the other plots were seeded with 18 000 large juvenile scallops (mean shell height 51mm). On one transect additional scallops were seeded by divers. Baseline information on the number of live or dead scallops in two 1m2. quadrants were recorded, at each of the 24 sampling points per transect. **The plots were sampled by divers**, one, two, three, and four days after seeding. The perimeter traps were hauled daily and the composition of the catch was recorded .

Velvet crab traps with a port width of 150 mm and a port height of 100 mm were laid down following the perimeter of a rectangle, with 24 traps on two opposite sides and 12 traps on the other sides which were broadside to the current. Traps were baited with mackerel each morning during the study. Crabs were identified and measured for carapace width, and sexed where this was possible. Studies took place over a five day period, 12-16 September 1994. Crabs were counted but not measured on the last day of study.

Additional information on the interactions between seeded scallops, predators and crab traps were gathered using **remote video equipment** deployed from the research vessel "*Lough Beltra*". Three video cameras were set up on the seabed close to "*Lough Beltra*" in order to examine the behaviour of :

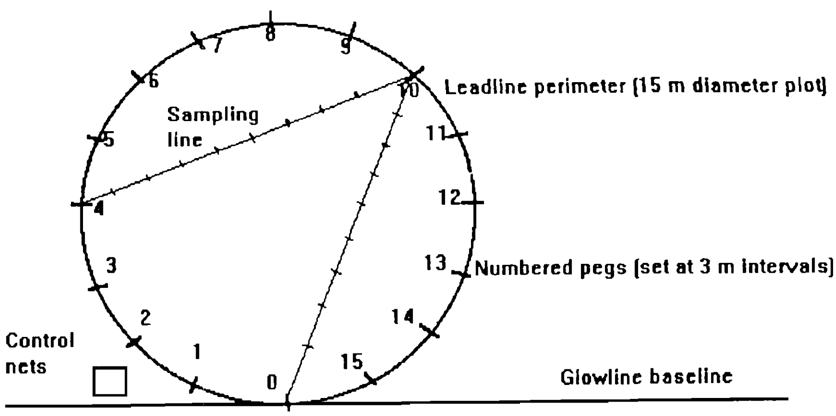
- crabs entering the traps,
- crabs feeding on two class sizes of scallops,
- crab behaviour on damaged versus undamaged scallops.

2.2.3. 3rd field work, in Ardtoe, Scotland, September 1995.

The third field work programme for the E.U. Concerted Action project was conducted at the Marine Farming Unit of Sea Fish Industry Authorities (S.F.I.A), in Ardtoe, Scotland, during September 1995. It aimed on the influence of placing decoy mussels together in the seeding area of juvenile scallops, on the survival of the seeded scallops .

Four circular plots (15 m in diameter) were constructed from 10 mm leadline laid out on the seabed. The leadline was progressively numbered (0-15) around the perimeter of the plot (*figure 7*).

Figure 7 - ***Scottish field work : circular plots with numbered pegs for pre-determined placement of transect lines.***



The stock used in the trial consisted of two year old scallops (40-55 mm) that had been obtained from a spat producer (Raasay Sound). Scallops were transported to the trial site in onion bags which were wet repeatedly. Scallops were aerially exposed for 90 minutes and were then seeded evenly over the plots by divers, giving an approximate density of 7.4 scallops/m2 in each plot. Two plots were seeded without mussels (A and C) and two plots with mussels (B and D) at a density corresponding to that of the scallop seeding.

Between 20 and 30 1m2 quadrats were sampled by two divers on each plot, 3 hours after seeding and then on each day for four days. The quadrats were placed every 2 m along pre-determined transect lines, chosen at random, across the plot. An area of 2 m radius around the centre was not sampled. Total recordings, numbers alive and numbers dead were noted in each quadrat.

One hundred scallops were placed in bouyed pearl nets (25 scallops per level) which were placed at the baseline. These scallops were handled in the same way as the plot scallops and controlled for mortality due to handling stress prior to seeding.

The area was trapped for crabs by five fleets of five creels (A-E) which were deployed in the area one week prior to the trial. The fleets surrounded the plots at a distance of 10 m. The creels were emptied twice over a period of five days before the trial and then daily during the trial. The number of each predator specie was determined in each fleet. One hundred of crabs were tagged by cable ties which were attached to either the left or right appendage of *Carcinas maenas* animals. Those crabs had been caught prior to the trial. Righthand tagged animals were displaced 100 m from the plots and lefthanded tagged animals were displaced 50m from the plots. Any tagged animals found in the plot during the trial was noted.

Concurrently, weak mussels (laid one afternoon under the Scottish sun) were presented to velvet crabs in a tank on-shore, but these observations just remained more qualitative than quantitative.

With regard to the different means and methods usually performed by these teams, it was observed that means were quite the same (similar sites, experimental seedings in the wild, monitoring by underwater video cameras and diver samplings along transect lines) ; but sampling methods, making use of these means, appeared to be somewhat different.

3 - RESULTS

First part of expected results were about **co-operation and team building**, with fruitful comparisons between different sites, different regulations, different supplies of spat, different practices and different approaches in scallop rearing (co-operation results). But, the group also had common reflection points (roundtable meetngs - *table C*) and common works (field works - *table D* *p.28*) which assisted the **understanding of scallop seabed cultivation** (scientific observations).

Table C : Annual table meetings .

date	*place*	*subjects*
June 1993	**Ardtoe** (Scotland)	• Review of the knowledge on scallop seabed cultivation : - in the European Union - outwith of Europe • Topics to be developed for scallop seedings • Field operations proposals
May 1994	**Bergen** (Norway)	• 1st annual progress report • The Norwegian Sea Ranching Programme (PUSH) • Common poster for Pectinid workshop Cork 1995 • Common diving code of practice • Criteria for seeding site selection • Analysis of previous field work in France • Plans for next field work in Ireland
May 1995	**Cork** (Ireland)	• Participation at 10th Pectinid workshop Cork 1995 • 2nd annual progress report • Co-operation : student and personnel exchanges • Juvenile scallop quality at seeding • Analysis of the previous field work in Ireland • Plans for next field work in Scotland
May 1996	**Brest** (France)	Final meeting : • 3rd annual progress report • Preparation of the final report • Dive monitoring of scallop seedings • Probleme of live transport of juvenile scallops

3.1. CO-OPERATION AND TEAM BUILDING.

As a result, the four teams had to learn to work together and therefore they set up a common diving code which agreed with their own national regulations. They also practiced and compared their different sampling techniques. In the aggregate, the Concerted Action created various exchanges of information and of students around the scallop industry.

3.1.1. Diving code of practice.

The first field work showed some divergences between the teams regarding the legal conditions of the diving practices at work. Consequently a common dive code of practice (*appendix 3.1*) was set up at the end of the first year in order to be able to mix the divers of the different teams. This has been a simple, direct code of practice that incorporated the experience and legal requirements of all the participating countries. It could serve as a practical example for future collaborative scientific diving in Europe.

3.1.2. Comparison of sampling methods.

At the final meeting emphasis was put on the comparison of the different tools (underwater video and scuba dive) and the three sampling techniques performed in the field works.

- Remote video monitoring.

With a camera fixed one meter off the sediment, less than one meter-square could be examined, and under these circumstances very few animals were observed : less than 10 juveniles /m² (standard density at seeding) ; if more were used, the juveniles spread out rapidly (Buestel and Dao 1979). After 2 or 3 hours, the scallops were covered with a film of mud, even if they had not recessed, and even the white ones could not be easily discerned. Problems were also encountered in holding the camera frame in the current or when the site became less sheltered from the wind. Therefore the different teams prefered to make use of the divers rather than remote video-cameras, except for specific small observations.

However, the video monitoring was useful in the identification of the predators behaviour, particulary at night (attractive effect of light).

- Behaviour survey by divers.

The renewal of filtering by the re-seeded scallops appeared ambitious to look at in the wild because the scallops were easily disturbed by divers (scallops closed when divers approached). In addition, this renewal occured soon after seeding, and requires continuous monitoring (such as video recording) more than intermittent observations (such as dives)

On the contrary, dive monitoring of dispersal and recessing was quite easy to do with a minimum of practice (just required careful divers). Many scallops could be sampled and significant differences could be shown between the batches.

- Method of sampling.

Various methods of monitoring were carried out in the Concerted Action field works :

- experimental units with marked animals) in the middle of large seedings (10-20 000 spat), in France (Fleury *et al.* 1996) ;

- systematic sampling along transects within large seedings (about 10-20 000 spat) randomly seeded from surface, in Ireland (Norman and Ludgate 1995);

- random sampling of small experimental seedings (several hundreds of m2) with animals evenly seeded by divers, in Scotland.

These methods were discussed and compared to the ones performed out of E.U.(*cf. § 4.1*).

3.1.3. <u>State of art of scallop seedings in the world.</u>

The initial meeting, in 1993, introduced the Concerted Action participants to each other and briefed the participants on the state of art of scallop cultivation in Europe and world-wide. Based on the opportunity of the 9th International Pectinid Workshop in Nanaimo, Canada (22-28 April 1993), information was collected to review the most important out-of-Europe programmes on scallop seabed cultivation, in Japan, New Zealand and Canada.

During final meeting, in 1996, the status of national scallop fisheries and cultivation were brought up to date and future prospects were discussed (*cf. § 4.5*).

3.2. <u>FIELD WORKS AND SCIENTIFIC OBSERVATIONS.</u>

The annual field works (*table D*) enabled a better understanding of the three key factors of a seeding success identified by the group : a good **site**, good **juveniles** and good **practices**.

The three field works provided the opportunity to work on **three different sites**. But there was no specific comparisons conducted between these sites. The problem of sites was mainly discussed at table meetings. Common experiments focused on the second factor, i.e. **juveniles** (Brest, France, 1993) and on the third, i.e. **practices** (Connemara, Ireland, 1994 and Ardtoe, Scotland, 1995), especially for **predator identification and avoidance**.

Table D - Annual field works.

da	*place*	*subject / method*
Oct. 1993	**Brest** (France)	Recessing behaviour and vitality of juvenile scallops at seeding according to 3 sizes of juveniles *- underwater video+ diver sampling* *- and biochemistry (vitality).*
Sept. 1994	**Kilkieran** (Ireland)	Effect of placing crab traps around the perimeter of the plots seeded with juvenile scallops, on the survival of the seeded scallops. *- underwater video (4 cameras) + diver sampling*
Sept. 1995	**Ardtoe** (Scotland)	Influence of placing decoy mussels together in the seeding area of juvenile scallops, on the survival of seeded scallops. *- diver sampling + video in tank*

3.2.1. The fitness of the seeding site.

The three field works made possible for the different teams to compare various sites :

- Brest, France (1993) : sheltered, dredged, with built-up surrouding, management by fishermen ;
- Connemara bays, Ireland (1994) : sheltered, poorly dredged, rather many predators, wild, managed by fishermen ;
- Ardtoe, Scotland (1995) : sheltered, not dredged, many predators, wild, private management.

This enabled the visiting teams to understand the problems encountered by the host team on its own site (overall predator abundance and regulations for collective management).

- The predator abundance.

Out of the biological criteria of site selection, the predator abundance, mainly crabs and starfish, appeared to be of prime importance (Minchin 1991).

The Concerted Action teams could compare scallop seedings on a site with few predators (field work 1993 in Brest Bay, France) and sites rich with various crabs (field work 1994 in Kilkieran Bay, Ireland, and field work 1995 in Ardtoe cove, Scotland). The main observed species of crabs were the shore crab (*Carcinus maenas*), swimming crabs (*Liocarcinus corrugatus and Liocarcinus depurator*), the velvet crab (*Liocarcinus puber*) and the brown crab (*Cancer pagurus*). In addition, a Mollusca, the whelk (*Buccinum undatum*), and two species of starfish (*Asterias rubens* and *Marthasterias glacialis*) were recorded.

Two small unrecognised predators of small juveniles could be identified in the first field work in Brest (Fleury and Minchin, *in preparation*) :

- a small crustacean decapod, the scorpion spider crab (*Inachus dorsettensis*) which attacked juvenile scallops by breaking the edge of the shell ;
- a small fish, the painted goby (*Pomatochistus pictus*) which pecked the tentacles of the scallop mantle, while it filtered.

- Regulations over the sites.

The Concerted Action enabled an international survey of 3 French students in law in IFREMER Brest, France, which showed that different status of the site, including the rights to access and exploitation, can be in effect, according to the various countries (Bouquet *et al.*, 1995). In the European Union, the status of the coastal sea can vary according to each country, but it is always public. Differences mainly concern the mode of allocation of the sites with differences between bottom, water and resources. The sites can be :

- a natural seabed, under direct state control (France, United Kingdom) ;
- a natural seabed, under control of a professionnal organization (Ireland) ;
- private fishing leases (United Kingdom, Norway) ;
- private sea-farming leases (France, Norway)

Most often the exploitation is performed with dredges. In addition, it could be carried out by scuba diving in Scotland and Norway

3.2.2. The fitness of juvenile scallops.

The production of good quality juveniles and their transportation to the cultivation site was outside the scope of the Concerted Action. However it was agreed by the Concerted Action that a key for successful seabed cultivation was good quality juveniles. The aptitude of animals to be re-seeded concerned two criteria : their **size** and their **vigour**.

- The size of the re-seeded scallops.

Standard seeding sizes for juveniles appeared to be very different according to each country : 30 mm in France (Dao *et al.* 1985), 50 mm in Ireland, after overwintering in cages (Norman and Ludgate 1995) and 60 mm in Scotland, from suspending techniques (Mikolajunas 1995). Though this size can vary according to sites, seasons, etc ...

The two first field works of the Concerted Action (in France and Ireland) matched with various sizes of animals at seeding.

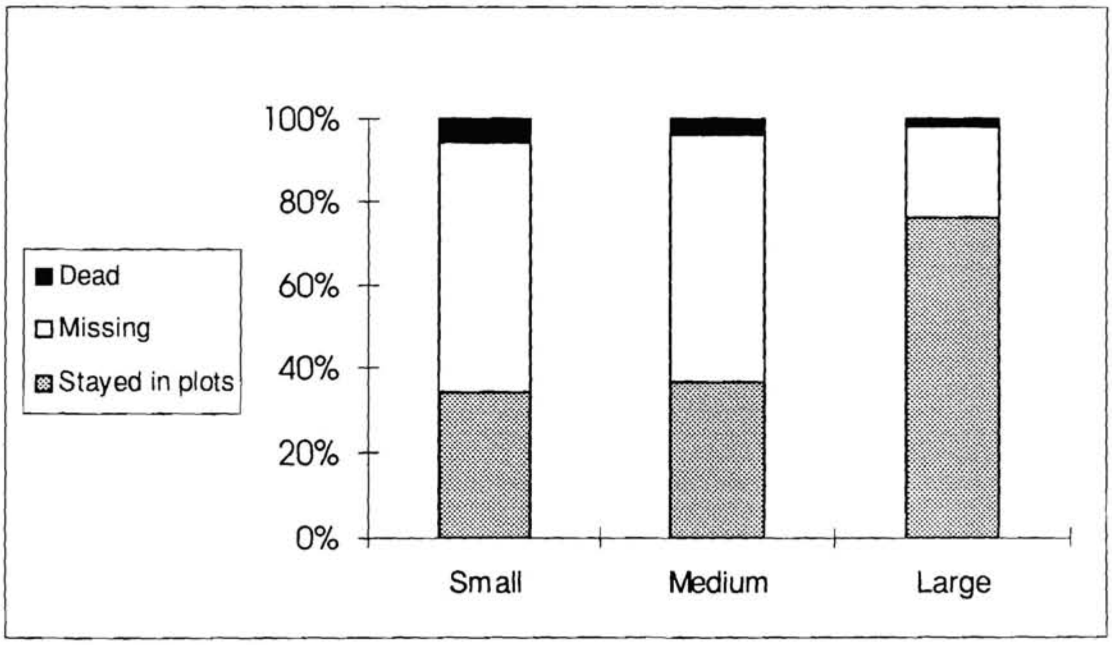
The French field work in October 1993 compared the dispersal and mortality of three different sizes of juveniles in Autumn : SMALL : average size = 14.9 mm (standard deviation = 4.3 mm) ; MEDIUM = 29.2 mm (3.6 mm) ; and LARGE = 42.8 mm (4.6 mm).

When considering dispersal, small and medium juveniles were subject to bigger dispersal than large ones (*figure 8*)

- two thirds (67 %) of the large scallops stayed in their 1m2 plot ;
- less than one third (28-29 %) of small or medium scallops remained in position.

But it was difficult to distinguish between mortality (as empty shells were rapidly moved away by the current), passive dispersion (weak scallops being carried away) or active swimming (used to escape from predators or to find a more suitable place to recess).

Figure 8 - ***Dispersal of juvenile scallops 4 days after seeding in Brest Bay, in Autumn, according to 3 different sizes.***



Little movements (within the limits of the plot) represent a few scallops, after 4 days.

Mortality by predation remained low.

Comparison of these three seeding sizes were continued in the French programme during other seasons, in April 1994 (Spring) and July 1994 (Summer) and was the subject of a total publication (Fleury *et al.* 1996).

In Connemara (field work 1994), there was a very high survival rate of both sizes of scallops (30-35 mm and 50-55 mm) during the study period, with both treatments (trapped and untrapped plots). However the highest mortality was observed with smaller scallops in the trapped plot, suggesting that the traps were attracting predators more than effectively removing them. The remote video observations reinforced the diver sampling results. The critical period, in terms of survival of seeded scallops, appeared to be over a longer time period than that studied during the field work (five days).

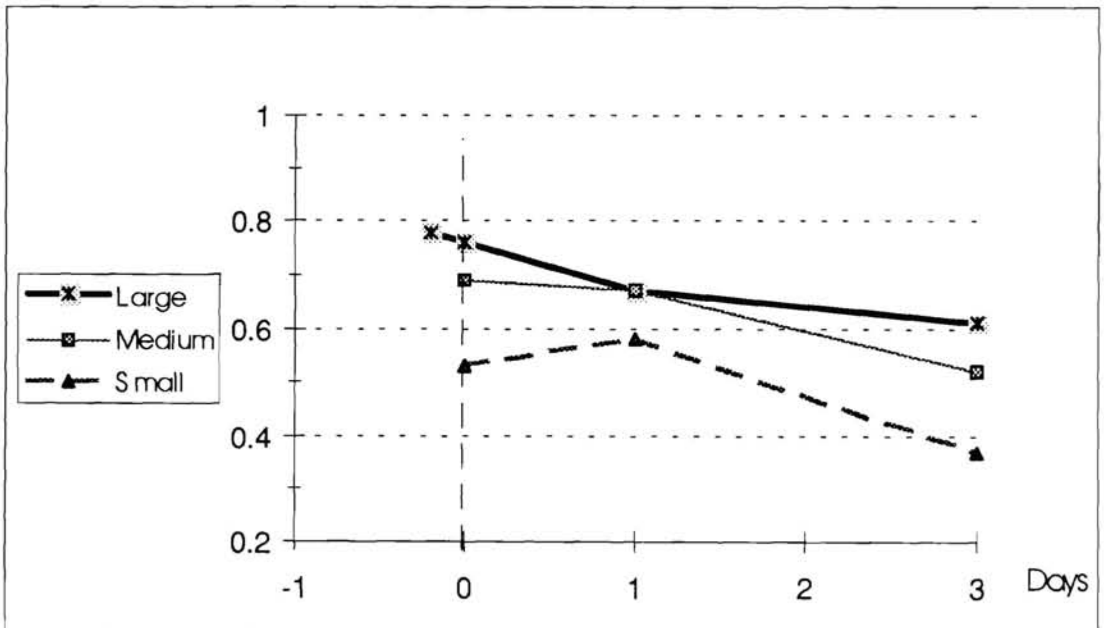
- <u>The vitality of the animals.</u>

Some connected studies of the field works pointed out the importance of the vitality of juveniles at seeding. In addition, the Concerted Action assisted the study of this subject by an Irish student in IFREMER, France in 1995 (Maguire *et al.* 1997).

The first field work in France (1993) tried to monitor the vitality of juveniles through the biochemical analysis of carbohydrates, protids, lipids in striated muscle and of the adenylic energetic charge (A.E.C.) in smooth muscle of animals sampled each day after the seeding.

The biochemical analysis of the storage reserves in muscle corroborated the lack of glucides with the autumnal poor survival in this season. The A.E.C. level was very low for the small scallops, and three days after the seeding none of the three size batches had recovered its initial vitality, i.e. its initial energetic level (*figure 9*).

Figure 9 - ***Evolution of the adenylic energetic charge in juvenile smooth muscle, after seeding.***



During the Irish field work (1994), 40 scallops that had been previously weakened by cutting a small part of the adductor muscle were placed in the wild in front of video cameras. They were very quickly preyed upon, principally by corrugated crabs, *Liocarcinus corrugatus* (46-58 mm carapace width). Eleven of the forty scallops representing two size distributions of scallops (30-35 and 50-55 mm) were selected by the crabs. Eight of these were from the smaller size distribution.

3.2.3. <u>The seeding practices and the predator avoidance.</u>

The predator avoidance was pointed out by the Concerted Action group, as the main action of the scallop-farmer toward his seedings. The 2nd and 3rd field works (in Ireland, 1994 and in Scotland, 1995) were particularly devoted to this subject.

- Kilkieran bay, Connemara, Ireland, September 1994 : a study of the effect of placing <u>crab traps</u> around the perimeter of plots seeded with juvenile scallops on the survival of the seeded scallops.

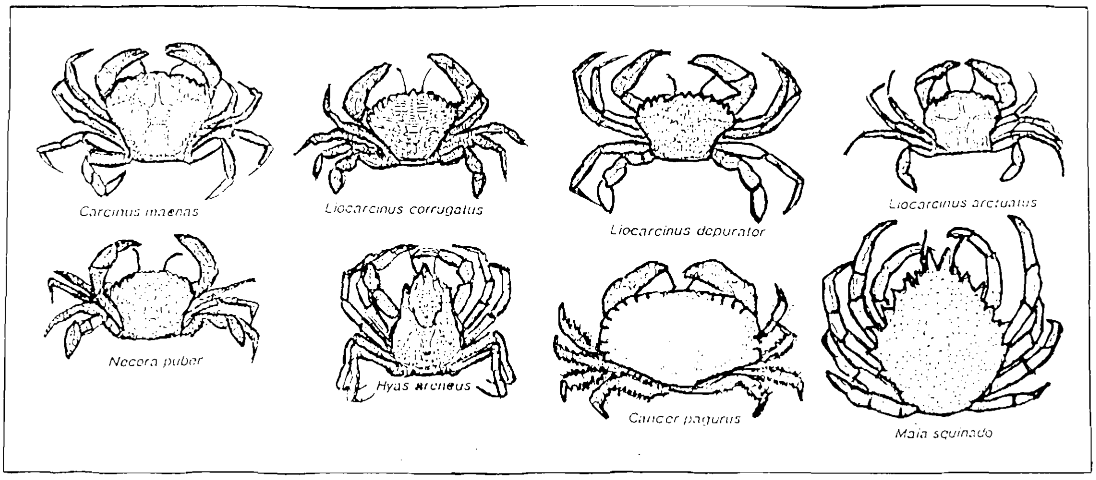
- Ardtoe, Argyll, Scotland, September 1995 : a study of the effect of placing <u>an alternative prey (mussels)</u> together in the seeding area of juvenile scallops on the survival of the seeded scallops.

- <u>Potting crabs</u> (Irish field work, 1994).

<u>*Crabs.*</u>

The plot area was trapped in advance of the sowing experiment and yielded between 62 and 138 kg per 72 traps per haul ; during the scallop seeding experiment this ranged from 47 to 54 kg per haul. Eight crab species (*figure 10*) were recovered in traps from the study area. The most frequent of these were the shore crab (*Carcinus maenas*) and the corrugated crab (*Liocarcinus corrugatus*). The largest crab was the brown crab (*Cancer pagurus*) which attained more than 700 g, and is capable of feeding on sown and adult scallops. This species is not trapped commercially in Connemara because of its low meat (muscle tissue) levels. There was a slight trend of <u>increased</u> numbers over the five day trapping period.

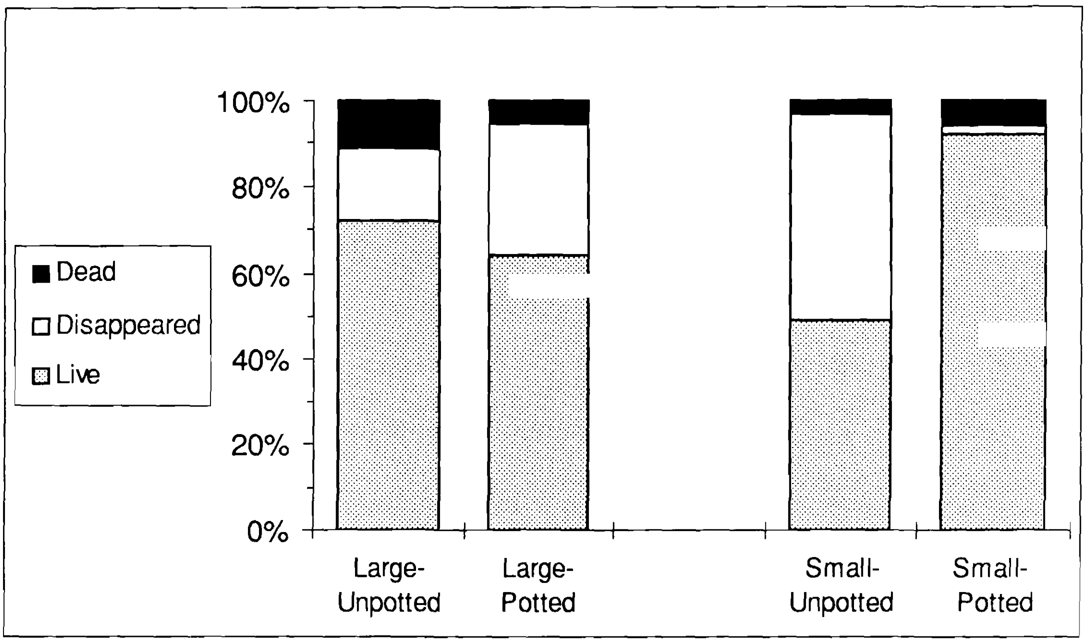
Figure 10 - ***Crab species captured in traps during the Irish field work, 1994.***



Scallops.

Two size distributions of scallops were presented to crabs with modes of 34-40 mm and 50-55 mm shell height. Few scallops were preyed upon in the plot area during the period of study, but a large part of them disappeared. Shell remains of 68 scallops that had been preyed upon following the sowing were recovered and these were almost exclusively from the smaller modal size group. Most of these shells were of single valves and the majority had been punched or smashed. With regard to missing scallops, there was no clear difference between potted and unpotted plots for the larger juveniles : 30% vs 17% ; but there was a significant one for the smaller ones : 2% vs 48% (*figure 11*).

Figure 11 - ***Impact of potting crabs at seeding on scallop survival and dispersal***



Scallops sown beside traps before video cameras remained undamaged. Scallops that had their adductor half-cut were more likely to be fed upon by crabs.

- Alternative prey : mussels (Scottish field work, 1995).

Predators.

Predators found in creels around the seeding area were mostly crustaceans (*Carcinus maenas, Cancer pagurus, Liocarcinus puber, Liocarcinus depurator, Pagurus bernhadus, Homarus gammarus*) with a mollusc (*Buccinum undatum*) and two starfish (*Asterias rubens* and *Marthasterias glacialis*). The shore crab (*Carcinus maenas*) was clearly the most abundant predator species caught (82% of animals). The velvet crab (*Liocarcinus puber*) was also found in substantial numbers (14%). The abundance of the other species caught was negligible.

The total number of predators caught in each fleet of creels on each day showed a decline in total numbers in fleets A, B, C and E during the 5 days before seeding. Upon seeding (day 5), total numbers dramatically increased in B and C, within two days, but continued to decline in fleet A, which was further away from the shore. The total number of predators caught in fleet D, which was closest to the shore, was consistantly higher than the other fleets; apart from a drop on day 6.

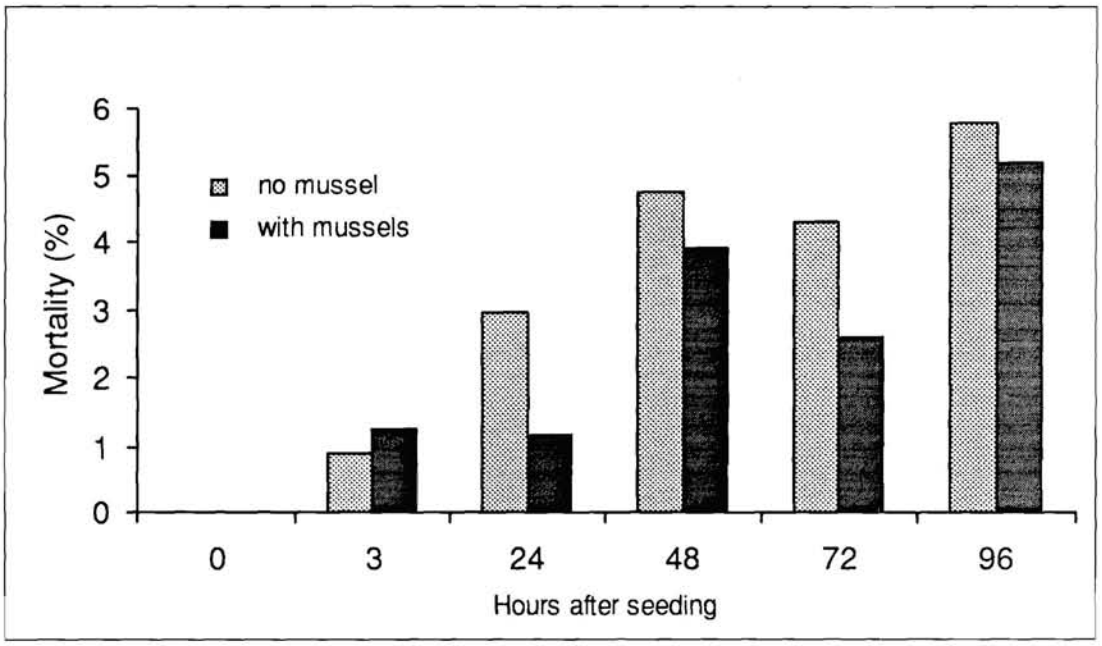
Tagged animals released 50 m and 100 m off the seeding area were mainly caught in fleet D which was in closest proximity to the shore.

Scallops.

A one-way analysis of variance test, performed upon logten(x+1) transformed data, indicated significant differences between mean total counts of scallops per quadrat ($P<0.05$) in the plots. Large variations in mean total counts per quadrat were observed in all plots; but there seemed to be a general decline of this value as the trial progressed.

The percentage mean of mortality is presented for each treatment on each sample day (*figure 12*). Large standard errors were observed in both treatments. This was attributable to plots A (no decoy) and B (decoy) having greater mortalities (approx. 7%) than plots C (no decoy) and D (decoy) (3-4%). A one-way analysis of variance test performed upon arc-sine transformed data collected after 96 hours (final sample) found no significant differences between treatments ($P>0.05$).

Figure 12 - ***Impact of decoy mussels at seeding on scallop mortality.***



On the contrary the small video experiments performed in the wild and in tank at Seafish during the Scottish field work clearly showed the preference of crabs for weak mussels (laid an afternoon under the Scottish sun) instead of juvenile scallops. But these succinct supplementary observations were not quantified.

In conclusion, the pool of knowledge brought together by the Concerted Action teams has resulted in a better state of art than was defined at the first table meeting. The Concerted Action improved the know-how in scallop seabed cultivation and obtained some data about the three key factors that it identified (sites, juveniles and practices) :

- Sites : scallop seabed cultivation is a form of sea-ranching and requires **broad surfaces at sea**. This implies the development of novel organisational or business structures that would have access to the extensive suitable scallop seabed cultivation sites ;

The abundance of predators, especially crabs, is an important criteria in the choice of a seeding site, but remains uneasy to avoid, in regions where crustaceans are fished from very little.

- Juveniles : From French and Irish field works, the results indicated a relationship between scallop size and animal dispersal on the seabed.

  The quality of animals was identified as an important factor, but was marginally studied in the Concerted Action (biochemistry in French field work, 1993), failing to have a satisfactory diagnostic tool.

- Practices : Concerted Action field works placed particular emphasis on seeding practices, especially relating to predator avoidance, and two techniques were tested : crab potting and decoy mussels offered to predators (crabs and starfish).

  The crab potting gave significant results with scallops of 30-35 mm and no difference with larger animals which were pred on by less crabs. However potting increased the predator abundance (increases as a result of the attractive effect of the bait ?).

  Live mussels as an alternative prey did not decrease the scallop mortality at seeding. On the contrary some small video trials with weak mussels seemed to show a clear preference of the crabs for such mussels, but this was not quantified.

These works have been disseminated in a number of ways : the Concerted Action intermediate reports ; the holding of seminars on scallop seabed cultivation ; posters and papers presented at the 10th. International Pectinid Workshop in Cork, Ireland in May 1995; as well as by conventional publications. The use of such a variety of methods of disseminating the gathered information ensures that the industry as well as the scientific community are aware and up to date of the state of art of this subject.

4 - DISCUSSION

The Concerted Action permitted numerous discussions between the European teams, at the same time about method (**monitoring of seedings**) and the analysis of the three key factors of successful scallop seebed cultivation that were identified by the group :

- the fitness of the **seeding site** ;
- the fitness of **juveniles** : suitable size and vitality of animals to be re-seeded ;
- the fitness of **practices**, especially predator avoidance.

At last the Concerted Action updated **present development and future perspects** of scallop seabed cultivation in Europe.

4.1. MONITORING THE SEEDINGS.

The participation of the group in the different field works and their criticisms at the debriefings arose many discusions about each method. Two angles have to be considered : the interest of **underwater video versus divers** and the **different sampling methods**.

4.1.1. Video or divers' observations ?.

Table E - ***Comparison of remote-video and diving.*** (+) PROS (-) CONS

	REMOTE-VIDEO	*DIVING*
Frequency of observations	(+) continual recording (slow motion possible)	(-) intermittent observations
Samples	(-) 1 mixed sample ; 10 scallops /batch	(+) 3 separate sowings ; observation of 20 plots
Surfaces	(-) 1 m2 maximum	(+) up to several hectares
Clarity of observation	(-) difficult to see small animals which were half-burried	(±) observation demanding a minimum of practice
Disturbance of animals	(+) Infra-red at night (-) increased density (-) frame of the video-camera	(±) movements by divers (-) night lights
Sampling taking	(-) impossible	(+) possible

At the end of the first field work, the group could draw up a table of pros and cons between video and divers' observations (*table E*). The two means appeared complementary to each other, but preference was given to divers who could monitor larger seedings than video.

4.1.2. Sampling methods.

Faced with specific needs and constraints in their own countries and programmes, the different teams used to run various methods of dive sampling on their experimental seedings . Differences could be due to constraints in means, in animals, in personnel and refered to :

- the way of sampling : in experimental units of 1m2 (Brest), or systematic sampling along transects in the whole seeding (Connemara), or random sampling in a small round seeding (Ardtoe) ;
- the size of the seedings (mainly due to spat supply facilities) ;
- the use of marked juveniles (Brest) or not ;
- the count of the total dead scallops, by summation of the successive samplings (on the assumption that dead scallops move with currents or predators) or only at the last sampling (on the assumption of no movement during the week).

The various alternatives for monitoring seeded scallops and the sampling protocol for experiments , the main options, their advantages and weaknesses have been detailed in *appendix 3.2 : Dive monitoring of re-seeded juvenile scallops.*

Anyway, two main objectives may be considered in a seeding monitoring, either it is required to look into the initial success of the seeding itself, which pay attention to vitality and activity of juvenile scallops and possible predators, or it is required to assess the numbers of scallops to quantify ulterior recapture.

- To look into the initial success of the seeding.

Various activities characterize scallop activity after the seeding stress, the first of them being the renewal of filtering, then swimming (dispersal) and recessing or death (Fleury *et al.* 1996).

The remote video recording identified predators and their behaviour. But it was of very little value for studying recessing and dispersal of scallops because of the small batch size and poor quality of the pictures.

As early as the first field work (Brest 1993) it appeared ambitious to look at the filtering behaviour of the scallops in the wild because they are easily disturbed by divers (scallops close when divers approach) ; in addition, the renewal of filtering occures soon after seeding and would require a continuous monitoring. This behaviour may be looked at in laboratory studies, probably with a device to record opening of the valves rather than a video camera or ponctual observations.

But recessing and dispersal of animals could be easily looked at by diver monitoring like it has been performed for years in France (Buestel and Dao 1979) or in Ireland (Norman and Ludgate 1995). These observations may be easily quantified from the initial density.

If there is not too much current in the first days, the count of found dead shells may represent the initial mortality.

- <u>To assess the numbers of scallops for ulterior recapture.</u>

The scallop seedings in the wild pose the question of **their monitoring** from year to year till the commercial size (2 or 3 years). Most often commercial operations just have dredges, which make the sampling of the seeding possible only shortly before the recapture period.

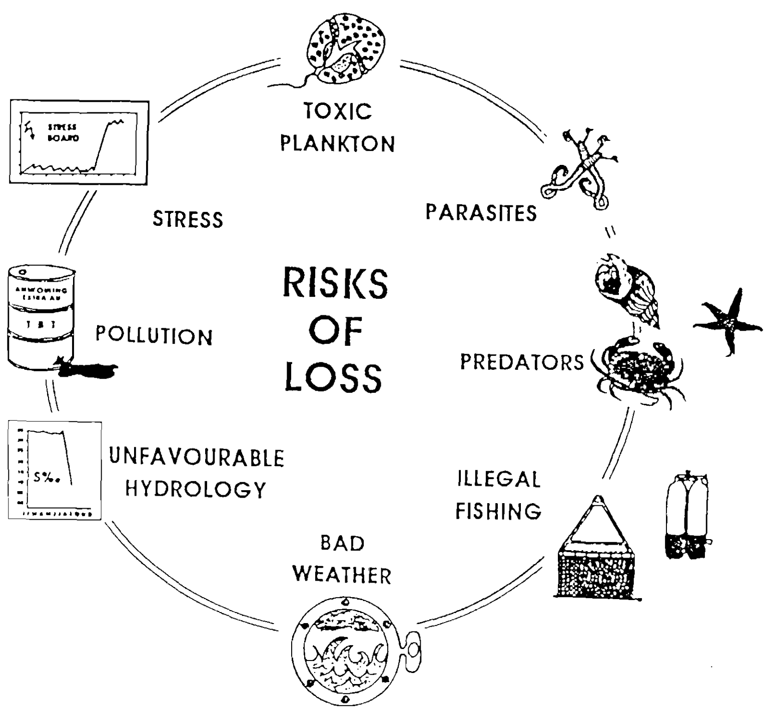
Divers are required at least for the first year after the seeding, which may be the most important in fact to detect an arrival of predators, an unrecessing of animals due to cold, pollution or other accident. Because of dispersal, a simple dive monitoring of dead and live scallops is not sufficient to estimate the survival rate of a seeding. It appears worth while to sample the animals, and various techniques have been proposed, connected to submarine constraints, such as experimental units with marked animals (French field work ; Fleury et al. 1996), systematic sampling along transects (Irish field work ; Norman and Ludgate 1995); random sampling (Scottish field work).

In seabed cultivation (sea-ranching) animals are sedentary but free, and **therefore survival rate is most often under-estimated**, run-away animals being counted as dead. The use of tethered control animals gives a better indication of the survival rate. These juvenile scallops can be either tied up to bottom sticks (Barbeau and Scheibling 1994) or to bottom line (Fleuryand Mingant *unpublished*).

4.2. <u>SEEDING SITES</u>.

Scallop seabed cultivation is an extensive aquaculture (sea ranching) requiring **broad coastal areas**. The choice of the site is a very important, if not the main, factor of success. Causes of loss to seeded stocks are numerous (*figure 13 fro*m Fleury and Dao 1992) and many factors, both natural (biology, ecology), and socio-economic (site use, rights and site security, potential harvesting techniques) must be considered (Pajot 1984 ; Fleury 1989).

Figure 13 - ***Risks of loss in scallop seedings.***



A list of criteria for a seeding site selection was set up by the group, including natural and socio-economic criteria (*appendix 4.1*). These characteristics or criteria could be ranked (*table F*).

Table F. - ***Ranking the criteria considered to impact scallop seedings.***

BASIC CRITERIA *inducing the seeding **feasibility***	SECONDARY CRITERIA *inducing the **reliability** of the result*
◊ **Sediment suitability :** - stable --> little dispersion of scallops - fine sediment --> enabling recessing.	◊ **Juridical status :** - title to the seabed (rights to body of the water, the seabed, the living resources ?) - social organisation : individual or collective management ?
◊ **Nuisance species :** - a few predators - a few competitors.	◊ **Potential technical support :** - at sea : access to the site, supervision - facilities on shore : pumping, tanks, ... - weather dependency - good communications.
◊ **Regulations and site security :** - low competition with fishing activities (especially towed gears) - low risks of poaching - compatibility with recreational activities.	◊ **Adequate water quality :** - current around 1 knot - non-persistent nuisances - no or rare toxic algal events - sanitary quality.

The three basic criteria for seeding sites were discussed :

4.2.1. Sediment suitability

Sediment texture, which may make the recessing of the scallops easier or harder, can be more or less soft ranging from mud to sand with maërl. This has to be studied further, for our results mainly on sandy-muddy sediment can only be transferred to similar places.

4.2.2. Nuisance species

The role and behaviour of large predators of scallops such as starfish (*Asterias* spp., *Marthasterias glacialis*), lobster (*Homarus* spp.), crabs (*Cancer* spp., *Necora puber, Carcinus maenas*, ...), whelks (*Buccinum undatum*) or even the anemone (*Anthopleura ballii*) have been related and studied for years in different part of the world, in Canada (Elner and Jamieson 1979, Barbeau 1994), in Scotland (Lake *et al* 1987), in Ireland (Minchin 1983 and 1991) and in France (Halary *et al* 1994) for example. The behaviour of small predators such as *Inachus* sp; and *Pomatoschistus* sp. in scallop attacking and disturbing was not observed previously.

The abundance of predators, especially crabs, is an important criteria in the choice of a seeding site, but remains uneasy to avoid, in regions where crustaceans are fished from very little. In addition, predation rate is influenced by various biological and physical factors such as prey size and water temperature, i.e. season of the year (Barbeau *et al.* 1994)

The question of what makes a site with comparatively few predators (Brest Bay) and others very rich with crabs (Connemara bays in Ireland or Scottish loc'hs) can be discussed. A first difference between Brest Bay and the Irish or Scottish sites is the importance of the dredge fishing in Brest, 90 boats throughout the winter. The question is about the dredge impact upon juvenile scallops and predator attraction by broken shells versus the effectiveness of the dredge against predators themselves.

With regard to the impact of dredging upon juvenile scallops, Dao *et al.* (1997) compared the recapture rates of two commercial seedings in Brest Bay, the first one in a closed area and another one on a vicinous site opened to yearly winter dredging. No significant difference was observed between the two recapture rates, the one of the opened area even being superior 25% versus 19 % after the first year of exploitation (3 years after seeding).

With regard to the impact of dredging upon predator attraction (broken shells, ...) or avoidance (disturbation ?), Thrush *et al.* (1995) in New-Zealand, and Currie and Parry (1996) in Australia observed that scallop dredging impacted a decrease of benthic population. Eleftheriou and Robertson (1992) in Scotland found no significant difference in molluscan and crustacean species, except killing of numerous Cancer. In France, the effect of trawling was studied by Hamon *et al.* (1991) in Saint-Brieuc bay, as far as the effect of dredges (Berthou *pers. comm.*) but they could not conclude on the positive disturbance of predators versus the negative attraction by broken shells.

The reason of such a difference in crab abundance can be also searched in the topography : Brest Bay may be less shallow and less indented than the Scottish or Irish ones. In the latter, rocky areas are never very far away from the seeding site, and such rocky areas are known to be the preferential habitat of shore crabs, velvet crabs, brown crabs or lobsters (Lake *et al.* 1987 in Scotland, Minchin 1991 in Ireland).

4.2.3. Regulations and site security

In addition, rights to access and to exploit such coastal areas appeared different within European countries, all of them being rather unsuited to vast areas and coastal management by professional groups. This implies new regulations and the development of novel organisational or business structures that would have access to the extensive suitable scallop seabed cultivation sites.

4.3. JUVENILE QUALITY.

Fitness of the juvenile scallops comprises two elements, their size and their vitality.

4.3.1. Seeding size

Suitable size could range from 15 to 60 mm and was determined in each area according to local constraints in spat supply and in sites (hardness of sediment, shelter from currents and swell, abundance of predators). From French and Irish field works, it was clear that size had an effect on dispersal of small animals. Till 15 mm scallops appear much too light to stay more or less in place after seeding. They are rapidly carried away by the swell or the currents when not by predators.

Very small juveniles (15 to 20 mm) can be seeded quite successfully in summer in Brest bay which appeared sheltered and quite poor in predators compared to other sites (Fleury *et al.* 1996). Irish bays, Scottish loc'hs or Norwegian coastal waters require larger animals over 5 cm (Norman and Ludgate 1995, Mikolajunas 1995, Strand *et al.* 1995)

The **deal** is between the **lowest costs for juvenile supply** (small size, about 15-20 mm) and the **lowest mortality at seeding** (large size, around 50-60 mm with high cost due to the overwintering of juveniles in nets or cages).

In France, the scallop industry in Brest bay used to deal with the minimum size, and national experiments were carried out to fit the minimum size with each season.

In Scotland (Mikolajunas 1995) and Ireland (Minchin 1995) producers used to overwinter the animals in lantern nets (Scotland and Ireland) or in cages (Ireland).

In Norway, practical use of fences and bottom net-tents for intermediate seabed cultivation of scallops are tried out by two companies. The results so far are promising , and the equipment which has been tested is considered to have great potential compared to traditional suspended nets or bottom cages (Strand *et al.* 1997).

4.3.2. Vitality of juveniles

The other point is the juvenile scallop vitality required to swimm after seeding in order to escape predators, to find a convenient place and to recess. This vitality varies widely according to previous rearing density in intermediate culture, and to duration and way of transportation up to the seeding site.

Then the concern for better knowledge on vitality of animals at seeding was pointed out by the Concerted Action group, but was marginally studied in the Concerted Action (some biochemistry in the French field work, 1993), failing to have a satisfactory diagnostic tool. Anyway a special discussion on this subject took place at the third meeting, in Cork (May 1995). Conclusions and recommendations are reported in the *appendix 4.3*. The problem with the live transport of juvenile scallops was pointed out too and was discussed by the group in its fourth meeting, in Brest (May 1996). Conclusions are reported in the *appendix 4.2*.

The problem of the vitality at seeding may be divided into three main phases :

- The **initial vitality** before seeding due to intermediate culture conditions (food supply according to the site, depth, season and animal density in cages)

- **Loss of vitality** at seeding, due to transportation (distance, temperature, shocks)

- Loss of vitality just after seeding due to **need of energy for swimming** to find a convenient place and and for recessing sediment), associated with potential swimmings to escape to predators predator abundance and activity)

With regard to the initial quality, the poor carbohydrate storage reserves in muscle found in Autumn, made the Brest bay technical pathway to be reconsidered with an earlier spawning in hatchery in order to practice Autumn seedings in September instead of October or November.

The biochemical analysis (adenylic energetic charge) in the smooth muscle of the animals sampled all along the French field work seedings showed that the stress (aerial exposure, handlings) before seeding and the post-seeding behaviour (swimming, recessing) may have a hight energetic cost for the scallops. The A.E.C. in smooth muscle showed that vitality is lower in 'Small' juveniles (but we cannot exclude artefacts, such as defrostings, at this very small size). Loss of vitality seemed to persist after the seeding, but has to be confirmed by a specific study with more numerous batches and over a longer period. It would be worth while too to look at the duration of the recovery period that juveniles require before being able to suffer new stresses such as unearthing by gales, predator attacks or dredge passing-by.

It was also a discussion between the Concerted Action group to set if it was better to look at A.E.C. in striated muscle (because that is the muscle in use for swimming, recessing and so) or in the smooth muscle (the one which fails when bivalves gape and die). A.E.C. in striated muscle may re-fills as soon as used, except close to death, and would be a poor index (Haugum *et al.* 1997) ; the smooth muscle may have a wider range of response (Fleury *et al.* 1996).

Anyway these quality aspects remain to be quantified. The scientist or farmer only looks at empirical and subjective estimations, such as noise (shell full or empty), aspect (flesh bright or dull), valve clappings (numerous or rare), which cannot give any serious comparison between batchs or between seeding practices. The biochemical analysis is difficult and lethal which excludes an individual monitoring of animals. Further studies would be made easier with a more simple, individual and non lethal index of vitality. The probleme is that **no simple tool or index exists at the present time**. The perfecting of such a simple tool could enable profitable comparisons in futural works. Such physiological indices are now being studied (Maguire *et al.* 1997).

4.4. PRACTICES AND CONTROL OF PREDATION.

Seeding practices were quite no existant at the beginning of the Concerted Action, that is to say just seed juveniles from the sea surface at a density of about 5 animals /m2, and eventually dive to have a look on the recessing and on the predator attraction ; then producers used to wait till the animals reach the commercial size (10 cm) or more according to local fishing size, that is to say 2 or 3 years later.

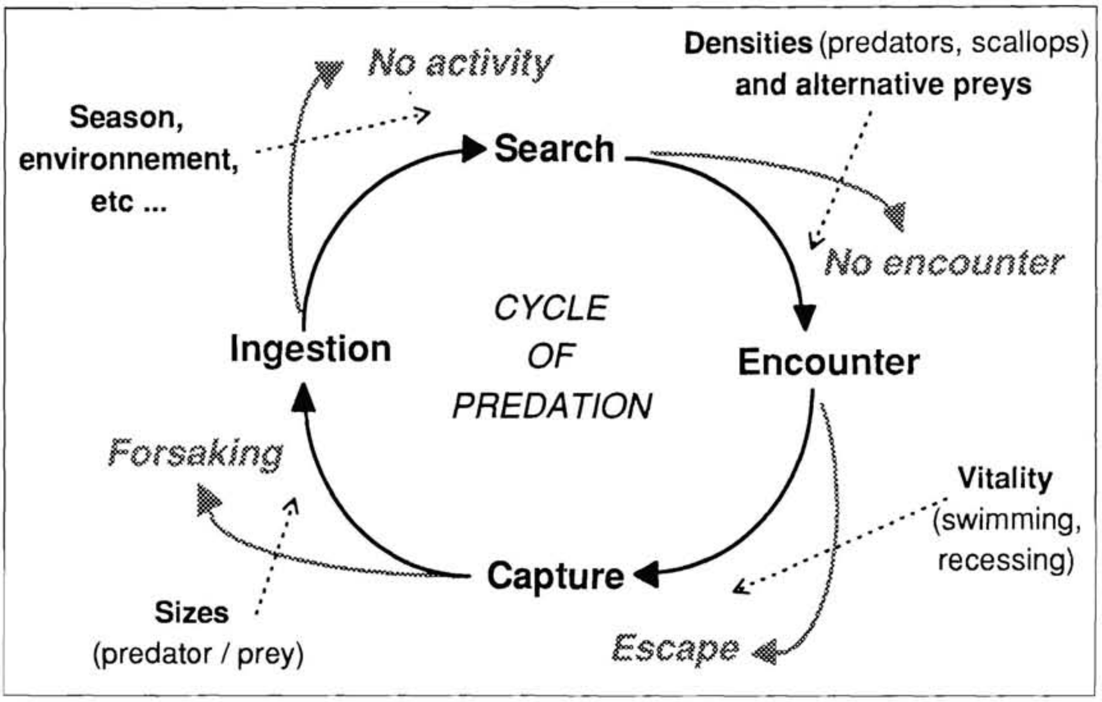
The cycle of predation (*figure 14*) includes successively search or no activity, encounter or not, capture or escape, and ingestion or forsaking. therefore, practices in sea ranching to avoid predation could include :

- the choice of the seeding season, of the seeding size of animals and of the seeding density ;

- the animal preparation, in order to restore or increase their vitality ;

- the site preparation, aiming to decrease the predator density or activity upon scallops.

*Figure 14 - **The cycle of predation.***



4.4.1. The seeding season, seeding size and seeding density.

The convenient seeding seasons and scallop sizes may differ widely according to the sites (*cf. § 4.3.1*).

The seeding density used to be about a few scallops per meter-square because they would spread away if they were too close to each other. An unpublished experiment in France monitored the survival of young scallops re-seeded at high density (40 scallops /m2) in two small leases (100 m2 each) in very shallow water. Leases were enclosed with a fence against crab arrival and scallop dispersal. They observed a low growth and a mortality of 50% the two first years till the density reached 10 scallops /m2, which can be considered as a very maximum for adult animals (recommanded density is 5 /m2).

Therefore scallop seabed cultivation is an extensive culture (< 1 kg /m2) compared to oyster seabed cultivation for example : 100 spat /m2 for the flat oyster *Ostrea edulis* (giving 30 adults x 70 g = 2 kg /m2) and about 50 half-grown animals /m2 for the Pacific oyster *Crassostrea gigas* (giving 40 adults x 75 g = 3 kg /m2).

In South Brittany and in Connemara, trials of mixed seedings were performed with both scallops and flat oysters, at the densities usually carried out for each species. The two rearings did not differ from single rearings. This results could allow a better return from the seeding areas.

4.4.2. The preparation of animals

Animal vitality is poorly studied (see above) and the aim is more often to maintain the vitality (transportation) than to increase it (acclimatization).

Various studies could be carried out to understand the variations in scallop quality, and then investigate possible improvments :

- the **effect of juvenile size and vitality** (physiology) faced to various sizes and types of predators, associated with type of escape to predator (swimming and therefore need of the vitality) or forsaking by predator after handling (and therefore importance of the juvenile size) ;

- the **time for scallop to recess**, according to their vitality and to the sediment, and the rate of protection this recessing offer to scallops against crabs or starfish (comparison between recessed and unrecessed scallops faced to various predators).

Such studies first require a simple tool to quantify the juvenile vitality.

4.4.3. The site preparation for predator avoidance.

The site preparation is rarely carried out, but could be improved to avoid ulterior predation upon re-seeded scallops. Different practices could be studied :

- Dredging with coton sweepers in order to remove starfish and seaweeds (in the same way as it is carried out by oysterfarmers);

- Potting crabs around and in the seeding area ;

- Placing alternative preys to predators, such as other Bivalves (weak mussels) or dead fish.

These two latest practices have been initially tested in two one-week field works of the Concerted Action : potting or not in the Irish field work (1994) and predator diversion towards fresh mussels in the Scottish field work (1995). But such field works were just preliminary studies, and they would require further experiments because the sea ranching still remains a very complex environment with need of replicates in the same site, other sites, other seasons.

• The crab potting gave significant results with scallops of 30-35 mm and no difference with larger animals which were pred on by less crabs. However potting increased the predator abundance (increases as a result of the attractive effect of the bait ?).

The continued high catch rate in traps over a period of a month suggests that either crabs are ineffectively captured in traps or that there is some immigration into the plot area. The brown crab may be capable of moving relatively long distances. The large spider crab also undergoes seasonal migrations and is capable of moving several kilometers. The movements of shore and corrugated crabs are however not well known and it is clear that these form the most significant numbers of all crabs trapped. There is a general trend of a decline of these two species over the five day period trapped.

The low mortality of scallops following their sowing was unexpected. It is not clear whether the use of bait in traps altered the behaviour of crabs or whether the large amount of crab biomass removed by trapping was responsible for the low mortality. The shells recovered were made up of approximately 68 scallops, mainly smashed or punched. Some were entire and may have been fed upon by starfish. Two species *Marthasterias glacialis* and *Asterias rubens* did occur in low numbers in the plot region.

In conclusion there was some indication from the Irish study that smaller scallops were more vulnerable to predation and that the use of baits at the time of scallop sowings might reduce the directed predation on scallops and thereby enhance their survival. Therefore, this was studied the followig year in the Scottish field work.

- Live mussels as an alternative prey, in the Scottish field work, did not decrease the scallop mortality at seeding. It was clear that fresh mussels had quite no effect on crab predation upon scallops.

On the contrary, the laboratory pre-experiment conducted in Scotland with weak mussels provided interesting observations. This could be worth while to experiment such decoy weak mussels for commercial seedings in the wild. In addition factors such as placement and density of mussel prey must be considered.

- Further investigations about predation.

Observations made during the field works were conducted over a short period of time (one week). It is clear that a longer time series would provide useful information on **effectiveness of traps in removing crabs** and in reducing seeded scallop mortality. The unexpected low mortality of scallops during these experiments requires further study. It is very necessary to determine why so few scallops were preyed upon during this normally vulnerable time.

The relationship of scallop sown size to local crab size distributions has been shown to be of value (Minchin 1991), but the capabilities of corrugated crabs to crush scallops of varying sizes are presently unknown. Maerl, where this crab species is commonly found, is a frequent substratum in the Connemara area and studies on their predation capabilities would be valuable.

The diurnal and seasonal **behaviour of crabs** may be important in determining the management of plots intended for scallop sowing.

The **distance of attraction of the crabs** towards the pots remained unknown.

At last the use of decoy mussels, dead fish, etc ... together with a scallop seeding should be studied.

4.5. PRESENT DEVELOPMENT IN EUROPE AND FUTURE PROSPECTS.

With regard to slow growth of animals and high costs of manpower and equipment in suspending culture and despite some biological unknowns and unsuited regulations, bottom culture seems to be the most suitable technique to European conditions and **the numbers of projects increases.**

4.5.1. In France

In France (*appendix 1.1*), the scallop seabed cultivation has taken place in the fishery management of the Brest bay. The prodution of juvenile in hatchery and intermediate culture is quite expansive compared to wild collecting and lantern nets. but the production has now reached over 5 millions juveniles (Dao *et al.* 1995). The success of seedings remains variable but generally provide recapture rates over 25 %. The result is that the contribution of cultived animals reaches one third to one half of the total production of the bay : 90 t out of 184 t in 1995 (Dao et al. 1997).

At the end of 1996, considerable technical success has been achieved in Brest, even if recapture rates can be variable. The economical success may be near. The theoretical study carried out in 1993 assessed the economical rentability on an average recapture ratre of 25-30%, in the case of an *ex nihilio* created rearing, with high profitability after the heavy start-up phase : investments, years without production, technical improvment, appropriation of the project by the fishermen (Paquotte and Fleury 1994). This phase has been completed now in Brest, with the extending and modernization of the hatchery, the acquaintance of seeding sites and the increasing financial participation of fishermen.

This example gives rise to a new interest in scallop culture from other professional groups around small scallop beds, especially in south Brittany and they ask for technical assistance for site selection, spat supply and transport, predator control and coastal management.

4.5.1. In Ireland

In Ireland (*appendix 1.2*), the collection of wild spat in the North Water, Mulroy Bay (Co. Donegal), continues to be the main source of seed. There are currently two companies collecting spat, Deegah Point Shellfish anf North Water Shellfish. A large part of this spat is still reared in suspension.

Seedings of scallops to enhance the natural fisheries are continuing in Valencia (Co. Kerry) and Kilkieran (Co. Galway). The fishery in Kilkieran is closed for the 1995 and 1996 seasons as part of the management and enhancement plan for the fishery (Norman 1997).

A private company, North West Shellfish, harvested eight tonnes of bottom cultured scallops in 1996. It was its first harvest.

The fishermen's co-operative in Kilmore Quay (Co. Wexford) have relaid trial quantities of scallops from an area of slow growth, where much of the population never reaches market size, to an inshore area with a better food supply.

In 1996, there is no overall national programme for the development of scallop aquaculture . However the Marine Institute has set up a scallop group as one of their "Innovations Committee's for Aquaculture" which provides a forum for industry and researchers to keep abreast of developments.

4.5.1. In United Kingdom

Scallop farming In United Kingdom (*appendix 1.3*) is based solely in Scotland at the present time although the Wales and South coast of England may be utilised in the near future.

Recent developments have been in the areas of seabed cultivation and the hatchery production of spat. The granting of the first commercial Several Fishery Order (legal ownership of the present or seeded stock of a defined area of seabed) in February 1993 has opened the way to further commercial development. The species of shellfish covered by the Several Fishery Order are specified within it. In Scotland only scallops have been included to date, although in England and Wales Several Fishery Orders have also been granted for mussels *Mytilus edulis* and oysters *Ostrea edulis*.

In Scotland there are currently 21 applications awaiting to be considered by the Secretary of State. There is unlikely to be any rapid increase in the production of scallops from seabed cultivation due to the timescales involved. However, many of the applicants already have stock on the seabed (without legal protection) and considerable expertise in this form of cultivation is being amassed.

To date only two Several Fishery Orders for scallops have been granted for England and Wales but they are planning spat purchase.

The funding for scallop cultivation work has largely come from central government either directly from the Ministry of Agriculture, Fisheries and Food, or indirectly via research council support of studentships and topic areas. The remainder of the money has come from the industry itself either via a levy on all fisheries (capture and culture) which S.F.I.A. collects, or from private sponsors such as the Worshipful Company of Fishmongers, London.

4.5.1. In Norway

The Norwegian Scallop Programme (*appendix 1.4*) was established in 1993-1994, aiming at encouraging and coordinating the efforts to develop scallop farming in western Norway on a long term basis. The initial main challenge was to bridge the existing expertice in the research sector with the private interests and experience in shellfish farming.

For several years bottom culture has mainly concerned the relaying of undersized harvested scallops (70-100 mm shell height) by some scallop fishermen. Subsequent growth and storageused to be performed. Data shows recapture rates of 86-94%, 16 months after release of this size class. In order to re-seed smaller scallops (40-60 mm), predation studies on brown crab (*Cancer pagurus*) are now carried out with 2 private companies (Strand *et al.* 1997).

In connection to the Norwegian sea ranching programme (PUSH) on salmon, archtic char, cod and lobster a commitee has presented a law proposal on regulations of sea ranching marine organisms. The essential ammendment of this proposal is that a granted licence gives the holder an exclusive right to recapture the ranched organism within a regulated area, which is proposed to cover considerable areas funded on migration patterns of the species. The proposal has so far been opposed particularly by the general public defence of common access to coastal araes and recources.The Ministry of Fisheries has in 1996 stated that scallop seabed cultivation, due to the sedentary behaviour of the scallop, should be treated apart

At last, in 1996, a governmental report, on the long term strategy of the Norwegian aquaculture, proposed the scallop *Pecten maximus*, along with the Atlantic halibut (*Hippoglossus hippoglossus*), as main species for aquaculture development.

Faced with increasing number of aquaculture S.M.E. or fishery professional organizations involved in scallop seabed cultivation in Europe, the national Research and Development authorities have more or less involved themselves in scallop studies and coastal management. But this needs **long term programmes**, demanding **basic research** (physiology), **experiments in the wild** (diving observations), **in an environment which remained poorly known** (need of ecology) **and poorly regulated** (need of law).

The Concerted Action enabled the setting up of a framework of informal European biological cooperation which identified and tried to break down the common problems in scallop seabed cultivation. But actually, very short studies were made through this Concerted Action (3 field works of one week each only). This cooperation has now to settle down in order to study the different research strands that were pointed out.

In addition it was apparent to the biologist teams that scallop seabed cultivation would broadly benefit from an harmonization of European regulation in rights to access and to use the sea ground, and overall an **adaptation of aquaculture regulations to large coastal areas** for coastal managements such as sea ranching (extensive culture) requiring protection of hectares of sea ground.

5 - REFERENCES.

Barbeau M.A., 1994. Predator-prey interactions between juvenile sea scallops *(Placopecten magellanicus)* and predatory sea stars (*Asterias* sp.) and crabs (*Cancer irroratus*). Ph.D. thesis Dalhousie University, Halifax, N.S. (Canada).

Barbeau M.A. and Scheibling R.E., 1994. Procedural effects of prey tethering experiments: Predation of juvenile scallops by crabs and sea stars. *Mar. Ecol. Prog. Ser.* **111**, 305-310.

Barbeau M.A., Scheibling R.E., Hatcher B.G., Taylor L.H. and Hennigar A.W., 1994. Survival analysis of tethered juvenile sea scallops *Placopecten magellanicus* in field experiments: Effects of predators, scallop size and density, site and season. *Mar. Ecol. Prog. Ser.* 115, 243-256.

Bouquet J., Benga S, Even A., Curtil O., Fleury P.G. and Dao J.C., 1995. Internatioanl juridical survey of scallop industry (fishery and aquaculture). *10th International Pectinid Workshop, Cork (Ireland) May 1995 (poster).*

Buestel D. and Laurec A., 1976. Croissance de la coquille Saint-Jacques *Pecten maximus* en rade de Brest et en baie de saint-Brieuc (*Growth of king scallop Pecten maximus in Brest and Saint-Brieuc bays*). *Haliotis,* **5**: 173-177.

Buestel D. and Dao J.C., 1979. Aquaculture extensive de la coquille saint-Jacques : résultats d'un semis expérimental (*Extensive aquaculture of the scallop : results of an experimental seeding*). La Pêche Maritime **1215**: 363-368.

Bull M., 1994. Enhancement and management of New-Zealand's 'Southern scallop' fishery. *9th International Pectinid Workshop,* Nanaimo, B.C., Canada, 22-27 April 1993. *Canadian Technical* Report of Fisheries and Aquatic Sciences, **2**: 131-136.

Cliche G., Vigneau S. and Giguère M., 1995. Statues of commercial sea scallop (*Placopecten magellanicus*) seeding project realized in the scope of the REPERE programme in Iles-de-la-Madeleine (Québec, Canada). *10th International Pectinid Workshop, Cork (Ireland) May 1995.*

Couturier C., 1990 - Scallop aquaculture in Canada : fact or fantasy ? World Aquaculture, **21/2** June 1990.

Currie D.R. and Parry G.D., 1996. Effects of scallop dredging on a soft sediment community : a large-scale experiment study. *Mar. Ecol. Prog. Ser.* **134**: 131-150.

Dao J.C., Buestel D., Gérard A., Halary C. and Cochard J.C., 1985. Le programme de repeuplement de coquilles Saint-Jacques *(Pecten maximus* L.*)* en France : finalité, résultats et perspectives (*The programme of re-stocking scallops (P. maximus) in France : aims, results, perspectives*). Colloque franco-japonais d'océanographie. Marseille septembre 1985.

Dao J.C., 1995. L'exploitation des Pectinidés dans le monde (*The exploitation of Pectinids in the world*). In 'Fisheries, biology and aquaculture of Pectinids'. 8th *International Pectinid Workshop, Cherbourg (France) 22-29 May, 1991.* Lubet P., Barret J., Dao J.C. (Eds) Actes des Colloques - IFREMER **17**: 1-27.

Dao J.C., Barret J., Devauchelle N., Fleury P.G. and Robert R., 1995. Rearing of *scallops (Pecten maximus)* in France, from hatchery to intermediate culture ; results of a 10 years programme (1983-1993). *Workshop on fish and mollusc larviculture."Improvement of the commercial production of marine aquaculture species". Puerto Montt (Chile), 5-9 December 1994. (in press).*

Dao J.C., 1997. L'exploitation des Pectinidés dans le monde (*The exploitation of Pectinids in the world*). Salon de la Pêche de Lorient, France, 1997.

Dao J.C., Barret J. and Fleury P.G., 1997. Scallop (*Pecten maximus*) seabed cultivation in the bay of Brest (France). *11th. International Pectinid Workshop, La Paz (Mexico), 10-15 April 1997.*

Dubois M., Gilles K.A., Hamilton J.K., Rebers P.A. and Smith F., 1956. Colorimetric method for determination of sugars and related substances. *Analytical Chemistry* **28**: 350-356.

Eleftheriou A. and Robertson M.R., 1992. The effects of experimental scallop dredging on the fauna and physical environment of a shallow sandy communauty. *Netherland Journal of Sea Research* **30**: 289-299.

Elner R.W. and Jamieson G.S., 1979. Predation of sea scallops, *Placopecten magellanicus*, by the rock crab, *Cancer irroratus*, and the American lobster, *Homarus americanus*. J. Fish. Res. Bd Can. 36 : 537-543.

Erwin D. and Picton B., 1987. Guide to Inshore Marine Life, *The Marine Conservation Society.*

Fleury P.G., 1989. Le choix d'un site de semis de coquilles Saint-Jacques : le cas du littoral Ouest-Cotentin (*The choice of a scallop seeding site : the example of the West coast of Cotentin, Normandy, France*). *Rapp. Internes IFREMER/DRV 89.032 RA*, 32 pp.

Fleury P.G. and Dao J.C., 1992. De la pêche à l'aquaculture : l'élevage de la coquille Saint-Jacques (*From fishery to aquaculture : the culture of scallop*). *Équinoxe* **38**: 20-27.

Fleury P.G., Halary C. and Dao J.C., 1995-a. The intermediate culture of *Pecten maximus* in Brittany (France). In 'Fisheries, biology and aquaculture of Pectinids'. 8th *International Pectinid Workshop, Cherbourg (France) 22-29 May, 1991.* Lubet P., Barret J., Dao J.C. (Eds) Actes des Colloques - IFREMER **17**: 103-110.

Fleury P.G., Dao J.C., Mikolajunas J-P. and Strand Ø., 1995-b. European concerted action (1993-95) on scallop seedings (*poster*). *10th. International Pectinid Workshop, Cork (Ireland),. 27 Apr.- 2 May 1995.*

Fleury P.G., Mingant C. and Castillo A., 1996. A preliminary study of the behaviour and vitality of reseeded juvenile great scallops, of three sizes in three seasons. *Aquaculture International* **4**, 325-337.

Halary C., Royer Y., Corlouer J.P. and Dao J.C., 1994. Effects of predation and competition on scallop, *Pecten maximus*, reseeded in Saint-Brieuc Bay : preliminary results. *9th International Pectinid Workshop,* Nanaimo, B.C., Canada, 22-27 April 1993. *Canadian Technical Report of Fisheries and Aquatic Sciences,* **2**: 39-49.

Hamon D., Berthou P. and Fifas S., 1991. Etude de l'impact des engins de pêche traînants en zone côtière. cas particulier du chalutage en Baie de Saint-Brieuc, Manche Ouest (*Study of the impact of active fishing gears in a coastal zone. Trawling in saint-Brieuc bay, West Channel*). *International Council for Exploitation of the Sea, 1991.*

Hatcher B.G., Scheibling R.E., Barbeau M.A., Hennigar A.W., Taylor L.H. and Windust A.J., 1996. Dispersion and mortality of a population of sea scallop (*Placopecten magellanicus*) seeded in a tidal channel. *Canadian Journal of Fisheries and Aquatic Sciences* **53**, 38-54.

Haugum G.A., Strand Ø., Svardal A. and Mortensen S., 1997. Survival and behaviour of scallops (*Pecten maximus*), after transfer to the seabed - effect of emersion treatment. *11th. International Pectinid Workshop, La Paz (Mexico), 10-15 April 1997.*

Ito H. , 1991. Japan. in : *Scallops : biology, ecology and aquaculture* (ed . S.E. Shumway) Elsevier. Amsterdam, 1017-1056.

Lake N.C.H., Jones M.B. and Paul J.D., 1987. Crab predation on scallop (*Pecten maximus*) and its implication for scallop cultivation. *J. Mar. Biol. Ass. U.K.* **67** : 55-64.

Le Coz J.R., 1989. La charge énergétique adénylique : mise au point, application à trois mollusques bivalves, synthèse et perspectives (*The adenylic energetic charge : perfecting and application to three bivalve molluscs, synthesis and prospects*). Mémoire IFREMER /Direction des Ressources Vivantes. 85 p.

Lowry O.H., Rosebrought N.J., Farr A.L. and Randall R.J., 1951. Protein measurement with the folin phenol reagent. *Journal of Biology and Chemistry.* **193**, 265-275.

Maguire J., Fleury P.G. and Burnell G., 1997. A method for quantifying scallop quality. *11th. International Pectinid Workshop, La Paz (Mexico), 10-15 April 1997.*

Mason J., 1957. The age and growth of the scallop *Pecten maximus* in Manx waters. J. Mar. Biol. Ass. U.K., **36**: 473-492.

Mikolajunas J.P., 1995. A review of developments in cultivation techniques for the king scallop, *Pecten maximus,* in Scotland. *10th. International Pectinid Workshop, Cork (Ireland),. 27 Apr.- 2 May 1995.*

Minchin D., 1983. Predation on young *Pecten maximus* (L.) (Bivalvia), by the anemone *Anthopleura ballii* (Cocks). *J. Moll. Stud.,* **49**: 228-231.

Minchin D., 1991. Decapod predation and the sowing of the scallop, *Pecten maximus.* In: *Scallop biology and culture,* S.E. Shumway & P.A. Sandifer (eds). World Aquaculture Workshops, Number 1, World Aquaculture Society, Louisiana, pp 191-197.

Minchin D., 1992. Biological observations on young scallops, *Pecten maximus. J. mar. biol. Ass. U.K.,* **72**: 807-819.

Minchin D., 1995. Some approaches to the cultivation of the scallop, *Pecten maximus,* in Irish waters. *10th. International Pectinid Workshop, Cork (Ireland),. 27 Apr.- 2 May 1995.*

Moal J., Samain J.F. Le Coz J.R. and Daniel J.Y., 1985. Protéines, glucides, lipides particulaires : aspects méthodologiques. *Océanis,* **11(5)**,498.

Moal J., Le Coz J.R., Samain J.F. and Daniel J.Y., 1989. Nucleotides in Bivalves : extraction and analysis by high-performance liquid chromatography (HPLC). *Comparative Biochemistry and Physiology,* **93 B (2)**, 307-316.

Norman M. and Ludgate R., 1995. Initial survival of juvenile king scallops, *Pecten maximus,* after seeding out in Connemara bays. *10th. International Pectinid Workshop, Cork (Ireland),. 27 Apr.- 2 May 1995.*

Norman M., 1997. Structures for scallop ranching. An Ireland perspective. *11th. International Pectinid Workshop, La Paz (Mexico), 10-15 April 1997.*

Pajot R. and Dao J.C., 1984. Etude préliminaire d'un semis de coquilles Saint-Jacques ; résumé des connaissances sur l'environnement de la région dieppoise (*A preliminary study before a scallop seeding ; summary of knowledge on environment of the Dieppe area, France*). *CCI Dieppe.*

Paquotte Ph. and Fleury P.G., 1994. Production costs in French scallop farming. *Proceedings of the 9th International Pectinid Workshop, Nanaimo, B.C. (Canada), 22-*

27 April 1993, Canadian Technical Report of Fisheries and Aquatic Sciences 1994, **2**: 66-75.

Strand Ø. and Nylund A., 1991. The reproductive cycle of the scallop *Pecten maximus* (L.) from two populations in Western-Norway, 60N and 64N. *In*: Sandra E. Shumway (Editor), An International Compendium of Scallop Biology and Culture. *Spec. Publ., World Aquaculture Society*. s. 95-105.

Strand Ø. and Mortensen S., 1995. Stort kamskjell. Biologi og dyrking. (The king scallop, biology and cultivation) *Kystnæringen forlag*, ISBN 82-7595-013-9. 84 pp.

Strand Ø., Andersen S., Eiken G., Hanson S., Magnesen T. and Mortensen S.H., 1995. Development of scallop (*Pecten maximus*) cultivation in Norway (*poster*). *10th. International Pectinid Workshop, Cork (Ireland), 27 Apr.- 2 May 1995.*

Strand Ø., Eiken G. and Mortensen S.H., 1997. The Norwegian Scallop Programme. In the point of intersection between research and development of a new industry (*poster*). *11th International Pectinid Workshop, La Paz (Mexico), 10-15.Apr. 1997.*

Thompson J.D., Fujimoto T., Moriya H. and Ikeda T., 1995. Tasmanian scallop enhancement with *Pecten fumatus*. *10th International Pectinid Workshop, Cork (Ireland) May 1995.*

Thrush S.F., Hewitt J.E., Cummings V.J. and Dayton P.K., 1995. The impact of habitat disturbance by scallop dredging on marine benthic communities : what can be predicted from the results of experiments ? *Mar. Ecol. Prog. Ser.* **129**: 141-150.

European Concerted Action on Scallop seabed Cultivation

(1993-1996)

Table meeting *(Bergen, Norway, May 1994).*

Field work : briefing *(Ardtoe, Scotland, September 1995).*

European Concerted Action on Scallop seabed Cultivation

(1993-1996)

Field work : sorting juvenile scallops *(Brest, France, October 1993).*

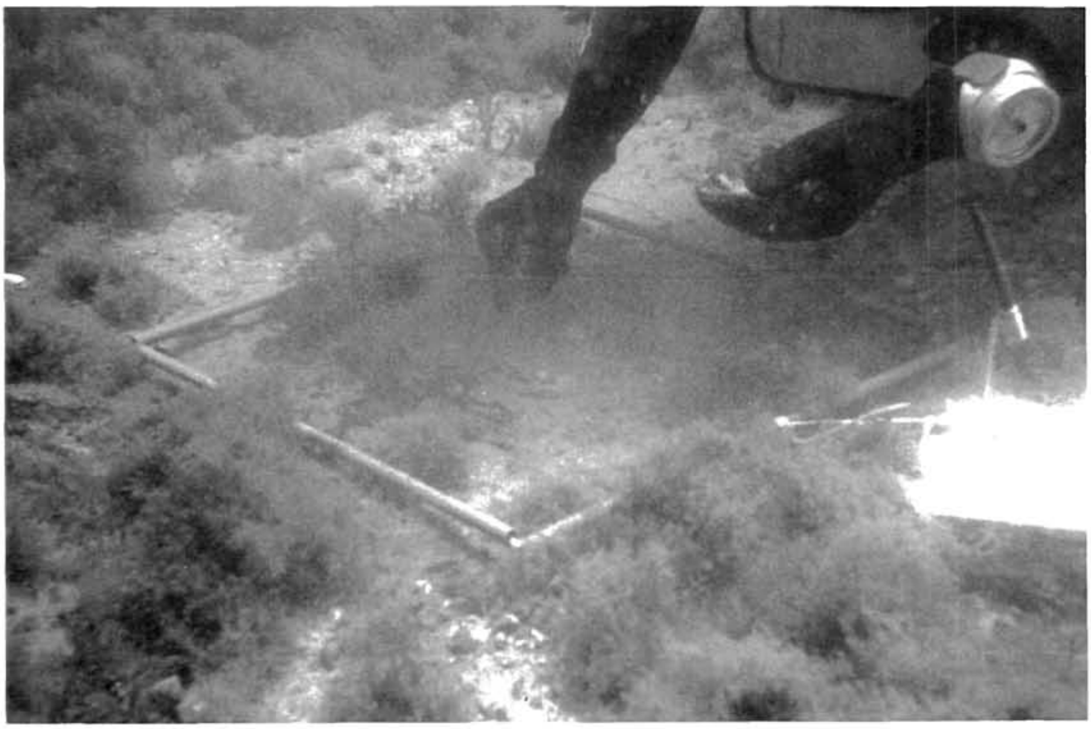
Field work : on board ship "Thalia" *(Brest, France, October 1993).*

European Concerted Action on Scallop seabed Cultivation

(1993-1996)

Field work : scallop seeding *(Brest, France, October 1993).*

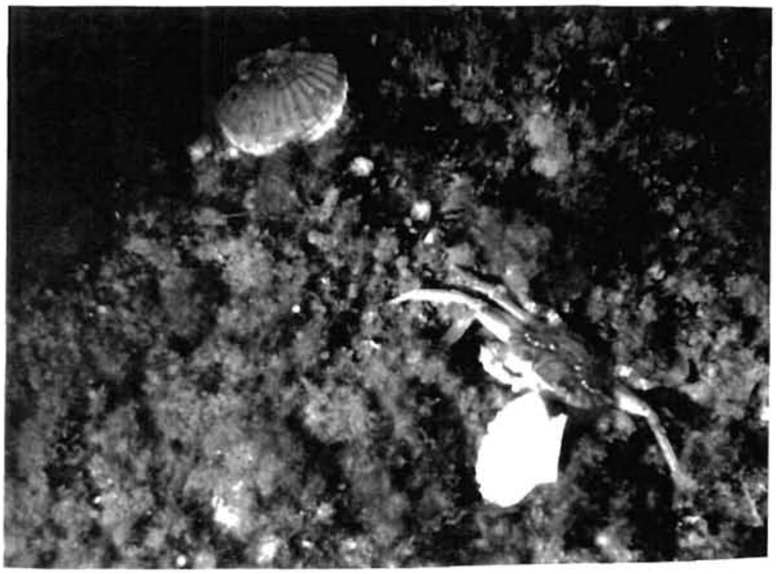
Field work : scuba observations and sampling *(Brest, France, October 1993).*



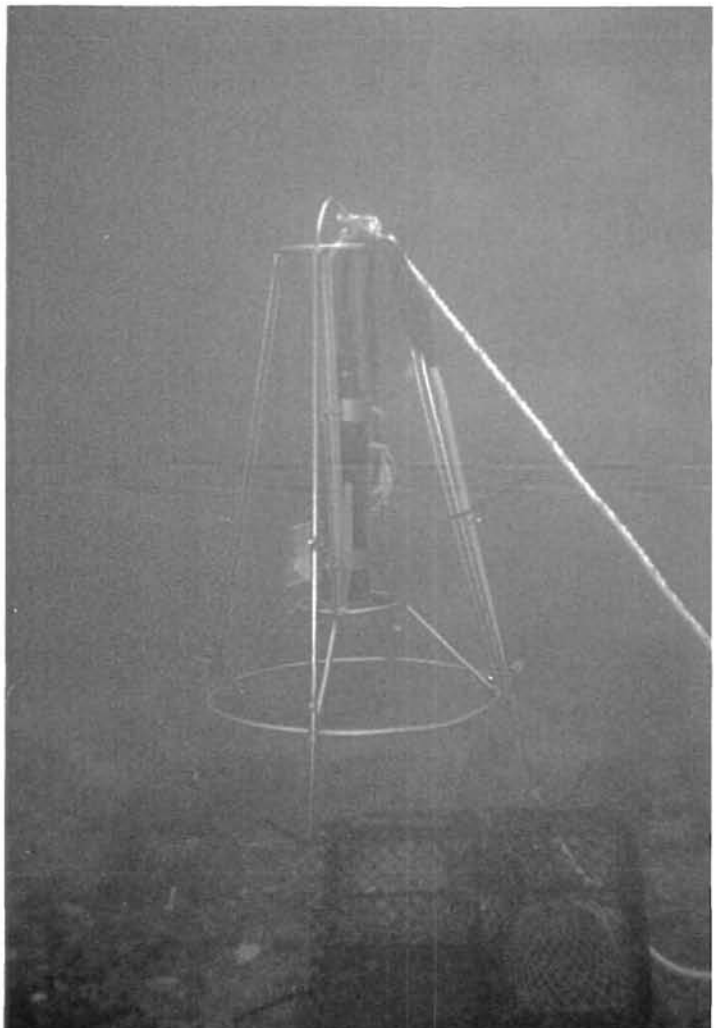
European Concerted Action on Scallop seabed Cultivation

(*1993-1996*)

Field work : a crab pred on a re-seeded scallop *(Connemara, Ireland, Sept.1994).*



Field work : underwater remote video camera *(Connemara, Ireland, September 1994).*



APPENDIX

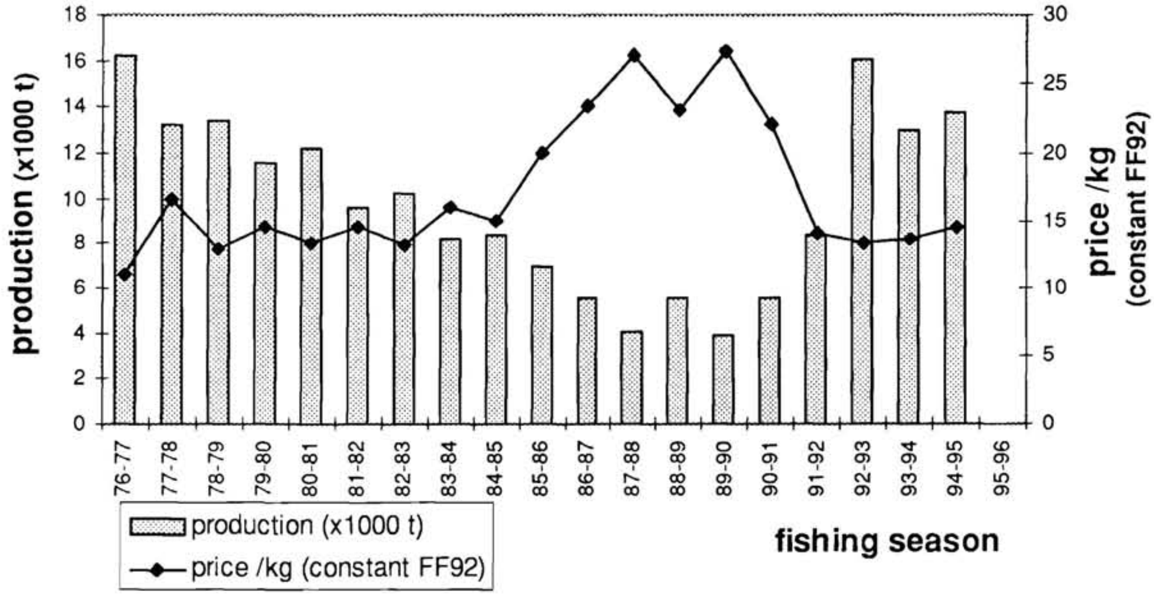
Appendix 1 - NEW BACKGROUNG ON SCALLOP AQUACULTURE IN EUROPE (Data 1996).

Contents :

1. FRANCE

French scallop production is based on fishery landings. Natural resources in commercial abundance occur on the Atlantic coastal areas and in the English Channel. Fishing gears (dredges) and regulations have remained unchanged for several years. The evolution of the fisheries show an increase of the production for recent years after a decade of a general trend of decrease (*figure 1 - sticks*). Abundance of the resource and catches are directly related to the recruitment in the fisheries.

Figure 1 - **French scallop landings and prices**



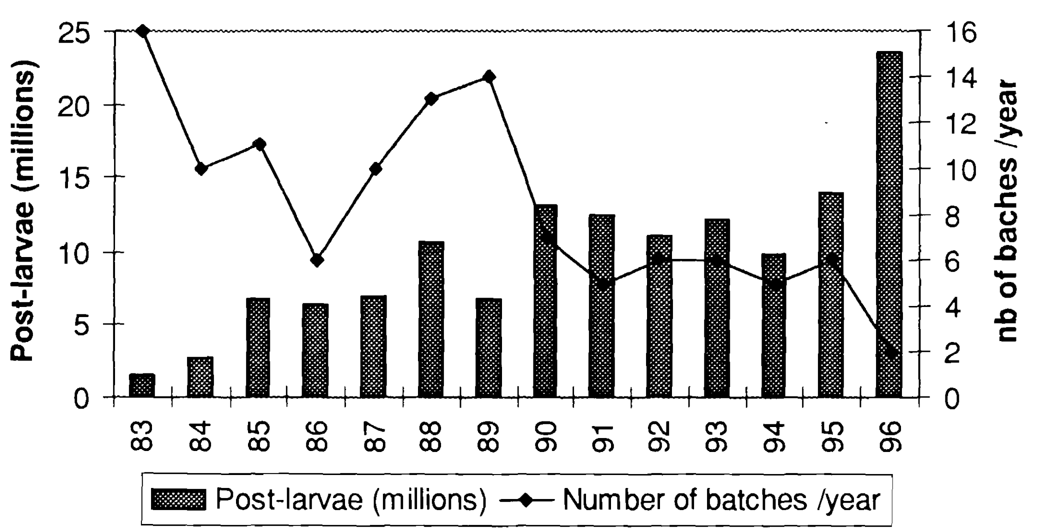
The socio-economic effects are very important for the coastal fishing fleet. More than 800 boats are operating seasonally. During the years 1980-85, the down-trend of the landings supported alternative management proposals. There was a great demand on aquaculture research in order to establish the technique for sea bed culture. The demand has been maintained up until 1993. Since 1992, the increase of production has induced a decrease in the price (*figure 1 - line*). French valuable market (alive animal in the shell) is limited and competed by British products. The excess has to be processed and then has to compete with frozen products from the entire world.

1.1. <u>First programmes (1982-93)</u>

Farming trials started in the late 70's by spat collection experiments and some spat importation trials from Scotland and Ireland in the early 80's in order to add consequent number of juveniles. The first attempt was conducted to identify the relation between an increasing spawning stock and the consecutive recruitment. At the level of the project (500 tonnes of spawning stock inside Brest Bay) it has proved to be non-efficient. But, the technique of seeding in the open sea bottom for direct exploitation, appeared to be an interesting management proposal, and Research /Development programmes have been focussed on this subject (including the improvement of hatchery reliability).

Two hatcheries have been operating in Brittany : one IFREMER experimental hatchery and one belonging to the fishermen organization of Brest Bay. The technique was first described in 1982 (Buestel *et al.* 1982) and has derived from the research conducted over a ten years period : composition and quantity of microalgae for scallop feeding at various sizes, design of tanks for larvae and post-larvae rearing, and for the maturation of the spawners. Several species have been successfully hatched (*Pecten maximus, Pecten jacobeus, Chlamys varia, Patinopecten yessoensis*). The aim was to support the production of juveniles for the seeding programme for two scallop beds in Brittany : Brest Bay and Saint-Brieuc Bay. In fact, the two hatcheries were continuously connected in order to combine their efforts for improving the production. The goal was defined as a yearly production of 10 million post-larvae which has been regularly attained since 1988-89 (*figure 2*).

Figure 2 - **French post-larvae production (1983-1996)**



The intermediate culture starts when the post-larvae reach a size of 2 mm. They are enclosed in trays covered inside by a small mesh net. The trays are put in a frame which lays on the sea-bottom in a sheltered area, closed to fishing gears. A field station was constructed in 1986 at Erquy in Saint-Brieuc Bay to manage the post-larvae received from the hatchery, on behalf of the local fishermen orgnization and the CECONOR (Comité d'expansion économique des Côtes d'Armor), associated with the Brest group. The goal was defined as a yearly production of 3,000,000 juveniles of 30 mm, in accordance to the calculated size at seeding. It has regularly been attained since 1990 (*table A*).

Table A - ***Number of juveniles issued from intermediate culture***

Hatchery production	**1992**	**1993**	**1994**	**1995**	**1996**
Nb Post-larvae 10^6	11,06	12,18	9,78	14	23
Nb Juveniles 10^6	3,7(1)	2,45(2)	2,12	1,25	2,7
Survival rate	**34 %**	**20 %**	**22 %**	**9 %**	**28 %**(3)

(1) 820.000 seeded at 15 mm size
(1) and (2) **50 % of the juveniles production** seeded out of Brest Bay.
(3) calculation on the first 1996 spawning.

The seeding /recapture strategies were not well defined at this time. Seeding densities (number of juveniles /m2), size of juveniles, type of scallop-ground, duration of the on-growing period, seasonal influence on seeding, predation/competition, minimum number required for a mass-seeding, bias... are questions which raised from the different trials issued from the production of juveniles. The 3 million yearly produced animals were shared equally between the 2 fishermen groups, excepted a small amount which was used for different trials by shellfish farmers in association with seabed culture of oysters (*Crassostrea gigas, Ostrea edulis*).

There is no clear figure on the general trend, but isolated results for some operations which have been completely followed without too many bias. Nevertheless, it can be assumed that the annual production should be 80 to 120 tonnes of live animal for the total landing from aquaculture. Results from other sites have been limited due to to the number of juveniles (trials of 10.000 to 40.000 individuals). There have been no attempt at hanging culture, following the bad results obtained in the Mediterrannean Sea in 1987-1990.

1.2. The Brest Bay project.

Since 1987, the hatchery has regularly produced larvae and post-larvae. After intermediate culture, juveniles are seeded on various sea beds in the area of distribution of the natural population. First recaptures by the fishermen have encouraged them to support the seeding operations.

Between 1991 and 1993 an important pluri-annual programme on water quality of Brest Bay has been initiated based on a "Contrat de baie" (Bay Contract), juridical body where all politics of the watershed are represented. Studies have been conducted during 4 years (1993-1996) to state on quality level, and pilot-operations have been developed to decrease the pollution level and to minimise the risks of eutrophication. The scallop is an exploited species whose population collapsed in 1963 and never recovered (fishing maintains at a 1/10th level since). One pilot-operation has been selected in order to understand the population dynamic and by using the aquaculture techniques to restore the resources to a better scale for the fishermen community.

During the last years studies were conducted on the technical pathway to develop a combination of fishery and aquaculture management. As the Bay is isolated and the production low for a local market, the general trend of national scallop management has not been observed.

- Hatchery production.

The scallop hatchery is located in Le Tinduff inside Brest Bay. Its belongs to the fishermen organisation. With the "contrat de baie" all equipment has been reviewed in connection with the latest research results. Up-to-date equipment has been developed for sea water management, larger micro-algae culture, conditioning of spawners (Muzellec *et al*, 1996). Micro-algae production has been multiplied by four in 1995, and by five in 1996. The established production of 10-12 million post-larvae per year has increased to 14 and 23.4 million post-larvae during the last 2 years (*figure 2*).

This production is not representative of the total capacity of the hatchery since abnormal mortalities have been observed : toxic phytoplankton *Gymnodinium* cf. *nagasakiense* during summer 1995 and larval and post-larval mortalities in September-October 1996. Large progress can be expected although mortalities can always occur.

- Intermediate culture production.

Juvenile production technique has not changed in the recent years (Dao *et al*, 1996), but lower yields are observed. It is partly a result of the increase of the number of animals by rearing, creating overcrowding problems and low handling processes. Husbandry methods have been strongly reviewed in 1996.

- Seabed on-growing.

Juveniles of 3 cm have been seeded on the fishing grounds (seeding restricted to Spring-Summer during the closed fishing season in order to let the juveniles get bigger and harder) and on reserved-areas (forbidden to dredging during all the on-growing period). Locations of the seeding have been largely discussed with fishermen but represent a compromise due to the lack of long term management.

Pre-Winter operations are always bad, Spring and Summer operations often good. These results confirm previous data between 1985 and 1993. The whole seeding and on-growing operation is summarised in *table B*. As part of the biomass only the commercial size is evaluated. Animals can contribute 2 to 4 times to natural spawning.

Detailed analysis has been conducted on one particular area : recapture rates fluctuated between 5 to 28%, in relation to the management of the seeding operations (Dao *et al*, 1996).

Table B - ***One year juveniles, biomass and recaptures in Brest Bay***

	1991	1992	1993	1994	1995	1996
juveniles (10^3)	698	556	165	233	852	?
biomass (t)		58	118	144	157	117
fishing (t)		40			20	90

- Management.

As mentioned in *table B*, fishing occurred in 1992 for a first operation then again in 1995 and 1996. Fishermen where faced with new exploitation constraints : limited space for the dredging, very high density of commercial scallops, rotation of reserved-areas,...The last operation represents a good model for future development.

On the technico-economical approach, data was given for the 1989-1993 period (Paquotte & Fleury, 1994). It was concluded as a financial equilibrium when the recapture rate reached 25 to 30% but with the technical results of scallop aquaculture during those years. Data has to be up-dated and risks included.

In Brest, the fishermen organisation has decided to develop this fishery-aquaculture technique (Carval, 1996). Management costs will be included in the annual licence regulation and a special fishing quota attributed to each fisherman when fishing on the reserved-area. Self-financing is expected for 1998. The organisation will maintain reserved-areas in connection with population enhancement. Some of the early beds will be seeded. The scale of the enhancement is fixed to a yearly production of 250 tonnes. With the traditional fishing Brest Bay will produce 350 tonnes. In accordance to the other species fished in the bay the commercial fleet will secure employment.

1.3. The French global approach.

The scallop can generate various types of management. All of them are based on an association between juveniles aquaculture and release and fishing, for a sedentary species, well appreciated by the consumers and being part of the coastal fisheries activities.

On large scallop beds, the major factor is the market. The best product is sold alive (perishable) and during special period (Christmas, festive seasons). Stock assessment and fishing regulations could smooth the landings and regulate the market. However, on a long term analysis, recruitment fluctuations cannot maintain a constant level of production and secure the market organisation. Looking to the fast improvement of the technical aspects of the aquaculture, stock-enhancement will be feasible. The first immediate step to understand is regulation to the access of the resource (Individual Transferable Quota, private lease,...).

On the small beds, as much as for private shellfish farmers, production is linked to local markets, with low competition for small roductions. The first demand is spat supply in oeder to make experimental seeding and conclusive recaptures in order to bring fishermen to a stock enhancement with local constraints. The example of Brest Bay for these cases is of great importance.

Three regulations have been developed for seabed culture. Oyster farmers can be given a renewable private right to cultivate the seabed for 35 years. Taxes are paid to the Administration. Rights are granted by a Commission of Marine Cultures involving different Administrations and following a public consultation. Fishermen manage a seeded area by using a closed area for definate period with limitations to fishing gears (trawling and dredging are forbidden). In Brest Bay the most efficient technique is to seed early during the Spring and summer closed fishing season in order to obtain animals of 60 mm lengh at the opening of the fishing season in Autumn. But fishermen must obtain a private right to harvest the scallops as part of the local regulation.

The technico-économic analysis done in 1993 concluded that the industry is feasible at the present level of technology and price on the French market. Improvements can be clearly expected, in hatchery production through better control of spawner maturation, but also through husbandry practices for manipulating the juveniles during the intermediate culture. It is assumed also that a seeding /recapture ratio of 25 to 30% could be obtained through a better knowledge of the sea-bottom phase during the on-growing and this goal constitutes one of the main objective for research. However, although adequate areas for extensive aquaculture seem abundant on the French coasts, development is faced with a more general management of the coastal resources and regulated to them.

2. IRELAND

The fisheries for scallops in Ireland have been of two distinct types : inshore and offshore. The inshore fisheries are exploited by boats of 7-10 m lenght and 40-120 hp typically using two dredges of 70-130 cm wide. The dredges vary from district to district, many are used without chain bags and are often towed wtih rope and hauled by pot haulers. Small inshore fisheries exist in most bays around the south, south-west and west coasts, many of these are however in decline. Such local fisheries are often over-fished to the point of extinction as the small multi-purpose boats exploiting them will fish for very small daily returns during the winter months when no other fishing opportunities exist.

The "off-shore" fisheries are off the South-East and east coasts and are exploited seasonally by part of the beam-trawl fleet. The boats are 18-25 m and 300-500 hp, and use 10 to16, 70 cm wide, spring loaded dredges.

Table C - ***Irish Scallop Landings***

Year	1984	1985	1986	1987	1988	1989	1990	1991	1992
Tonnes	321	388	594	202	247	989	N.A.	967	926

Data : B.I.M.

2.1. Spat supply for aquaculture.

- Hatchery

There has been no hatchery production of scallop spat since 1993, the hatchery in Carne, Co. Wexford, has been converted for another use, Red Bank hatchery, Co. Clare, continues as an oyster and clam hatchery .

- Wild Collection

The collection of wild spat in the North Water, Mulroy Bay (Co. Donegal), continues to be the main source of seed. There are currently two companies collecting spat, Deegah Point Shellfish anf North Water Shellfish. There was a poor survival of settled spat on the collectors in 1995 which resulted in an inadequate supply for ongrowing.

- Other Sources

Scallop spat were imported from Scotland in November 1995 and again in June 1996. The survival of spat transported over this distance (and time) is unpredictable with current knowledge.

A project to produce scallop spat in mesocoysms suspended in the open sea was started in 1996 by Halcyon Shellfish (Co. Cork). Trial quantities (200 000) spat have been successfully harvested from one of the mescosyms.

2.2. Ongrowing.

- Suspended Culture

Japanese longline culture trials are being carried out by Fastnet Mussels (Co. Cork), Valentia Harbour Fishermens Society (Co. Kerry) and North West Shellfish (Co. Donegal).

- Bottom Culture

Trials have been under way in Ireland for some fifteen years. Trials in the early 1980s concentrated on japanese style culture; suspended systems holding scalp in pearl and lantern nets, and trials with ear-hanging and "bondo" culture. During this period the North West Plastic Tray (N.W.P. Trays) was adopted as the method for intermediate culture. The trials failed to produce an economically viable culture system. A second strategy have been used with adapted "oyster cages" stacked on the seabed. The former method has been tried by several community groups (some formally organised into cooperatives), while the latter is being tested by mussel farmers. There is also a large company (Lett and Co. whose core business are bottom mussel cultivation and shelfish processing) carrying out scallop trials with the Japanese scallop, *Patinopecten yessoensis,* using Japanese longlines.

Sowing culture is under development in : Valencia (Co. Kerry) by local fishermen with funding and technical advice from B.I.M., Ventry (Co. Kerry) by local fishermen co-operative with funding and technical advice from Taighde Mara and Udaras na Gaeltachta, Connemara (Co. Galway) by Muirin Teo., a joint venture between the local co-operative and Taighde Mara Teo. with Udaras na Gaeltachta financial help. The Connemara project is the only one with full time personnel working on it (two people). There are a number of other smaller sowing trials on the South-West and South coasts.

The two projects in Kerry use N.W.P. trays in single stacks, strung together on the seabed as an intermediate culture system, and have sown scallops at 32-40 mm average shell heights. There are no results available to date on the success of the sowings.

Muirin Teo. (funding of which has only be available on a year by year basis) has developped handling systems for intermediate culture based on N.W.P. trays and IFREMERs frame for holding these on the seabed. The first trial sowings were in September 1991, and were carried out in conjunction with an IFREMER field team. The first sowings were unsuccessful due to a high initial mortality by crabs (*Liocarcinus* sp. and *Cancer* sp.) and starfish, and dispersal of survival by current (2 knots +). A further sowing in November 1991 with 58 000 juveniles (two batches with mean shell height of 39 mm and 43 mm) on a shallow (-5 m) site with lower current velocity and a sandy mud substrate was more successful. A further 250 000 juveniles (meanshell height of 37 mm) were sown on an adjacent site in November 1992. Ninety days after sowing a survival of 87% was estimated from sampling, but forty days later a 100% mortality was recorded due to starfish (mainly *Asterias* sp.).

In 1996, seedings of scallops to enhance the natural fisheries are continuing in Valencia (Co. Kerry) and Kilkieran (Co. Galway). The fishery in Kilkieran is closed for the 1995 and 1996 seasons as part of the management and enhancement plan for the fishery. A private company , North West Shellfish harvested eight tonnes of bottom cultured scallops in 1996 , it's first harvest.

2.3. Regulation of farming.

The Department of the Marine (D.O.M.) is responsible for the licensing and control of aquaculture. Scallop farming woul require a culture licence under one of the Fisheries acts, and a "foreshore licence" for the structures in use (long lines, etc...). The licensing system for aquaculture is under review and hopefully the current delays in the system (six months to six years) will be sorted out in the near future.

2.4. Research and development

Research into scallop culture has in the past been carried out by : Fisheries Research Centre (D.O.M.), Shellfish Research Laboratory (University College Galway), Taighde MaraTeo. and University College Cork. None of these institutions has a current scallop programme. Much of the recent research has been carried out by industry, supported by research and development grants from Bord Iascaigh Mhara (B.I.M.) or Udaras na Gaeltachta. Some funding has also been available from philantropic organisations such as the International Fund for Ireland.

In 1996, there is no overall national programme for the development of scallop aquaculture. However the Marine Institute has set up a scallop group as one of their "Innovations Committee's for Aquaculture" which provides a forum for industry and researchers to keep abreast of developments.

3. UNITED KINGDOM

The standard gear used is a 0.75 m wide spring loaded dredge. However, in the western channel fishery, up to 20% of the scallop landings may be by non-target fishing eg. beam trawl by-catch. The fisheries are subject to minimum landing size regulations of 110 mm in the Irish Sea and 100 mm elsewhere. The Irish Sea stocks are also subject to a closed season from June to October inclusive. The total landings amount 7 to 8 thousand metric tons (*table D*).

Table D - ***Scallop landings by United Kingdom vessels in metric tons and value***

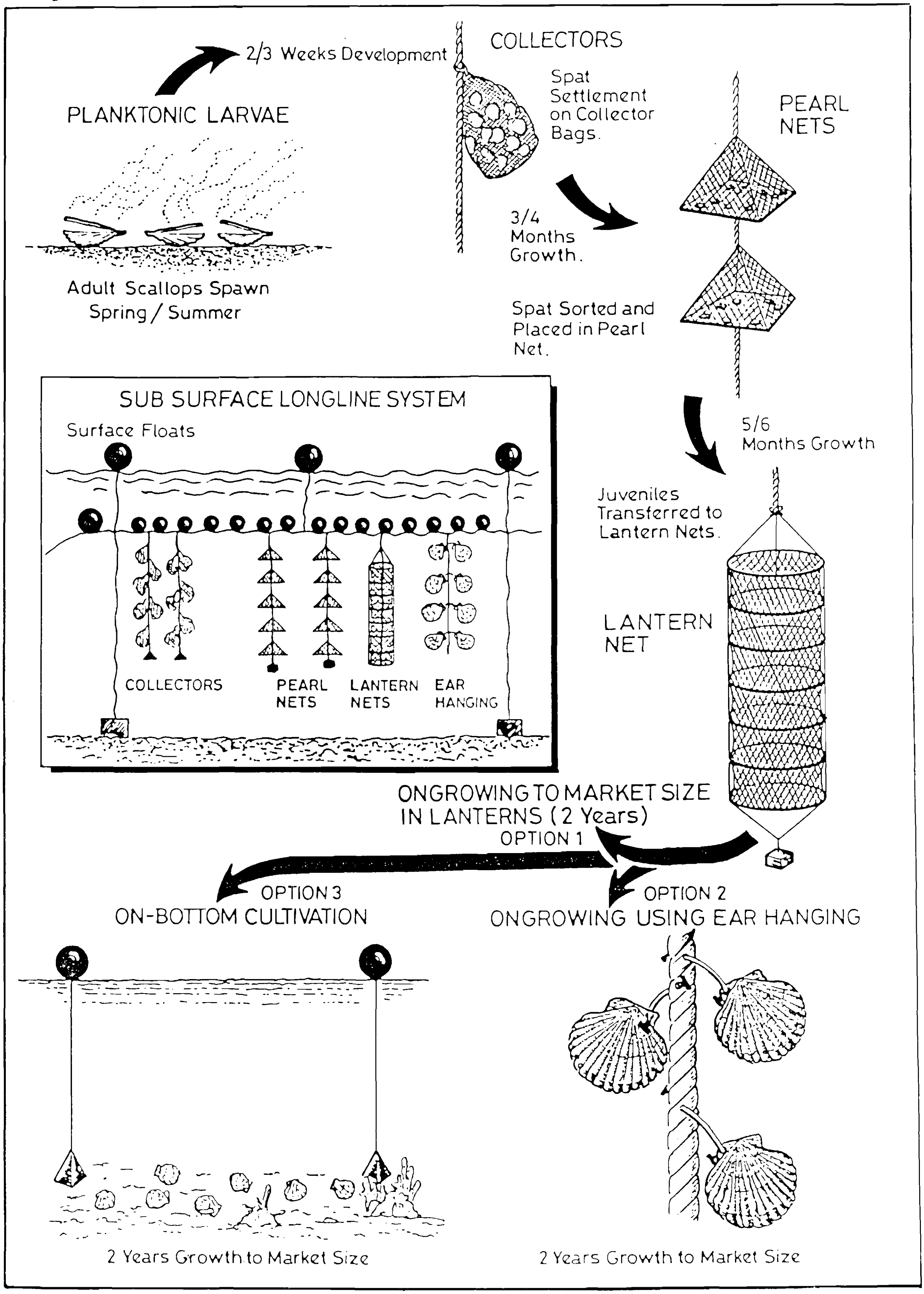
England and Wales	2 589 mt :	£ 3.74 million
Scotland	4 947 mt :	£ 7.92 million
Northern Ireland	246 mt :	£ 0.36 million
Totals	7 782 mt	£ 12.02 million

3.1. Farming Production

Scallop farming is based solely in Scotland at the present time although the Wales and the South coast of England may be utilised in the near future. Cultivation is based solely on the collection of wild spat and ongrowing in suspended cultivation (*figure 3*). Total farmed production amounted to a total of 60 t which was a 55% increase on the previous year. Official figures are likely to have underestimated the true total production (100-150 t ?). The industry is set for expansion as more farms come on stream over the next 2 years. At the present time 24 farms are producing for the table, 9 for further ongrowing and a total 31 have not yet reached the production stage. Active businesses are concentrated mainly within the Highland and Strathclyde regions.

Recent developments have been in the areas of seabed cultivation and the hatchery production of spat. The granting of **the first commercial Several Fishery Order** in Scotland during February 1993, to Scallop Kings Plc, Crinan, Argyll, has opened the way to further commercial development. The Several Fishery Order confirms on the holder legal ownership of the stock that are present or seeded onto a defined area of seabed. The first Several Fishery Order in Scotland was granted in 1988 to S.F.I.A. for a research area in the North Channel of Loch Moidart (Ardtoe). The Several Fishery Order extends to approximately 120 hectares and was granted for a period of 15 years. The species of shellfish covered by the Several Fishery Order are specified within it. In Scotland only scallops have been included to date, although in England and Wales Several Fishery Orders have also been granted for mussels *Mytilus edulis* and oysters *Ostrea edulis*. To date only two Several Fishery Orders for scallops have been granted for England and Wales and these are not in production. In Scotland there are currently 21 applications awaiting to be considered by the Secretary of State. This is a lengthy process involving consultation with the other users of the seabed in the area (Fishermen, Nature conservation Groups, Ministry of Defence, Crown Estate Commissioners, Department of Transport etc.). Typically it has taken about 5 years for an application to be granted assuming agreement by all interested parties !

*Figure 3 - **Marine farming cycle in Scotland.***



There is unlikely to be any rapid increase in the production of scallops from seabed cultivation due to the timescales involved. However, many of the applicants already have stock on the seabed (without legal protection) and considerable expertise in this form of cultivation is being amassed. Scallop Kings Plc are aiming to be producing 2-3 million scallops per year by 1995.

- Hatchery Production of Spat

In recent years two operations have been established for research purposes. Orkney Water Test Centre on the island of Flotta in the Orkneys and the Ministry of Agriculture, Fisheries and Food Fisheries Research Laboratory, Conwy.

The Orkney Water Test Centre project was funded by a government initiative. Both Scallop Kings Plc and S.F.I.A. were industry partners in this venture. The project was designed to look at the large scale production of spat for cultivation. Due to various management and logistical problems, progress has been disappointing.There is currently an investigation underway to determine the industry's requirements for a commercial hatchery.

The Ministry of Agriculture, Fisheries and Food have successfully produced small numbers of spat for the last 2 years. Research is not directed towards supply of the industry *per se*, but issues relating to monitoring of stocks eg. genetics, growth characteristics etc. Full details of the MAFF Programme will be presented by Dr. Sue Utting/Pete Millican.

- Regulation of the Industry

Scallop cultivation is relatively new to the UK, while the fisheries are well established. As such there is no specific body which represents the scallop farming industry. However, within Scotland the Association of Scottish Shellfish Growers is the lead organisation, while within the UK the Shellfish Association of Great Britain represents the industry. Both Associations are comprised of fee paying members, to which they play an advisory and representational role, although neither has direct control of cultivation operations. Moves are currently underway to establish an industry steering group in an attempt to bring industry groups together, and to provide a long term development plan.

The key government body involved with both scallop fisheries and aquaculture is the Ministry of Agriculture, Fisheries and Food. The Ministry have statutory roles in terms of the gathering of fisheries statistics and the enforcement of British and EC regulations. This includes the setting of measures to prevent the introduction and spread of shellfish diseases. Recently this role has been expanded to consider the environmental impact of fishing and cultivation operations within the marine environment.

With respect to licensing of shellfish cultivation operations there is a statutory requirement to notify the Ministry of the establishment of a farm and record and supply documentary evidence of the movement of shellfish to and from the site.

In terms of establishing a cultivation site which involves fixed structures being placed on the shore or seabed a Crown Estate lease is required (in most instances). The Crown Estate Commissioners represent the interests of the head of state in terms of management of lands and property. When the Crown grants a lease on an area of seabed/seashore it sets an annual rental. This is based on the species being cultivated and the extent of equipment to be used. The Crown Estate Commissioners have the right to grant or refuse an application based on their own judgement without statutory public consultation. This is probably the most contentious issue (other than the granting of Several Fishery Orders!) presently affecting the industry.

There are no restrictions on the pumping of seawater from the sea other than the need for a Crown Estate lease for the fixed equipment (if any) on the seabed. However, discharges back to the sea are controlled by River Purification boards in Scotland and Water Companies in England and Wales. These bodies will grant a consent to discharge license for any outfall where the water quality is appreciably degraded in terms of contaminants, these include suspended solids (mainly organic material), biochemical oxygen demand (BOD), pH, temperature etc. Exceeding the consent may result in a fixed penalty while seeking a consent attracts an annual premium. This may have implications for any hatchery developments.

3.2. <u>Research and Development.</u>

- <u>Research organisations involved in scallop cultivation in the U.K.</u>

The principal organisation involved has been S.F.I.A. funded largely by the U.K. government. The Ministry of Agriculture, Fisheries and Food has been involved in specific research proposals eg. hatchery development.

Various universities have embarked on specific research projects with MSc and Phd students. The most notable studies have been undertaken by Liverpool University at the Port Erin laboratory on the Isle of Man. This work is under contract to the Isle of Man government (the Isle of Man is not a member state of the E.U.).

It is difficult to assess the total number of people working on scallop cultivation research. At S.F.I.A. Marine Farming Unit the team is in the shadow of the halibut team and was recently reduced to 2 man years.

The funding for scallop cultivation work has largely come from central government either directly from the Ministry of Agriculture, Fisheries and Food, or indirectly via research council support of studentships and topic areas. The remainder of the money has come from the industry itself either via a levy on all fisheries (capture and culture) which S.F.I.A. collects, or from private sponsors such as the Fishmongers Company (Worshipful Company of Fishmongers, London).

- <u>Programmes</u>

Most programmes are not specific of seabed cultivation. For example, in 1996 in S.F.I.A., the research focuses on :

- scallop spat collector bags, to enhance settlement, survival and quality of spat according to various types of bags ;
- nursery trials from hatchery post-larvae ;
- juvenile scallop transportation, both dry transports for large animals (> 25 mm) and wet transports with buffers for pH control for small spat (10 mm) ;
- but also : industrial development trials with preliminary re-seedings in Loch Ewe.

4. NORWAY.

4.1. Production and research.

The scallop production in Norway is dominated by the fishery for Iceland scallop (*Chlamys islandica*) in northern coastal and oceanic waters. The coastal fishery was in 1994-95 at a very low level of 50 tonnes (live weight), which was 20% of the quota. The offshore fishery, consisting of 1-2 wessels, which has been partly operating in russian waters of Barents sea, landed 5010 and 6200 tonnes live weight in 1994 and 1995 respectively. Formerly exploited beds in northern areas will be surveyed in 1996.

A governmental report released in 1996, on the long term strategy of the Norwegian aquaculture, proposed the scallop *Pecten maximus*, along with the Atlantic halibut (*Hippoglossus hippoglossus*), as main species for aquaculture development. This report will be treated politically in near future. An approvement of this report will, along with the priorities already done by the Norwegian Research Council and the Institute of Marine Research, set the terms for an increased effort on the attempts to develop scallop cultivation in Norway.

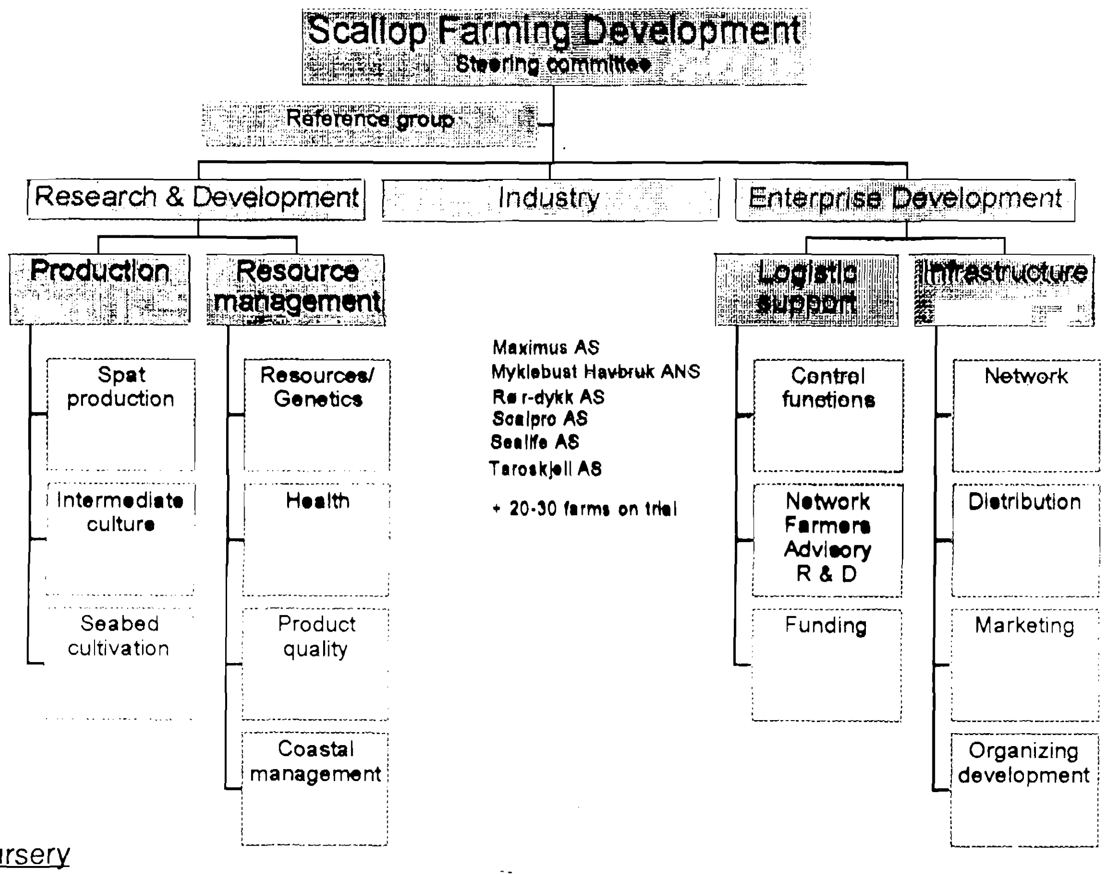
The Norwegian Scallop Programme (N.S.P.) was established in 1993-1994, aiming at encouraging and coordinating the efforts to develop scallop farming in western Norway on a long term basis. The initial main challenge was to bridge the existing expertice in the research sector with the private interests and experience in shellfish farming. The private interest is significant, but consist of many small enterprises with low ability to make the expected financial contribution to the development. N.S.P. was commited to assamble this interest as the industry contribution. In 1995 the programme included involvement from six County Counsils and Regional Ministry of Fishery's along the coast, Institute of Marine Research, University of Bergen and estblished and pre-established shellfish farmer enterprises. N.S.P. is organized in a R&D (research & development) branch and a ED (enterprise development) branch (*figure 4*), whith private involvement in both activities. Institute of Marine Research (IMR) is leading the R&D, and has a similar organized internal shellfish research activity. The County of Hordaland is leading the ED and function as secratary for the whole programme.

4.2. Spat production

- Hatchery

The production of post-larvae in the hatchery in Øygarden has increased significantly since it was reopened in 1993, and was 4.7 million in 1995. This increased production has mainly been caused by change in husbandry strategy, whith insignificant changes in survival at different stages (Christophersen and Magnesen 1996). The hatchery has been operated by University of Bergen with research support and cooperation from IMR. Studies on scallop nutrition have been conducted at Austevoll Aquaculture Researchstation (IMR). In 1996 the operation of the hatchery in Oygarden was taken over by Scalpro AS, a company with N.S.P. participating farmers as shareholders. The production of post-larvae in 1996 has been lower than expected.

*Figure 4 - **the Norwegian Scallop Programme.***



- Nursery

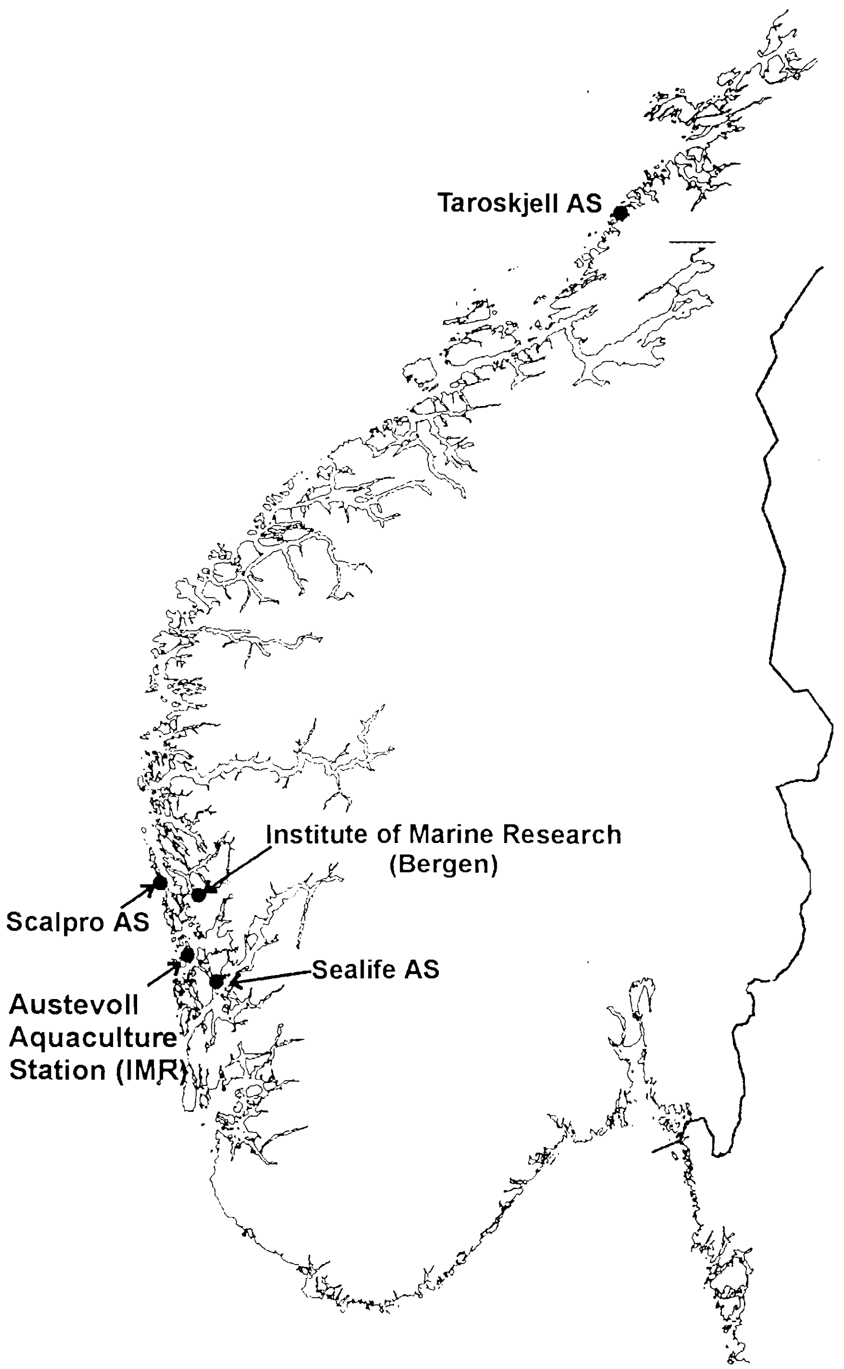
A bottleneck in scaling up spat production in the hatcēry has been the transfer of post-larvae from the hatchery to seaconditions during spring. Acceptable survival (>20%) has been obtained only after the seawater temperature were above 8-10° C in May-June (Christophersen and Magnesen 1996), and this obstruct the possibilities to extend the production season. Production of spat (5-15 mm) in Øygarden increased from 200.000 spat in 1993, 700.00 spat in 1994 and to 1.0 million in 1995 (*table E*).

The experiences of using heliothermic marin basins in oyster and clam spat production (Strand, 1996) were the basis for preliminary trials in 1994, on growing scallop post-larvae in this system. The post-larvae were grown in a landbased nursery using water from the basin, where temperatures of 10° C may be obtained in early april. In 1995 0.5 mill spat (15-30 mm) were produced in this nursery system, with a survival of 50% from post-larvae (Christophersen and Magnesen 1996).

*Table E - **Production of post-larvae (2 mm) and spat (5-15 mm) in Øygarden and Espevik (poll).***

	Pos-tlarvae	Spat (poll)	Spat
1993	1.1		0.2
1994	1.7		0.7
1995	4.7	0.5	1.5

Figure 5. - **Main organisms involved in scallop culture in Norway.**



The funding of R&D on spat production of a one year basis, and less, has created some unworkable problems. The need of a long term strategy has continously been adressed and measures are now taken by IMR to set up a coordinated longterm project.

4.3. Intermediate culture

Intermediate culture trials have been cunducted along the coast of western Norway by farmers participating in the N.S.P.. This work is aiming at farmer training, gathering a better understanding on criterias for site selection and how environmental factors influence production. Trials runned for about 10 months, from set out in autumn, were carried out at 6 sites in 1994-95 and at 18 sites in 1995-96. High survival (>70%) and good growth have been obtained at 4-5 sites, while many has suffered high mortality. Insufficient husbandry, unsuitable sites (influence of brackish water) and extremely low temperatures during January-February 1996 are probable explainations for the mortality.

The use and handling of enclosures on the seabed for intermediate culture of scallops have been examined by the companies Ror-dykk AS and Taroskjell AS. The equipment is considered to have a great economical potential compared to the traditional cultivation in nets or cages suspended in the watercolumn.

4.4 Bottom culture

Relaying of undersized harvested scallops (70-100 mm shellheight) for subsequent growth and storage are done by some scallop fishermens. Data shows reqapture rates of 86-94%, 16 months after release of this sizeclass.

The behaviour of the scallop, their environmental requirements, predator biology and predator-scallop interactions are still badly understood. In cooperation with the companies Ror-dykk AS and Taroskjell AS, IMR started work on experimental seedings in Trondelag and in Hordaland in 1995. Studies are done on interactions between the brown crab *Cancer pagurus* , which is a main predator, and seeded scallops (40-60 mm).

4.5 Harvesting natural stocks

The harvest of natural scallop beds is done by diving. The harvesting activity has increased during resent years, to an expected harvest of about 150 000 scallops (40 tonnes) in 1996. The main increase has been due to harvest of beds on the west coast and northwards from the main harvesting areas in South-Trondelag. The commercial sale of scallops is regulated, while harvest of natural stocks is unregulated. The increasing interest and activity on scallops and the potential conflicts towards the recreational use of molluscs has been preliminarily adressed by the Ministry of Fisheries.

The scallops are sold mainly to the fresh markets in Oslo (restaurants and hotels). Minor quantities are supplied to other domestic markets and for export. Two categories are supplied, standard scallops at 100-120 mm shellheight prized at about 12NOK (ECU1.5)/scallop and superior scallops at >120 mm shellheight prized at 14-15NOK (ECU1.8)/scallop.

4.6. Enterprise development

As a part of a long term strategy for industry development N.S.P. has accomplished the first stage of farmer training in 1995. This training included courses on scallop biology and cultivation (Strand and Mortensen, 1995) and the development of a business plan for scallop cultivation in their enterprise. The participants were also invited to conduct intermediate culture trials (see above). Business considerations on scallop spat production and farming has been given by Myrseth (1994), and further approaches are prepared by N.S.P..

4.7. Legal aspects

The cultivation of shellfish requires a licence issued by the Ministry of Fisheries, according to the act no. 68. In 1995 the Ministry of Fisheries issued a regulation pursuant to this act on the exclusive right for participants of N.S.P. to apply a licence for intermediate culture trials at up to 10 point sites granted for 15 months. The implementation of the licence is based on a simplified process.

The definition of activities requiering an licence according to the act has been unclear regarding the issue of cultivating organisms on the seabed, particularly when scallop seabed cultivation is considered.

In connection to the Norwegian searanching programme (PUSH) on salmon, archtic char, cod and lobster a commitee has presented a law proposal on regulations of searanching marine organisms. The essential ammendment of this proposal is that a granted licence gives the holder an exclusive right to recapture the ranched organism within a regulated area, which is proposed to cover considerable areas funded on migration patterns of the species. The proposal has so far been opposed paricularly by the general public defence of common access to coastal araes and recources. A law will be considered politically.

The Ministry of Fisheries has in 1996 stated that scallop seabed cultivation, due to the sedentary behaviour of the scallop, should be treated as an activity regulated by act No 68. Instructions are given to provide conditions requiring less restrictions on access and fishing activities in the area which should allow for increasing the licensed area. The licence is again exclusive for participants of N.S.P. or R&D related activities and is granted for up to 5 years.

REFERENCES.

Cf. Appendix A5 - Main publications of the Scallop Concerted Action members

Appendix 2 - OUT OF EUROPEAN UNION BACKGROUND ON SCALLOP

Contents :

1. JAPAN.

Scallop aquaculture in Japan is the most advanced culture of pectinids in the world. Annual production in 1990 reached almost 400 000 metric tons from a single species *Patinopecten yessoensis.* There have been some trials with other species, *Pecten albicans* in Shimane prefecture and Oki Islands which have been unsuccessful and *Chlamys nobilis* in Kagoshima prefecture which remains on a small scale.

The culture of *P. yessoensis* is equally divided between hanging and bottom production (*figure 1*) in the North part of Japan where conditions for the species are favourable (water temperature mainly). The main area for scallop sea bed cultivation is the North coast of Okhotsk sea in Hokkaïdo although 15 000 tons are produced in Honshu Island in the north-east part of Mutsu Bay (*figure 2*).

Figure 1 - ***Patinopecten production in Japan.***

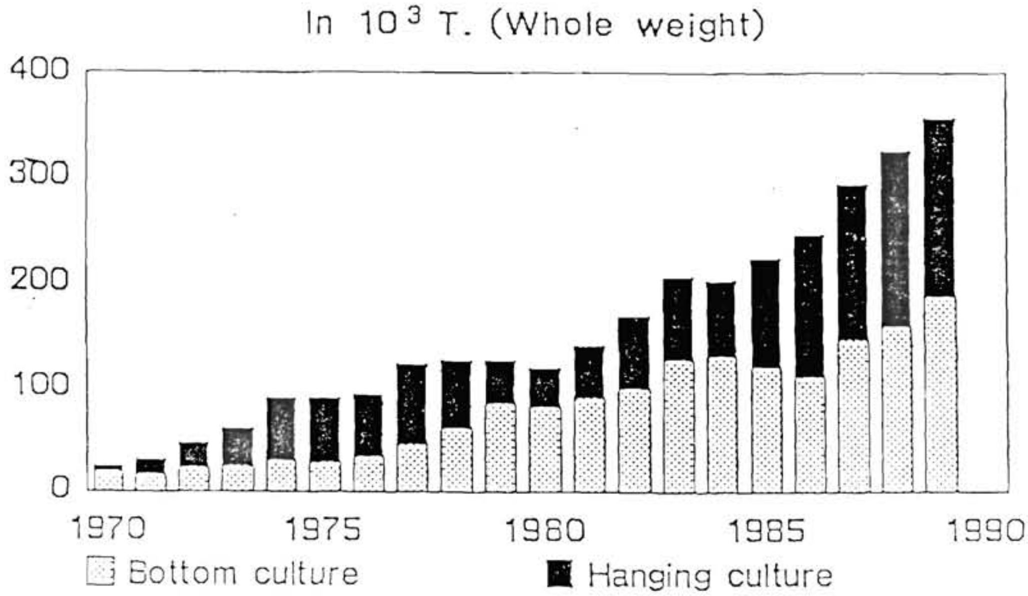
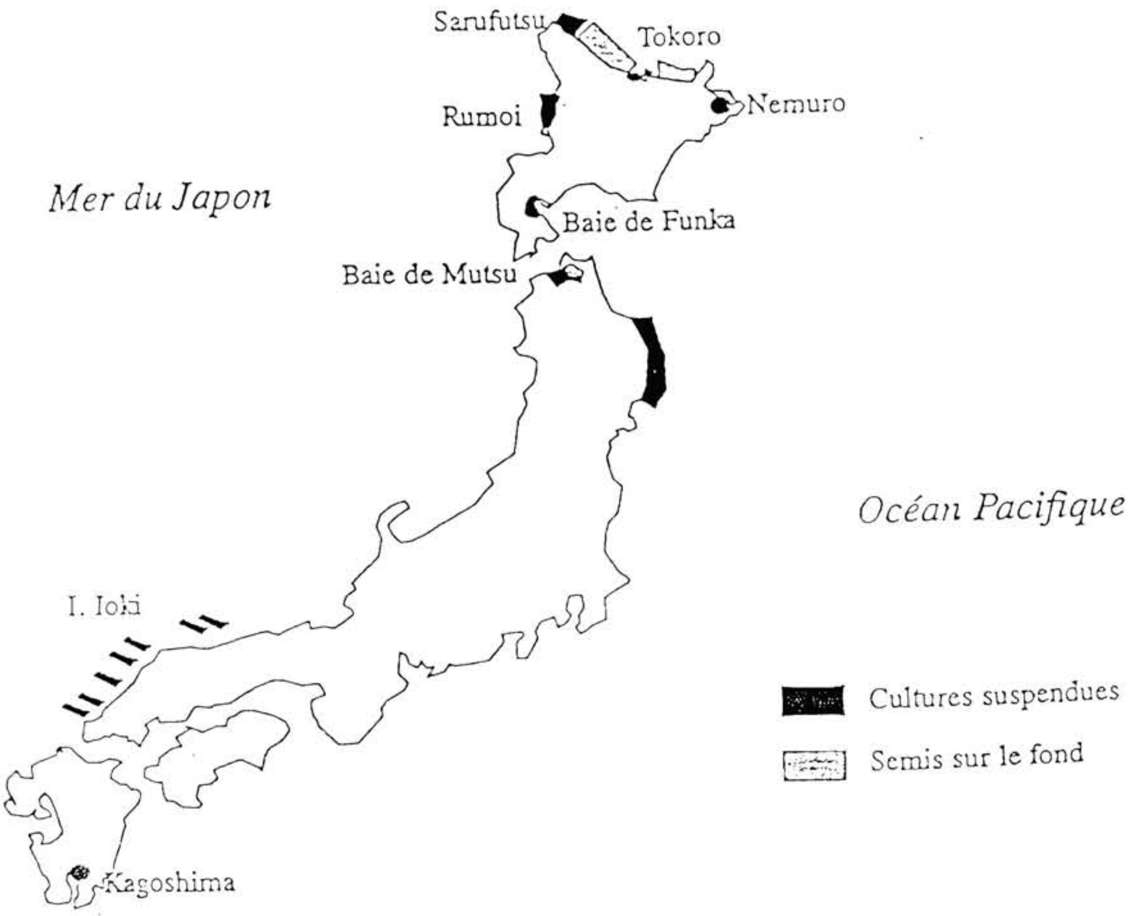


Figure 2 - ***Scallop cultivation areas in Japan.***



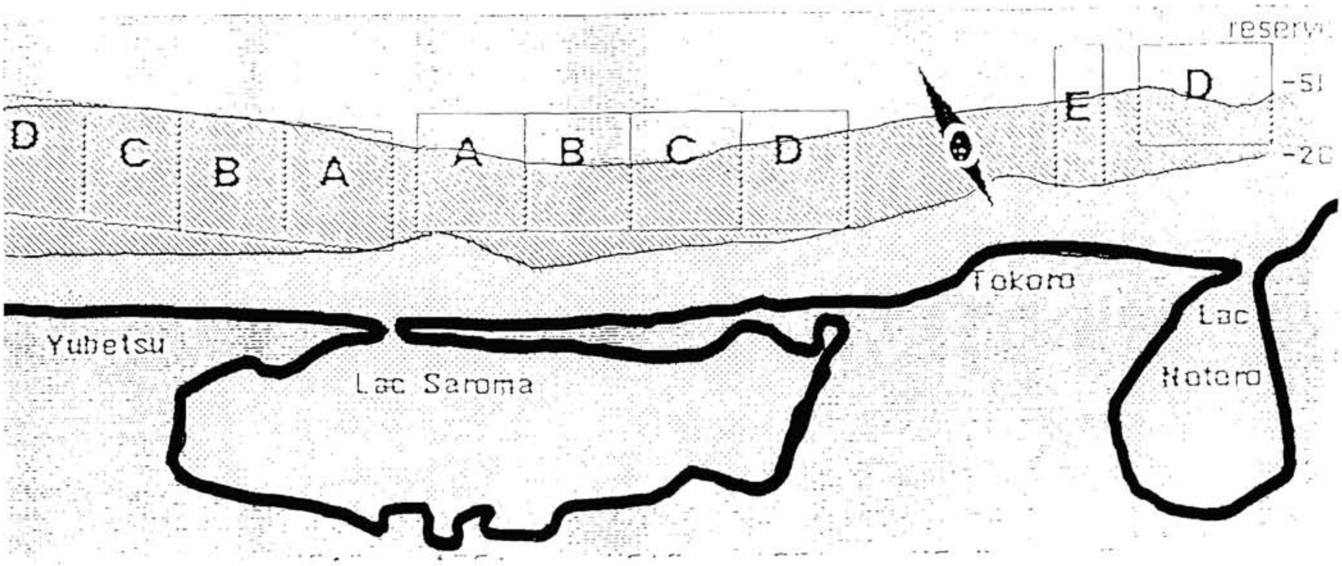
This review does not aim to report on every culture area but just to show two applications of coastal management which are competitive on the world market of frozen muscle in the sea-food industry. These represent good examples for the Concerted Action. Data have been collected from Japanese fishermen cooperatives while visiting in Hokkaïdo and Aomori prefectures in November 1990.

1.1. Tokoro cooperative.

Tokoro is a fishing community on the Okhotsk Sea. It is partly located on the Saroma Lake which was one of the early scallop production centres (hanging culture) in the 70's following the success of local natural spat collection.

Up to 1976, seeding operations had been conducted on the entire outside area, without any preparatory work of the grounds. The main predators (starfishes in large number) had not been eliminated. The spat used for restocking were 3 cm, and were mainly the excess spat from hanging culture. Fishermen operated with the "keta ami" dredge on the whole area, and the undersized scallops were discarded several times before reaching recruitment at age 3. The results have been poor, with no significant increase of the natural production (1 500 tons/year) despite large number of spat (150 to 250 millions /year in 1973 to 1975).

Figure 3 - ***Bottom culture of*** *Patinopecten yessoensis* ***in Tokoro cooperative (Hokkaido).***



Year	Area	Year	Area	Year	Area	
1976	**B**	1980	**B**	1984	**B**	
1977	**D**	1981	**D**	1985	**D**	
1978	**A**	1982	**A**	1986	**A**	
1979	**C**	1983	**C**	1987	**C**	Etc ...

table A - Patinopecten yessoensis ***production in Tokoro cooperative (Hokkaido).***

Year of seeding	Juveniles number (million)	landings after 3 years (thousand tons)	Recapture rate (%)
1976	185	10.1	28%
1977	240	10.6	22%
1978	220	11.1	25%
1979	260	16.2	31%
1980	210	10.2	24%
1981	350	31.4	45%
1982	295	17.6	30%
1983	230	19.2	38%
1984	295	28.5	54%
1985	325	45.0	63%
1986	260	32.0	50-55%
1987	285		

They decided to adopt a more rational use of the scallops beds in 1976. Four surface units labelled A to D were identified each averaging 25 to 30 km^2 at a depth from 30 to 60 meters (6 km of coast line per unit). A 5th smaller unit E was set aside as a reserve in case of under-production. Each area is exploited every four years and is followed by a new seeding. Density at seeding is about 10 juveniles/m^2 (*figure 3*).

Originally the fishermen belonging to the cooperative (200 members) had to provide 800 000 juveniles (4 tons) per member from the natural spat collection in Saroma lake (the cooperative paid 2 yens per spat to the fishermen). This regulation provides 160 million juveniles for seeding. A supplement is provided by the bordering cooperative which shares the management of the grounds. During the last decade, the cooperative has varied the origin of the spat which have also come from Funka and Mutsu Bay.

Surveys are regularly conducted in order to follow the increase in biomass and the occurrence of predators (starfishes). Fishing boats are appointed by the cooperative to catch the scallops from June/July to November. They have a daily catch-quota of 6 tons /day that they usually fish in 3-4 hours. The scallops are landed during the morning and sent to processing plants very close to the port.

Results of management (seeding numbers and production) are given in *table A*. During the latter years the cooperative has seeded about 300 million spat per year to harvest 30 000 tons of scallop. Since there is no sign of wild animals in the catch, the recapture rate is given by the ratio of adults fished to the number of juveniles seeded. This value started at an average of 25% and has significantly increased in recent years (about 50%) following the improvements in husbandry.

1.2. Sarufutsu cooperative.

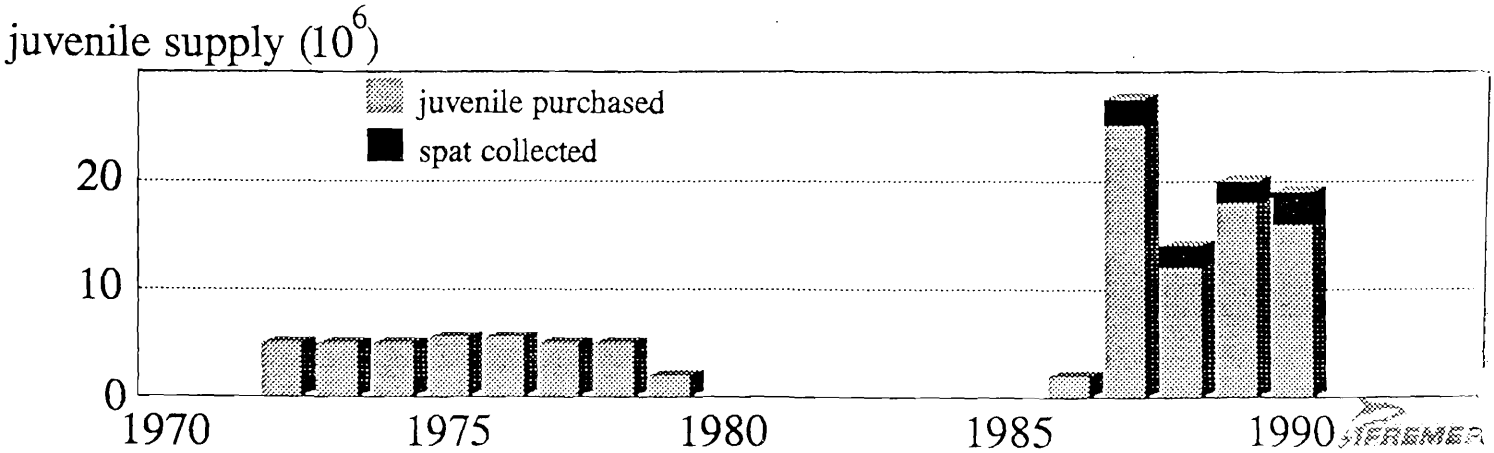
The Sarufutsu cooperative is also located on the Okhotsk Sea. The fishery collapsed in the early 60's due to overfishing. Like the Tokoro cooperative, they had attempted bottom seeding since there was no sheltered area to develop hanging culture. The management plan has been to seed 50 million spat/year from 1970 when juveniles were available. The cooperative has the rights to 30 km of coast line and the space has been divided in 272 elementary units in order to identify the seedings which have been dispersed over the wole area during the first 15 years (one seeding = 3 to 12 units).

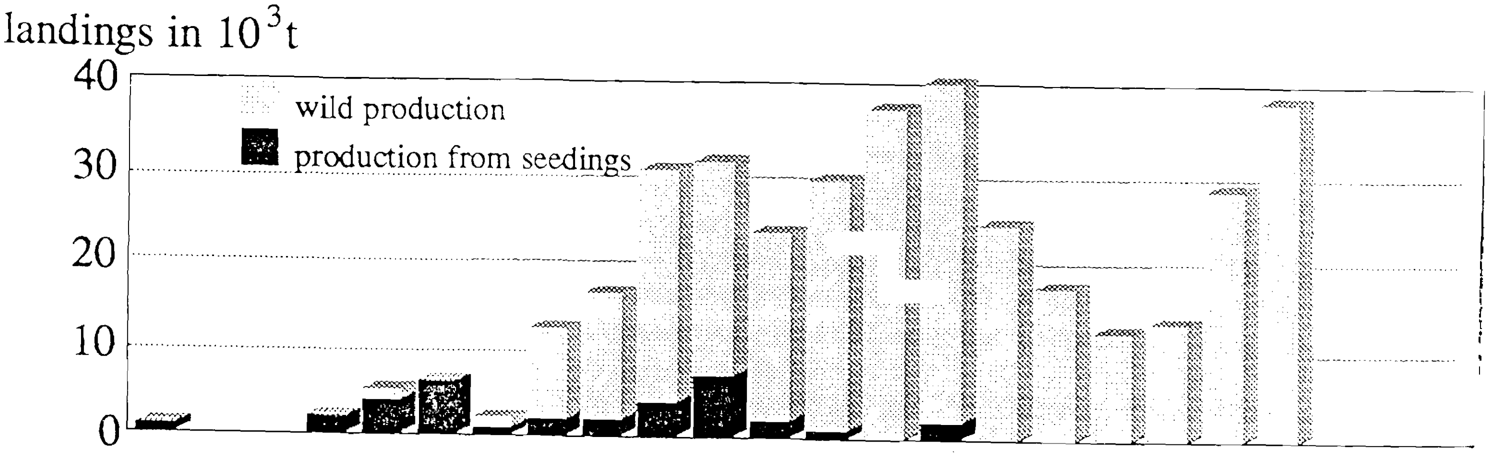
In 1977, the 4th year of recapture, fishing of the seeded area produced 9 800 tons, much higher than expected, and most of the catch originated from natural recruitment. This trend increased during the following years with the catch averaging 30 000 tons per year for four years. It continued to increase in 1983 and 1984 to a peak of 40 000 tons, but fell off to a half of that in 1985 (*figure 4*). There was no need for introduced spat and no seeding occured during those years.

Management of the grounds were based on a four year rotation of the fishing areas, with predator control for starfishes and also for sea-urchins which might graze on the bottom and eat large number of small scallop postlarvae. Fishing and processing do not differ from the Tokoro cooperative : they have a daily catch-quota in accordance with the processing plants.

In 1985 the decrease of the production was due to a mass mortality occuring on the grounds : in some areas, the natural recruitment was between 10 to 15 animals/m^2, and it created an additional biomass which overloaded the carrying capacity of the area. It was this extra stock which generated the mortality. This exceptional recruitment (spatfall from

Figure 4 - ***Production of*** *Patinopecten yessoensis* ***in Sarufutsu cooperative (Hokkaido).***





1982 or 1983) has not been seen since but has encouraged the cooperative to copy Tokoro, in simplifying the management of the space and investing in a regular seeding programme after the cleaning of the seabed (predators, juveniles). The expected catch for 1990 was 30 to 35 thousand tons.

1.3. Conclusions.

Those two examples indicate that scallop sea bed culture can constitute an excellent opportunity for ground management in the open sea : the large production and low operating costs make the supply competitive on the world scallop meat market. The species is big enough (10-40 muscles /lb) and the processing is carried out quickly under conditions in order to reach the top-quality required. In 1990, Japanese exports represented 20% of their annual production, to U.S. and France mainly (before the ban of import in France for the lack of P.S.P. control). But one has to consider that the spat supply in Japan is plentiful and cheap.

On the biological side, it is interesting to note 3 results :

- 1° The catch is proportional to the number of juveniles seeded, and the recovery rate increased with the experience of farming (better handling of animals, control of predators, fishing techniques, rotation of areas).

- 2° In some cases, there is a secondary effect on the natural recruitment. It is obvious that the introduced spat grow and reproduce in the wild. Then the larvae drift with the local currents. In closed bays this manifested itself in the regular increase in spat collection (Funka bay, Mutsu bay, Saroma lake). In Sarufutsu this has positively affected the natural settlement. However there are still various hypothese as to the origin of the spawning stock (self-sustained recruitment or drift from another hanging culture area). Exclusive use of the restocking effect (no spat added) appears to be difficult to manage on a long term basis, especially where there is a large market to maintain (regular production for processing and marketing).

- 3° Overpopulation can be reached by bottom culture when density arrive to 1.5 to 2.5 kg /m^2 (10 to 15 animals of a commercial size). The same effect has occured in hanging culture areas with mass mortality of 30 to 60% of the animals. In all cases there has been subsequent recovery without the outbreak of disease.

This success, achieved with the Japanese species in its native environment, has yet to be demonstrated in European waters with the local species. It is encouraging to see that bottom culture techniques have been transfered to New-Zealand waters where their scallop is closely connected to the European one (genus *Pecten*).

REFERENCES.

Annual Report of TOKORO Cooperative : 1976, 1984, 1989

Annual Report of SARUFUTSU Cooperative : 1984, 1989

Annual Report of MUTSU BAY Cooperatives : 1976, 1984, 1989, 1990

Scallop Aquaculture, Fishery Journal, published by YAMAHA ENGINES, n°34, Oct 90.

2. NEW-ZEALAND.

2.1. Production.

The fishery for the New-Zealand scallop (*Pecten novaezelandiae*) began in 1959. The Southern Scallop fishery in the northern tip of the southern island has been the most important. The catch peaked at 10 000 tons in 1975 (*figure 5*), and 190 vessels (10-15 m length rage) were involved at that time. The main commercial beds occur in an open bay situated in 19-25 m on a soft muddy substrate, while the smaller fisheries around the northern island, which started in mid 1970's, occur on beds with predominatly hard sand.

Trials carried out in 1970's on scallop spat catch from collectors and ongrowing using Japanese hanging culture techniques indicated that hanging culture of *P. novaezelandiae* was unlikely to be economic under New-Zealand conditions, mainly because of fouling, while it was concluded that bottom seeding was likely to be a more viable option. After depletion of the stocks during late 1970's and no fishery in 1981-82 a joint program with the Overseas Fishery Cooperation Foundation in Japan was run for three years, aiming to testing the feasibility of enhancing the scallop beds through release of spat caught in collector bags. The initial aim was to seed 10 million spat per year. Spat collection the first year using 44 000 collectors resulted in a release of 35 million spat. Similar scale operation was carried out until it increased to 150 million spat in 1989-90, 500 million in 1990-91 and 1 billion spat in 1991-92.

The main seabed cultivation activities have been conducted in Tasman bay and Golden Bay (figure 6).

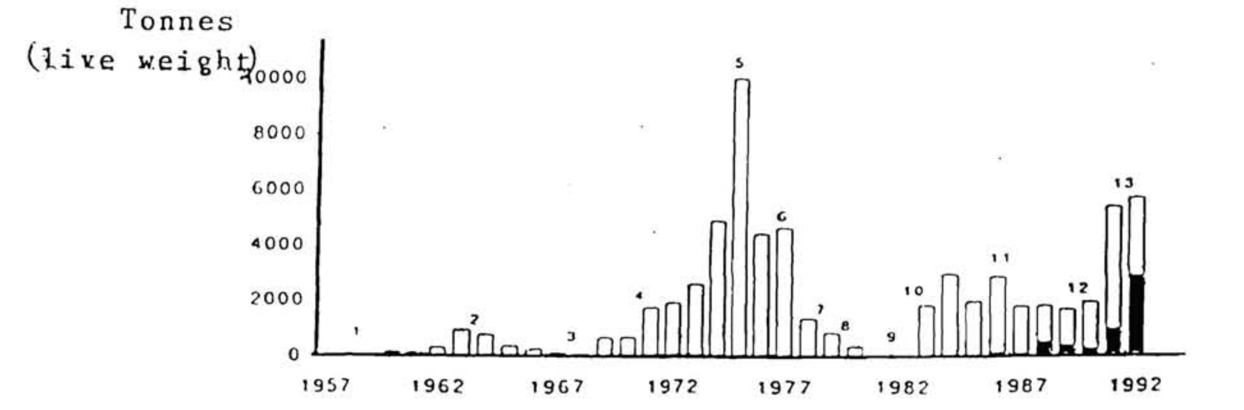
2.2. Spat production and seeding.

Spat (8-20 mm) are harvested from collectors (1 000-3 000 in each) after months growth during summer. In addition to the collected spat, the settlement on the outside of the bags which are released before harvesting are dredged from the bottom during winter. In Bull (1988) three different methods for bottom culture of scallops were tested in Golden Bay. "Direct release", release of spat to the seabed from collector bags; "intermediate culture", release after intermediate culture in pearl nets; and "natural release", enhancement of post-larval settlement success by the provision of simple artificial settlement materials. Prediction of costs, the likely levels of seed production and survival rate to harvest were made for a commercial operation. It was concluded that both the direct release and the natural release should give excellent returns to capital but the intermediate culture would not be economical. Assumed survival rates were 15 % for direct release, 30 % for intermediate culture and 40 % for scallops transplanted from a natural release.

In 1991-92, 300 000 bags were harvested, giving 1 billion spat, while another 200 000 young scallops were dredged in winter and transplanted to sites for seabed cultivation. The spat are seeded at a density of 4-6m^2. The dredged scallops are bigger (25-50 mm) and can be seeded on beds unsuitable for smaller scallops due to existence of predators. The number of re-seeded juveniles and seeding surfaces have increased from year to year :

- 1983 : 35 million spat, over 3.5 km2
- 1991 : 630 million spat, over 84 km2
- 1995 : 800 million spat, over 133 km2.

Figure 5 - ***History of landings and management changes in the Southern scallop fishery of*** *Pecten novaezelandica* ***(New-Zealand).***

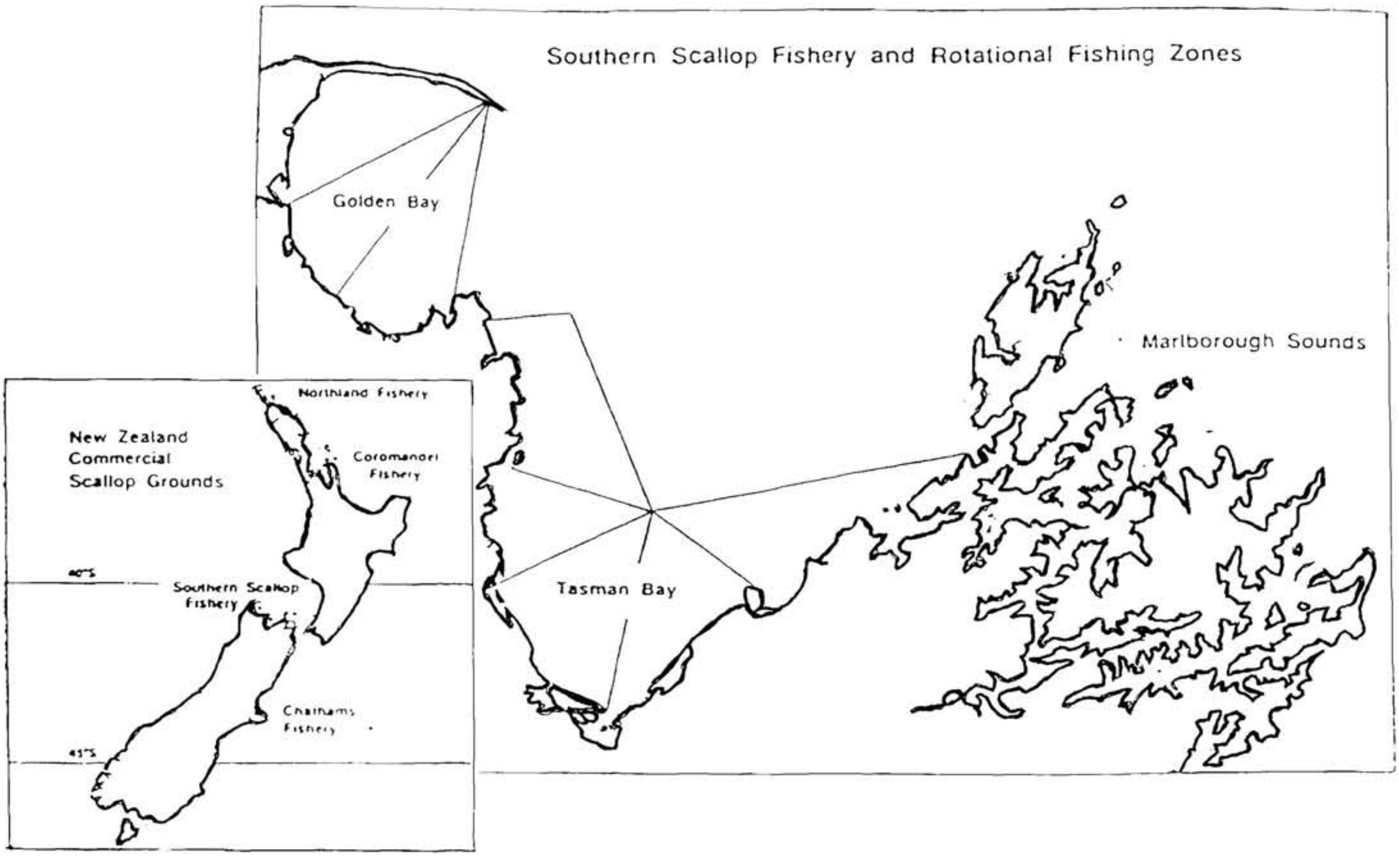


Management changes	
1	Fishery commenced
2	4" size limit introduced
3	Closed season 15 Feb - 14 July introduced
4	Restriction on gear to two 8 ft dredges per boat
5	Daylight only fishing introduced
6	Five day week introduced
7	Controls on boat numbers imposed
8	Size limit removed for 1979/80 seasons, season shortened
9	Fishery closed 1981/82 seasons
10	Scallop enhancement programme started
11	First harvest of seeded stock
12	Rotational fishing started, size limit reduced from 100 to 90 mm
13	ITQ system introduced

□ wild stock

■ seeded stock

Figure 6- ***Areas of bottom culture of*** *Pecten novaezelandica* ***in New-Zealand.***



- Recapture

Recapture is very variable, but it is expected that survival to harvest would be 15 % for spat harvested from collectors and 30 % for dredged spat.

- Growth

Studies of size frequency and tagged scallops indicate growth rates to be highly variable between different areas. Aging from the shell is not yet possible. It is estimated that the majority of shells in commercial beds reach catchable size (100 mm, meatweight of 9-12 g) about 2-2.5 years after settlement, while instances of catchable size after 18 months and undersized scallops after 3.5 years have been reported.

2.3. Status on seabed cultivation.

Seeded stocks are now contributing an estimated 40-50 % of the landings in the main fishery 700 tons meat weight in 1992).

- Management

Within the first ten years since the beggining of the scallop fisheries, controls were introduced establishing a minimum size (100 mm), restrictions on number and size of dredges and an annual five months closed season. Tn the late 1970's strict controls were placed on boat numbers through introduction of ontranferable licenses, and later on controls including daylight only and five day fishing weeks, daily quotas and shortened season lenghts were introduced.

In connection to the enhancement program a rotational fishery with a cycle of three years were introduced in 1989. The two main areas in the Southern Scallop fishery, Golden Bay and Tasman Bay are each divided into three sectors. Three years after seeding, market sized scallops (> 90 mm) on the beds are fished down to the minimum economic density, and the following autumn the beds are reseeded. Predator control is not performed.

In 1992, a system of transferable quotas was introduced to the fishery. During a five year phase-in period fishermen receive an equal share of the first 640 tons available each year and the Government tenders out any additional stock that is available on a one year lease basis. It is hoped that by 1997 there will be more knowledge regarding the long term productivety of the fishery. Additional stock will then be tendered out on a permanent basis and each fisher man will then be converted to proportional holdings which will vary according to preseason stock assessment. These regulations were aimed at prevention of biological overfishing, maximising the long term economic return form the fishery and providing stability for participants in the fishery.

- Constraints

Main predators are fish, octopus and starfish. In many areas harvesting is probably the main cause of mortality.

2.4. Future.

Maximum yield during the 1980 's was about 3 000 tons while landing in excess of 5 000 tons were made in 1991 and 1992. This higher landings were partly a result of better spartfall but there was a significant contribution from seeded scallops. Prospects for the following years are for a further significant increase in landings with the major contribution being from seeded stock.

According to M. Bull, the need of development and research into scallop cultivation and the fishery, has not yet been sufficiently stressed. Main effort have been towards the management of the enhanced fishery by seeding operations.

REFERENCES.

Bull, M.F. 1976. Aspects of the biology of the New Zealand scalp, Pecten novaezelandiae Reeve 1853, in the Marlborough sounds. Ph. D. Thesis, Victoria University of Wellington, New Zealand.

Bull, M.F. 1987. Scallop seeding trials in New Zealand. International Pectinid Workshop, Menai Bridge, Wales.*

Bull, M.F. 1991. New Zealand. In : S.E. Shumway (ed) Scallops : Biology, Ecology and Aquaculture. P.853-859. Elsevier, Amsterdam. *

Bull, M.F. 1993. Enhancement and mangement of the New Zealand's "Southern scallop" fishery. International Pectinid Workshop, Nanaimo, Canada.*

3. CANADA.

Many species of scallops can be found along the Canada's coasts but most are slow growing or rare.

In British Columbia (B.C.) only four species have been harvested in commercial fisheries : Weathervane scallop (*Patinopecten caurinus*), Rock scallop (*Crassadoma gigantea*), Pink scallop (*Chlamys rubida*) and Spiny scallop (*Chlamys hastata*). Because of too few spat being collected from the wild and the slow growth of these native species, it is the exotic Japanese scallop (*Patinopecten yessoensis*) which is being investigated for cultivation.

Conversley in the Maritimes provinces on the east coast, the Sea scallop (*Placopecten magellanicus*) fishery is very important (20-100 000 mt), but decreasing, and cultivation trials are being run in the hope they will enhance the scallops beds with spat collected from the wild. The non native Bay scallop (*Argopecten irradians*) first introduced into Prince Edward Island, is now cultured in Nova Scotia (N.S.)

3.1. Suspended culture.

Excepted *Placopecten magellanicus* which is collected from the wild (with yields of hundreds or thousands spat /collector bag), all the cultivation obtains spat from 2 Canadian commercial hatcheries : the Island Scallop Ltd hatchery in B.C. (8 million spat of japonese scallop) and the Mountain Island hatchery in N.S. (bay scallop).

Ongrowing in private waters is carried out most often using suspended culture in pearl nets.

- British Comumbia :	5 sites (*Patinopecten yessoensis*) --> 50 mt / year
- Nova Scotia. :	4 farms (*Placopecten magellanicus*)
	1farm (*Argopecten irradians*)
- New Brunswick :	1 farm (*Placopecten magellanicus*)
- Newfoundland :	4 fishermen's co-ops (*Placopecten magellanicus*).

Because of the low winter temperature (for *Argopecten irradians*) and the low growth in suspended culture which is also labour intensive, cultivated scallops are usually sold before winter at 50 mm (*Argopecten irradians*) or 60 mm (*Placopecten magellanicus*).
However some Japanese scallops and Sea scallops are marketed as meats (adductor muscle) only and then an extended growout period of 1 or 2 years is necessary to reach the minimum size of 80 mm.

In any case the heavy costs of equipment and labour force some companies to turn towards on-bottom seeding.

3.2. On-bed seedings projects.

"Island Scallop" in B.C. have a seeding site of 375 ha, with a depth ranging from 20 to 50 m, sandy sediment and a very small starfish population. It is now intending to seed 8 million juveniles on a third of the lease every year (e.g. 6-7 shells /m^2).

in the Maritimes Provinces the government have also attempted to seed scallops for public fishing and as part of fishing co-ops to enhance fisheries of *Placopecten*. These trials are supported by different research programs :

- OPEN (Ocean Production Enhancement Network) in Nova Scotia, New Brunswick and Quebec ;
- REPERE (Recherche sur le Pétoncle à des fins d'Elevage et de Repeuplement) in Quebec ;
- and a development program in Newfoundland.

OPEN provides CAN $ 400 000 of founding for a 3 year research program (1991-93) investigating basic seeding criteria : physiology, behaviour and predation. Several experimental seedings (10-20 000 juveniles each) have occured on 2 leases in N.S. and have shown a great variability in results. A new direction for OPEN was to be determined in may 94.

REPERE is a development project for spat collection and sowing in the Madeleine Islands in the middle of the gulf of Saint-Laurent. It was in 1991 and has been extended for 2 more years (april 93 till march 95) with CAN $ 600 000. First trials have moved from hatchery supply of spat and turned to wild collection : 800 spat /collector bag has been reached and a futurel average of 500 /bag looks reliable. Trials have also shown a good feasability for intermediate culture in pearl net in a lagoon inside the islands (very sheltered water). So the aim is now to collect 5 million spat with 10 000 bags and to carry out 2 batches of intermediate culture per year : half of the spat in summer being seeded at 35 mm in autumn, while the second part stored in collector bags is put into pearl net in autumn for intermediate culture over winter and seeding in the spring, also at 35 mm. Seeding sites are on natural beds around the islands. Some of them have been tested with some success.

In the Newfoundland some seedings have been attempted in Fortune Bay (South coast) but was predated and dispersed. New trials should be established by a 14 fisherman co-op in Port-au-Port Bay (West coast) : 7 000 collector bags were put in the water in autumn and collected 25 million seed (4 000 /bag). Since 1989 a large proportion of these spat (20 million /year) are sown onto a 300 ha lease (100 ha /year ; 2 juveniles/m^2).

In Northumberland Strait, between New Brunswick and Prince Edward Island, collecting trials provided good results (1 300 spat /bag) and the aim is to set up a first re-seeding in 1996.

Table B - ***Summary of the different scallops projects in Canada***
(from Gilbert & Leblanc 1991)

PROVINCE	SPECIES	TYPE OF PRODUCTION	LEVEL
British Columbia	*Patinopecten yessoensis* (Japenese scallop)	Hatchery-nursery Suspended culture On-bottom culture	R/D projects (375 ha)
	Crassadoma gigantea (Rock scallop)	Hatchery-nursery Suspended culture	R/D ?
Prince Edward Island	*Argopecten irradians* (Bay scallop)	Suspended culture	R/D commercial projects
Nova Scotia	*Argopecten irradians* (Aay scallop)	Hatchery-nursery Suspended culture	R/D commercial projects
	Placopecten magellanicus (Sea scallop)	Hatchery-nursery Collecting in the wild Suspended culture On-bottom culture	R/D (OPEN)
New Brunswick	*Placopecten magellanicus* (Sea scallop)	Collecting in the wild Suspended culture On-bottom culture	R/D
Québec	*Placopecten magellanicus* (Sea scallop)	Collecting in the wild Suspended culture On-bottom culture	R/D (REPERE) projects
Newfoundland	*Placopecten magellanicus* (Sea scallop)	Collecting in the wild Suspended culture On-bottom culture	R/D and commercial projects

3.3. Conclusion.

Scallop farming is increasing slowly in Canada. Two commercial hatcheries can provide spat for exotic species (*Patinopecten yessoensis* and *Argopecten irradians*) and the eastern native species (*Placopecten magellanicus*) can be provided in large quantities by collection from the wild (Newfoundland and the Madeleine Islands).

Under these circumstances, suspended cultivation appears expensive for such quantities and for 5 years cultivation has been directed at different types of seabed cultivation. If siccessful, the Canadian scallop farming industry with its many sites and excellent spatfall, may become significant in the near future.

REFERENCES.

BOURNE N.F. and BUNTING B.L., 1991 - The potential for scallop culture in British Columbia, Canada. 8 th International Pectinid Workshop Cherbourg.

CLICHE G., 1997. L'élevagedu pétoncle dans les Provinces maritimes canadiennes. 5e réunion annuelle de transfert de technologie (*rearing of Petoncle in Canadian Maritimes. 5th meeting for transfer of technology*). Programme REPERE. Iles de la Madelaine, 6-7 March 1996.

COUTURIER C., 1990 - Scallop aquaculture in Canada : fact or fantasy ? World Aquaculture, 21(2) june 1990.

GILBERT E. et LEBLANC Y. , 1991 - La culture du pétoncle géant : état de la situation et analyse bioéconomique de différents scénarios d'élevage. MAPAQ

WATERHOUSE J., 1992 - Atlanteco economic study (Newfoundland, Canada).

Appendix 3 - AN EUROPEAN COOPERATION.

Contents :

1. COMMON DIVING CODE OF PRACTICE.

In order to be able to dive together, members of the European Concerted Action on Scallop Seabed Cultivation have drawn up a common diving code issued from their own national regulations.

1.1. The dive team.

Each dive will require a full dive team. A dive team will consist of the following personnel :

1 dive superintendent

1 boatman (must be competent)

1 diving attendant (or crewman).

2 divers (one diver to act as dive leader)

- Dive Superintendent

Must be a diver or ex-diver and is ultimately responsible for the diving operation. This includes responsibility for ensuring that dive briefings are conducted prior to all dives, taking into account, conditions and the difficulty of the dive (§ 3.5)

- Boatman

He must have the following certification and knowledge :

- First Aid Certificate (or equivalent European standard)
- VHF licence (or equivalent European standard)
- Knowledge of the diving operation

The boatman is responsible for the safe operation of diver deployment / recovery and diver safety cover. He is to liaise with the dive leader prior to diver deployment with regard to positioning and conduct of his vessel during diver operations. The manning of the hand held VHF radio will become the boat person's responsibility should the attendant / crewman be engaged in standby diver deployment / retrieval.

- Attendant / Crewman

Preferably a qualified diver who continually watches the float(s) marking the diver(s). Attends the standby diver if required, manning the standby's lifeline to pass and receive signals as necessary.

The attendant will also assist the boat person in the routine aspects of diver deployment and recovery or vessel anchorage.

- Divers

- Dive Leader
Before a dive commences a dive leader is to be appointed. He / She must ensure :

1° Safety of all members of the diving group.

2° Members of the group including boatmen are fully instructed in the task to be performed, and fully understand any special requirements that might affect the conduct of the dive.

Dive leader will co-ordinate activities with the relevant project personnel.

- All Divers
All divers engaged on project work are responsible for assessing their own fitness to dive on the day. If a diver feels unfit / unable to dive they will inform the Dive Superintendent as soon as possible (ASAP). Any injury sustained during the dive or any post dive ailment experienced by a diver, is to be reported immediately to the dive superintendent.

Divers are responsible for all pre-dive checks relevant to their own personal equipment; demand valves, depth gauges, knives and adjustable buoyancy life jackets etc...

- Standby Diver
If paired diving (buddy) is undertaken eg. night diving, then a standby diver is not required, as on-task divers will provide standby cover for each other.

When a single diver is engaged in sampling, or other work, a standby diver is to be at immediate notice to dive (ie: fully dressed with mask off). If practical, he should descend to working depth prior to commencement of the dive, to ensure he can clear his ears.

The standby diver's lifeline is to consist of 8mm diameter cordage (minimum) with sufficient length to allow the standby diver to render the necessary assistance without any impedance. It should be attached to a suitable point on the diver's harness. If it is more appropriate that the dive support vessel be detached from a fixed mooring point in order to render assistance, then the standby diver is to enter the water with a surface marker buoy (SMB). The vessel should then maintain station near that float in order that it can render immediate assistance or respond to manual float signals from the standby diver. It may be necessary to anchor the dive support vessel in the event of the standby diver being deployed. Such action will be at the discretion of the boat person.

1.2. Equipment for Dive Team Members

- Personal Equipment

All personal diving equipment, and its satisfactory functioning remains the responsibility of the individual diver.

- Breathing Air

The quality of breathing air must be of acceptable standard, irrespective of method of filling, be it portable or fixed compressor.

- Surface Marker Buoys (SMBs)

Must be carried by each diver entering the water, except when the standby diver is deployed who will carry a lifeline. The SMB lines must compromise of 8mm cordage with sufficient length to accommodate envisaged water depth (depth x 1.3). The surface buoy will consist of an orange 200mm float (Marked diver 1 or diver 2).

- Decompression Tables

Both divers and attendant are to familiarise themselves with the relevant decompression tables used for the dive. Tables are not to be exchanged for another type between dives if a repetitive dive is planned.

- Underwater Torches / Lamps

These are to carried by both divers during night dives. There should be sufficient spare batteries available. Light sticks will also be attached to each diver and their SMB during night dives.

- Boat Equipment for Dive Support Vessel

This is the responsibility of the boatman assigned for the dive.

1° Fuel & spare can and hose
2° Handheld VHF radio set on pre-arranged channel
3° Basic First-Aid kit
4° Dive flag
5° Paddles
6° Anchor
7° Basic tool kit
8° Lamp for night dives
9° Anchor and cable
10° Baler

- First Aid Equipment

All dive support vessels will carry a basic first-aid kit. A more comprehensive kit including O_2 will be held on the main dive support craf in addition to a diving first-aid manual.

- Surface Decompression Facilities

Should any diving personnel require therapeutic decompression, a suitable chamber at a nearby location should be placed on standby for the duration of diving operations. The anticipated travel time from dive site to chamber should be less than two hours. Oxygen will be administered to the affected diver during transfer to the decompression chamber.

3. Dive operations.

- Dive Briefings

Dive briefings will take place in the morning prior to the first dive of the day. At this point, dive teams including leaders will be appointed for the day's sampling work. Subsequent dives during the day will rely upon the appointed leaders liaising with the appointed field work supervisor and their respective dive teams. Night dives will be undertaken after a formal briefing has taken place involving the Dive Superintendent / Field Work Supervisor, dive teams and support staff.

- Dive Log Sheets

All dives undertaken are to be recorded by the boat attendant(s) during the actual dive. The details will then be transferred into a project master dive log by the Dive Superintendent.

- Radio Protocol

During the periods that divers are deployed on sampling work or other work, radio communications are to be maintained until diving operations are completed. Assigned radio operators are to familiarise themselves with regard to "working", and "emergency" channel protocol.

- Minimum Cylinder Contents - Resurfacing Procedure

In the event of a divers cylinder contents being depleted to 50 bars, the divers should prepare to surface immediately, or if appropriate, return to original entry point.
Paired divers are to regularly monitor their partners cylinder contents during the dive.

- Factors affecting the level of difficulty of dive

The difficulty of dive has to be appreciated at the briefing according to various factors such as :

- Day or night diving

- Visibility

- Weather conditions

- Tide and currents

- Proximity to the shore

- Type of work - Taking into account "Bounce" diving

- Whether SMB is necessary if divers are operating along a fixed groundline or close inshore in calm shallow water, and taking into account the risk of entanglement.

There may be a requirement to provide additional support personnel / craft when dives incur additional hazards such as:

- Depth in the range of 9-30metres

- Entrapment risk (Also relevant for use of SMBs.)

- Night dives

- Where current speeds are > 0.5 knot

- When the sea state is poor or visibility is low.

Additional support personnel or dive teams utilised for these dives will attend the pre-dive briefing.

- Signals

- Manual Signals

In the absence of an alternative method, manual signals by lifeline / SMB line are used for communication between the divers and surface control. The signals are of two kinds :

- Pulls : Long, steady and distinct pulls.

- Bells : Paired, short, sharp, bell pulls made with the same timing as striking a ships bell.

Communication between submerged divers and surface cover using this method should be relatively straightforward as the diving work is reasonably predictable and working signals should not be necessary. SMB signals from diver to surface cover should only be necessary in the following circumstances :

- Diver to Attendant:

1 pull - to call attention / have made bottom / I am well
4 pulls - I intend to surface

- Attendant to Diver

1 pull - to call attention / are you well?
4 pulls - come up
4 pulls + 2 bells - come up/hurry up (emergency signal)

In the event of a standby diver being deployed, diver may be attached to a lifeline or to an SMB. He will communicate through that to the attendant using a combination of general and emergency signals to assist the recovery of the diver. All signals from attendant to diver apart from the emergency signals are to be preceded by one pull to attract attention.

This code may be supplemented by special pre-arranged signals but to avoid confusion, these should be kept to a minimum.

- *Visual Signals Upon Surfacing*

  - In Daylight :
    - One arm raised - I am well
    - Both arms waved violently or water being slapped - I require assistance.

  - At Night :
    - Horizontal sweep of torch - I am well
    - Rapid erratic movement - I require assistance

In addition to the abovementioned points, regulations realting to the nation hosting the dives, will take precedence over all other regulations.

2. DIVE MONITORING OF RE-SEEDED JUVENILE SCALLOPS.

2.1. Introduction.

The success of scallop seabed cultivation is measured as recapture rate, which comprises survival of the scallops on the bottom, their no dispersion (active or passive) and harvesting efficiency. In the Concerted Action project, work was concentrated on the rate of the re-seeded juvenile scallops remaining in the seeding area (= survival - dispersion). This 'survival rate' of scallops may be expressed by :

$$DN / Dt$$

where DN is the change of number of individuals in the seeding area over a time interval DT.

In the monitoring of survival of seeded scallops one may consider the whole growout period, from seeding to harvest, or shorter time interval at specific phases of the growout. The problems adressed in the Concerted Action project and related projects has mainly been to estimate the success of a juvenile scallop seeding, namely to get a figure of the 'survival rate', after a while such as :

- about a few days : success of the recessing : scallops usely don't move from the place they recessed in after a couple of days ; then, after a period of recovery, which has to be precised their ulterior survival is the same as for natural scallops, namely about 15-20% /year (Fifas *et al*, 1990).

- after the 1st winter period : to study the effect of the winter on the seeding ; post-winter mortality are regularly observed, in both natural (Thouzeau and Lehay 1988) and seeded stocks (Halary *et al* 1994).

- after the fishing season : impact of dredge for instance on juvenile scallops.

- at the commercial size (2 or 3 years after the seeding) : to know the total effect of the seeding (recapture rate).

Monitoring of survival may aim at a single seeding, or at comparison of several seedings in order to study the effect of variables, such as site, juvenile size, juvenile quality, predator avoidiance technique, etc. (cf Concerted Action annual field works). The time period (Dt) needed in a survival estimate varies. In a case of studying effects of juvenile quality on predator avoidance, the monitoring of the first period (days) may be sufficient for the comparison.

2.2. Factors affecting the monitoring of seeded scallops.

Juvenile scallops re-seeded on the bottom :

- may die, due to seeding stress (depending on handlings, juvenile size and vitality) and the need of recessing (site dependent), or due to predation (varying upon numbers of seeded animals, juvenile size and vitality, predator activity and efficiency namely site and season) ;
- or may dispersed by themselves (high seeding density, escape to predators) or with currents (weak animals).

Therefore in addition of the aimed comparison itself, various parameters have to be taken into account :

- The numbers of seeded scallops.

The probleme appears rather different depending the numbers of scallops are 100 or 100 000 ! But as far as possible (according to spat supply) the numbers should be high to get a real effect on the benthic fauna (predators attraction, competitors avoidiance) and limit the edge effects. The Concerted Action teams consider than 20 000 shells are good numbers for an experimental seeding.

- The density.

The scallop seeding densities are quite low in comparison with other Bivalves, about 5 to 10 shells /m2. Over 10 shells /m2 the dispersal becomes very high.

- The size of the seeding area.

As Surface = Numbers/Density, for Numbers = 20 000 and Density = 5 to 10 /m2, the initial required surface ranges from 2 000 to 4 000 m2 (namely about 60 m x 60 m). But after a few days, according to currents, waves, ... the total area can cover more than 1 ha. The shapeless area and the low densities on the edge make very uneasy to size the surface.

- Juvenile size.

The seeding size ranges from 20 mm (less than 1 year old spat) to 50 mm (over-wintered animals of nearly 2 years old) with various standard sizes according to each country and sites (cf. 'juvenile scallop quality at seeding' , in appendix 8). The larger the size is, the easier is the survey : animal visibility increases and its mobility decreases. On the other hand, economical interest leads to study ability of small spat recessing.

• The constraints of an underwater work.

In most cases, overall during the first year, monitoring of the seeding requires divers, even if video observations or dredgings may also be achieved. Therefore in addition to the seeding parameters, some factors such as depth, currents, underwater visibility can greatly limit the underwater work.

2.3. The choice between two monitoring methods.

The Concerted Action teams used to practice various methods in scallop seeding samplings. And these different techniques (with divers) were experimented in the course of the 3 field works of the Concerted Action programme.

Actually the monitoring techniques can be divided into two main methods :

- the sampling of the whole seeding , randomly (cf. Ardtoe field work, 1995) or systematicly (cf. Connemara field work, 1994) ;
- the monitoring of experimental units (cf. Brest field work, 1993).

• The sampling of the whole seeding.

Here plots are drawn from the whole seeding. They can be **random or systematic samplings.** Some problemes are encountered in the wild with such a method :

- Very heterogeneous density (0 to 50 spat /m2) implies high variance and therefore many plots ;
- Random plots imply locating them in the seeding area, with new spottings at each sampling ;
- Overall, the estimation of the real surface area is uneasy, the seeding having no specific shape and no sharp limits (density decreasing progressively from centre to edges).

Therefore this method has to be advised only for small seedings and short monitorings (before dispersion of animals : cf. Ardtoe fieldwork 1995).In other cases the data processing does not give an approximation of the survival rate, but an **average density only**, as far as the surface area remains unknown.

• Monitoring experimental units.

Here plots are **experimental units** (as experimental rows in an agronomic field).
The whole seeding remains necessary, but only to create a standard seeding environment to avoid the edge effects on the experimental units : natural dispersion, predators attraction, ... (Fleury *et al*, 1996)

Advantage here is that both initial numbers of seeded animals (in the experimental units) are exactly known and that experimental surfaces don't move in future. But the probleme turns to identify the animals issued from the plots, namely the need of marking them. And marking does not avoid the risk of animal dispersal out of the plots. Therefore one may need to tether the juveniles. According to Barbeau and Scheibling (1994) the predation rate on tethered scallops (*Placopecten magellanicus*) by crabs (*Cancer irrodatus*) does not differ significantly from that on free scallops.

Figure 1 : ***crossed anova (agronomic block technique) for comparison of 3 seedings (A, B, C)***

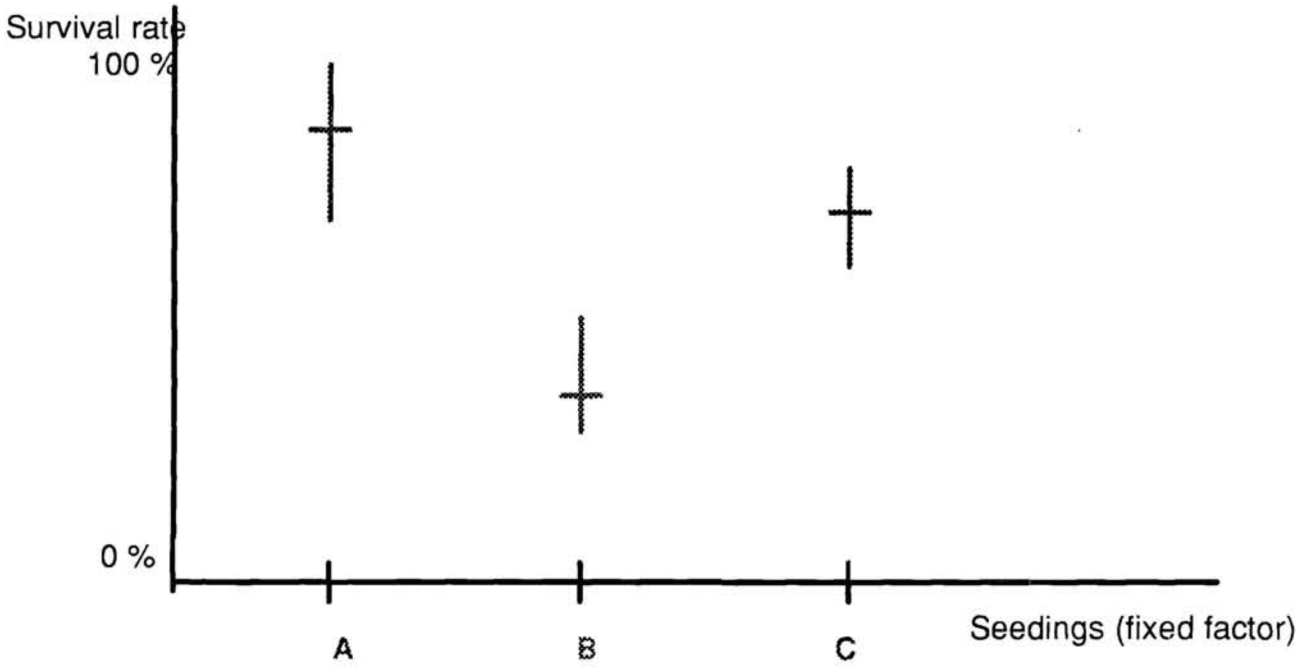
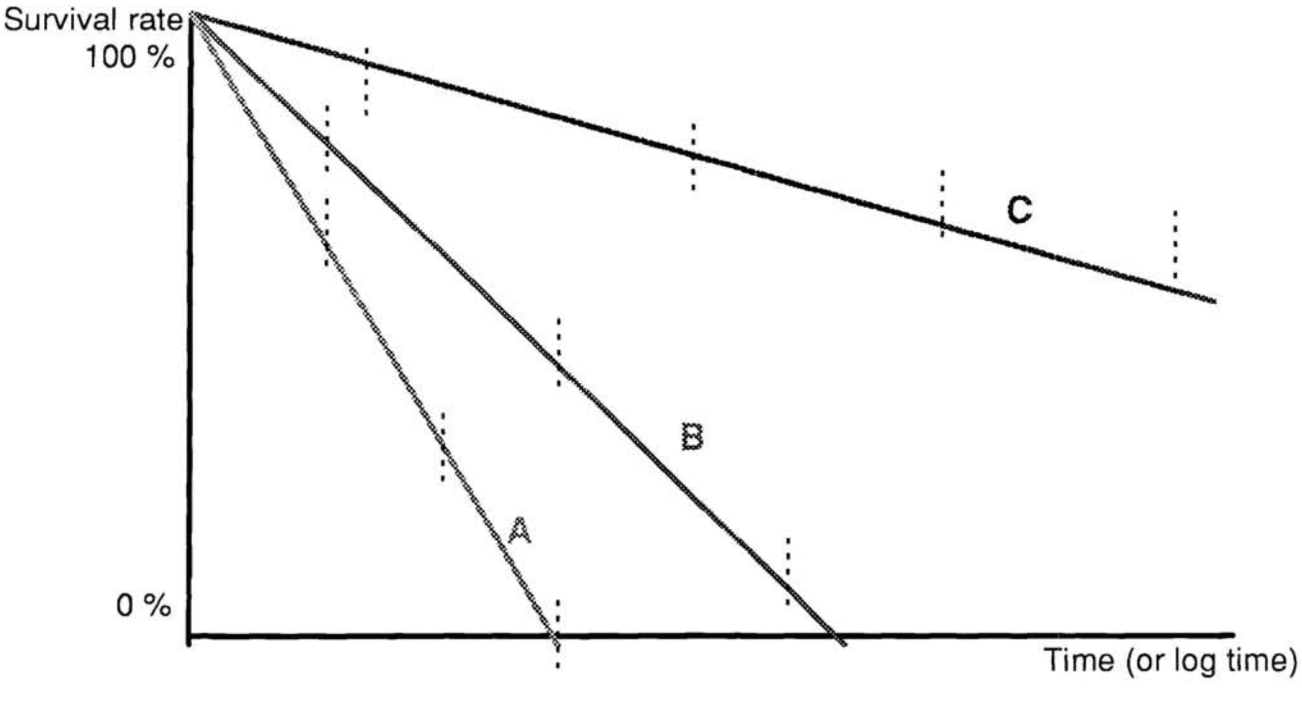


Figure 2 : ***Regression : comparison of 3 seedings (A, B, C) with successive samplings in experimental units.***



Instead of an average density, the data processing gives here a **survival rate :**

$$S = \mu / no$$

with no = initial number /plot and μ = average number in sampling plots.

With marked scallops **S** = survival in place (**1-S** = dead or dispersed scallops)
With tethered scallops **S** = survival estimation (**1-S** = dead)

Comparisons between different seedings are easier, because initial conditions can be similar (such as density) and therefore allow data processings such as anova (after transformation of the survival rate (binomial data) in normal distribution by an Arcsin transformation). The crossed anova involved here, with one fixed factor (studied parameter : juvenile batch, ...) and one random factor (plots) is directly issued from the agronomic block technique, which is particularly efficient for large distribution of results between plots (high variance). (*figure 1*). In the case of successive samplings along the time, regression coefficients can be compared (*figure 2*). The pros and cons of the 2 methods (samplings or experimental units) are summed up in the *table A*.

Table A. ***Comparison between sampling and experimental units :***

	Sampling	**Exp. units**
Underwater work	very uneasy	quite easy
Initial area	± known	exactly known
Final area	large error	exactly known(= initial one)
Data processing	gives average density	gives average survival rate
Major constraints	- locating plots - estimate areas	identify animals without stress (marking or tethering)

2.4. Proposed methods.

Two methods using the experimental units can be recommanded according if animal may remain in pots (marked scallops) or may be dispersed (tethered scallops).

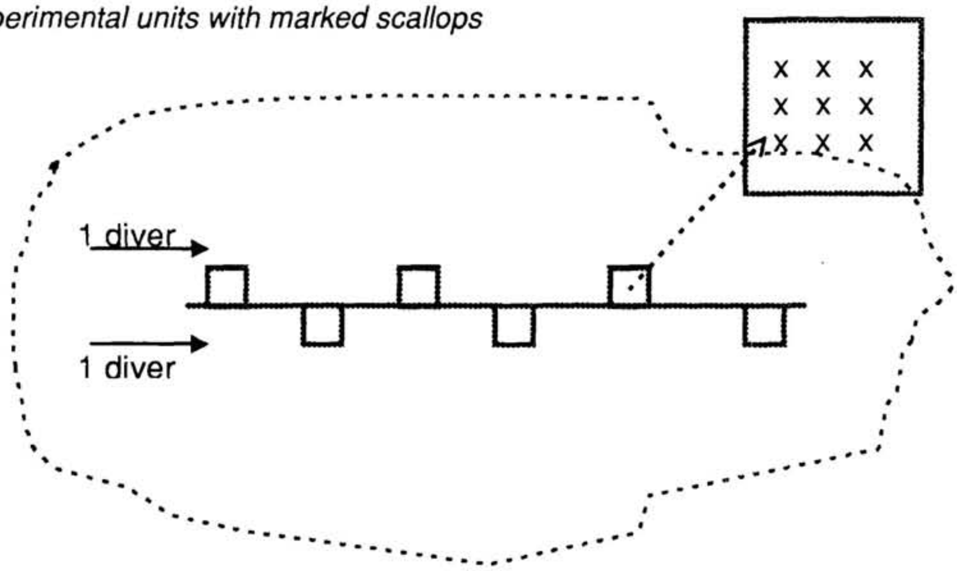
- Marked scallops.

Marking can be made with a felter pen if the experi mement is not supposed to spend a long time (less than a couple of months) or with a notch in the shell (on the ear) if it has to spend quite long.

For each seeding, the experimental units (15 to 20 plots of 1 m2) are set up along a line (50 or 100 m) in the centre of the main seeding. 9 marked scallops are laid per plot (*figure 3*), with a total of N = 135 to 180 scallops.

Samplings requires to number animals in each plot (by diving). Probleme is to be sure to count all of them (if it is forgotten a recessed scallop would be counted for a dispersed one). This may imply a light raking in the place where missing scallops are supposed to be found

Figure 3 : Experimental units with marked scallops



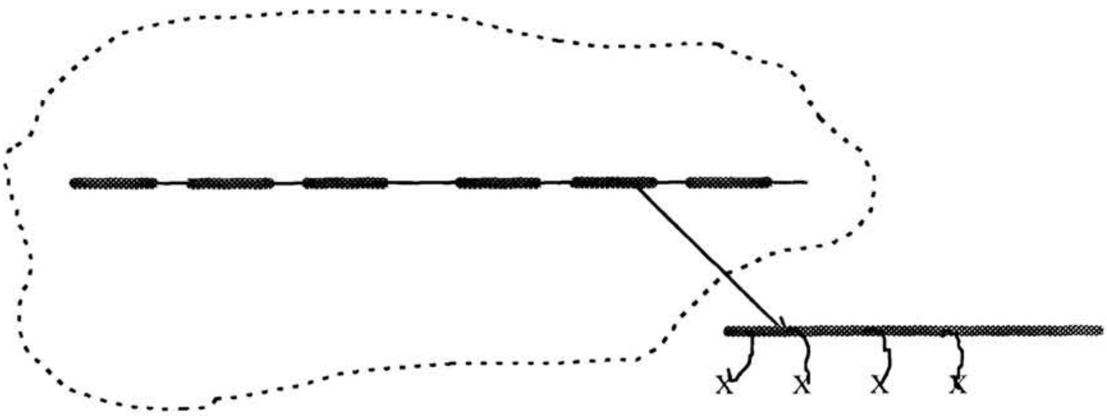
For xi = numbers of scallops in each plot and N = total numbers of scallops,

S = Σxi / N is the survival rate of scallops remaining in place
1-S = dead + dispersed scallops ===> **S** is very under-estimated.

This allows anyway some comparisons between seedings.

- Tethered animals.

*Figure 4 : **tethered scallops***



This kind of method has been experimented successfully in Canada (Barbeau and Scheibling 1994) with another species, *Placopecten magellanicus*, which is uselly more swimmy than the European species, *Pecten maximus*.

The tethering procedure is to clean a small area of the upper valve with a cotton swab and acetone (with care to be taken not to expose the scallop's mantle edge to acetone), to dry it and to glue a string on it with a strong glue such as cyanoacrylate or araldite. This string is tied to a rope. For 100 scallops, it requires 10 weighed lines x 10 m with 1 tethered scallop /meter (*figure 4*). 1 block = 1 line = 10 scallops.

For xi = numbers of scallops in each plot and N = total numbers of scallops,

S = Σ**xi / N** is the survival rate of scallops
1-S = dead scallops (found tethered in place, excepted rare cut tethers)

Then **S** is lightly under-estimated (stress of tethering, obligation of recessing in place what any the sediment is, difficulty to escape to predators).

REFERENCES.

Barbeau M. and Scheibling R.E., 1994. Procedural effects of prey tethering experiments : predation of juvenile scallops by crabs and sea stars. *Mar. Ecol. Prog. Ser.* **111**: 305-310.

Fifas S., Dao J.C. and Boucher J., 1990. Un modèle empirique du recrutement pour le stock de coquilles Saint-Jacques (*Pecten maximus*), en baie de Saint-Brieuc (Manche, France). aquat. living Resour., **3**: 13-28.

Fleury P-G., Mingant C. and Castillo A., 1996. A preliminary study of the behaviour and vitality of reseeded juvenile great scallops, of three sizes in three seasons. *Aquaculture International* **4**: 325-337.

Halary C., Royer Y., Corlouer J.P. and Dao J.C., 1994. Effects of predation and competition on scallop, *Pecten maximus*, seabed cultivation in Saint-Brieuc bay : preliminary results. in *Canadian Technical Report of Fisheries and Aquatic Sciences (Proceedings of the 9th international Pectinid workshop, Nanaimo, B.C. Canada, April 1993*. **2**: 39-49).

Thouzeau G. and Lehay D., 1988. Variabilité spatio-temporelle de la distribution, de la croissance et de la survie des juvéniles de Pecten maximus issus des pontes de 1985, en baie de Saint-Brieuc. (Spatio-temporal variability of the distribution, growth and survival of Pecten maximus juveniles from the 1985 summer spawning, in the Bay of Saint-Brieuc. *Oceanol. Acta* **11/3**: 267-283.

3. EXCHANGES OF KNOW-HOW (FOREIGN COURSES AND MEETINGS BETWEEN STUDENTS, RESEARCHERS AND PRODUCERS).

The Concerted Action itself was born from previous bi-lateral exchanges between IFREMER Brest (France) and the Connemara Shellefish Co-operative (Ireland), which were set up annually, in September 1991, Novembre 1992 and Septembre 1993.

3.1. Exchanges of students and personal.

In addition to its roundtable meetings and fieldworks, the Concerted Action enabled other bi-lateral exchanges of personnal and know-how. Different types of exchanges were carried out (*table B*) :

- divers for the preparation of the Concerted Action fieldworks (picking up the juveniles, setting up the bottom lines for sampling, potting the seeding area for predators), with the opportunity of operating the host practices in scallop farming (intermediate culture, sampling techniques) ; stays in Ireland and Scotland ;

- a technician-diver helping an host company in scallop farming : similar help and aim, but outside of the Concerted Action fieldworks ; in Norway ;

- a student course (master) about a Concerted Action priority subject (juvenile vitality) ; in France.

An international juridical survey about scallop legal status in national fisheries and farms was also carried out with IFREMER and 3 French students from the law University of Brest. They found foreign correspondants in members of the Concerted Action. Their preliminary results were presented as a poster at the 10th International Pectinid workshop (Cork, May 1995).

Table B - ***Exchanges of students and personal***

name	***organism***	***date***	***place and work***
Geir ASKVIK-HAUGUM (student ; diver)	University of Bergen, Norway	Septembre 1994	In C.S.C., Ireland, to assist the preparation of the 2nd Concerted Action fieldwork (funded by IMR)
Julie MAGUIRE (student)	University College Cork, Ireland	March-July 1995	student course in IFREMER Brest on juvenile scallop vitality (funded by EU Leonardo - Aqua-TT)
Geir ASKVIK-HAUGUM (student ; diver)	University of Bergen, Norway	Sept. 1995	In Seafish, Scotland, to assist the preparation of the 3rd Concerted Action fieldwork (funded by IMR)
Dan MINCHIN (researcher ; diver)	Fisheries Researh Centre of Dublin, Ireland	Sept. 1995	In Seafish, Scotland, to assist the preparation of the 3rd Concerted Action fieldwork (funded by FRC)
Bob LUDGATE (technician ; diver)	Connemara Shellfish Co-op, Ireland	Aug-Oct. 1996	In Taroskjell AS, Norway on scallop cultivation techniques (funded by EU Leonardo - Aqua-TT)

3.2. Visits of farms and people meetings.

The meetings or fielworks of the Concerted Action also enabled the opportunity of meeting local people involved in scallop cultivation :

- Visits of scallop farms.

  - Visit of the platform of the Comité d'Expansion des Côtes d'Armor, Erquy, France : a juvenile scallop producer in cages (during the French field work) ;

  - Visit of the hatcheries of Austevoll and Øygarden, Norway (Bergen meeting) ;

  - Visit of the scallop hatchery of Le Tinduff, France (final meeting in Brest).

- Meetings with researchers and producers.

  - MAAF Fisheries Lab., Conwy, Wales : an experimental hatchery (during Ardtoe meeting, in Scotland) ;

  - Taroscallop Ltd, Trondeim, Norway : a scallop fishing company (Ardtoe meeting) ;

  - Taighde Mara Teo, Ireland : a scallop farm (Irish field work).

  - Fishery Local Committee of Quiberon, France (Scottish field work).

- Seminars and workshops.

Although they were not a direct part of the Concerted Action itself, the Concerted Action enabled contacts for setting up some seminars about scallop cultivation :

- Scallop Seabed Seminar in Kilkieran, Ireland, in Septembre 1994 (during the Irish field work) with 50 producers and administratives involved in Irish scallop industry ;

- two AquaTT short training course in scallop cultivation, in Bessaker, Norway, in August 1995, with two speakers from Ireland : Mark Norman and Iarflatith Connellan ;

- AquaTT short training course in scallop cultivation, in Carna Ireland, in Septembre 1995, with two speakers from Norway : Øivind Strand and Gunnar Bengtson.

In addition, the choice of the date and place of the 3rd annual meeting fit with the 10th International Pectinid Workshop in Cork, Ireland, and enabled the Concerted Action group to meet over 100 researchers involved in scallop culture all around the world. In addition to their own papers or posters on national scallop industries and seedings, the Concerted Action team produced a poster about the European Concerted Action itself. Alltogether these papers and posters give an up to date (1995) of king scallop cultivation in Europe :

- P.G. Fleury, J.C. Dao, J.P. Mikolajunas, M. Norman and Ø. Strand : European concerted action (1993-95) on scallop seedings (poster).

- P.G. Fleury *et al.* : A study of the recessing behaviour of reseeded scallops, according to three seasons and to three different sizes.

- M. Norman and R. Iudgate : Initial survival of king scallops (Pecten maximus) after seeding out in Connemara bays.

- D. Minchin : Some approaches to the cultivation of the scallop, Pecten maximus, in Irish waters.

- J.P. Mikolajunas : A review of developments in cultivation techniques for the king scallop, Pecten maximus, in Scotland.

- Ø. Strand *et al.* : Development of scallop (Pecten maximus) cultivation in Norway (poster)

Appendix 4 - INITIAL CONDITIONS OF A SCALLOP SEEDING SUCCESS.

Contents :

1. CRITERIA OF SELECTION FOR KING SCALLOP SEEDING SITES.

As king scallop (*Pecten maximus*) seedings are carried out for **extensive cultures**, the choice of the site is an important (if not the main) factor of success. Causes of loss to seeded stocks are numerous and many factors, both natural (biology, ecology), and socio-economic (site use, rights and site security, potential harvesting techniques) must be considered (Pajot, 1984).

1.1. Introduction : biology and extensive rearing of the scallop.

The reproductive cycle, biology and growth of the king scallop (Mason 1957, Buestel and Laurec 1976, Strand and Nylund 1991) and the ecology of its young stages (Minchin 1992) has been well described, and enabled to assess a spat supply for rearing.

Scallops once sown on the sea-floor are subject to many variables, although the effect of all of these are not fully understood there are some features that are known about scallop physiology and behaviour that will greatly aid in the selection of sites for the sowing of scallops : scallops are filter feeders typical of most bivalves, but have an unusual set of characteristics as molluscs : they are capable of **swimming** short distances and **recessing**. They also requires cool well-oxygenated oceanic waters and are sensitive to aerial exposure, to brackish water and to any environmental deterioration (remnant pollutants, phyto-toxins) ; At last they are predated, particularly when small, by various animals especially starfish, crabs, fish and whelks.

Therefore natural scallop beds are found on soft sediment, permanantly covered by seawater (therefore inaccessible by foot) and are rather distant from estuaries (sources of fresh water, pollutants and turbidity). Densities are rather low, as few as 0.1 to 1 scallop /m^2 or less.

The rearing techniques have been well described too (Fleury 1991' 1992). They first **require spat**. Most often, the spat are obtained by collecting in the wild (*Pecten maximus* in

The rearing techniques have been well described too (Fleury 1991' 1992). They first **require spat**. Most often, the spat are obtained by collecting in the wild (*Pecten maximus* in Ireland and Scotland, *Pecten novaezelandiae* in New-Zealand, *Pecten fumatus* in Tamania, *Placopecten magellanicus* in Quebec), sometimes by artificial spawning in hatchery (such as *Pecten maximus* in France and Norway).

Then post-larvae usually need an **intermediate culture** in cages for several months, in order to get a size large enough for seeding. This size ranges from 2 to 5 cm, according to the season and site (Barbeau 1995, Fleury 1996), and mainly to predator abundance (Norman 1995). The larger the seeding size is, the more the juveniles escape to predation. But the probleme of fouling, the poor growth in cages after 5 or 6 cm for *Pecten* sp. and the need of numerous cages at large sizes induce heavy costs and limit the juvenile size at seeding.

Fouling, poor growth and heavy costs in equipment and manpower are also the reasons why **more and more scallops ongrowings turns to seedings** instead of suspended culture (Mikolajunas 1995). Another factor is that, as much as for aquaculture itself, seedings can be carried out for stock enhancement and fishery management, such as for king scallop *Pecten maximus* in France and Ireland (Minchin 1985-b, 1994, Fleury 1992), for *Pecten novaezelandiae* in New-Zealand (Bull 1994), for *Pecten fumatus* in Tamania (Thompson 1995) or for *Placopecten magellanicus* in Nova Scotia (Hatcher 1993) or Quebec (Cliche 1995).

Harvesting requires a boat capable of working large off-shore areas. It is usually achieved by dredging (France, U.K., Ireland, New-Zealand, Tasmania), and to a lesser extent, by diving (Norway, U.K.). These methods limit the workable depth to 80-100 m for the dredges and 20-30 m for the divers.

1.2. Natural criteria.

- Coastal topography, hydrodynamics and sediment.

The coastal topography, hydrodynamics and sediment are 3 closely linked factors, which must be considered so as to avoid juvenile dispersion following seeding and to make recessing easier.

Exposed open bays may not be suitable because of active sediment movements resulting from storm activity or strong current movements encouraging dispersal of stocks outside of the planned cultivation area. Additionally they can have scallop strandings as a result of undertows during storms. On the other hand, closed water areas experience settlement of soft sediments, such as mud, in which scallops bury too deeply, and may be smothered. At last estuaries must also be avoided as they can release significant quantities of pollution and fresh water (even if only at the surface most of the time), increase turbidity and produce strong currents.

Optimal conditions for scallop seabed culture occur in more or less **sheltered bays**. It is considered that currents of less than two knots may be suitable and **about one knot** optimal, providing food and oxygen, and avoiding turbidity. Although scallops are known to occur on a wide range of substrata, more suitable sediments are those linked to these moderate currents : **sandy-muddy, small gravel, maërl,** as they are both soft and stable.

- Extent of the site.

Even if the seeding densities are higher than those on natural beds, they remain quite low : 10 scallops /m^2 seems to be a maximum (Fleury 1992) ; if over, scallops spread away. Site size therefore plays an important role in choosing a site, as extensive aquaculture, with rather low productivity, only be of interest for coastal managements using **large areas** : hundreds of hectares (Bull 1994).

The sea floor expanse where the cultivation occurs may also have a direct effect on the success of the culture operation. Small sowing sites within a bay which is interrupted by reef, boulder fields, etc... may have a different result at harvest to large areas free of rock. Predators may be facilitated for their feeding sojourns if there is adequate cover distributed throughout the bay.

- Depth.

In very shallow bays conditions may be unsuitable because of aerial exposure or wave movements. On the other hand scallops may be found to depths of 180 m but it may be impractical to consider ranching at depths of more than about 50 m. This is because of reduced growth and high rates of dispersion (Gibson 1956). Should diver harvesting be necessary, then depths that can be economically harvested will be a function of scallop density, underwater visibility, current speed and non-decompression limitations on diver time. Most of times 20 or 30 m is a maximum

Generally, shallow depths are more convenient for monitoring and harvesting stocks, but disadvantages will be associated with site use conflicts and stock theft.

- Physical conditions.

At temperatures much below 4 °C scallops become torpid and should this be for sustained periods will die. The upper limitations are about 20 °C but scallops will tolerate temperatures of up to 22 °C for short periods. Optimal temperatures range between **9-17 °C**.

Salinities below 20 ‰ are not tolerated. **Below 28 ‰ growth ceases** and should temperatures be about 5 °C growth can take place down to 26 ‰.. Synergistic effects occures between low salinities and low temperatures (Strand 1993).

Oxygen needs to be **near saturation**.

Turbidity should be low, especielly during the growing season. Many shallow bays may have high levels of turbidity during the winter, but most often turbidity is not a great problem in oceanic water, and in Spring and Summer periods.

- Harmful algal blooms.

At seeding size (2 to 5 cm), juveniles are less sensitive to phyto-toxins than during early stages (larvae and post-larvae). But algae blooms produce anoxia or phyto-toxins (eg, *Gymnodinium* sp.) weakening the animals and producing growth stops and mortalities (Minchin 1985-a, Shumway 1994). Therefore sites where algal blooms occur regularly should be avoided and under no circumstance should seedings take place during an algal bloom incident.

- Community interactions.

The interactions with other members of the benthos also will modify the population dynamics, this is perhaps the least well understood area as these interactions involve many species that have different behaviour patterns (Minchin 1985-b, Barbeau 1994-b).

The sea-grass *Zostera marina* provide stability to the seabed, but eventually hardens the sediment too much, preventing the scallops from recessing following re-seeding. Sea-grass also provides an habitat for small predators (small crustaceans and fish). In addition, in shallow bays and lagoons where there are extensive beds of *Zostera* the levels of dissolved oxygen saturation will vary greatly, with lowest levels during the summer on still nights.

Sowings in such areas should ultimately be retrieved at harvest by diving. Damage to stands of this angiosperm by dredging may result in changes to beach erosion patterns by destabilisation of the seabed.

Competition for food or space from species such as *Mytilus* sp. and *Crepidula fornicata* may render potential sites unsuitable for cultivation. In addition crepidula settle on scallops, making them weaker and produces extra work during harvest and processing. Control of competitors is unlikely to be economically feasible.
Crepidula is especially a probleme in France where it has rapidly invaded large areas of seabed on which it avoids scallop seedings (Halary 1994), but it is also found in Irish waters (Minchin 1995-a).

Predation is known to occur from a wide range of species, **starfish, crabs, lobsters, whelks, fish**, yet several newly discovered predators have been found than range from anthozoa (Minchin 1983) to small spider crabs and gobies that crop tentacles (*Brest field work, 1993*). In general the smaller the scallop, the wider the range of predatory species that feed upon them. Therefore the scallop seedings have to be controlled at the time of seeding and during the first year.

The predators that are of the most significance are those that may feed on a wide size range of scallop sizes such as *Cancer* sp. As for competitors,predator removal is costly and may prove not to be economically viable, in which case the size of the site will be important in terms of the ability to control predators. The larger the site is, the lower the predator attraction may be, but the higher the cost of avoiding predators (potting, ...) may be too.

Usually, spring is a period for high predator activity and may require an increased effort for control, especially as spring may be also interesting for scallop seedings. Therefore it is also a good period for a site predator survey.

1.3. Socio-economic criteria.

Human activities utilising the seashore or the sea-surface may conflict with cultivation activities and must be taken into account, as much as natural factors, for their compatibility with any scallop seeding.

- The site uses and surroundings.

As other species within or around a seeding site may be exploited or available for exploitation, the main interaction to be taken into account is the surrounding fishery. A distinction is needed between **towed gears** (trawl or dredge, usally limited to off-shore activity) which are not conducive to scallop seabed cultivation, and **static gear** (pots and nets, usually located close to the shore) which may help to reduce predator numbers. In fact the interest of potting a scallop site remains uneasy to say, according if potting catches more predators than the bait attracts towards the seeding site.

In general, the influence of all the **coastal industries** needs to be considered, whether the sea is used for its resources (fishing and aquaculture), or for access or mooring (maritime trade, military exercises, yachting) or as an outlet for wastes associated with harmful pollutants (towns, industry, agriculture).

The surroundings activities may result in loss of man-days in policing the site, if not complete exclusion. They also may result in slow growth, bad survival or low selling price due to water quality.

- Water quality.

Water quality needs to be assessed taking into consideration two main factors :

- for the suitability of growth and survival of the scallops (biological quality) ;
- for the growth of food intended for human consumption (sanitary quality).

From a **biological standpoint**, the water needs to be of sufficient quality to promote suitable growth and survival. Therefore, water quality must provide suitable levels of phytoplankton (which is generally linked to the site hydrodynamics) and nutrient (emminating from shore based activities). Factors to be avoided include toxic or residual pollutants such as heavy metals and pesticides (produced through industry and agriculture). It is not often possible to locate the source of such pollutants, although thier prescence is quite readily identified. They can be found in the water but will tend to accumulate in sediments making them more relevant to scallops cultivation.

It is important to note the effects of Tri-butyl Tin (T.B.T.) which used to be found in anti-foulant paints (Minchin 1995-b). Increasingly, the European regulations prohibit the use of these paints for ships, but without substitute products (which are likely to be toxic in order to function as an anti-foulant), T.B.T. based paints are still in use, particularly on large ships. T.B.T. is known to be very remnant in sediment and harmful to phytoplankton and zooplankton (scallop food) and shellfish larvae at very low concentration : 1 ng/l (Alzieu 1989). Therefore it still causes severe problems near commercial and military ports.

With respect to the **sanitary water quality**, scallops feed using filtration and will, therefore concentrate large quantities of micro-organisms. Micro-organisms of human diseases may be accumulated within molluscs and diseases may be passed to consumers if the water is polluted with enteric bacterias (eg; typhoid) or viruses (eg; viral hepatitis). The European regulation on this matter, will only allow direct sale for human consumption, from the best water quality areas (class A : < 300 faecal coliforms/100 ml Mollusc meat). If the contamination is above this level, the animals have to be purified before the marketing (classes B and C), with associated extra costs and an inferior image ; some areas of particularly low quality, are closed to any Mollusc exploitation (class D).

* <u>Aim of the project, legal status of the site and stock security</u>.

The aim of the scallop project, private industry or collective fishery management, and the way the fishermen receive it, play the larger role in the site security. Some fishermen, for instance, may poach the site area, if they don't agree with the scallop seedings (there are several examples where scallops, in research projects, have been exploited). The present or potential legal status of the selected site is also fundamental to a cultivators ability to police a site and ensure stock security (Bouquet 1995).

Certain conditions within the varying legal or licensing conditions impose constraints on the development of low density sowing of scallops on the seabed. The ownership of the seabed is vested in the state and there are conflicts of public ownership involving **collective management** (eg : classified beds), and **private development** (generally associated with a fee), particularly where there is a scallop fishery, marginal though it may be.

The fees due for the licensing of an area may economically overwhelm the viability of a project by adding additional costs at a time before an income is generated from harvesting. It should be possible in time to address these difficulties by means of reasoned approaches.

In most Anglo-Saxon countries (Common Law), the status of the site makes a distinction between exploitation of the body of water using cages or nets (leases) and exploitation of the seabed and its living resources (several fishery orders). Seabed exploitation is more relevant to scallop seedings, but is difficult to obtain without a consensus of other users of the area.

* <u>Potential logistics</u>.

The potential and required logistic supports and facilities have to be assessed in terms of sea and shore-based requirements :

> - Sea requirements include the range from a pier or dock to the site, for the work vessel to be used. The security of the site may be dependant on its visibility from the shore and accessability by vessels.
>
> - On-shore, the availability of land based facilities will require a site with electricity and water (if necessary for handling , packaging etc.), permission to erect a building (shed or handling shelter) and must take into account the distances from a supply of spat (preferrably short distances), processing plants equipment suppliers, staff and markets.

1.4. <u>A proposal of synthesis : ranking the criteria.</u>

Each of the criteria considered when assessing a site, will have a different level of significance placed on it. The level of importance of each criteria will be dependant on the implications to the venture, were the criteria not met. The criteria may be divided into two groups; requirements for seabed cultivation success (basic criteria) and additional benefits toward a successful venture (secondary criteria) (*table A*).

*Table A. - **Ranking the criteria considered to impact scallop seedings.***

BASIC CRITERIA *inducing the seeding **feasibility***	SECONDARY CRITERIA *inducing the **reliability** of the result*
◊ **Sediment suitability :** - stable --> little dispersion of scallops - fine sediment --> enabling recessing. ◊ **Nuisance species :** - a few predators - a few competitors. ◊ **Site security :** - low competition with fishing activities (especially towed gears) - low risks of poaching - compatibility with recreational activities.	◊ **Juridical status :** - title to the seabed (rights on body of the water, the seabed, the living resources ?) - social organisation : individual or collective management ? ◊ **Potential technical support :** - at sea : access to the site, supervision - facilities on shore : pumping, tanks, ... - weather dependency - good communications. ◊ **Adequate water quality :** - current around 1 knot - non-persistent nuisances - no or rare toxic algal events - sanitary quality.

1.5. Conclusion : limitations of the primary criteria and the need for pilot studies in a site selection.

The criteria mentioned above will enable a site to be assessed in terms of its suitability for seabed cultivation. But a large part of unknown still remains about some of the basic criteria, such as predators or site security, for instance.

Then, by investigating the site using acoustic (Magorian 1995), underwater video equipment, diving and small scale pilot seedings (Norman 1995, Fleury 1995, Hatcher 1996), natural and site specific variations to expected results, may be examined before committing larger funds to a venture. Such pilot studies will :

- improve the data relating to sediment, competitors and predators ;

- give a more accurate zoning of the area ;

- eventually enable an assessment of expected juvenile behaviour following small scale seedings monitored over a short period.

Ultimately, the choice of the site has to be confirmed by two or three **pilot seedings** (about 20 000 juvenile can be suggested as large enough to avoid a major part of the site size effect) which is the only way of determining :

- post-seeding behaviour of juveniles : recessing, dispersion ;
- the predator attraction towards the seeding ;
- scallop growth ;
- survival and recapture rates ;
- the causes of mortality : hydrological factors, predators, theft, ... ;
- the level of interest of partners in the seeding and in the industry.

REFERENCES.

Alzieu, C., 1989. L'étain et les organoétains en milieu marin. Biochimie et écotoxicologie. *Rapports Scientifiques et Techniques de l'IFREMER*. **17**. 93p.

Barbeau, M.A., Scheibling, R.E., Hatcher, B.G., Taylor, L.H. & Hennigar, A.W., 1994-a. Survival analysis of tethered juvenile sea scallops (*Placopecten magellanicus*) in field experiments : effects of predators, scallop size and density, site and season. *Mar. Ecol. Prog. Ser.,* **115**: 243-256.

Barbeau, M.A., 1994-b. Predator-prey interactions between juvenile sea scallops *(Placopecten magellanicus*) and predatory sea stars (*Asterias* sp.) and crabs (*Cancer irroratus*). Ph.D. thesis Dalhousie University, Halifax, N.S. (Canada).

Bouquet. J., Benga. S, Even, A., Curtil, O., Fleury, P.G. & Dao, J.C., 1995. Internatioanl juridical survey of scallop industry (fishery and aquaculture). *10th International Pectinid Workshop, Cork (Ireland) May 1995 (poster).*

Buestel, D. & Laurec, A., 1976. Croissance de la coquille Saint-Jacques (*Pecten maximus*) en rade de Brest et en baie de saint-Brieuc. *Haliotis*, **5**: 173-177.

Bull, M., 1994. Enhancement and management of New-Zealand's 'Southern scallop' fishery. *9th International Pectinid Workshop,* Nanaimo, B.C., Canada, 22-27 April 1993. *Canadian Technical* Report of Fisheries and Aquatic Sciences, **2**: 131-136.

Cliche, G., Vigneau, S. & Giguère, M., 1995. Statues of commercial sea scallop (*Placopecten magellanicus*) seeding project realized in the scope of the REPERE programme in Iles-de-la-Madeleine (Québec, Canada). *10th International Pectinid Workshop, Cork (Ireland) May 1995.*

Fleury, P.G., 1989. Le choix d'un site de semis de coquilles Saint-Jacques : le cas du littoral Ouest-Cotentin. *Rapp. Internes IFREMER/DRV 89.032 RA,* 32pp.

Fleury, P.G., Dao, J.C., Caisey, X. & Mingant, C., 1991. King scallop farming in France. (*Poster).* 'Aquaculture Europe '91, Dublin (Eire) 10-12 Jun 1991, *Special Publication of European Aquaculture Society. ISSN 0774-0689,L*, p.103 (*abstract only*).

Fleury P.G. & Dao J.C., 1992. De la pêche à l'aquaculture : l'élevage de la coquille Saint-Jacques (From fishing to rearing : the culture of scallop). *Équinoxe,* **38**. 20-27.

Fleury P-G., Mingant C. and Castillo A., 1996. A preliminary study of the behaviour and vitality of reseeded juvenile great scallops, of three sizes in three seasons. *Aquaculture International* **4**, 325-337.

Gibson, F.A., 1956. Escallops (*Pecten maximus*) in Irish waters. *Sci. proc. Roy. Dub. soc.* (N.S.), **27**: 253-270.

Halary, C., Royer, Y., Corlouer, J.P., & Dao, J.C., 1994. Effects of predation and competition on scallop, *Pecten maximus,* reseeded in Saint-Brieuc Bay : preliminary results. *9th International*

Pectinid Workshop, Nanaimo, B.C., Canada, 22-27 April 1993. *Canadian Technical Report of Fisheries and Aquatic Sciences*, **2**: 39-49.

Hatcher, B.G., Scheibling, R.E., Barbeau, M.A., Hennigar, A.W & Taylor, L.H., 1993. Why not just throw 'em on the bottom ? Seabed seeding of scallops in Nova Scotia. *Proceedings of the 10th annual meeting of the aquaculture association of Canada*, **93-4**: 132-134.

Hatcher, B.G., Scheibling, R.E., Barbeau, M.A., Taylor, L.H., Hennigar, A.W. and Windust, A., 1996. Mortality and dispersion of juvenile sea scallops (*Placopecten magellanicus*) seeded in a tidal channel. *Canadian Journal of Fisheries and Aquatic Sciences* (*in press*).

Magorrian, B., Service, M. & Clarke, W., 1995. An acoustic bottom classification of Strangford Lough. *10th International Pectinid Workshop, Cork (Ireland) May 1995.*

Mason, J., 1957. The age and growth of the scallop *Pecten maximus* in Manx waters. J. Mar. Biol. Ass. U.K., **36**: 473-492.

Mikolajunas, J.P., 1995. A review of developments in cultivation techniques for the king scallop *Pecten maximus* in Scotland. *10th International Pectinid Workshop, Cork (Ireland) May 1995.*

Minchin, D., 1983. Predation on young *Pecten maximus* (L.) (Bivalvia), by the anemone *Anthopleura ballii* (Cocks). *J. Moll. Stud.*, **49**: 228-231.

Minchin, D., 1985-a. Possible effect of an intense algal bloom of *Gyrodinium aureolum* on a year class of escallops (*Pecten maximus*). *5th International Pectinid Workshop,* La Coruña. 6-8 May 1985. 25pp.

Minchin, D., 1985-b. Some considerations in the future management of escallops (*Pecten maximus*) in Connemara bays. *5th International Pectinid Workshop,* La Coruña. 6-8 May 1985. 28pp.

Minchin, D., 1992. Biological observations on young scallops, *Pecten maximus. J. mar. biol. Ass. U.K.,* **72**: 807-819.

Minchin, D., & Ní Donnachada, C., 1994. Optimising scallop sowings for the restocking of an adult population in Mulroy Bay, Ireland. *Proceedings of the 8th International Pectinid Workshop.* Lubet P., Barret J., Dao J.C. (Eds) Actes des Colloques - IFREMER, **17**: 95-100.

Minchin, D., Oehlmann, Duggan, C.B., Stroben, E. & Keatinge, M. 1995-b. Marine TBT antifouling contamination in Ireland, following legislation in 1987. *Mar. Pollut. Bull.,* **30**: 633-639.

Norman, M. & Ludgate, R., 1995. Initial survival of juvenile King scallops (*Pecten maximus*) after seeding out in Connemara bays. *10th International Pectinid Workshop, Cork (Ireland) May 1995.*

Pajot, R. & Dao, J.C., 1984. Etude préliminaire d'un semis de coquilles Saint-Jacques ; résumé des connaissances sur l'environnement de la région dieppoise. *CCI Dieppe.*

Shumway, S.E. & Cembella, A.D., 1994. The impact of harmful algal blooms on scallop culture and fisheries. *9th International Pectinid Workshop,* Nanaimo, B.C., Canada, 22-27 April 1993. *Canadian Technical Report of Fisheries and Aquatic Sciences,* **2**: p.98 (*abstract only*).

Strand Ø. and Nylund A.. 1991. The reproductive cycle of the scallop *Pecten maximus* (L.) from two populations in Western-Norway, 60N and 64N. *In*: Sandra E. Shumway (Editor), An International Compendium of Scallop Biology and Culture. *Spec. Publ., World Aquaculture Society.* s. 95-105.

Strand, O., Solberg, P.T., Andersen, K.K. & Magnesen, Th., 1993. Salinity tolerance of juvenile scallops (*Pecten maximus*) at low temperature. *Aquaculture,* **115**: 169-179.

Thompson, J.D., Fujimoto, T., Moriya, H. & Ikeda, T., 1995. Tasmanian scallop enhancement with *Pecten fumatus. 10th International Pectinid Workshop, Cork (Ireland) May 1995.*

2. LIVE TRANSPORT OF JUVENILE SCALLOPS.

2.1. Introduction : the need of juvenile scallop transportation.

According to the members of the Concerted Action group about scallop seedings, the 3 key factors of a scallop seeding success are :

- the quality of the site ;
- the quality of the animals
- the quality of the know-how and handlings.

But sites are not always convenient for all the stages of the scallop rearing, from hatching to harvest, because the required site criteria differ for hatchery (stable quality of the water), spat collecting (presence of a breeding stock, low current for little dispersion of larvae), intermediate culture (medium current for wild food supply), seeding and bottom ongrowing (sheltered zones, few predators, large free areas).

In addition, hatchery, spat collecting in the wild, intermediate culture and bottom ongrowing are quite different trades, requiring different know-how and different equipments. Then they naturally trend to separate activities with the set up of markets for intermediate products (post-larvae, spat or juvenile).

Therefore the scallop industry requires most often spat or juvenile transportation from hatchery or collector bags to intermediate culture and, later, to seeding sites. These live transports can be very short (1 or 2 hours) if the sites are in the same area (for example, when worked by the same fisherman group) but may also be quite a long haul when the juveniles are sold from a spat producer to an ongrowing group. In same case they even can be an import-export trade. Some shipment trials have been practiced for example from spat collectors in Scotland to Irish or French ongrowers. Success have been very variable : between 0 and 90% of survival !

2.2. Means of transport.

Various means of transport can be convenient with their own pros and cons, but they first have to be shared in two main groups : transports in air ("dry") and transports in water (viviers) :

- **Dry transports** (in wet atmosphere in fact) : van and lorries are the cheapest and carry the loads from door to door without transhipment of cargo. For oversea shipments, plane may be suggested, as quicker, but it is expensive and requires most often connected flights with some wait in a shade or on the tarmac (risk of thermal shock from the wind, or the sun).
- **Vivier transports** (in vivier lorry or vivier ship) looks the best solution for long distances, but requires various equipments in order to prevent shocks, crushing (piling), anoxy, ammonia, thermal shocks, ...

Possibilities and limits of these various means of transport have not really been studied yet.

2.3. Studies.

The development of reliable methods for the haul live transport of commercially viable numbers of juvenile scallops has been identified by both industry and peer review groups to be a research priority both for the stabilisation and further expansion of the European scallop cultivation industry.

The first stage in reducing mortalities during transport has been the clarification of the major stress factors. Death has been shown ultimately to be caused by low oxygen availability and subsequent respiratory dysfunction. Concomitant stresses, as a result of the accumulation of excretory and respiratory waste products and bacteria, temperature shock, desiccation and handling, also have been identified as reducing the tolerance of scallops to low oxygen availability. The magnitude and consequences of these stresses will vary with the transport regime used, the scale of the operation, the husbandry techniques employed before and after transport and the destination of the ongrower site, where conditions may differ from supply areas. For example, post-transport mortalities may occur as a result of thermal shock after export from suppliers in Scotland to the continent, where seawater temperatures are higher. Practical solutions for minimising all these stresses and mortality are required.

For example, in Seafish Ardtoe where the transport has been pointed out as a theme of research, studies have focused upon reducing the stresses resulting from the accumulation of respiratory waste products. The accumulation of respiratory waste products results in a decline in pH, a condition called respiratory acidosis, which damages gill tissues and reduces the affinity of respiratory pigments for oxygen. Some bivalves can counter this effect by mobilising shell carbonates. However, previous studies have shown this capacity to be only partially present in scallops, which can consequently suffer high mortality both during and after transportation, placing constraints upon the transport of stock at high densities.

The potential for maintaining appropriate pH levels using Tris/HCl based buffers was investigated both in immersed (water) and emersed (air) transportation trials. Results have shown that buffers can maintain appropriate pH levels, can enhance post-transport survival and do not have any discernible short-term lethal effects. The inclusion of buffers potentially also may allow for the transport of juveniles at higher stocking densities. The legislation regarding the use of buffers in the live transport of juvenile scallops in the U.K. is not particularly restrictive (Schedule 5 of the Bivalve Molluscs Regulations 1992 -SI 3164- and the Bivalve Molluscs (Import Controls and Miscellaneous Provisions) Regulations 1994 -SI 2782) although some stipulations under the Shellfish Hygiene Directive regarding the tainting of shellfish may apply. If the buffer is readily depurated by the time of harvesting (for consumption) the process would be acceptable.

In IFREMER (France) studies aimed to find indexes to measure the decrease of vitality in animals (see annexe 'Vitality of juvenile scallop). Beside chemical indexes such as the Energetic Adenylic Charge (ratio of phosphore energetic links), more simple indexes looks quite significant and reliabe, such as the muscle strength or the uprighting abilty.

Future cooperation will involve an integrated approach to monitoring all identified stresses during long haul commercial scale (100, 000) transport trials (both immersed and emersed) from Scotland to France. Special focus will be paid to :

- husbandry techniques and the merits of pooling animals before transport ;
- cold temperature transport for reducing rates of metabolism, and thereby the rate of pH decline, ammonia accumulation and oxygen depletion ;

- determining the thermal tolerance range of scallops, to establish suitable transport temperatures and to assess the importance of temperature shock upon mortality ;

- the effects of seasonal variations in the condition of scallops upon transport mortalities.

- comparison between transports in water and dry ones (in wet atmosphere in fact).

3. JUVENILE SCALLOP VITALITY AT SEEDING.

3.1. Introduction.

Scallop handlings and on-bottom seedings (with air exposure, thermal shocks, swimming, predator escape, recessing) induce stresses which, according to initial quality of the animals, have very various impacts on their ability to survive on the seabed.

Stress has been defined in fish as "the reaction of an organism by a disturbed physico-biological balance to an abnormal impact of the environment" (Dhert 1993). Stress is quite obvious when it has lethal effects with part of (or all) animals dying quite soon after the stress. In fact that is the method used to quantify most of toxic pollutants : lethal dose inducing 50% of animals within 24 hours (LD50-24 h). But most often stress has **sublethal consequences** causing a reduced or negative scope for growth, and generally decreasing the animal's vitality. A short trouble may even have no visible effect on animals (no mortality, no significant reduced growth), but may make them nearly to die. Stresses also have to be divided into short term stresses requiring an immediate ability to respond (**vitality**) and long term stresses requiring sustained quality **(stamina)**. Short term stresses can be an air exposure, handling, transportation, seeding, escaping a crab attack. Long term stresses can be winter, chronic pollution, adverse conditions in intermediate culture, reduced food (such as high density storages). Effects and indicators may differ between these 2 categories.

The first part of the scallop ability to survive a seeding is the animal size. The suitable seeding size appears to be very various according to the sites (softness of sediment, strength of current, activity of predators) but also to the national practices. In France 2 mm post-larvae from hatchery require an intermediate culture in cages till 25-30 mm before seeding. This seeding size is lightly larger (30-40 mm) in New-Zealand with a very close species (Pecten Novae-Zelandiae). In Ireland, Scotland and Norway, where the sites are wilder with numerous predators (little fishery of them), seeding size used to be 50 mm. Some farmers in Scotland, even grow wild collected spat in intermediate culture up to 60-80 mm before seeding. And in Norway wild collected stock (40-100 mm) are relayed (seeded) on bottom culture. In conclusion a wide range of scallop sizes are seeded on seabed cultivation. Animal origin (genetical pattern, food richness of the site) and culture conditions are also involved in the initial juvenile quality.

Members of Scallop European Concerted Action (1993-96) all agree **this initial quality of animals is a main point in seeding success.** The probleme of quality at seeding can be divided in three main phases : the animal's quality before seeding, loss of quality due to seeding and recovery capacity. But these quality aspects have **to be quantified**. The scientist or farmer only looks at empirical and subjective estimations, such as noise (shell full or empty), aspect (flesh bright or dull), valve clappings (numerous or rare), which cannot give any serious comparison between batchs or between seeding practices.

3.2. Objective.

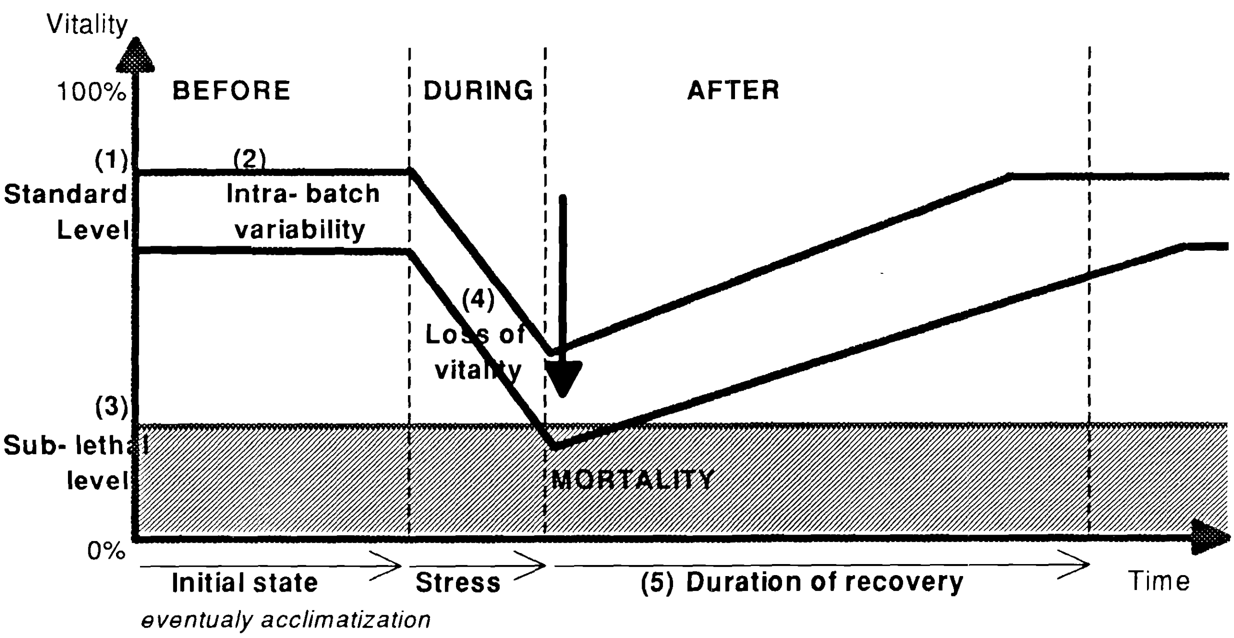
The first objective is to **get a test or a tool** (eventually several tests) which permit us to quantify the quality (vitality) of scallop juveniles.
As any measuring apparatus this test has to be :

- **reliable** : the exact same stress has to give the same response ;
- **significant** : a range of stress has to give a range of responses.

A reliable and significant test has to be as **simple** and **quick** as possible, in order to be able to get numerous and individual data (large variations in a same batch), and to be **non-lethal**, in order to monitor the vitality of each animal before and after the stress (statistical method of couples).

Therefore the objective is to get reference data about (1) the standard quality of juveniles before seeding, (2) intra-batch variability, (3) sub-lethal level where problemes may occure (4) loss of quality due to stress and (5) duration of recovery (*figure 1*). The final aim is to improve juvenile quality before seeding (correct density, food), at seeding (handling, anaesthetics) and after seeding (site preparation, predator control).

Figure 1 - **STRESS and RECOVERY**



3.3. Background (state of Art)

Animal quality is a complex subject, even paradoxical between general condition or stamina (active metabolism, growth, energetic stocks) and vitality or aptitude to sudden new environment.

The Concerted Action group has separated the quality criteria into 4 main sorts :

- husbandry criteria (growth and survival) ;
- behavioural criteria ;
- biochemical criteria ;
- physiological criteria.

- Husbandry criteria.

The husbandry criteria are the ones classically employed by the farmer to evaluate the success of his rearings, in other words economical criteria, that is to say survival rate and growth (including morphology).

Survival : the first criteria of course is survival.

- either the ***mean survival rate of a batch***, which is a non-individual criteria and difficult to estimate in the wild (dispersal of animals) ;

- or the ***individual duration of survival,*** after a stress (Eertman *et al.* 1993 for the blue mussel). The exact time of animal death is also difficult to get, but can be estimated by the observation of sub-lethal behaviour, such as gaping valves or absence of reaction when touched (Strand *et al.* 1993). Because it is lethal, this criteria cannot be used to study the recovery stage or to compare different stresses with the same animal. However this simple criteria can be used to test reliability and sensitiveness of other indices.

Growth : a second type of criteria is growth (length or weigh) with different possible indices.

- ***condition index.*** Various condition indices (weight /volume, or more easily : weight /length x height x thickness, ...) have been proposed for Bivalves, most often in adults (Crosby and Gale 1990), sometimes in spat (Walne and Millican 1978). However the fresh weight of Bivalves is quite difficult to get since the inter-valve liquid can vary in weight according to the way the animals are drained. The difficulty increases for scallops, the valves of which are not very tight and hardly keep the inter-valve liquid.

- ***daily growth rings*** : Eventually stress gives obvious thick ring or shell deformation when spat is under 10-15 mm. This stress can be quantified in several stages according to ring aspect (Antoine 1978, Baillon 1992). Unfortunately it is less obvious with juveniles (20-40 mm), and we can only quantify the stress duration rather than its intensity.

Morphology :

- ***shell deformations*** can be observed on young spat when stressed by a toxic phytoplankton environment, such as Gyrodinium sp. blooms (Erard-LeDenn *et al.* 1990), but such deformations remain very specific and difficult to quantify.

- ***calcification abnormalities linked to brown shell coloration.***: Calcification abnormalities have been observed on scallop shells , suffering from environmental stress conditions (Larvor *et al.* 1993). These abnormalities can be rapidly detected on internal shell layer of young scallop, using microstructural observations and spectral analysis of the reflectance. This criteria remains complex but could be quantified and may be non-lethal (just requiring a small sample from the edge of shell).

- Behaviour criteria.

Scallop is quite an active animal, compared to other Bivalves, which permits some observations in its behaviour.

- ***spat re-settlement*** : till 10 mm spat attaches to substratum with its byssus, an can do it again if detached. The mean attachment rate of a batch or the mean duration for re-settling are simple criteria and seem quite significant (student studies in University College Cork and in IFREMER Brest). Unfortunately, juveniles loose their byssus after 10 mm and this criteria, which is useful to study the transfer of post-larvae, is not available for seeding studies.

- ***recessing in the sediment*** : First field work of Scallop Concerted Action (Brest, October 1993) has monitored, with divers and remote-video, the recessing of juveniles in the sediment. The recessing behaviour can be easily described by four or five stages (Fleury *et al.* 1996). As for animal survival or spat re-settlement, it can be monitored by batch (mean recessing rate after 2 or 3 days) or individually (recessing stage day after day). In the wild this criteria depends on sediment type, water movements, predator, attacks, ... This criteria is probably more significant when sediment is smooth (sandy-muddy). As for the survival, we may use it to estimate the reliability and significance of other potential quality indices.

- ***filtration renewal*** : Second criteria monitored by Concerted Action group at Brest field work is filtration renewal after seeding. It appeared that this one comes very soon after seeding, that the different stages are not easy to separate and that scallops often close as divers approach. Therefore this critera has been given up in the wild. However it can be used at laboratory if animals are in a quiet place and carefully observed. (Strand *et al.* 1993).

- ***swimming activity***. The swimming ability is quite rare in Bivalves, excepted in Pectinids. Swimming activty of scallops has been described since long (Baird 1958). The ability to swim (duration, frequency) on certain stimuli should reflect the vitality (and ability to escape to predators). Swimming activity according to pre-seeding stress (handling and so) can be monitored by video in tanks. But some PhD student's experiments in Bergen showed no significant effect of the emersion treatment of 12 hours on swimming activity. Therefore this criteria may not be significant, in addition with its great need of standardisation.

- ***valve movements*** : another way to look at filtration or activity of scallops is to observe the valve movements which can be monitored on a data recording cell (distance between valves). Such monitorings are usually set up with mussels in order to observe behaviour of animals according to sea water pollution (Kramer *et al.* 1989). First trials with scallops in IFREMER (France) do not seem sensitive to animal quality, because the responses are very "flat".

- ***righting behaviour*** : the righting behaviour of scallops when turned upside down may be quite a simple criteria, because the duration before turning over increases with weakness of animals (IFREMER Brest, first trials). The litterature is very poor about this criteria. Studies currently in progress (in IFREMER Brest and University College Cork) would set the range between duration and weakness.

• Biochemical criteria.

First field work of Concerted Action has also monitored juvenile stress at seeding with successive samplings for biochemical analysis. The choice of analysis may differ according to long term quality (then long term store products such as proteins, lipids and carbohydrates should be recommanded) or immediate vitality (then energy storage and expenses have to be regarded). The choice of the organ is important too : in scallop, the muscle with nutrient storage and energy supply seems to be the most appropriate.

- ***organic stocks (proteins, lipids and carbohydrates)*** are mainly stored in the striated part of the muscle (long fibres) which is therefore the best organ to analyse. The main variations are observed in the glycogen rate (Vazquez-Baanante and Rosell -Perez 1979)

- ***adenylic energetic charge (A.E.C.)*** which represents the energy that can be immediately used by scallop (quick energy used in valves clapping for swimming and recessing) is also mainly stored in the striated part of the muscle (long fibres). So it seemed quite convenient for assessing scallop vitality at seeding (swimming and recessing), although it needs heavy equipment and analysis, e.g. storage in liquid nitrogen, long chemical extraction and high performance liquid chromatography for analysis (Moal *et al.* 1989). This criteria has been studied in IFREMER (France) and Bergen University (Norway). It seems that scallops have a very high capacity to "refill" A.E.C. in the striated muscle. Some analysis of A.E.C. in the smooth part of the muscle (short fibers) presented a larger range of data (0.5 tà 0.95) but this has to be confirmed.

- ***octopine.*** Level of phosfo-kreatin, the precursor of A.T.P or a product of the A.T.P.<---> A.D.P. process like octopine might be a better (and easier, less expensive) index (Gäde *et al.* 1978) but none of these indices have been studied in the Concerted Action teams.

In addition, these biochemical indices are obviously lethal and uneasy for individual monitoring, then should lack sensitiveness.

• Physiological criteria.

Physiological index in scallop have been poorly studied.

- ***oxygen consumption*** : this criteria expresses metabolism. As for growth it explains an active metabolism more than an aptitude to stress.

- ***compensation to hypoxy*** : On the other hand the abilty to regulate oxygen consumption according to the oxygen level in water seems to be a necessary attribute for adaptating to a new environment. Scallops are generally poor oxygen regulators (Bricelj and Shumway 1991), and a critical value where oxygen consumption becomes dependent of ambient tension was determined for *Pecten maximus* to be approx. 50% at 10°C (Brand and Roberts 1973).

- ***muscle strength*** : for muscle has an essential role in scallop (storage of energy, especially immediate energy for valves clapping in striated part) scallop vitality should be evaluated with muscle strength and its loss along seeding stress. An instrument able to record this strength evolution on a data recording cell is to be studied in IFREMER Brest (France).

- ***cardiac rythm*** : Cardiac rythm may be modified by environmental and endogenous physiological factors (Benninger and Le Pennec 1991) and resting heartbeat frequency for *Pecten maximus* have been measured by Brand and Roberts (1973).

Physiological indices seem to be more reliable and significant than biochemichal analysis. Overall they are non-lethal, and so far can be monitored on individual scallop. But they have been poorly studied in scallops.

Futural cooperation works would set up a diagnostic test (as simple and cheap as possible) for individual animal quality measurements, which then can give a rapid dagnostic (< 1 hour) of mean quality of a batch (20-30 animals). This tool has first a scientific use for Bivalves studies (scallop, but with little adjustments : oyster, mussel, clam, ...). If very simple, it also could be used as a professional tool for the farmer (control of the rearing practices) and for commercial transactions between spat collectors and ongrowers.

REFERENCES.

Antoine L., 1978. La croissance journalière chez *Pecten maximus* (Daily growth in *Pecten maximus*). 4e Congrès de la Société Française de Malacologie. in *Haliotis* **9/2**: 117-126

Baillon N., 1992. Analyse des stries de croissance des post-larves de coquille Saint-Jacques *Pecten maximus* ; méthodologie et perspectives d'application pour la description de stress d'élevage. (Study of growth rings in scallop *Pecten maximus* post-larvae ; methodology and prospect of application for the description of stresses in rearing). *Rapport Interne IFREMER* /DRV 92.003.

Baird R.H., 1958. On the swimming behaviour of escallops (*Pecten maximus*). Proc. Malac. Soc. Lond. **33**: 67-71.

Benninger and Le Pennec M., 1991. Functional anatomy of scallops. In Scallops : Biology Ecology and Aquaculture. Shumway S. (ed), *Developments in Aquaculture and Fisheries Science*. **21**: 133-209.

Bricelj and Shumway S., 1991. Physiology: Energy aquisition and utilization. In Scallops : Biology Ecology and Aquaculture. Shumway S. (ed), *Developments in Aquaculture and Fisheries Science*. **21** :305-337.

Brand A .R. And Roberts D., 1973. The cardiac responses of the scallop *Pecten maximus* to respiratory stress. *J. Exp. Mar. Biol. Ecol.* **13**: 29-43.

Crosby M.P. & Gale L.D., 1990. A review and evaluation of bivalve condition index methodologies with a suggested standard method. *J. Shellfish Res.* **9/1**: 233-237

Dhert P., Lavens P., Sorgoloos P. 1993. Stress evaluation : a tool for quality control of hatchery-produced shrimp and fish fry. *Aquacult. Eur.* **17/2**: 6-10.

Eertman R.H.M., Wagenvoort A.J., Hummel H. and Smaal A.C., 1993 - Survival in air of the blue mussel *Mytilus edulis* as a sensitive response to pollution-induced environmental stress. *J. Exp. Mar.Biol. Ecol.* **170**: 179-195.

Erard-LeDenn E., Morlaix M. and Dao J.C., 1990. Effects of *Gyrodinium* cf. *aureolum* on *Pecten maximus* (post-larvae, juveniles and adults). In : Toxic Marine Phytoplankton pp. 132-136 (Graneli E., Sundström B., Edler L. and Anderson D.M. (Eds). New York: Elsevier/North Holland.

Fleury P-G., Mingant C. and Castillo A., 1996. A preliminary study of the behaviour and vitality of reseeded juvenile great scallops, of three sizes in three seasons. *Aquaculture International* **4**: 325-337.

Gäde G., Weeda E. and Gabott P.A., 1978. Changes in the level of octopine during the escape responses of the scallop *Pecten maximus. J. comp. Physiol.* **124**: 121-127.

Kramer K.J.M., Jenner H.A. and DE Zwart D., 1989. The valve movement response of mussels : a tool in biological monitoring. *Hydrobiologia* **188/189**: 433-443.

Larvor H., Cuif J-P., Devauchelle N., Dauphin Y., Denis A., Gautret P. and Marin F., 1993 - Development of brown internal coloration in the scallops shell (*Pecten maximus*). Study of microstructural characteristics and analyses of crystal organic matrices. *(in press) Bull. Inst.*

Océ. Monaco, 7th International Symposium on Biomineralisation, 17-20 nov. 1993, Monaco, France.

Moal J., Le Coz J. R., Samain J. F., Daniel J.Y. (1989). Nucleotides in Bivalves: Extraction and Analysis by High Performance Liquid Chromotography (HPLC). *Comp. Biochem. Physiol.* **93B, 2**: 307-316.

Strand Ø., Solberg P.T., Andersen K.K. and Magnesen Th., 1993 - Salinity tolerance of juvenile scallops (Pecten maximus) at low temperature. *Aquaculture* **115**: 169-179.

Vazquez-Baanante I. & Rosell -Perez M., 1979. (Seasonal fluctuations of the glycogen in the adductor muscle of the Pecten maximus). *Invest. Pesq. (Barc.)* **43/2**: 409-416

Walne P.R. & Millican P.F., 1978. The condition index and organic content of small oyster spat. *J. Cons. CIEM.* **38/2**: 230-233

Appendix 5 - MAIN PUBLICATIONS OF THE SCALLOP CONCERTED ACTION MEMBERS.

Contents :

1. BIOLOGY OF SCALLOPS

Maguire J., Fleury P.G. and Burnell G., 1997. A method for quantifying scallop quality. *11th. International Pectinid Workshop, La Paz (Mexico), 10-15 April 1997.*

Minchin D., 1983. Predation on young *Pecten maximus* (L.) (Bivalvia), by the anemone *Anthopleura ballii* (Cocks). *J. Moll. Stud.,* **49**: 228-231.

Minchin D., 1992. Biological observations on young scallops, *Pecten maximus. J. mar. biol. Ass. U.K.,* **72**: 807-819.

Strand Ø. and Nylund A., 1991. The reproductive cycle of the scallop *Pecten maximus* (L.) from two populations in Western-Norway, 60N and 64N. *In*: Sandra E. Shumway (Editor), An International Compendium of Scallop Biology and Culture. *Spec. Publ., World Aquaculture Society*. s. 95-105.

Strand Ø., Solberg P.T., Andersen K.K. and Magnesen T, 1993. Salinity tolerance of juvenile scallops (*Pecten maximus*) at low temperature. *Aquaculture,* **115**: 169-179.

2. SCALLOP CULTURE

Buestel D., Cochard J.C., Dao J.C. and Gérard A., 1982. Production artificielle de naissain de coquille Saint-Jacques, *Pecten maximus* ; premiers résultats en rade de Brest (*artificial production of scallop spat, Pecten maximus ; first results in Brest Bay*). *Vie Marine,* **4**: 24-28.

Caisey X., Fleury P.G. and Vincent G., 1992. Coquilles de semis / Scallops from seedings. *Video film* (French and English versions). IFREMER production. 12 minutes

Dao J.C.,1986. La coquille Saint-Jacques en Bretagne (*King scallop in Brittany*). In *Aquaculture Tec. et Doc.* Lavoisier ed. 428-439.

Dao J.C., Buestel D., Gérard A., Halary C. and Cochard J.C., 1985. Le programme de repeuplement de coquilles Saint-Jacques *(Pecten maximus* L.*)* en France : finalité, résultats et perspectives (*The programme of re-stocking scallops (P. maximus) in France : aims, results, perspectives*). Colloque franco-japonais d'océanographie. Marseille septembre 1985.

Dao J.C., Barret J., Devauchelle N., Fleury P.G., and Robert R., 1995. Rearing of *scallops (Pecten maximus*) in France, from hatchery to intermediate culture ; results of a 10 years programme (1983-1993). *Workshop on fish and mollusc larviculture."Improvement of the commercial production of marine aquaculture species". Puerto Montt (Chile), 5-9 December 1994. (in press).*

Fleury P.G., Dao J.C., Caisey X. and Mingant C., 1991. King scallop farming in France. (*Poster). 'Aquaculture Europe 91', Dublin (Ireland) 10-12 Jun 1991, Special Publication of European Aquaculture Society. ISSN 0774-0689,L*, p. 103.

Fleury P.G. and Dao J.C., 1992. De la pêche à l'aquaculture : l'élevage de la coquille Saint-Jacques (*From fishery to aquaculture : the culture of scallop.*). *Équinoxe* **38***:* 20-27.

Fleury P.G., Halary C. and Dao J.C., 1995. The intermediate culture of *Pecten maximus* in Brittany (France). In 'Fisheries, biology and aquaculture of Pectinids'. 8th *International Pectinid Workshop, Cherbourg (France) 22-29 May, 1991.* Lubet P., Barret J., Dao J.C. (Eds) Actes des Colloques - IFREMER **17**: 103-110.

Fleury P.G., Mingant C., Philippe R. and Budimawan, 1996. Transfer of scallop (*Pecten maximus*) post-larvae from hatchery-nursery to off-shore cages : stress and re-settlement. *Oral presentation at International symposium on settlement and metamorphosis of marine invertebrate larvae. Plymouth (U.K.), 15-18 July 1996.*

Mikolajunas J.P., 1995. A review of developments in cultivation techniques for the king scallop, *Pecten maximus,* in Scotland. *10th. International Pectinid Workshop, Cork (Ireland),. 27 Apr.- 2 May 1995.*

Minchin D., 1995. Some approaches to the cultivation of the scallop, *Pecten maximus,* in Irish waters. *10th. International Pectinid Workshop, Cork (Ireland),. 27 Apr.- 2 May 1995.*

Norman M., 1997. Structures for scallop ranching. An Ireland perspective. *11th. International Pectinid Workshop, La Paz (Mexico), 10-15 April 1997.*

Strand Ø. and Mortensen S. 1995. Stort kamskjell. Biologi og dyrking. (*The king scallop, biology and cultivation*) *Kystnæringen forlag*, ISBN 82-7595-013-9. 84 pp.

Strand Ø., Andersen S., Eiken G., Hanson S., Magnesen T. and Mortensen S.H., 1995. Development of scallop (*Pecten maximus*) cultivation in Norway (*poster*). *10th. International Pectinid Workshop, Cork (Ireland), 27 Apr.- 2 May 1995.*

Strand Ø. 1996. Enhancement of the bivalve production capacity in a landlocked heliothermic marine basin. *Aquaculture Research,* **27**: 355-373.

3. SEABED CULTIVATION AND PREDATION

Buestel D. and Dao J.C., 1979. Aquaculture extensive de la coquille saint-Jacques : résultats d'un semis expérimental (*Extensive aquaculture of the scallop : results of an experimental seeding*). La Pêche Maritime **1215**: 363-368.

Dao J.C., Fleury P.G., Norman M., Lake N., Mikolajunas J.P. and Strand Ø., 1994. Concerted Action on scallop sea bed cultivation in Europe. intermediate report n°1 (work 1993). Specific Communauty programme for research, technological development and demonstration in the field of agriculture and agro-industry, inclusive fisheries. AIR 2 - CT 93 - 1647. 40 p.

Dao J.C., Fleury P.G., Norman M., Mikolajunas J.P. and Strand Ø., 1996. Concerted Action on scallop sea bed cultivation in Europe. intermediate report n°2 (work 1994). Specific Communauty programme for research, technological development and demonstration in the field of agriculture and agro-industry, inclusive fisheries. AIR 2 - CT 93 - 1647. 52 p.

Dao J.C., Fleury P.G., Norman M., Mikolajunas J.P. and Strand Ø., 1997. Concerted Action on scallop sea bed cultivation in Europe. intermediate report n°3 (work 1995/96). Specific Communauty programme for research, technological development and demonstration in the field of agriculture and agro-industry, inclusive fisheries. AIR 2 - CT 93 - 1647. 51 p.

Dao J.C., Barret J. and Fleury P.G., 1997. Scallop (*Pecten maximus*) seabed cultivation in the bay of Brest (France). *11th. International Pectinid Workshop, La Paz (Mexico), 10-15 April 1997.*

Fleury P.G., Dao J.C., Mikolajunas J-P. and Strand Ø., 1995. European concerted action (1993-95) on scallop seedings (*poster*). *10th. International Pectinid Workshop, Cork (Ireland),. 27 Apr.- 2 May 1995.*

Fleury P.G., Mingant C. and Castillo A., 1996. A preliminary study of the behaviour and vitality of reseeded juvenile great scallops, of three sizes in three seasons. *Aquaculture International* **4**, 325-337.

Halary C., Royer Y., Corlouer J.P. and Dao J.C., 1994. Effects of predation and competition on scallop, *Pecten maximus*, reseeded in Saint-Brieuc Bay : preliminary results. *9th International Pectinid Workshop,* Nanaimo, B.C., Canada, 22-27 April 1993. *Canadian Technical Report of Fisheries and Aquatic Sciences,* **2**: 39-49.

Haugum G.A., Strand Ø., Svardal A. and Mortensen S., 1997. Survival and behaviour of scallops (*Pecten maximus*), after transfer to the seabed - effect of emersion treatment. *11th. International Pectinid Workshop, La Paz (Mexico), 10-15 April 1997.*

Minchin D., 1991. Decapod predation and the sowing of the scallop, *Pecten maximus*, In : Shumway, S.E., Sandifer, P.A. (eds) An international compendium of scallop biology and culture. *World Aquaculture Workshops No.1. World Aquaculture Society, Baton Rouge,* pp. 191-197.

Norman M. and Ludgate R., 1995. Initial survival of juvenile king scallops, *Pecten maximus*, after seeding out in Connemara bays. *10th. International Pectinid Workshop, Cork (Ireland),. 27 Apr.- 2 May 1995.*

4. ECONOMICS

Bouquet J., Benga S., Even A., Curtil O., Fleury P.G. and Dao J.C., 1995. International juridical survey of scallop fishery and aquaculture (*poster*). *10th. International Pectinid Workshop, Cork (Ireland),. 27 Apr.- 2 May 1995.*

Dao J.C., Fleury P.G. and Paquotte Ph., 1992. La filière d'élevage de la coquille Saint-Jacques : éléments de réflexion pour l'évaluation économique (Scallop rearing : elements for an economical evaluation).*Équinoxe* **37**: 4-18.

Dao J.C., 1995. L'exploitation des Pectinidés dans le monde (T*he exploitation of Pectinids in the world*). In 'Fisheries, biology and aquaculture of Pectinids'. 8th *International Pectinid Workshop, Cherbourg (France) 22-29 May, 1991.* Lubet P., Barret J., Dao J.C. (Eds) Actes des Colloques - IFREMER **17**: 1-27.

Paquotte Ph. and Fleury P.G., 1994. Production costs in French scallop farming. *Proceedings of the 9th International Pectinid Workshop, Nanaimo, B.C. (Canada), 22-27 April 1993, Canadian Technical Report of Fisheries and Aquatic Sciences 1994,* **2**: 66-75.

Strand Ø., Eiken G. and Mortensen S.H., 1997. The Norwegian Scallop Programme. In the point of intersection between research and development of a new industry (*poster*). *11th International Pectinid Workshop, La Paz (Mexico), 10-15.Apr. 1997.*