ACTES de COLLOQUES - n° 17 - 1995

8th International Pectinid Workshop
8e Atelier international sur les Pectinidés
Cherbourg (France), 22-29 mai 1991

FISHERIES, BIOLOGY and AQUACULTURE of PECTINIDS

PÊCHES, BIOLOGIE et AQUACULTURE des PECTINIDÉS

UNIVERSITÉ de CAEN - Équipe de biologie et biotechnologies marines
IFREMER - Laboratoire de recherche aquacole, Centre de Brest

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8th INTERNATIONAL PECTINID WORKSHOP
8e ATELIER INTERNATIONAL SUR LES PECTINIDÉS
CHERBOURG (FRANCE), 22-29 mai 1991

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UNIVERSITE DE CAEN
BASSE-NORMANDIE

Le

8e Atelier International
sur les "Pectinidés"

s'est tenu à

CHERBOURG, du 22 au 29 mai 1991

Il a été organisé par

L'UNIVERSITÉ DE CAEN
Équipe de biologie et de biotechnologies marines

et

L'IFREMER
Direction des ressources vivantes - Brest

avec l'appui de

LA VILLE de CHERBOURG

LA RÉGION de BASSE-NORMANDIE

et la collaboration de

LE COMITÉ RÉGIONAL DES PÊCHES MARITIMES
de BASSE-NORMANDIE

LE COMITÉ LOCAL des PÊCHES du NORD COTENTIN

8TH INTERNATIONAL PECTINID WORKSHOP

8ème Atelier International sur les Pectinidés

Cherbourg - France - 1991

L'Atelier "Pectinidés" est né en 1976, sous l'impulsion de deux chercheurs travaillant sur la coquille Saint-Jacques, l'un en Écosse et l'autre en Irlande. La première réunion s'est tenue en Irlande, dans une ambiance chaleureuse et passionnée, regroupant une quarantaine de participants, chercheurs, enseignants et étudiants. C'était l'époque du début de l'aquaculture en Europe, les perspectives semblaient sans limites. Mais les connaissances étaient encore embryonnaires et les démarches empiriques. La référence incontestable était représentée par le Japon qui démarrait alors depuis quelques années un spectaculaire développement d'une espèce voisine.

Cette réunion s'est avérée être un forum particulièrement animé et positif sur l'ensemble des thèmes abordés, non seulement l'aquaculture, mais aussi la pêche et la biologie des Pectinidés. Il a alors été décidé de reconduire ces rencontres, en maintenant le style informel, un rythme pas trop fréquent, et en ouvrant l'Atelier aux chercheurs d'autres pays, d'autres espèces, sur toutes les problématiques d'aménagement. Le président serait chargé de l'organisation de la réunion à venir.

L'Atelier "Pectinidés" s'est ainsi successivement déplacé à Brest (1978), à l'île de Man (1981), à Aberdeen (1983), à La Corogne (1985), à Menai Bridge (1987). Il est sorti d'Europe pour les États-Unis, à Portland (1989). Chaque réunion a permis d'accueillir de nouveaux résultats, plus rigoureux, plus thématiques au fur et à mesure que se sont affinées les connaissances sur les mollusques bivalves en général et les Pectinidés en particulier. Le rapport entre les communications sur les expériences zootechniques de captage de naissain et d'élevage, sur l'évolution des pêcheries et celles sur la physiologie, la nutrition, la pathologie et la génétique s'est inversé au profit des recherches thématiques. Mais l'ambiance enthousiaste de communication, d'échanges, s'est soigneusement maintenue et a fait la réputation internationale de cet Atelier, qui s'est choisi comme période le début du printemps boréal, cette intersaison permettant de satisfaire la majorité des calendriers d'expérimentation sur le terrain, hémisphère sud compris.

C'est au Professeur Pierre Lubet, de l'Université de Caen qu'est revenu l'honneur d'organiser en France la réunion de 1991. Il a choisi la ville de Cherbourg en raison des avantages que lui offraient la région de Basse-Normandie, le département de la Manche et la ville de Cherbourg, très tournée vers les activités maritimes et pratiquant la pêche de la coquille Saint-Jacques. Plus de cent chercheurs, en provenance d'une vingtaine de pays des quatre coins du monde, se sont retrouvés pendant une semaine pour débattre des thèmes sur les pêches des différentes espèces, les essais et les développements aquacoles, les équilibres écologiques de ces ressources et les bases biologiques de la famille des Pectinidés.

Le regroupement des communications ne permet qu'une appréciation imparfaite des échanges. On peut cependant mesurer la somme de travail sous-jacent, autant dans la progression des connaissances sur la biologie, l'écologie et les techniques de pêche et d'élevage, que dans le développement des productions : l'aquaculture s'est maintenant hissée à une place de premier plan, dépassant en volume celle des pêches.

8TH INTERNATIONAL PECTINID WORKSHOP

Cherbourg - France - 1991

The first pectinid workshop was initiated in 1976 by a team of scientists working on the sea scallop and its related species. This research group was then relatively small, composed mainly of European nationals.

The fist meeting was held in Ireland for a period of one week. It resulted in a very positive interaction among the participants, discussing such topics as aquaculture, fisheries and the biology of these bivalves. Due to this initial success, it was decided that meetings were to be held every two years in a similar informal style. However, invitations for participation were extended to scientists of other countries such as Japan, U.S.A., Canada, South America, Australia and New Zealand.

The 7th Workshop brought together over one hundred researchers in Portland, U.S.A. It ended, as tradition demands, with the election of the new president, responsible for the following meeting. At this time, Professeur Pierre Lubet was awarded the honour to organize the 1991 meeting in France. Professeur Lubet chose the city of Cherbourg due to the advantages offered by the region of Basse-Normandie, the Department of La Manche and Cherbourg itself.

One hundred scientists, coming from approximately twenty countries including China and the USSR, met in Cherbourg May 22-29, 1991. The main themes of discussion were:

- *Fisheries status for various pectinid species*
- *Aquaculture development and trials*
- *Reproduction, growth, nutrition and genetics of pectinids*

8th International Pectinid Workshop. Cherbourg (France) May 22-29, 1991
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Abstracts

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INTRODUCTION

L'EXPLOITATION DES PECTINIDÉS DANS LE MONDE

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Les Pectinidés, qui appartiennent à la famille des mollusques bivalves comprenant la coquille Saint-Jacques, sont activement exploités dans différents pays, répartis pour la plupart dans les zones froides ou tempérées. Depuis le début des années 1970, la situation a considérablement évolué en raison de deux composantes opposées : la surexploitation par la pêche et le développement de l'aquaculture dans certains bassins de production.

LES RESSOURCES NATURELLES EXPLOITÉES.

Les Pectinidés exploités sont des animaux benthiques que l'on trouve sur des substrats divers, de préférence meubles (sablovaseux à gravier). Ils ont des durées de vie extrêmement variables, certaines espèces disparaissant dès la seconde année, d'autres pouvant se maintenir pendant une vingtaine d'années. Le cycle biologique comporte une phase planctonique à partir de l'émission des gamètes dans l'eau et pendant toute la vie larvaire. Elle dure quelques semaines, en fonction des espèces et de la température. Elle est suivie par une phase benthique qui commence par la fixation par un byssus en début de métamorphose.

La période byssale varie suivant les espèces : certaines perdent ce comportement très rapidement (*Amusium* sp.), d'autres le conservent quelques mois (*Pecten* sp., *Patinopecten* sp.), certaines l'ont en permanence (*Chlamys* sp.) avec, cependant, la possibilité de se détacher, de se déplacer et de refaire un byssus sur un autre support. Une espèce présente un mode de vie différent : *Crassadoma gigantea* se cimente au rocher par sa valve inférieure après sa période byssale. Certains Pectinidés non fixés vivent plus ou moins enfoncés dans le sédiment en se creusant une dépression (*Pecten* sp.).

Les Pectinidés présentent la particularité de se déplacer par claquement des valves qui provoque une chasse de l'eau de la cavité palléale en avant ou sur le côté : ils peuvent ainsi nager dans les deux sens. L'enchaînement de ces mouvements permet des bonds variables allant jusqu'à plusieurs dizaines de mètres et des vitesses de quelques mètres/seconde.

Le groupe est assez hétérogène en ce qui concerne la reproduction : certaines espèces sont hermaphrodites comme la coquille Saint-Jacques *Pecten maximus*, dont les organes sexuels sont rouges pour la partie femelle et blanc pour la partie mâle (appelés le "corail" en gastronomie). D'autres ont les sexes séparés, d'autres encore changent de sexe au cours de leur vie.

Les pontes produisent une grande quantité d'oeufs -plusieurs millions par animal-, que dispersent les courants durant la vie larvaire. Les gisements se forment au passage des animaux à la vie benthique , mais aussi lorsque certains courants ont tendance à concentrer les larves. La stabilité d'un gisement tient notamment à l'ensemble de ces facteurs écologiques : population parente, courants à effet de concentration, fonds récepteurs meubles et appropriés. Leur conjonction (simultanée) privilégie les baies et les zones à courant tourbillonnaire.

La dispersion lors de la phase benthique est faible. Elle pourrait, cependant, survenir peu après la métamorphose, lors d'une remise en suspension, lorsque les postlarves sont petites et très légères.

Les gisements exploités sont rarement stables. L'exemple de référence est celui de *Patinopecten yessoensis* en baie de Mutsu. Entre 1910 et 1970, l'espèce japonaise alterne périodes de grande abondance et de complète absence (fig. 1). On considère maintenant que ces variations de recrutement dans une pêcherie ont pour origine une grande sensibilité du mécanisme biologique de la reproduction aux conditions climatiques, associée à une très grande vulnérabilité des animaux à la pêche et aux engins utilisés : dragues, chaluts.

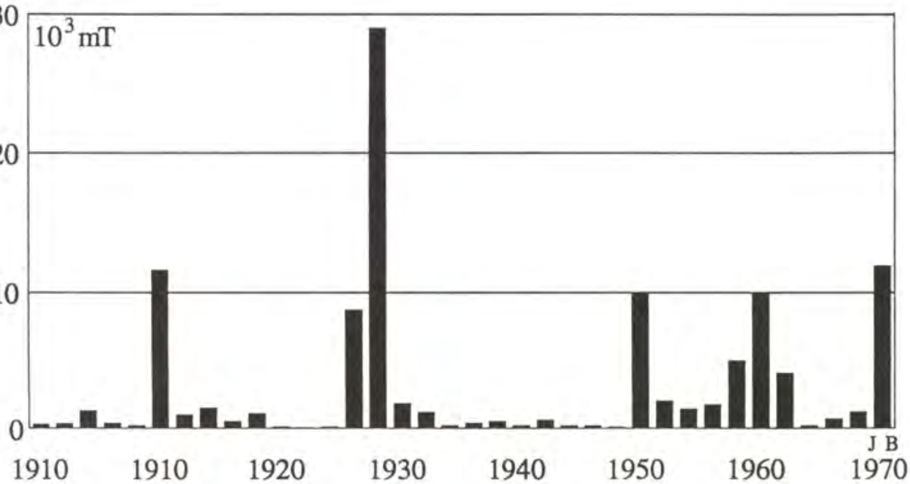

Figure 1. Fluctuations of scallop catches in Mutsu Bay. (data in 10^3 MT)
Fluctuations des captures de coquilles dans la baie de Mutsu (données en milliers de tonnes)

L'aquaculture de ces espèces est très récente et la pectiniculture se développe depuis un quart de siècle, à partir du Japon. On identifie deux étapes dans la conduite des élevages, le captage du naissain et le grossissement jusqu'à la taille commerciale.

Le captage consiste à placer des collecteurs aux dates et endroits où les larves sont concentrées par les courants. Les capteurs de Pectinidés présentent la particularité que le support offert à la fixation des animaux est contenu dans un sac à petites mailles qui empêchent les juvéniles de s'échapper lorsqu'ils se détachent de leur byssus. Ces sacs, par ailleurs, constituent une protection contre les prédateurs. Le naissain est récolté avant que les collecteurs ne soient trop envahis de salissures, et il est élevé sur place dans d'autres structures ou vendu à d'autres éleveurs.

L'élevage se pratique en semis sur le fond ou en structures suspendues. Ces dernières sont des enceintes fermées pour maintenir des animaux capables de déplacements. Il faut plusieurs structures successives pour le grossissement du fait des salissures qui s'opposent au passage de l'eau. A chaque opération on utilise des mailles de plus en plus grandes, selon la taille des coquillages. Les semis sur le fond doivent être pratiqués sur des surfaces suffisamment grandes pour que les déplacements désordonnés se fassent à l'intérieur du périmètre fixé. Le choix d'un site de semis se fait en fonction de la stabilité des fonds et du possible contrôle des prédateurs et des pêcheurs.

Depuis quelques années se développent des méthodes d'aquaculture plus complètes où la production de naissain est réalisée en écloserie. Cette technique a été considérée jusqu'à présent comme plus onéreuse que le captage et peu applicable pour l'obtention de grandes quantités de juvéniles. La situation évolue rapidement et devrait dépendre des espèces et des caractéristiques des sites d'élevage.

LA PRODUCTION MONDIALE

La production mondiale atteint 900.000 tonnes (fig. 2). Elle est très intensive et suit la forte demande de trois zones de consommation : États-Unis, Japon et France. On consomme principalement le muscle, mais aussi le corail sur le marché français et, à moindre titre, le marché japonais. La coquille est considérée comme un des meilleurs produits de la mer, ce qui en fait une espèce à haute valeur marchande, très recherchée.

Il s'agit d'une production concentrée dans les pays à eaux tempérées ou froides. Il y a peu d'espèces exploitées en zone tropicale : dans la plupart des cas, il s'agit de zones de remontées d'eau profonde comme le Mexique et la côte pacifique d'Amérique du Sud. Le groupe d'espèces tropicales est celui des *Amusium sp.* que l'on trouve de la Nouvelle-Calédonie à la Thaïlande et, à un moindre titre, celui des *Argopecten sp.*

Sur les principaux gisements on exploite les animaux dès le recrutement. Du fait de la pression de pêche, celui-ci correspond rarement au maximum de productivité biologique ou économique des populations. Dans le cas d'animaux à faible longévité (*Argopecten sp.*, *Amusium sp.*), la pêche reste opportuniste et se traduit par des captures hautement variables et imprévisibles. Dans le cas des espèces à longue durée de vie (*Placopecten magellanicus.*, *Pecten sp.*) on peut espérer des gains de productivité à long terme par une gestion rigoureuse des ressources.

Les espèces les plus septentrionales ont un mode d'exploitation particulier. Du fait des conditions climatiques, l'accès aux zones de pêche est intermittent et réservé à des bateaux de fort tonnage. Leur rentabilité est assujettie à de très forts rendements de pêche qui exigent des populations vierges (*Chlamys sp.*, *Patinopecten caurinus*). En eau froide, la croissance des animaux est très lente et les gisements s'épuisent très vite.

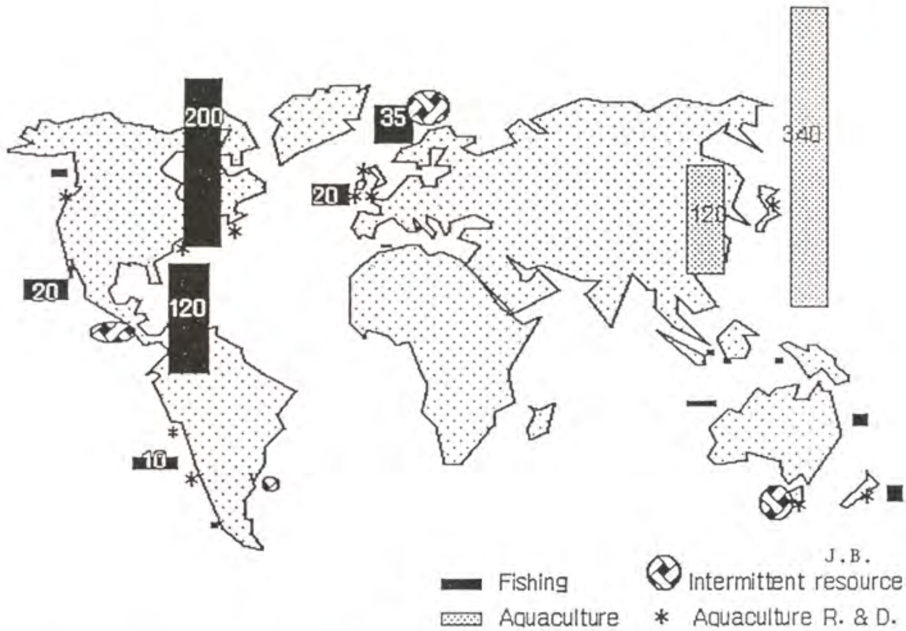

Figure 2. Scallop world production. (data in 10^3 MT)
Production mondiale de Pectinidés. (données en milliers de tonnes)

En 1988 la part de l'aquaculture a, pour la première fois, dépassé celle de la pêche. L'aquaculture est une production établie dans deux pays : le Japon et la Chine. Il s'agit de deux espèces, *Patinopecten yessoensis* pour la coquille japonaise et *Argopecten irradians* pour la chinoise. La première est locale et reste le modèle de développement aquacole pour le groupe d'espèces des Pectinidés, la seconde est d'importation récente. D'autres pays commencent à apparaître sur le marché comme le Chili, la Nouvelle-Zélande, l'Écosse, le Canada, la France... Cette tendance devrait s'accentuer dans les années futures.

REVUE DES PRINCIPALES ESPÈCES EXPLOITÉES

Chlamys islandica.

Le pétoncle, *Chlamys islandica*, est présent sur toutes des côtes septentrionales de l'Atlantique Nord (fig. 3). Il fait l'objet de pêches côtières importantes en Islande et aux îles Féroé. Il fait partie des captures accessoires des flottilles de coquilliers du Canada à Terre-Neuve et sur le banc Saint-Pierre. En Norvège, la pêche est récente et a montré sa présence jusqu'au Sptizberg et au Groenland. Il est reconnu sur les côtes russes de Mourmansk.

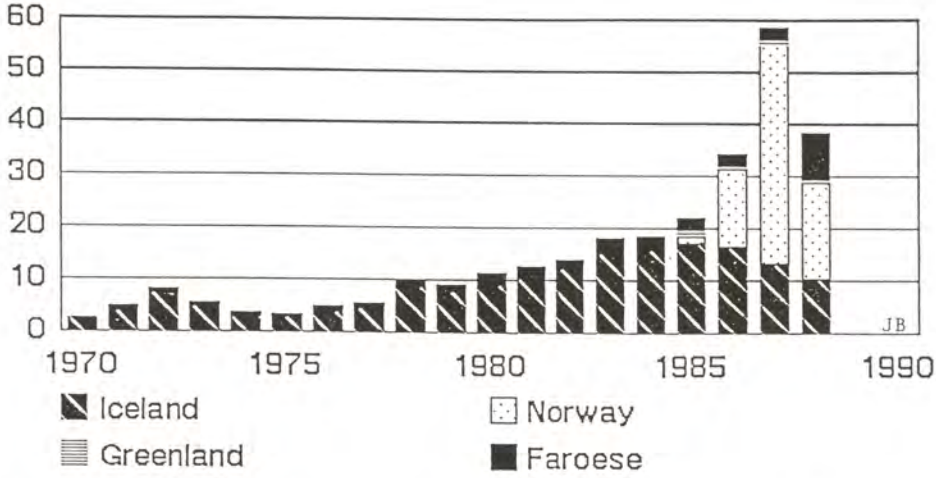

Figure 3. *Chlamys islandicus* production in Scandinavia. (data in 10^3 MT, whole weight)
Production de *Chlamys islandicus* en Scandinavie. (données en milliers de tonnes)

C'est une espèce de taille moyenne, vivant en eau froide fixée sur les fonds par un byssus permanent. Elle forme des gisements denses et peut coloniser l'espace en tant qu'espèce dominante. C'est un animal à croissance lente qui n'est exploitable qu'au-delà de la cinquième année. Les individus les plus recherchés ont huit/dix ans.

Jusqu'en 1985, il n'a joué qu'un rôle mineur sur le plan mondial, par une production modérée mais régulière en provenance des côtes islandaises. Le produit était décortiqué à terre et vendu sur le marché américain, et accessoirement français. Sur ce dernier, l'absence de corail et la petitesse du muscle constituait un handicap par rapport aux autres Pectinidés.

A partir de 1982-83, de nouvelles zones de pêche ont été exploitées lors de la reconversion de navires-usines norvégiens, aménagés pour de longues campagnes dans des zones peu accessibles et exposées au mauvais temps. La coquille est décortiquée à bord mécaniquement et conditionnée en tunnel de congélation. Les bateaux travaillent 24 h./24. En trois ans de 1986 à 1988, cette flottille a débarqué 75.000 tonnes destinées à l'exportation, et ces quantités (8 à 10.000 T de noix) ont pesé sur les cours mondiaux.

Cette explosion de pêche prend déjà fin : il faut rentabiliser ces grosses unités durant les quelques mois d'été et il est nécessaire de produire de grosses quantités quotidiennes (2 - 3 T. de noix/jour). Les conditions ne sont remplis que sur des gisements vierges qui, du fait de la très faible vitesse de croissance des animaux, ne se reconstituent que très lentement. En 1990 il ne restait plus qu'un seul navire-usine.

La raréfaction de cette espèce sur un marché demandeur, a incité les Islandais à reprendre leur exploitation traditionnelle.

3. 2 - *Placopecten magellanicus*

Le pétoncle géant -"sea-scallop"- est une espèce de l'Atlantique du Nord-Ouest que l'on trouve de l'estuaire du St-Laurent jusqu'à l'État de Virginie. C'est une ressource exploitée par les flottilles canadiennes et américaines sur des fonds de 100 mètres comme sur le banc Georges, mais aussi sur des fonds plus côtiers comme en baie de Fundy ou en baie des Chaleurs (fig. 4).

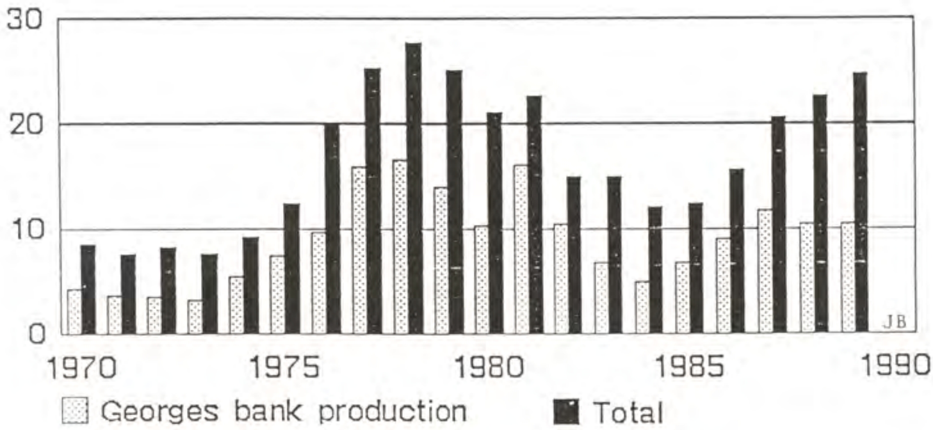

Figure 4. *Placopecten production* - U.S.A. and Canada - (10^3 MT, whole weight)
(données en milliers de tonnes)

C'est une espèce qui peut atteindre une grande taille, et vit posée sur le fond. Sa croissance est relativement lente en eau froide : les animaux n'atteignent leur taille de première capture qu'à partir de quatre à sept ans suivant les gisements. Il nage facilement par bonds et échappe fréquemment aux engins de pêche. L'efficacité des dragues est de l'ordre de 10 à 15 %.

La pêche est une activité traditionnelle et date du début du siècle. Elle s'est pratiquée en baie de Fundy et a donné lieu dès 1918 à des réglementations pour organiser la gestion des ressources. On dispose ainsi d'une longue série d'observations qui indique de fortes fluctuations des captures annuelles. La pêcherie du banc Georges est une des premières du monde en tonnage. Elle représente de 40 à 120.000 tonnes en poids total. C'est une exploitation pratiquée par deux pays, États-Unis et Canada, qui ont leurs zones de pêche séparée depuis l'instauration des 200 milles (ZEE). L'accès à la ressource est contrôlé avec un nombre de licences limité, des engins de pêche spécifiques et une taille minimale du produit débarqué. La coquille est décortiquée en mer et seuls les muscles sont conservés. La réglementation en vigueur impose un minimum de 78 muscles/kg de chair ce qui évite que les bateaux ne pêchent sur les secteurs où se trouvent les animaux de moins de 4 ans. Le passage à une réglementation plus contraignante de 34 muscles/kg devrait permettre d'augmenter de 50 % les tonnages débarqués en concentrant les captures sur les animaux de 5 à 7 ans.

Le *Placopecten m.* pèse sur le marché international de la coquille. La production canadienne est destinée principalement à l'exportation, ce qui représente l'équivalent de 20 à 100.000 tonnes en poids total. Dans les années 80, cette espèce constitue la moitié de la production mondiale, destinée principalement au marché américain. L'aquaculture de cette espèce est expérimentée dans différentes baies de la côte est du Canada. On maîtrise les élevages en cultures suspendues sur le plan technique, mais la faisabilité, économique reste à démontrer.

Argopecten sp. d'Amérique du Nord

Des espèces de petite taille appartenant au même genre sont exploités aux États-Unis. Il s'agit d'*Argopecten irradians* , appelé "bay-scallop", d'*Argopecten gibbus*, "calico-scallop" que l'on trouve sur la côte est. *Argopecten circularis* sur la côte pacifique n'est exploitable que dans les pays plus au sud, du Mexique au Panama. Ces espèces ont en commun une vie très courte (1 à 3 ans) et une croissance rapide. Les deux premières constituent une part importante des pêches américaines.

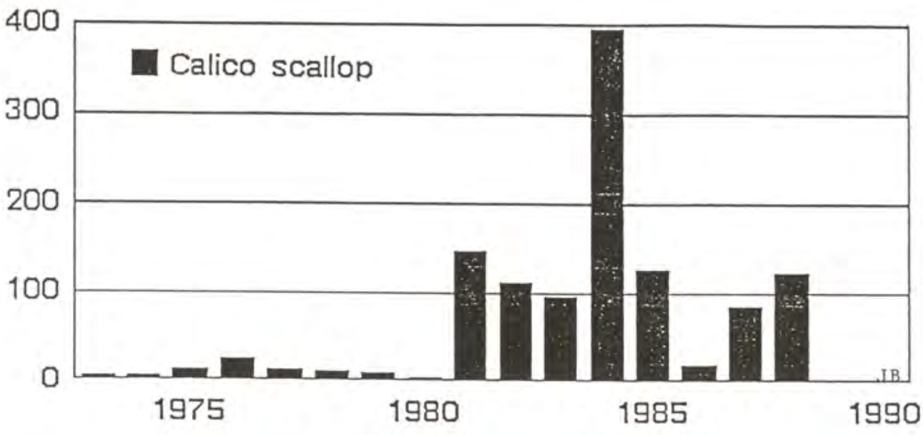

Figure 5. *Argopecten gibbus* production in U.S.A. (data in 10^3 MT, whole weight)
Production d'*Argopecten gibbus* aux États-Unis (données en milliers de tonnes)

A. gibbus est une espèce qui forme des bancs très importants au large de la Floride sur des fonds de 30 à 50 mètres. La production a fait un bond considérable à partir de 1980, en raison de l'exploitation de nouveaux gisements mais aussi de la mécanisation des opérations de décorticage (fig. 5). Le rendement en muscle est d'environ 5 %, et la pêche record - près de 400.000 tonnes en 1984 - s'est traduite par 18.000 tonnes de noix à un prix beaucoup plus bas que les autres Pectinidés, de l'ordre de 25 % du prix de la coquille. La production annuelle moyenne a été estimée à 100.000 tonnes, mais les bancs ont été décimés par un protozoaire parasite à la fin de 1988. La ressource serait en cours de restauration.

A. irradians est une espèce très côtière et plus nordique que la précédente. La production est de plusieurs milliers de tonnes. Elle provient de petites pêcheries artisanales sur le littoral où cette espèce est traditionnellement exploitée. C'est un animal d'estuaires et de baies peu profondes fréquemment associée aux herbiers. Dans les principaux États américains où elle est pêchée, il existe des réglementations limitant l'accès à la ressource, la saison de pêche, une taille marchande minimale et des quotas. Cet animal présente l'intérêt d'être hermaphrodite avec une glande bisexuée très similaire à celle de la coquille Saint-Jacques.

L'aquaculture de cette espèce est techniquement réalisée depuis près de 15 ans. La production de juvéniles en écloserie est facile à réaliser, mais le grossissement reste à démontrer sur un plan économique : en semis sur le fond la survie est trop faible du fait d'une prédation importante, et en cultures suspendues le prix de revient du matériel et de la main-d'oeuvre est trop élevé.

Chlamys sp. et *Argopecten purpuratus* d'Amérique du Sud

L'exploitation des Pectinidés en Amérique du Sud est récente et destinée au marché américain. La première espèce a été *Chlamys tehuelcha* dont la production a atteint plus de 10.000 tonnes en 1970, pour disparaître aussi soudainement et ne réapparaître qu'en 1983. Les ressources sont en fait distribuées sur deux gisements contigus, l'un exploité en plongée qui fournit des petites quantités chaque année et le second à recrutement fort mais intermittent. La gestion de ce dernier consiste en une rotation de zones de pêches, lorsque la ressource est présente.

L'aquaculture de cette espèce a été expérimentée entre 1980 et 1985. Le captage de naissain s'est avéré possible mais aléatoire et les essais d'élevage en suspendu n'ont pas été probants sur le plan économique.

Argopecten purpuratus a commencé à être exploité au Pérou en 1979, pour donner lieu à une pêche très intensive à partir de 1982. On associe le spectaculaire développement au phénomène El Niño qui provoque sur les côtes un réchauffement des eaux. La production a atteint plus de 50.000 tonnes en 1985 (fig. 6), pour retomber depuis au dixième.

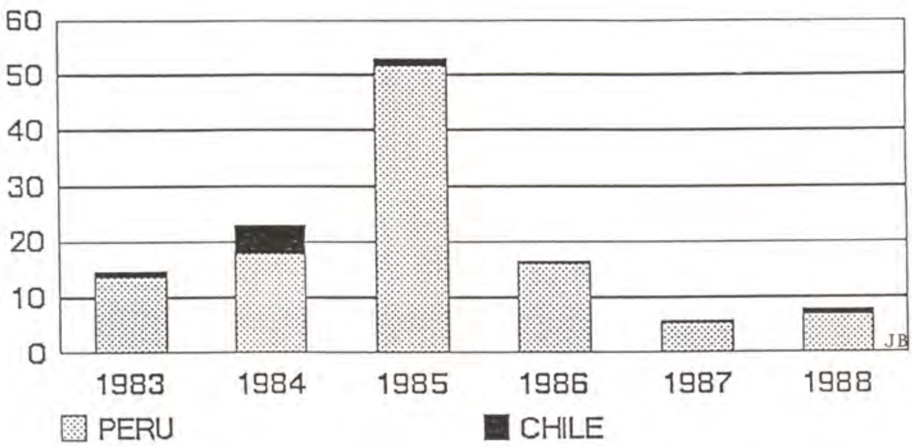

Figure 6. *Argopecten purpuratus* production (data in 10^3 MT, whole weight)
Production d'*Argopecten purpuratus* (données en milliers de tonnes)

L'engouement pour la coquille est à l'origine d'essais d'aquaculture à partir de la récolte des juvéniles, en semis dans des enclos sur le fond comme en cultures suspendues. Mais les statistiques rendent mal compte de la part de l'aquaculture et de celle de la pêche dans la production actuelle.

L'espèce est présente dans le nord du Chili où l'on a observé le même phénomène qu'au Pérou avec un recrutement exceptionnel à la suite d'El Niño : la production de 1984 a été cinq fois supérieure à celle des années voisines. Le phénomène n'a pas eu l'ampleur de celui du Pérou, mais il a été suffisamment incitatif pour que se développe une pêcherie qui, par la suite, a contribué à la surexploitation. La pêche est tombée à quelques centaines de tonnes par an avant d'être interdite.

Les cultures se substituent à la pêche depuis quelques années et on assiste maintenant à un développement de la production. Les juvéniles sont captés dans le milieu naturel et élevés en paniers suspendus ou en "boucle d'oreille". Parallèlement, des essais de reproduction artificielle sont menés dans le nord du pays et devraient rapidement déboucher sur des productions massives de juvéniles, qui sont à l'heure actuelle le facteur limitant : les zones d'élevage potentielles s'étendent jusqu'au 45°S au-delà de la distribution naturelle de l'espèce. C'est une espèce qui se prête particulièrement bien à l'aquaculture du fait de sa grande taille (calibre des muscles de 10 à 120/kg), sa vitesse de croissance élevée (commercialisation à partir de 15 mois d'élevage) et sa résistance dans les structures (mortalités faibles). La production aquacole dépasse 500 tonnes/an pour les années 1988 et 89.

Sur la partie sud du continent on trouve une autre espèce *Chlamys patagonica*, dont la production par la pêche oscille de 300 à 1.300 tonnes. L'espèce est exploitée au Chili mais pas en Argentine.

Patinopecten caurinus

Les coquilles du nord-est Pacifique sont représentés par *Patinopecten caurinus* ("weathervane"), espèce voisine de la coquille japonaise. Elle est présente de la Californie à l'Alaska, où elle est pêchée par une flottille qui alterne les métiers selon leur rentabilité : poissons, crustacés ou coquillages. Les rendements et/ou les prix de vente sont déterminants ; 1990 serait une année de bonne capture.

Il s'agit d'un animal qui peut atteindre une grande taille, avec une vitesse de croissance moyenne. Les individus exploités ont en général plus de cinq ans.

Les essais d'aquaculture en Colombie Britannique n'ont pas été probants, l'espèce apparaît moins compétitive en écloserie que les deux autres coquilles étudiées, *Crassadoma gigantea* ("rock scallop") et *Patinopecten yessoensis*. Cette dernière donne lieu à un début de production en cultures suspendues.

Patinopecten yessoensis

La coquille japonaise est la référence en développement des cultures de Pectinidés : d'une situation de surexploitation dans les années 60, avec des pêches de quelque milliers de tonnes, le Japon a produit en 1990 près de 350.000 tonnes d'animaux issus d'une activité de pêche/aquaculture prospère (fig. 7).

Le développement s'est effectué dans le nord du pays, à partir de l'espèce *Patinopecten yessoensis*, appelée "otate-gai", dès que la technique du captage de naissain puis du préélevage du juvénile a été maîtrisée puis pratiquée massivement. Les essais d'écloserie ont été abandonnés en 1976 devant le succès du captage qui produit un naissain abondant et bon marché.

On distingue deux étapes de développement dans le captage de naissain. Sur un gisement peu abondant, celui-ci est faible, avec des rendements par collecteur peu élevés. Lorsque la population parente se développe, les rendements augmentent sans commune mesure : ils sont passés de quelques individus par collecteur à plusieurs dizaines de milliers en baie de Mutsu. Ce résultat est généralisable aux baies abritées (baie de Funka, lacs Saroma et Notoro), mais dans une moindre mesure sur les gisements ouverts (Sarufutsu, Nemuro).

Les baies protégées ont été les premières bénéficiaires de cette technique avec un développement des cultures suspendues dans un premier temps (meilleure valorisation d'un espace limité, privatisation). Les semis sur le fond ont été plus tardifs à démarrer et font l'objet d'une production à grande échelle sur la côte nord de Hokkaïdo (mer d'Okhotsk, détroit de Nemuro), en mer, au large, sur des fonds de 30 à 50 mètres. La protection du mauvais temps hivernal est assurée par les glaces qui se forment à partir de décembre, et la concurrence pour l'occupation de l'espace est faible.

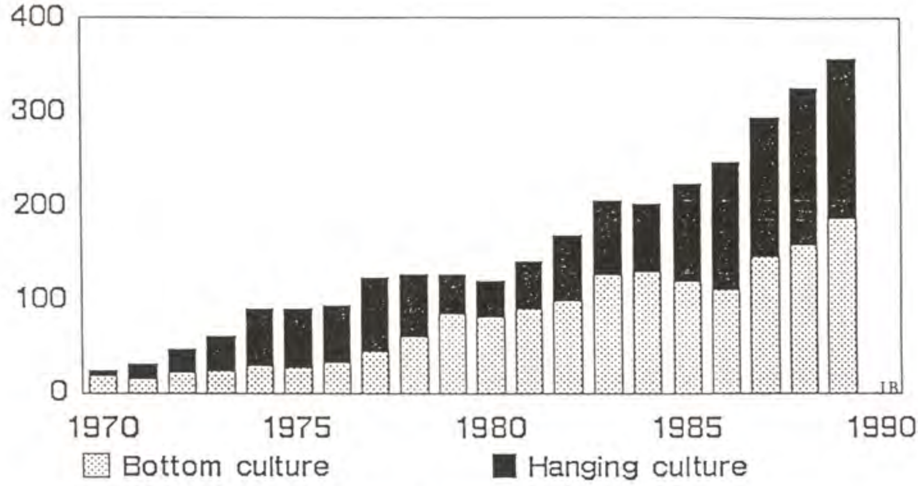

Figure 7. *Patinopecten* production in Japan (data in 10^3 MT, whole weight)
Production de *Patinopecten* au Japon (données en milliers de tonnes)

Depuis quelques années, des signes de saturation sont apparus : les principales zones d'accueil sont colonisées et des phénomènes de surpopulation ont été notés. Ils se traduisent par des mortalités massives, non seulement en baie fermée sur des cultures suspendues qui constituent des charges en animaux très denses, mais aussi en mer ouverte lors de semis trop importants. Ces mortalités n'ont pas provoqué l'apparition de pathogènes mais remettent en cause la gestion globale d'un bassin.

La présence de toxines phytoplanctoniques, PSP et DSP, pose, depuis le début des années 80, des contraintes de commercialisation qui pèsent sur la conduite des élevages : interdictions périodiques, taille et période de vente des produits d'élevage.

La concurrence à *P. yessoensis* est faible. Les importations d'autres Pectinidés sont réduites et les produits présentés répondent mal à la demande du consommateur japonais. Sur le plan intérieur, *Pecten albicans* n'a pas répondu aux essais de développement ; *Chlamys nobilis* se produit à partir d'écloseries mais à petite échelle. La taille réduite du muscle en fait un mauvais compétiteur.

Chlamys farreri et *Argopecten irradians* en Chine

Le gouvernement chinois a lancé un important programme d'aquaculture de Pectinidés à la fin des années 70-80, basé sur des écloseries de différentes espèces de pétoncle, *Chlamys farreri* et *Chlamys nobilis*.

En 1985, a été introduit *Argopecten irradians* en provenance des États-Unis, qui s'est avéré très performant dans les conditions d'environnement chinoises : eaux peu profondes de climat continental, main-d'oeuvre abondante et bon marché. Les sources statistiques chinoises sont peu crédibles en valeur absolue mais il est certain, de l'avis des observateurs, que les Pectinidés se développent très rapidement sur la base de l'aquaculture d'*A. irradians* : le chiffre de 120.000 tonnes pour la production 1988 est vraisemblable.

Suivant les latitudes, les espèces de complément sont *C. farreri* et *C. nobilis*. Des projets de culture de *Patinopecten yessoensis* existent, sans qu'il soit possible de conclure à un développement économique en cours.

Amusium balloti

L'espèce est présente en eau subtropicale de part et d'autre des côtes australiennes. *Amusium balloti* ("saucer-scallop") occupe ainsi deux aires géographiques distantes de plusieurs milliers de kilomètres.

Le groupe des *Amusium sp.* a une morphologie particulière pour un pectinidé : la coquille est lisse, brillante et sans côte. Son aptitude à la nage est remarquable, elle peut faire des bonds atteignant la centaine de mètres à la vitesse de 3 à 5 noeuds. Ce sont des espèces à croissance très rapide mais à très faible longévité (2 ans). *A. balloti* atteint 90 mm en un an ce qui correspond à sa taille de recrutement.

Les animaux sont exploités dans une pêcherie mixte au chalut à tangon coquilles-crevettes pénéides, et constituent généralement des captures accessoires (fig. 8). Les deux stocks se trouvent dans les eaux de deux États et ont une gestion différente. Le stock Ouest est a un système de licences transférables avec des droits d'accès limités. Il y a un bon compromis entre l'effort de pêche, la campagne de pêche qui débute après la ponte des premiers individus en hiver, la valorisation de l'animal par la commercialisation des animaux quand le muscle stocke des tissus de réserve.

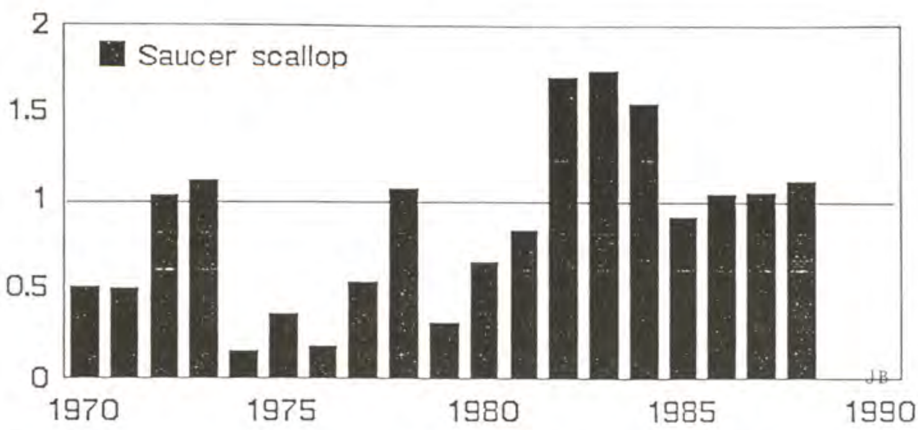

Figure 8. *Amusium balloti* production in Australia (data in 10^3 MT, whole weight)
Production d'*Amusium balloti* en Australie (données en milliers de tonnes)

Le stock Est se situe devant la Grande Barrière de corail. L'excès d'effort de pêche (1.100 bateaux) se traduit par une surexploitation au cours des dernières années.

Les premières tentatives d'aquaculture sont encore très expérimentales. L'espèce perd son byssus très tôt, ce qui rend le captage de naissain impossible. En écloserie quelques juvéniles ont été très récemment obtenus.

Pecten fumatus

La pêche des coquilles Saint-Jacques est une des plus anciennes pêches d'Australie. Elle est signalée au siècle dernier en Tasmanie. Elle a pris son plein développement à partir de la seconde guerre mondiale pour assurer une demande locale de consommation, puis un marché à l'exportation (fig. 9).

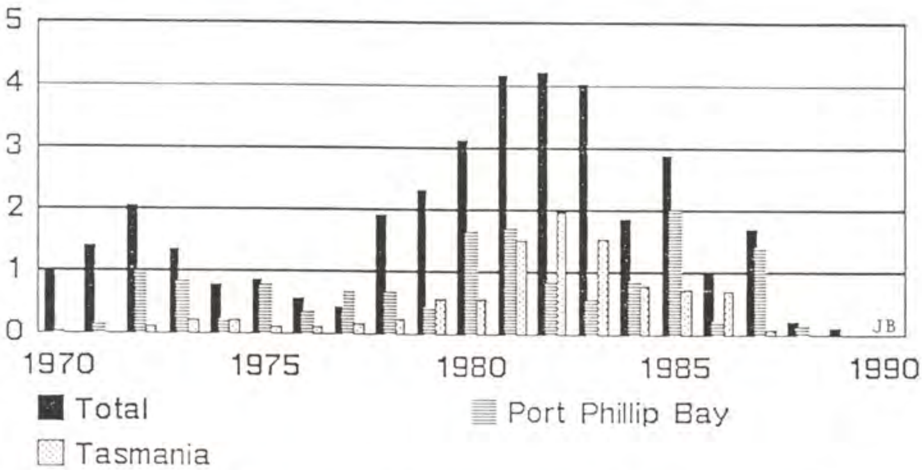

Figure 9. *Pecten fumatus* production in Australia (data in 10^3 MT, meat weight)
Production de *Pecten fumatus* en Australie (données en milliers de tonnes, en noix)

L'espèce est très proche des coquilles Saint-Jacques européennes : c'est un animal hermaphrodite vivant dans une dépression à la surface du sédiment. La croissance est à peine inférieure à celle de *P. maximus* et la taille commerciale est atteinte en un peu moins de deux ans. Les principaux gisements se trouvent sur des fonds de 10 à 50 mètres.

Deux États ont eu une activité régulière, le Victoria et la Tasmanie, tandis que les États voisins n'ont eu qu'une production épisodique (Australie de l'Ouest et du Sud, Nouvelles-Galles du Sud). Dans ces derniers, la pêche correspond à l'apparition d'une classe d'âge pléthorique, sans suite pendant une dizaine d'années.

Les trois gisements principaux ont donné lieu à une pêche spécialisée à Port Phillip Bay, Lake Entrance et dans le détroit de Bass. Les deux États riverains ont eu recours à des stratégies de gestion différentes, développant un système d'allocation de pêche transférable pour le Victoria et non transférable en Tasmanie.

Le bilan est identique dans les trois cas avec une surexploitation des gisements qui a conduit à la fermeture de la pêche depuis 1989. L'Australie est donc passée d'une situation de pays exportateur, à celle de pays importateur (marché mondial, Nouvelle-Zélande). Cependant les dernières prospections de stocks font apparaître un recouvrement naturel de la ressource.

Le retour à une exploitation professionnelle fait l'objet de discussions à Port Phillip Bay. On accuse en effet la pêche à la drague d'être destructrice et de déséquilibrer les fonds meubles. Un moratoire pour l'interdiction de la drague comme engin de pêche est demandé ainsi qu'une utilisation récréative de la ressource.

En Tasmanie au contraire, la coquille Saint-Jacques fait l'objet de programmes de mise en valeur soutenus. Un accord de coopération avec le Japon vise la relance de la pêche à partir du captage de naissain en milieu naturel, avec un complément de production en écloserie. L'élevage intermédiaire est réalisé en cultures suspendues avant les semis sur des zones interdites à la pêche. Près de 10 millions de juvéniles ont été semés en 1990. A côté de ce programme, d'autres essais d'aquaculture plus ponctuels sont en cours.

Pecten novoezelandiae

L'espèce existe dans les deux îles de Nouvelle-Zélande. Il s'agit d'une exploitation récente identique à celle d'Australie, lorsque le marché international de la coquille Saint-Jacques a commencé à se structurer. La production a atteint 10.000 tonnes en 1975 pour retomber à 0 sur le gisement concerné en 1981 et 1982.

La situation néo-zélandaise peut être comparée à celle de Tasmanie avec quelques années d'avance et un contexte socio-économique différent. Un accord de coopération avec les Japonais a amené ces derniers à investir dans des opérations de captage de naissain après des essais positifs menés par une entreprise privée dès 1979. Entre 1984 et 1986, respectivement 35, 19 et 50 millions de juvéniles ont été captés, avec des rendements de 1.000 à 2.000 individus/collecteur. En 1986, la première récolte par la pêche a été de 100/120 tonnes de chair. Le projet de développement en cours porte sur 1.000 tonnes.

La simplicité des opérations laisse augurer un développement technique rapide (rotation de zones de pêche, interdiction de chalutage, transplantation de naissain), mais limité par les contraintes socio-économiques pour l'organisation d'une flottille d'effectif modéré. La gestion porte aussi sur une saison limitée dans le temps, une taille minimale de 100 mm en longueur et un quota individuel.

Pecten maximus* et *Pecten jacobeus

La coquille Saint-Jacques est l'appellation française de deux espèces exploitées depuis très longtemps : *Pecten maximus* dont l'extension géographique couvre les côtes atlantiques de la Norvège au Maroc, et *Pecten jacobeus* sur les côtes méditerranéennes.

P. maximus est une espèce de grande taille à vitesse de croissance moyenne, à grande longévité. Comme tous les *Pecten*, les animaux vivent sur des fonds meubles dans une dépression et peuvent être considérés comme sédentaires. La facilité de capture et le prix offert sur le marché en font une espèce particulièrement vulnérable, qu'il reste rentable d'exploiter jusqu'à sa quasi-extinction (1 individu pour 100 à 200 mètres carré).

La coquille pond durant l'été avec de larges variations suivant les gisements européens. Elle atteint la maturité sexuelle à l'âge de 2 ans en France. La taille minimum dépend des réglementations nationales, et la majorité d'entre elles se fondent sur une taille comprise entre 10 et 11 cm. Suivant les gisements en latitude et en profondeur, elle est atteinte en deux ans ou plus.

L'espèce a un recrutement très variable qui se traduit par des fluctuations de capture en France où les pêches sont axées sur une ou deux classes d'âge. Les évaluations en baie de Saint-Brieuc donnent une amplitude de variation d'abondance de 1 à 30. A plus long terme, on note des évidences de quasi-disparition de la ressource (rade de Brest, coureaux de Belle-Ile) et des phénomènes de renaissance de gisement après 20 ans d'absence (baie de Saint-Brieuc en 1962, qui se maintient encore).

Les pêcheries européennes se sont développées au début des années 70 (fig. 10). Elles ont comme pôle d'attraction le marché français qui place la coquille Saint-Jacques parmi les produits les plus prisés du consommateur. Plusieurs facteurs économiques, comme le décorticage en noix près des lieux de production, les moyens de transport et de stockage ont facilité l'écoulement du produit et incité à l'expansion des pêches.

Les flottilles nationales des principaux pays producteurs adoptent deux stratégies différentes. En Angleterre et en Écosse, on trouve des bateaux de grande taille en petit nombre qui passent d'un gisement à l'autre dès que les rendements baissent. En France, et à un moindre titre en Irlande et à l'île de Man, les unités sont de petite taille et inféodées à un gisement précis par un système de licence non transférable. L'exploitation est saisonnière, en hiver, basée sur le recrutement car la pression de pêche élevée fait disparaître les classes âgées. La coquille Saint-Jacques dans les baies abritées constitue en effet une des seules espèces accessibles pour la flottille côtière.

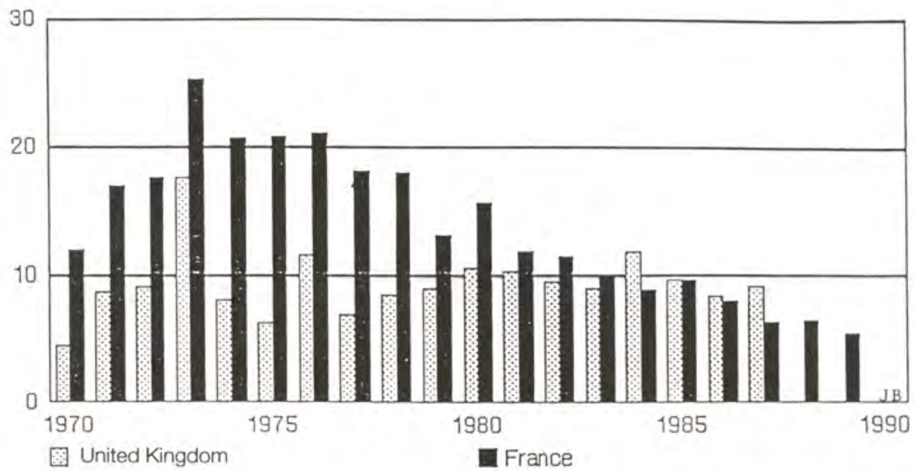

Figure 10. *Pecten maximus* production in U.K and France (data in 10^3 MT, whole weight)
Production de *Pecten maximus* au Royaume-Uni et en France (données en milliers de tonnes)

L'évolution des captures au cours des dernières années indique une nette tendance à la régression sur la plupart des gisements, comme le montre l'évolution des deux principaux gisements français, la baie de Saint-Brieuc et la Manche-Est (fig. 11). L'adéquation entre la pêche et ses effets indirects comme le labourage des fonds est actuellement posée.

Les essais d'aquaculture ont débuté dans les années 1975 dans divers pays européens. L'approvisionnement en juvéniles se fait par captage de naissain en Irlande depuis 1982 et en Écosse depuis 1985. Cette technique a été essayée à l'île de Man, en France, en Espagne et en Angleterre sans donner de résultats pouvant déboucher sur une activité économique. La France s'est orientée vers une production en écloserie qui, à partir de 1983, a satisfait ses programmes de recherche/développement.

Le grossissement a été expérimenté en cultures suspendues en Irlande et aussi, en Écosse où elles donnent lieu à un début de production. Les essais de la France en Méditerranée n'ont pas été concluants. En semis sur le fond, seule la France mène un programme depuis 1977 et obtient des résultats encourageants dans la rade de Brest, les baies de Morlaix et de Quiberon (30 à 50 tonnes en 1990).

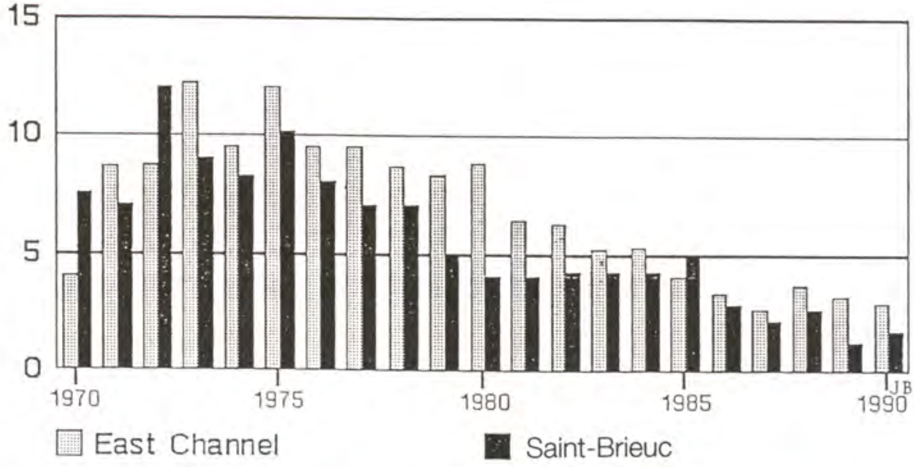

Figure 11. *Pecten maximus* production in France (data in 10^3 MT, whole weight)
Production française de *Pecten maximus* (données en milliers de tonnes)

P. jacobeus est présent en Méditerranée. Les pêches sont occasionnelles sauf en Adriatique où il donne lieu à une exploitation régulière en Italie. Peu de données existent sur cette espèce qui a le même comportement que l'espèce atlantique.

Des essais d'aquaculture ont été réalisés en France, mais très limités. Les techniques d'écloserie sur l'espèce atlantique sont applicables mais l'élevage jusqu'à la taille de commerce reste à faire.

Chlamys opercularis

La pêche du pétoncle blanc , *Chlamys opercularis*, appelée "queen-scallop", est associée à celle des coquilles Saint-Jacques européennes, car les espèces fréquentent les mêmes zones de pêche. Elle représente près de 10.000 tonnes, mais n'est systématique que dans le nord de l'Europe entre l'île de Man et les Shetlands, où les animaux ont une plus grande taille.

L'espèce a une durée de vie beaucoup plus courte, de l'ordre de cinq ans en France. Son comportement diffère des *Pecten,* car il vit posé sur le fond et se déplace facilement par bonds de faible amplitude, mais rapidement à la moindre sollicitation.

L'aquaculture du pétoncle a évolué dans le sillage de celle de la coquille Saint-Jacques. Lors de la pose des collecteurs, se fixent de très importantes quantités de *C. opercularis* qui par la suite s'élèvent facilement en cultures suspendues.

Cependant, la petite taille des animaux et de leur muscle, la difficulté de la conservation après débarquement en frais sont un handicap à leur commercialisation. Le prix payé au producteur n'est pas très attractif.

BILAN ET PERSPECTIVES

Le marché des Pectinidés

La production totale est insuffisante pour approvisionner le marché mondial. Les trois pôles sont le Japon, les États-Unis et la France. Le négoce se fait sous la forme de muscles congelés, la glande reproductrice n'étant commercialisée que sur le marché français. Sur les marchés de la coquille fraîche, des comportements locaux différents existent, comme la distribution d'animaux vivants au Japon ou l'expédition de coquilles fraîches entières d'Écosse vers les centres français.

Le négoce international repose sur trois critères qui sont le calibre du muscle, la qualité du conditionnement et la fraîcheur du produit.

Le calibre se compte en nombre de muscles par livre anglaise (avec ou sans gonade), de 10 en 10. Trois gammes de prix sont pratiqués suivant les calibres 5-40 pour les grosses au meilleur prix, 40-80/100 pour les moyennes et au-delà de 100 pour les petites noix qui sont sérieusement décôtées (calico-scallop, produits chinois...).

La qualité du conditionnement a fait l'objet d'une revue récente en France pour normaliser la perte en eau lors de la décongélation. Deux pratiques sont courantes au décorticage, le trempage dans un bain non seulement pour nettoyer le muscle des impuretés mais pour le faire gonfler d'eau (gain 20 à 40% en poids), ainsi que le passage rapide de la noix congelée en eau pour provoquer la formation d'une pellicule de glace qui améliore la conservation. Pour la première, la France impose un taux teneur en eau/protéines inférieur à 5, pour la seconde, le glazurage, il est demandé à l'expéditeur une compensation forfaitaire en produit.

La fraîcheur est d'appréciation subjective par l'utilisateur qui doit juger de la dégradation de la qualité du produit entre la sortie de l'eau de l'animal vivant et la congélation du muscle ou de la coquille entière. Les pratiques sont identifiées suivant les pays et les prix offerts dépendent de la connaissance qu'ont les acheteurs des conditions de manutention et de la renommée du gisement d'origine.

La demande continue d'augmenter dans les pays consommateurs et de nouveaux pays développent leur marché. En Europe, la coquille Saint-Jacques reste un produit très demandé. A côté de sa renommée pour son goût, il faut citer les attraits complémentaires de facilité de préparation, d'absence d'arêtes et de déchets, de symbole de pureté attribué aux fruits de mer.

On assiste en France à une évolution de la consommation qui se maintient sur le marché du produit entier et vivant, et développe celui de la noix fraîche ou congelée, ainsi que celui du plat préparé surgelé à chauffer au four à micro-ondes.

La pêche

La pêche des Pectinidés montre ses limites face à l'augmentation de la pression de pêche : la plupart des gisements se maintiennent difficilement ou annoncent des réductions importantes de productivité : la Norvège, le Pérou, l'Australie et la France, pour ne citer que ces quatre exemples, montrent une incapacité à maintenir la ressource à un haut niveau de productivité, avec ou sans réglementation.

La gestion est d'autant plus difficile qu'elle est à deux vitesses : la variabilité annuelle du recrutement nécessite une réglementation fluctuante de l'effort de pêche peu facile à suivre ; elle est doublée d'une variabilité à plus long terme, avec des périodes d'apparition et de disparition de la ressource qu'on ne sait pas encore prendre en compte. La pêche elle-même est suspectée de contribuer à la disparition des gisements par les mortalités qu'elle induit sur le prérecrutement du fait des engins de pêche.

Cependant, par leur vulnérabilité aux engins, la pêche des Pectinidés reste une activité hautement rentable. Il est possible d'en améliorer la productivité. Sur nombre de gisements, les tailles de première capture sont très en-deçà des optimums calculés par les évaluations de rendement par recrue.

Il reste par ailleurs quelques zones non exploitées parce que d'accès difficiles, comme dans l'hémisphère sud, en Argentine. Il restera à trouver le difficile équilibre pêche/ressource.

L'aquaculture

L'aquaculture montre son importance par la production de deux pays, le Japon et la Chine, sur deux espèces différentes que sont *P. yessoensis* et *A. irradians*. Dans les deux exemples, le point de départ du développement a supposé la conjonction de quatre facteurs :

- espèce tolérante facile à produire,
- technique de culture artisanale,
- main-d'oeuvre abondante et bon marché,
- espace approprié disponible.

L'absence d'une des conditions se traduit par une stagnation des productions aquacoles. C'est le cas dans les pays industrialisés où il faut substituer la main-d'oeuvre par une mécanisation, laquelle se met au point lentement.

Cependant, un bon nombre d'espèces se trouvent dans les eaux tempérées sur les côtes de pays développés dont certains ont fortement investi dans l'aquaculture. Les recherches entreprises ont maintenant un acquis important et il faut s'attendre à quelques pôles de développement dans les années qui viennent : déjà un certain nombre d'entreprises se créent, qui pratiquent des cultures suspendues ou des semis sur le fond.

L'avènement des techniques d'écloserie donne une autre dimension aux projets d'aquaculture. Non seulement elles représentent la possibilité de production pendant une saison beaucoup plus large que la seule période de reproduction naturelle, mais elles permettent d'envisager l'application de techniques plus ou moins complexes pour produire des espèces non indigènes ou pratiquer la domestication et les applications génétiques : sélection sur la taille du muscle et la vitesse de croissance, résistance aux maladies,...

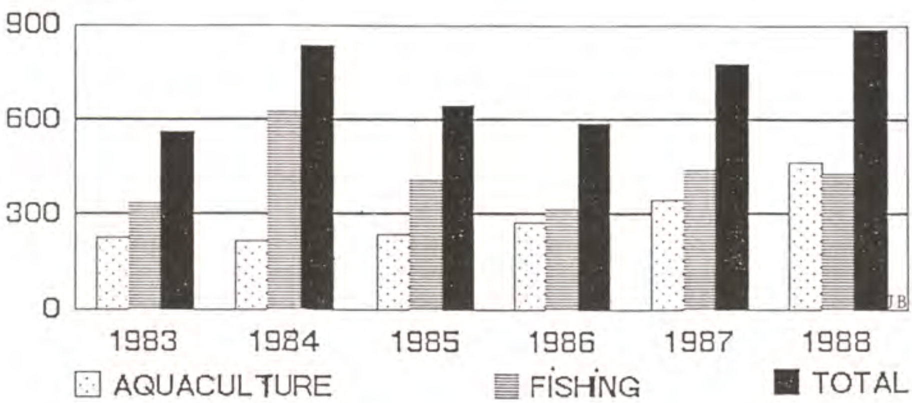

Figure 12 Part of fisheries and aquaculture in the world scallop production. (data in 10^3 MT, whole weight)
Évolution de la production aquacole de Pectinidés par rapport à la pêche.

L'opposition entre pêche et aquaculture a peu de signification sur ce groupe comme l'ont montré les Japonais qui pratiquent des cultures suspendues en baies abritées et des semis sur le fond avec rotation des zones de pêche. (fig. 12)

CONCLUSION

L'intérêt pour les Pectinidés devrait continuer à se développer. Les produits offerts correspondent aux tendances de consommation et de distribution qui se développent dans les pays industrialisés. Parmi les mollusques bivalves, ce groupe d'espèces offre les plus grands avantages : prix à la production, facilité du conditionnement après décorticage et congélation, calibrage et homogénéité du produit. La sécurité du consommateur est aussi prise en compte après l'élimination des parties de chair contaminées par les toxines de phytoplancton, même si cet aspect nouveau va rester conflictuel pendant encore quelques temps.

Cependant, certaines espèces sont peu tolérantes et réclament, en plus d'un milieu de bonne qualité ? une absence de variations brutales des facteurs écologiques. Il peut y avoir par ces contraintes un important frein au développement, en particulier du fait de polluants divers.

Mais on peut donc rester optimiste pour les années à venir sur le développement des productions avant que n'apparaisse une saturation du marché.

CHAPTER 1.

FISHERIES

PÊCHES

Abstracts

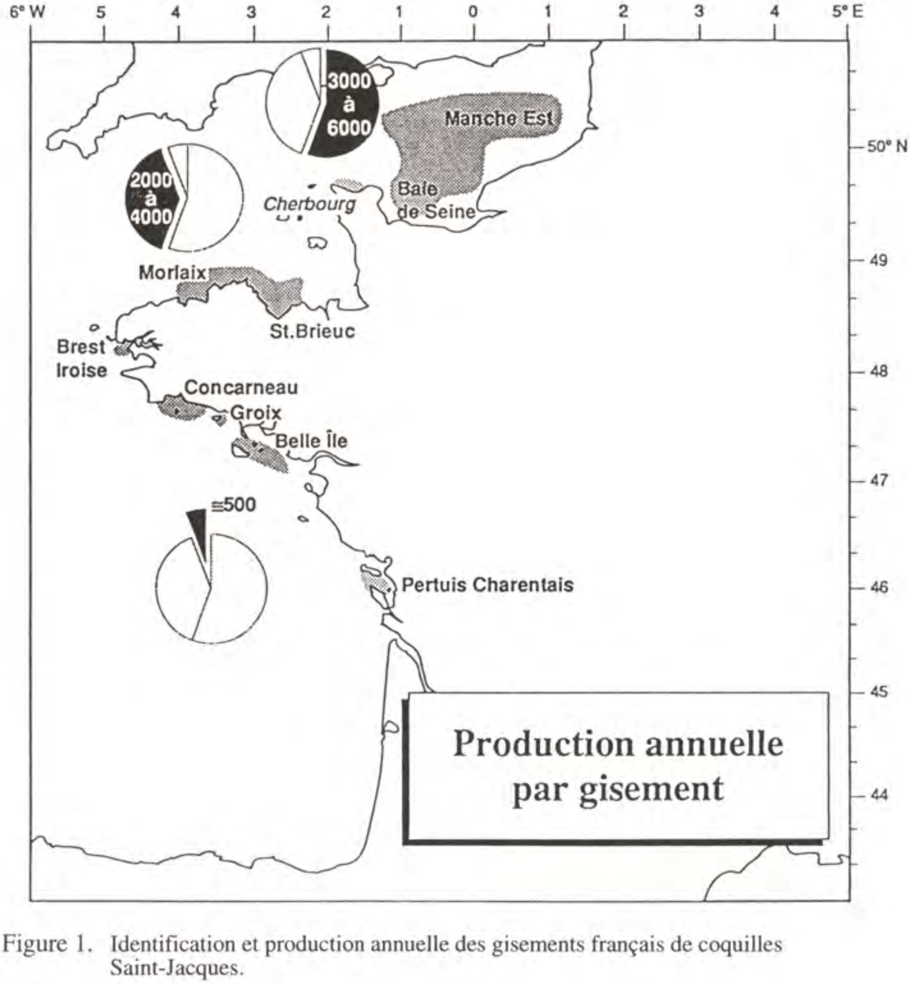

Figure 1. Identification et production annuelle des gisements français de coquilles Saint-Jacques.

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IFREMER, ACTES de COLLOQUES - N° 17 - 1995

EASTERN CHANNEL SCALLOP STOCK MANAGEMENT

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Abstract : *Regional economic importance of this resource is so great that its exploitation is annually carried out from the ports of this area in a passionate atmosphere. IFREMER, confronted with professional realities, has set up direct stocks surveys, very expensive in time and manpower, owing to the large area to be prospected. This method has been prefered to analytic fisheries assessment approaches using annual catch and effort data, leading to quotas recommendations. Indeed, there is incompatibility between this analytic method and scallops population structure, constituted essentially by two age groups directly depending on recruitment. Only an area by area and short-dated management could be considered. This management is based on immediate recommendations given during meetings with fishermen who decide regional rules, reconsidered each year, in order to adapt fishing effort to stock condition while saving socio-economic requirements.*
The only one measure based on biological arguments, beside boxes, is the minimal capture size. The choice of that one results from a compromise between growth characteristics, its annual variability, and first age maturity. It is, at present, the only one measure that EEC could agree in order to apply it to all vessels fishing in eastern channel.
IFREMER Laboratory has chosen an assessment method adapted to stock characteristics and to exploitation background. Would it be possible, in scientific terms, to conceive a better way of management which could remain realistic in scientific cost and in fishermen opinion.

Key words *: Scallop, stock assessment, stock management, eastern channel*

INTRODUCTION

Les côtes françaises disposent de nombreux gisements de coquilles Saint-Jacques (*Pecten maximus*) qui s'étendent de la côte atlantique au pas de Calais (fig. 1). La superficie et la production sont très variables selon les gisements. Les plus importants, en particulier ceux de Saint-Brieuc et de la Manche-Est, font l'objet, depuis plusieurs années, d'une gestion à base scientifique concertée avec les professionnels.

POIDS ÉCONOMIQUE

Les gisements de la Manche Est, les plus étendus géographiquement (environ 12000 km^2), sont exploités par les flottilles des ports riverains (fig. 2). Pendant l'ouverture de la pêche, la quasi-totalité des bateaux aptes aux arts traînants, plus de 200 unités, en pratiquent prioritairement le dragage. Dans certains ports, la coquille représente selon les années plus de 60% des apports et correspond à plus de 70% de la valeur des produits débarqués. Au niveau régional, la coquille représente donc un poids économique important, qui justifie le climat passionnel dans lequel s'effectue généralement son exploitation.

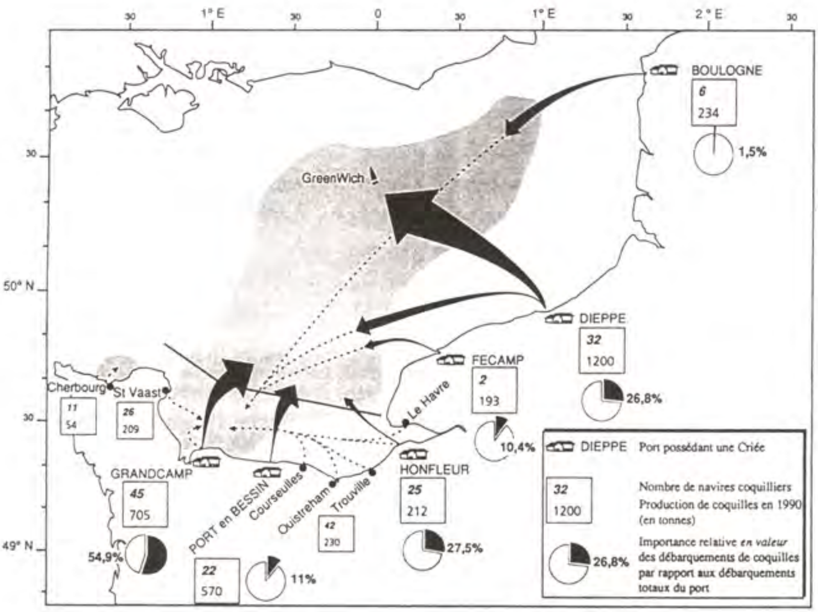

Figure 2. Identification des ports pratiquant la pêche de la coquille, leur stratégie et leur production en 1990.

ÉVALUATION DU STOCK

Depuis une dizaine d'années, l'attrait de cette ressource régionale est fortement contrarié par une baisse de rendement et des difficultés d'exploitation (gestion des stocks, marchés,...). L'IFREMER a souhaité s'investir dans ce domaine et, confronté aux réalités de terrain, a mis en place une méthode de prospection répondant à l'attente de la profession. Des campagnes annuelles d'évaluation directe en mer ont été effectuées. Celles-ci s'avèrent très riches en informations pour une meilleure gestion de la ressource. Elles sont par contre coûteuses et contraignantes car :
- les résultats, servant de base de réflexion pour l'organisation annuelle de l'exploitation, sont à fournir dans un délai très court;
- la superficie à prospecter est très importante, ce qui exige de trouver un compromis entre la précision des évaluations et le poids financier de l'opération, en temps et en personnel embarqué (campagne d'un mois par an minimum).

Afin de tirer le meilleur parti de ces prospections, plutôt qu'un échantillonnage systématique, nous avons adopté un plan d'échantillonnage stratifié accordant un poids relatif plus important aux zones les plus exploitées, qui sont généralement les zones les plus sensibles du point de vue gestion (fig. 3).

MODE DE GESTION

La gestion des gisements de la Manche-Est , repose sur les résultats des évaluations directes. Il ne nous semble pas envisageable d'utiliser les méthodes de gestion basées sur les données annuelles d'effort et de production aboutissant à des recommandations annuelles de quotas. En Manche-Est et, plus particulièrement en baie de Seine, l'exploitation repose essentiellement sur deux, voire même quelquefois une, classes d'âge (fig. 4). Seules, peuvent donc être faites des prévisions à très court terme, avec recommandations immédiates à la profession, mais pas en termes de quotas.

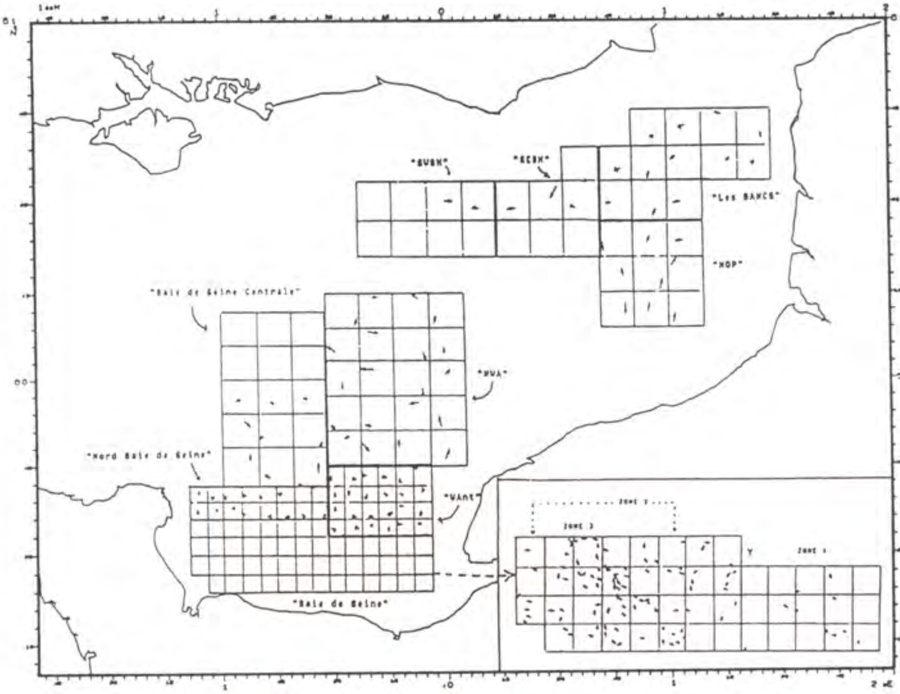

Figure 3. Campagne de prospection en Manche Est (1990)
Stratégie d'échantillonnage et position des traits effectués.

MESURES DE GESTION

Les recommandations proposées au cours de réunions avec les professionnels conduisent ceux-ci à adopter des mesures de gestion régionales, réactualisables chaque année, et visant essentiellement à encadrer l'effort de pêche par un système de : dates de campagne de pêche, licences, quotas individuels.

Les décisions professionnelles, concernant plus particulièrement la bande des 12 milles, tiennent compte des recommandations de l'IFREMER relatives à l'état du stock, mais aussi, et surtout, de considérations socio-économiques, dont l'état du marché au jour le jour. Face à des changements de mode d'exploitation très rapides décidés par les pêcheurs en cours de campagne, l'IFREMER cherche à disposer, par échantillonnage sur les quais, d'un bon suivi des compositions en âge des apports. Tout déséquilibre important vers des apports de trop jeunes individus est signalé à la profession et aux autorités pour modifications de la campagne. A titre d'exemple, en 1991, fut créé, en fin de campagne, un cantonnement important destiné à protéger les individus du groupe I, de plus en plus nombreux dans les apports.

En terme de gestion, la seule mesure reposant sur des arguments strictement biologiques est donc la taille minimale de capture qui vise à protéger entièrement le groupe I et à épargner une grande partie du groupe II qui n'a pas, ou trop incertainement, contribué à la reproduction. Cette mesure a pour autre objectif de conserver un reliquat de ce groupe II pour la saison suivante, et de jouer ainsi un effet tampon entre les années de fort et de faible recrutement.

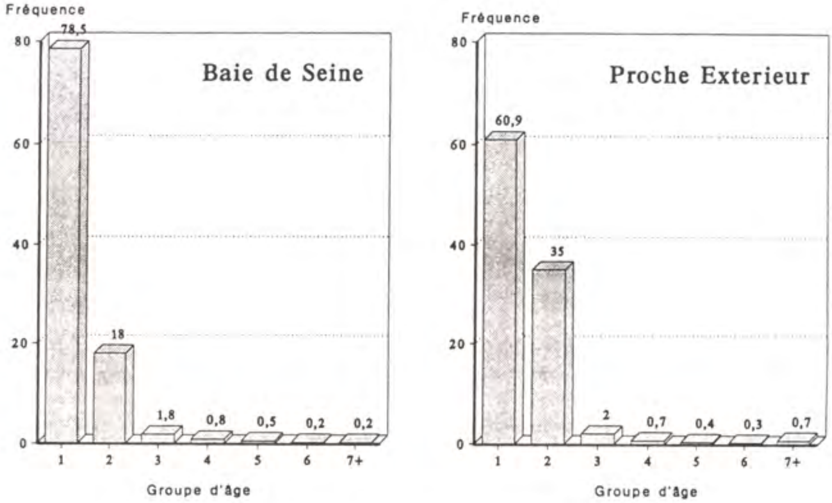

Figure 4. Indices d'abondance -campagne COMOR XX- 1990.

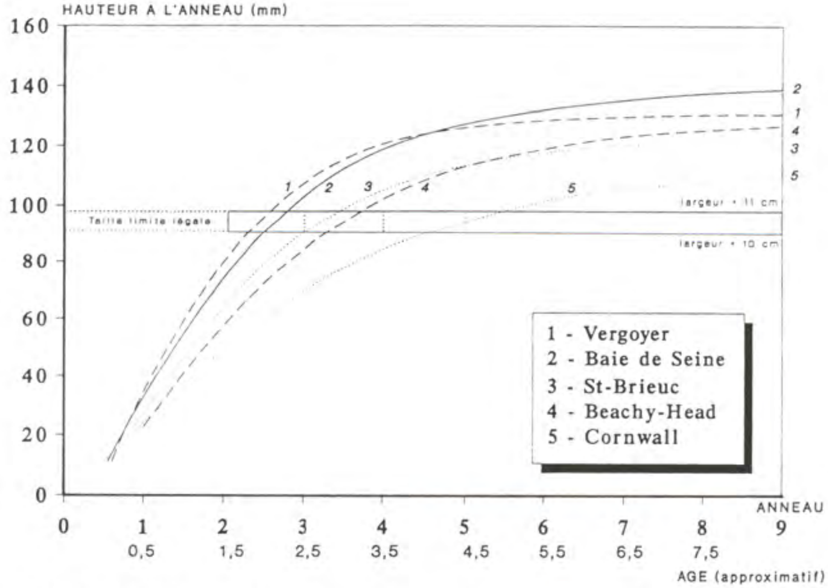

Figure 5. Courbes théoriques de croissance pour différents gisements. (L. Antoine, 1979).

La taille minimale actuellement adoptée en Manche-Est -11 cm en largeur- résulte d'un compromis entre :
- la croissance qui, dans cette zone, et plus particulièrement en baie de Seine, est plus rapide que sur les autres gisements, notamment celui de Saint-Brieuc (fig. 5),
- la variabilité annuelle très dépendante des conditions d'environnement ; l'idéal serait de pouvoir modifier cette taille minimale en fonction de la croissance annuelle, ce qui n'est bien sûr pas envisageable pour des raisons de réglementation communautaire,
- l'âge de première maturité.

Un problème majeur subsiste cependant concernant cette mesure de gestion. La taille minimale de 11 cm, en Manche-Est, est applicable uniquement aux bateaux français. Une demande est en cours pour que cette décision soit entérinée par la CEE et soit ainsi applicable à tous les navires européens pêchant la coquille en division CIEM VII_d. Ce règlement viendrait alors conforter un remarquable consensus entre professionnels et scientifiques autour d'une mesure qui n'était pas encore évidente à adopter il y a quelques années

CONCLUSION

Le laboratoire IFREMER s'est orienté vers un mode de gestion adapté aux caractéristiques du stock de la Manche-Est, ainsi qu'au contexte de son exploitation. Cette démarche, différente de celle adoptée pour la gestion du gisement de Saint-Brieuc, a pour souci d' apporter une réponse rapide à une demande régionale et ainsi de travailler en relation directe avec la profession.
Par contre, il est impossible d'effectuer des prévisions à long terme, hormis sous forme de tendances, et les discussions préalables aux prises de décision ont lieu dans un climat de tension perpétuel, encore incompatible avec une gestion plus rigoureuse.
Mais est-il possible, au niveau scientifique, d' améliorer la gestion des gisements de coquilles Saint Jacques en Manche-Est, en faisant en sorte que celle-ci reste réaliste en coût scientifique et aussi aux yeux des professionnels?

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MASS MORTALITY IN THE CALICO SCALLOP, *Argopecten gibbus*, CAUSED BY *Marteilia* sp.

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***Abstract** : In January, 1989 mass mortality was observed in the calico scallop, **Argopecten gibbus**, population located on the eastern coast of Florida. Histological examination pointed to the presence of a protozoan in the digestive diverticulum as the probable cause. The protozoan pathogen was later identified as an ascetosporan of the genus **Marteilia**. By the time this determination was made there was no further evidence of the protozoan in the remaining scallop population. Prior to this event there have been no reported cases of this pathogen in the bivalves of North American waters. In February of 1991 the protozoan pathogen reappeared in the Cape Canaveral calico scallop population. Presence of this protozoan has resulted in mortality approaching 100% of the total scallop population. The pathogen results in severe pathology in the scallop with massive infestation of the tubules of the digestive diverticulum resulting in mortality due to starvation in less than a month.*

***Key words** : Argopecten, Ascetosporan, Histopathology, Marteilia, Mortality, Scallops,*

INTRODUCTION

In January of 1989 evidence of wide spread mortality in the calico scallop *Argopecten gibbus* population located on the eastern coast of Florida off Cape Canaveral was noted. Histological examination of scallops collected at the time led to massive infestation of the tubules of the digestive diverticulum by an unknown protozoan. The pathology of the animals was identical to that of animals experiencing starvation.

Further examination led to the conclusion that the protozoan pathogen was most likely an ascetosporan of the genus *Marteilia.* By this time there was no further evidence of the protozoan in the few remaining scallops. It was therefore not possible to confirm the identification using electron microscopy to examine the ultrastructure.

In February of 1991 the protozoan pathogen reappeared in the Florida calico scallop population again accompanied by massive and wide spread mortality. The decimation of the scallop population has resulted in the cessation of all fishing activities for this species. While *Marteilia* has been identified as a pathogen in Europe and Australia (Comps, 1970; Wolf, 1972; Perkins & Wolf, 1976; Alderman, 1979) infestation of the A. gibbus population off Florida by *Marteilia* is the first recorded occurrence of this protozoan pathogen in North American waters. This also appears to be the first time that *Marteilia* has been identified as a pathogen in scallops.

METHODS

Scallops collected were fixed in Helly's fixative made with zinc chloride and then embedded in paraffin using standard histological techniques (Barszcz & Yevich, 1975). The slides obtained were stained either in Hematoxylin and Eosin (Luna, 1968) or with Cason's Trichrome stain for connective tissue (Cason, 1950).

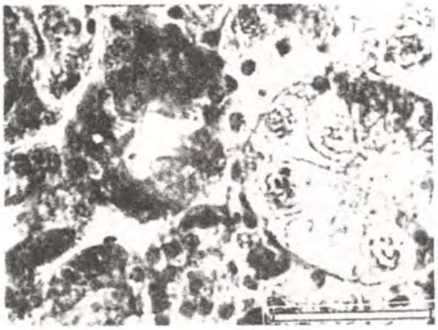

Figure 1. Digestive diverticulum of a normal calico scallop scale bar = 50 ~m.

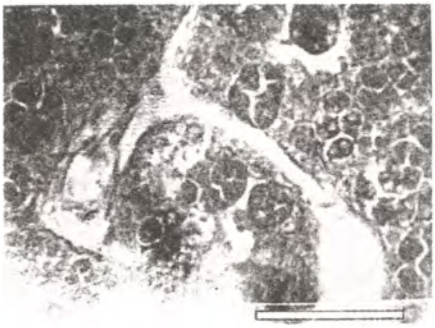

Figure 2. Digestive diverticulum of a calico scallop infected by Marteilia scale bar = 50 ~m.

Figure 3. Intestine of a normal calico scallop scale bar = 100 ~m.

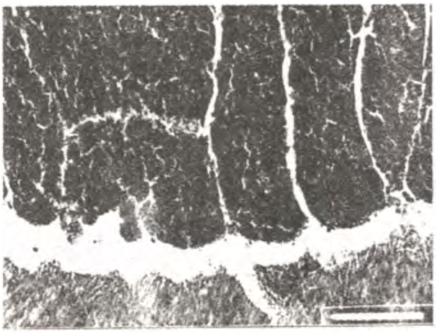

Figure 4. Intestine of a calico scallop infected by Marteilia scale bar = 100 ~m.

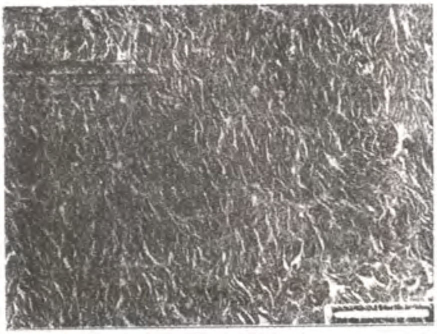

Figure 5. Adductor muscle of a normal calico scallop scale bar = 100 ~m.

Figure 6. Adductor muscle of a calico scallop infected by Marteilia scale bar = 100 ~m.

RESULTS

With the initial mortality in January of 1989 59 calico scallops collected over a 1 month period were examined histologically. In all of these animals a protozoan parasite later identified as *Marteilia* was found throughout the tubules of the digestive diverticulum. Attempts to locate additional scallops for analysis were unsuccessful until July of 1991. At that time there was no further evidence of the *Marteilia.* Ongoing studies dictate that samples are collected for histological examination on a monthly basis.

In February of 1991 scallops were collected from 3 locations over a 110 km north to south area following early reports of mortality from scallop fishermen. A total of 45 scallops were examined. The *Marteilia* pathogen was again observed in the digestive diverticulum of the majority of the scallops examined. Distribution of infected scallops varied considerably with location however with 86%, 27%, and 69% of the scallops collected from the northern, central and southern stations infected with the *Marteilia* pathogen.

Figures 1 and 2 compare the digestive diverticulum of a normal calico scallop with a scallop infected with *Marteilia.* In the infected scallop the lumen of the tubules of the digestive diverticulum become filled with the *Marteilia* plasmodia. There is no evidence in any of the animals examined of the pathogen moving into surrounding epithelial cells or the connective tissue. The percentage of the digestive diverticulum exhibiting evidence of the pathogen varies but appears to be progressive. The most extensive infestation appears to be found in those animals at or near death at which time virtually 100% of the tubules are infected. The highly refringent plasmodia are quite easily discerned with either Hematoxylin and Eosin staining or Cason's Trichrome stain. The Cason's stain results in the refringent plasmodia appearing pink against a blue background leading to rapid identification of those animals exhibiting signs of infestation by the *Marteilia*.

In those scallops exhibiting extensive infestation refringent plasmodia are also observed in the intestine of the animal. Figures 3 and 4 compare the intestine of normal and *Marteilia* infected scallops respectively. It appears that the plasmodia in the intestine are being excreted rather than invading surrounding tissue. It is not known whether this is a response by the scallop to the infestation or part of the normal excretion of undigested material.

Scallops in which large portions of the digestive diverticulum are infected by the pathogen do not appear to be able to extract sufficient energy from available food levels to maintain routine metabolic energy costs. Extensively infected animals show evidence of catabolizing body tissue. This is particularly evident in the adductor muscle as depicted in Figures 5 and 6 comparing normal and *Marteilia* infected scallops.

DISCUSSION

There are at least 5 species of *Marteilia* that have been identified as pathogens in various animals (Figueras & Montes, 1988). The host commonly involved is the oyster. Different species of *Marteilia* are associated with particular oyster species. The most extensively studied is *Marteilia refrinqens* with the primary host being *Ostrea edulis.* The pathogen *Marteilia refringens* has been cited as the cause of mass mortalities in the oyster population in the Bretagne region of France in the early 1970's (Comps et al., 1975; Grizel et al., 1974).

Marteilia species have also been implicated as a pathogen in other species. Mortality in the Sydney rock oyster *Crassostrea commercialis* in the early 1970's was attributed to a haplosporidium later identified as *M. sydneyi* (Perkins & Wolf, 1976). Besides the european flat oyster *M. refringens* has been found in *Mytilus edulis, Cardium edule*, and *Crassostrea gigas* (Comps et al., 1975; Gutiérrez, 1977). Other species of *Marteilia* parasitize *Saccostrea cuculata*, *Mytilus galloprovincialis*, *M. edulis* and *Scrobicularia piperata* (Comps et al., 1982; Figueras and Montes, 1988). There is however no reports in the literature of a *Marteilia* pathogen parasitizing a scallop species prior to this time nor of any animal being affected in North American waters.

It appears clear that the recent mass mortalities observed in the calico scallop are the result of the appearance of *Marteilia* in North American waters where it has never before been observed. The epizootics of this case appears to be the classic consequence of a marine shellfish population being exposed to a pathogen with which it had no previous evolutionary experience and to which it was susceptible (Sindermann, 1990). It remains to be determined if increased resistance among survivors has been or will be developed in this population. Initial indications are that infestation levels are lower in 1991 than were observed in 1989.

The *Marteilia* prevents the scallop from obtaining sufficient nutrition from the water column possibly by consuming ingested material prior to assimilation by the scallop. There is no evidence of inflammatory or other immunological responses by the scallop to the presence of the parasite. Death appears to be caused by starvation.

Marteilia has been known to cause significant population reductions during epizootic periods resulting in extensive economic repercussions (Grizel, 1983, 1985). The mass mortalities reported in this paper among the calico scallop population off the east coast of Florida has also resulted in drastic reductions in the scallop industry. Since the initial outbreak more than half of the companies involved in scallop production have ceased production and the future viability of this fishery is currently unknown.

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DISTRIBUTION AND ABUNDANCE OF TWO SCALLOP SPECIES, *Placopecten magellanicus* AND *Chlamys islandica*, IN NAFO SUBAREA 3 (DIV. 3PS)

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Abstract *: The spatial distribution and temporal variation in abundance of sea scallops (**Placopecten magellanicus**) and Iceland scallops (**Chlamys islandica**) off the south coast of Newfoundland (NAFO Subarea 3) are described.*
The larger sea scallop is towards the northern limit of its distribution range and commercial aggregations (beds) are confined to waters shallower than 30 fm (55 m). This restricts overall distribution on the Bank to less than 2,294 n mi^2. of this area only about 720 n mi^2 contain sea scallops in densities sufficient to attract commercial effort.
Directed fishery for this species is typically characterized by disproportionate dependence on sporadic recruitment of a single or a few well-spaced year-classes. The Iceland scallop is more widely distributed, its bathymetric range extending down to 100 fm (185 m) corresponding to an area of 4,582 n mi^2 on St. Pierre Bank. The better catches come from 40-50 fm (70-90 m). The slow growing Iceland scallop has been more persistent particularly along the northern aspect of the Bank. Iceland scallops here remain underutilized. Consequently, we do not know how resilient the stocks might be to fishing.

INTRODUCTION

Sea scallop beds of sufficient extent and density to support commercial fisheries occur from Virginia Capes, U.S. (latitude 36 50'N) to Port au Port Bay, Newfoundland, Canada (latitude 48 40'N). Offshore, sea scallops have been exploited commercially on Georges Bank, the mid-Atlantic Shelf, Browns Bank, German Bank, Lurcher Shoals, Grand Manan, around Sable Island, Middle Ground, Banquéreau Bank, and on St. Pierre Bank (fig. 1). In the center of its range (Georges Bank and Middle Atlantic Shelf), scallops have been quite successful and have withstood moderate to heavy exploitation. Towards the extremes of their range, sea scallops generally have been less successful and have not withstood continued heavy exploitation (Dickie and Medcof, 1963).

Three discrete offshore plateaus are recognized off Newfoundland, viz. St. Pierre Bank, Green Bank, and Grand Bank. Collectively, they are commonly referred to as the Grand Banks of Newfoundland. They are among the most biologically productive continental shelves in the world and support significant fisheries. St. Pierre Bank and Green Bank are westward extensions of this vast apron of shelf, and together, are contained within NAFO Div. 3Ps. The benthic communities here are composed of primarily Arctic-boreal and boreal species. While polychaetes are the most numerous, molluscs and echinoderms account for the greater percentage of weight (Hutcheson *et al.*, 1981). St. Pierre Bank is unique in that in some areas

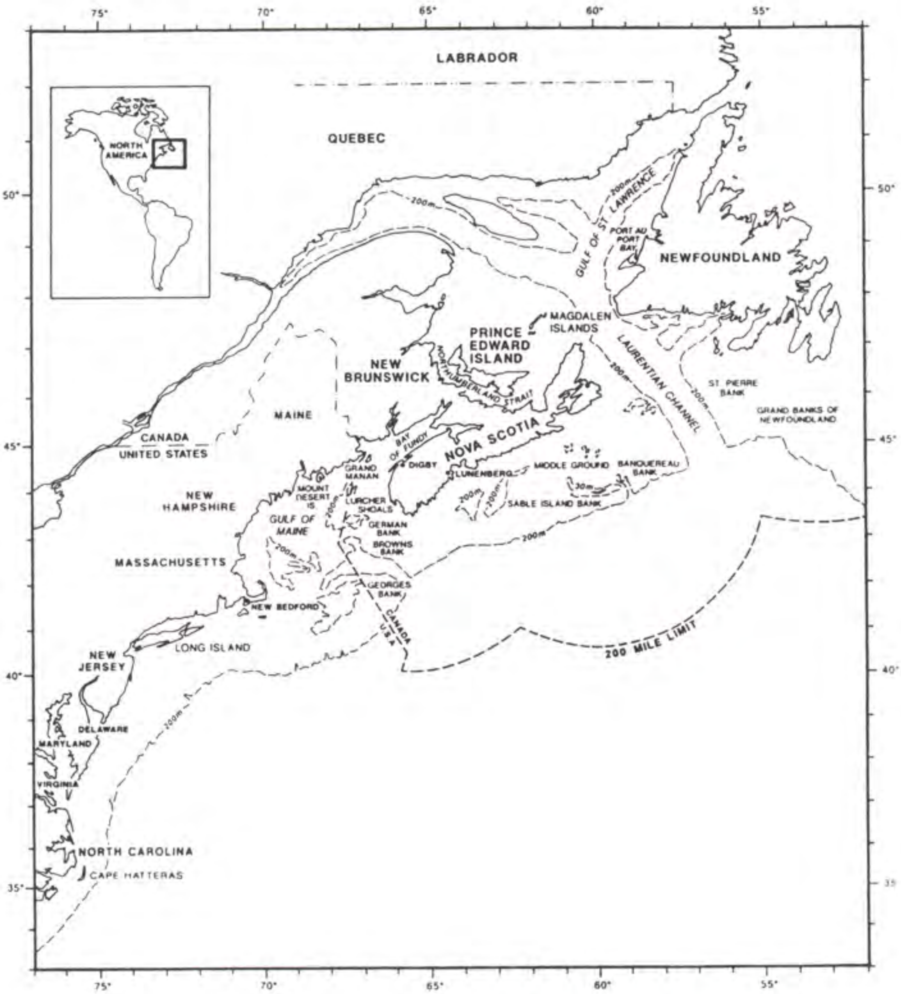

Figure 1 Principal sea scallop, Placopecten magellanicus, fishing grounds in the Northwest Atlantic.

two scallop species (sea or giant scallop, *Placopecten magellanicus* and Iceland scallop, *Chlamys islandica*) occur, frequently on the same beds. The sea scallop is towards the northern limit of its distribution range and commercial aggregations (beds) occur only in waters shallower than 30 fm (55 m). This restricts its overall distribution on the Bank to less than 2,294 n mi^2. of this only about 720 n mi^2 contains sea scallops in high enough densities to warrant commercial effort. The Iceland scallop is more widely distributed, its bathymetric range extending down to 100 fm (185 m) corresponding to an area of 4,582 n mi^2 on St. Pierre Bank. Best catches come from 40-50 fm (70-90 m).

Table 1. Canadian and French scallop landings (t, round) from NAF0 Div. 3Ps.

	Canada			
Year	Newfoundland	Mainland	France	Total
1958	-	2	-	2
1959	-	-	-	-
1960	-	-	-	-
1961	594	-	-	594
1962	1	-	-	1
1963	-	306	-	306
1964	652	2336	-	2988
1965	19	113	-	132
1966		-	-	-
1967	22	1317	-	1339
1968	44	74	-	118
1969	88	684	-	772
1970	189	1054	-	1243
1971	46	227	-	273
1972	-	238	-	238
1973	-	301	-	301
1974	29	-	-	29
1975	4	-	-	4
1976	18	-	-	18
1977	86	-	-	86
1978	41	75	-	116
1979	130	9	-	139
1980	67	189	-	256
1981	30	-	-	30
1982	169	5805	-	5974
1983	102	4697	-	4799
1984	312	3433	-	3745
1985	211	317	-	528
1986	328	1274	2	1604
1987	404	305	23	732
1988	1591	6597	98	8286
1989	573	2548	20.5	3141.5
Means	230.0	1450.3	35.9	1303.3
National x	801.1		35.9	

Numerous offshore explorations have been conducted on St. Pierre Bank (e.g. Naidu *et al.*, 1983a, 1983b; Naidu and Cahill, 1984). Most of the earlier Canadian surveys were targeted primarily for the larger sea scallop (Dickie and Chiasson, 1955; Somerville and Dickie, 1957; MacPhail and Muggah, Jr., 1965; Rowell *et al.*, 1966, fig. 2). These exploratory surveys were conducted primarily to ascertain presence or absence and, therefore, pose undue problems from the viewpoint of estimating biomass. France has also conducted research surveys on St. Pierre Bank (e.g. Migayrou and Moguedet, 1990).

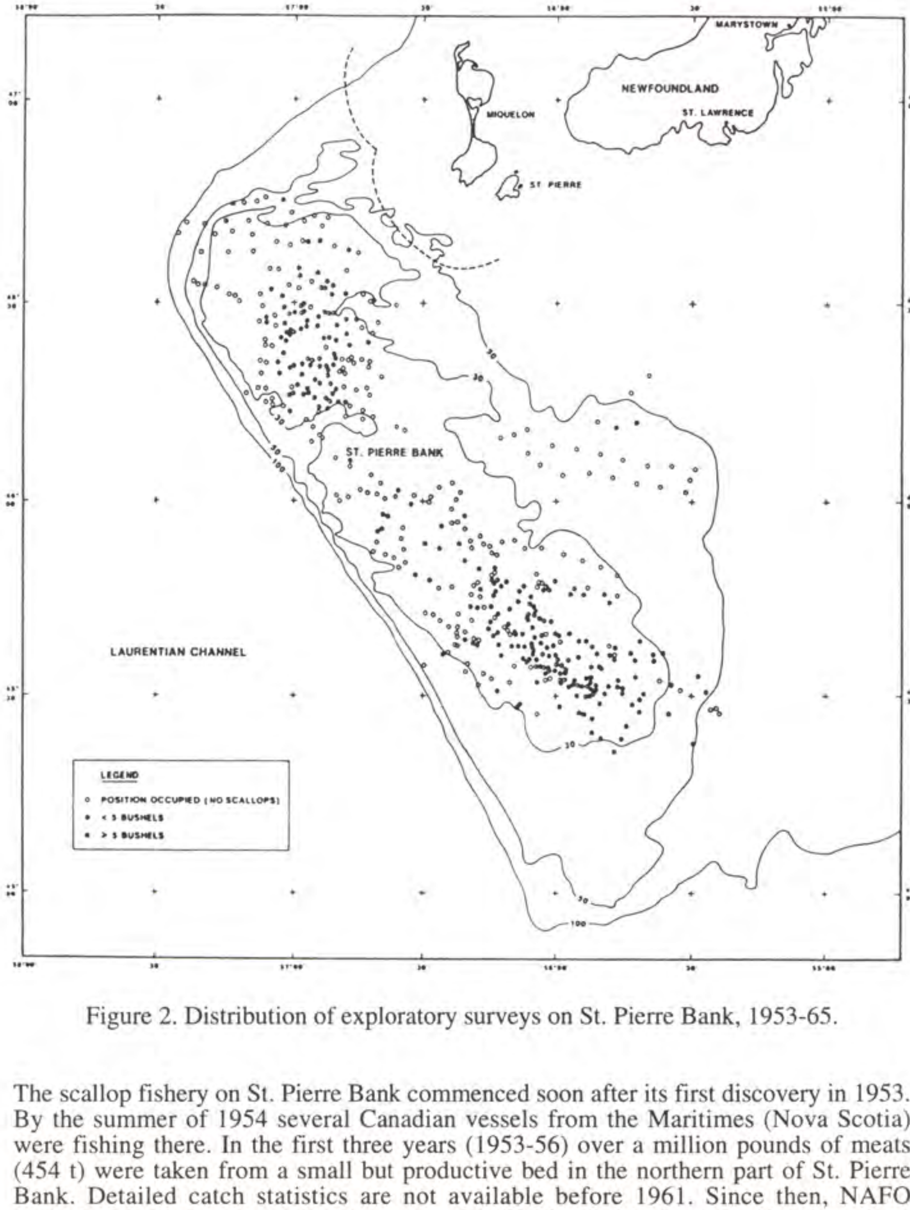

Figure 2. Distribution of exploratory surveys on St. Pierre Bank, 1953-65.

The scallop fishery on St. Pierre Bank commenced soon after its first discovery in 1953. By the summer of 1954 several Canadian vessels from the Maritimes (Nova Scotia) were fishing there. In the first three years (1953-56) over a million pounds of meats (454 t) were taken from a small but productive bed in the northern part of St. Pierre Bank. Detailed catch statistics are not available before 1961. Since then, NAFO Statistical Bulletins report landings annually (Table 1). Much of the Newfoundland landings come from inshore beds. All other Canadian landings reported here are from offshore scallop beds on St. Pierre Bank. Scallops caught offshore are sometimes discharged in Newfoundland. This accounts for some of the anomalous landings for Newfoundland.

Systematic work on the distribution and population dynamics of scallops on St. Pierre Bank commenced in 1970's (Naidu *et al*., 1983 ; Kopp and Dupouy, 1986). Surveys for sea scallops are now conducted annually in each of the two areas where scallop beds are formed during favourable years of larval settlement (fig. 3). However biomass estimates derived for industry for the purpose of establishing Total Allowable Catches (TAC's) and Enterprise Allocations (EA's) are based on aggregations most likely to attract commercial effort. Typically, estimates of fishable sea scallop biomass have ranged from less than 100 t to about 2000 t of meat corresponding to 833-16,700 t round weight respectively (table 2). Only the adductor muscle is taken. All shucking is done at sea. Each of the two principal areas conducive to the formation of sea scallop beds where assessments are generally conducted is approximately 360 n mi^2 (fig. 3). Sea scallops are generally restricted to shallower than 30 fm (55 m) (table 3). They occur over a variety of bottom types ranging from rock, coarse gravel to sand (fig. 4).

Table 2. Estimates of sea scallop biomass [numbers and weights (t, round)] on St. Pierre Bank (NAF0 Div. 3Ps). Based on dredge-caught samples and a gear efficiency of 20X.

Year	95 % Confidence limits (mean)	
	Number (millions)	Round weight (t)
1979	12-26 (x = 19)	3,405-7,210 (x = 5,310)
1983	3-9 (x = 6)	521-1,157 (x = 838)
1984	10-27 (x = 19)	1,224-3,377 (x = 2,300)
1985	25-49 (x = 37)	2,234-2,873 (x = 2,554)
1986	22-37 (x =30)	2,077-2,738 (x = 2,408)
1987	87-157 (x = 122)	6,895-10,855 (x = 8,875)
1988	139-205 (x = 172)	15,225-21,454 (x = 18,339)
1989	36-50 (x = 43)	4,937-6,517 (x = 5,727)
1990	12-19 (x = 16)	1,765-2,420 (x = 2,093)

The ten-year research data base has given us a composite picture of the distribution of the two scallop species (Fig. 5). Two major and one minor sea scallop aggregations are usually recognized (fig. 6). Occurring as they do towards the northern extreme of its distribution range, sea scallops here have not been able to withstand continued heavy exploitation. The fishery is typically characterized by a disproportionate dependence on sporadic recruitment of a single or a few intermittent and sometimes, well-spaced year-classes (fig. 7). The 1982 year-class, for example, was one of the strongest cohorts in recent years. With harvesting regulations in place primarily to discourage growth overfishing, record removals were realized in 1988. But, as in other fringe areas, the sea scallop fishery here must cope with wide and, sometimes, catastrophic temporal fluctuations. The question of whether sea scallop aggregations here are self sustaining has not been unequivocally resolved. Overall, the evidence for the existence of discrete stock units is not persuasive (Zouros and Gartner-Kepkay, 1985; Volckaert *et al*., 1990) and suggests larval exchange between areas (Naidu and Anderson, 1984).

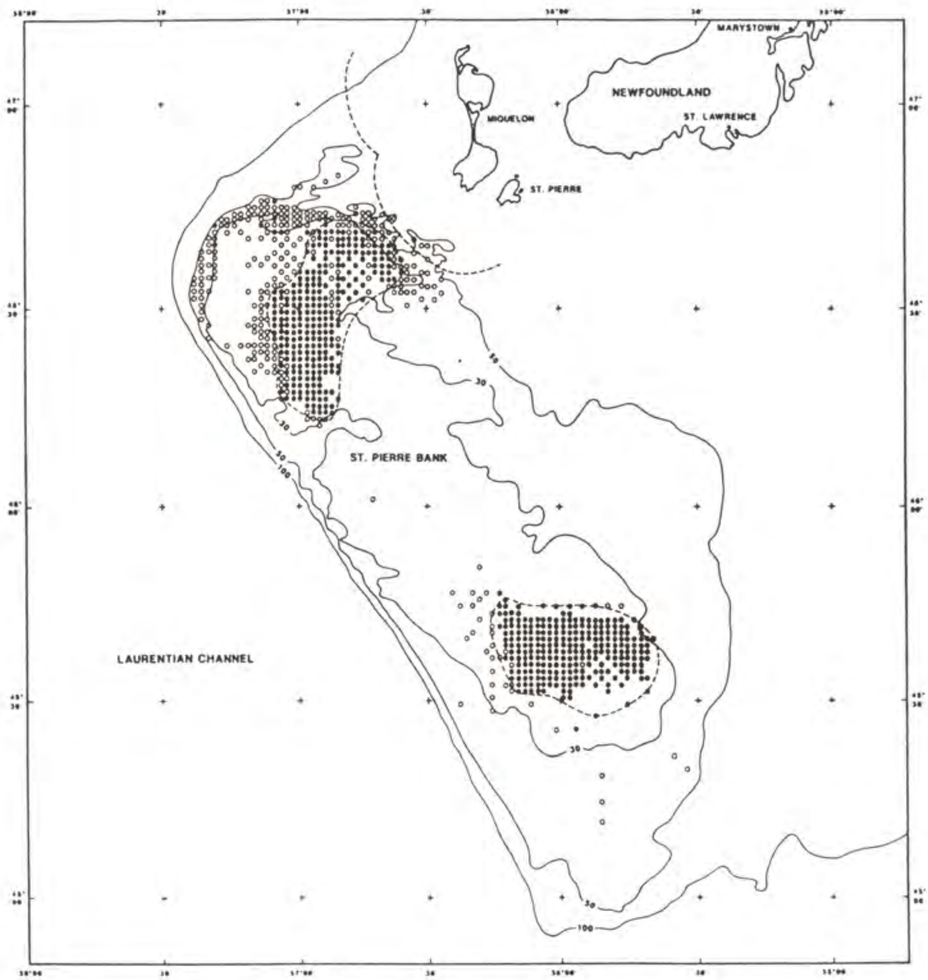

Figure 3. Areas favourable for sea scallop settlement on St. Pierre Bank. Each circle represents a research survey station. Closed and open circles represent presence or absence respectively (1983-90).

Iceland scallops, *Chlamys islandica*, have also been known to occur in this area for some time (e.g. MacPhail and Muggah, Jr., 1965). While there are a lot of Iceland scallops dispersed over much of St. Pierre Bank (Fig. 8), there are only limited areas where the density of scallops is such that commercialization is likely. The bulk of Iceland scallop aggregations is located within 40-75 m (Table 3) along the northern edge of St. Pierre Bank north of 46°30' (Fig. 9). Iceland scallops are predominantly associated with fine to coarse gravel (Fig. 4).

Table 3. Mean numbers of sea scallops and Iceland scallops/tow in relation to depth (m) on St. Pierre Bank, 1985-90.

DEPTH	SPECIES								
	ICELANDIC				SEA				
	Number		Weight		Number		Weight		
	Mean	STD	Mean	STD	Mean	STD	Mean	STD	N
30	0.00	0.00	0.00	0.00	5.75	2.87	1.64	0.92	4.00
35	42.85	205.50	1.91	9.73	185.77	386.45	22.43	39.34	206.00
40	195.77	734.00	9.81	34.35	367.74	814.06	36.66	64.92	627.00
45	1297.47	1358.3	11.75	38.75	186.63	421.82	20.16	38.89	369.00
50	2087.6	4714.3	79.08	157.23	151.72	255.55	14.71	17.33	61.00
55	1473.6	3925.8	56.26	112.69	21.60	59.40	1.55	2.23	20.00
60	4.00	4.24	0.21	0.18	15.75	19.09	3.91	4.58	4.00
65	31.50	40.31	2.50	3.13	0.00	0.00	0.00	0.00	2.00
70	2.50	0.71	0.20	0.14	0.00	0.00	0.00	0.00	2.00
75	0.00		0.00		0.00		0.00		1.00
80	5285	7474.1	344.45	487,12	0.00	0.00	0.00	0.00	2.00
365	0.00		0.00		0.00		0.00		1.00
380	0.00		0.00		0.00		0.00		1.00

Shell height distributions appear to be normal over several years pointing to greater stability in recruitment than observed in sea scallops (Fig. 10). Overall, the fishable biomass in this area is projected to be between 1640 and 3700 t meats (equivalent to between 11,714 and 26,428 t round weight (K.S. Naidu, unpub. data)). Elsewhere they are extremely patchy and, frequently, intermixed with sea scallops. Relative contributions are highly variable and may pose undue problems to species-specific management. While significant fisheries occur for the sea scallop here and elsewhere along the Atlantic seaboard, Iceland scallops remain underutilized. Fuller utilization of the species has been constrained by problems attendant with manually extracting meats from this mollusc (Naidu, 1987). While Iceland scallops sometimes contribute to the sea scallop by catch, they are culled heavily by offshore vessels retaining them and only the large ones shucked for meats. Very attractive scallop prices in 1984 encouraged several offshore vessels to target for this underutilized species (Naidu and Cahill, 1985). Approximately 80 % of removals (413 t meats) during 1984 are estimated to have been drawn from this species. A rejuvenated attempt at exploiting this resource has now begun. Beginning in 1989, components of the mid-shore fleet (45-64.9 ft ; 13.7-19.8 m LOA) operating out of Newfoundland started to prosecute this fishery. An experimental fishery commenced in 1989. Approximately 40 t meats were landed in 1990. With the availability now of equipment to mechanically extract meats there is renewed corporate interest in prosecuting this species.

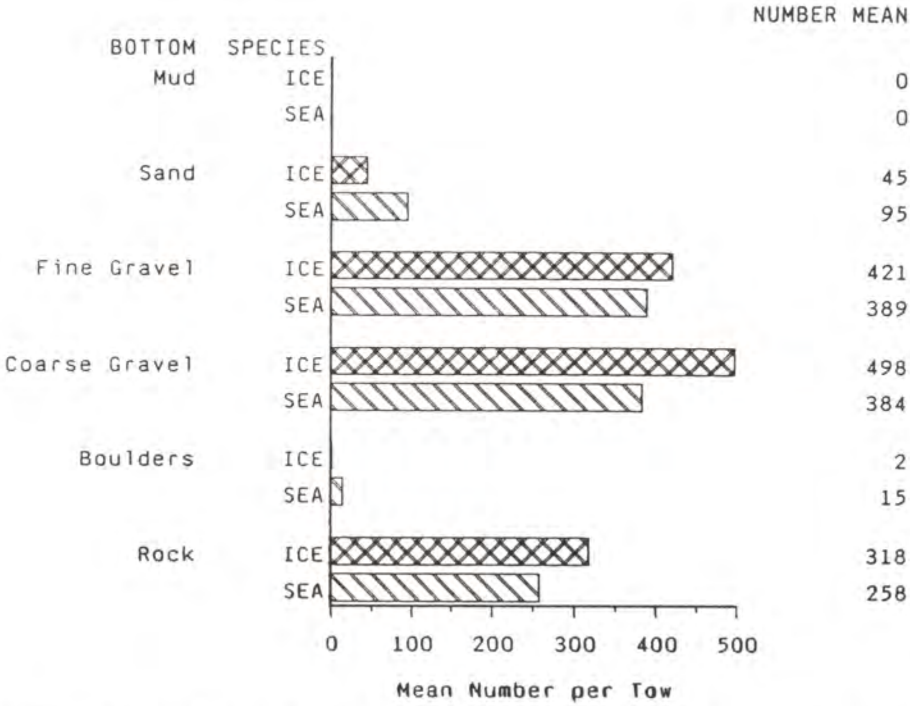

Figure 4. Species substrate association on St-Pierre Bank (based on 1299 observations).

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CAFSAC = Canadian Atlantic Fisheries and Scientific Advisory Committee (Comité scientifique consultatif des pêches canadiennes dans l'Atlantique)

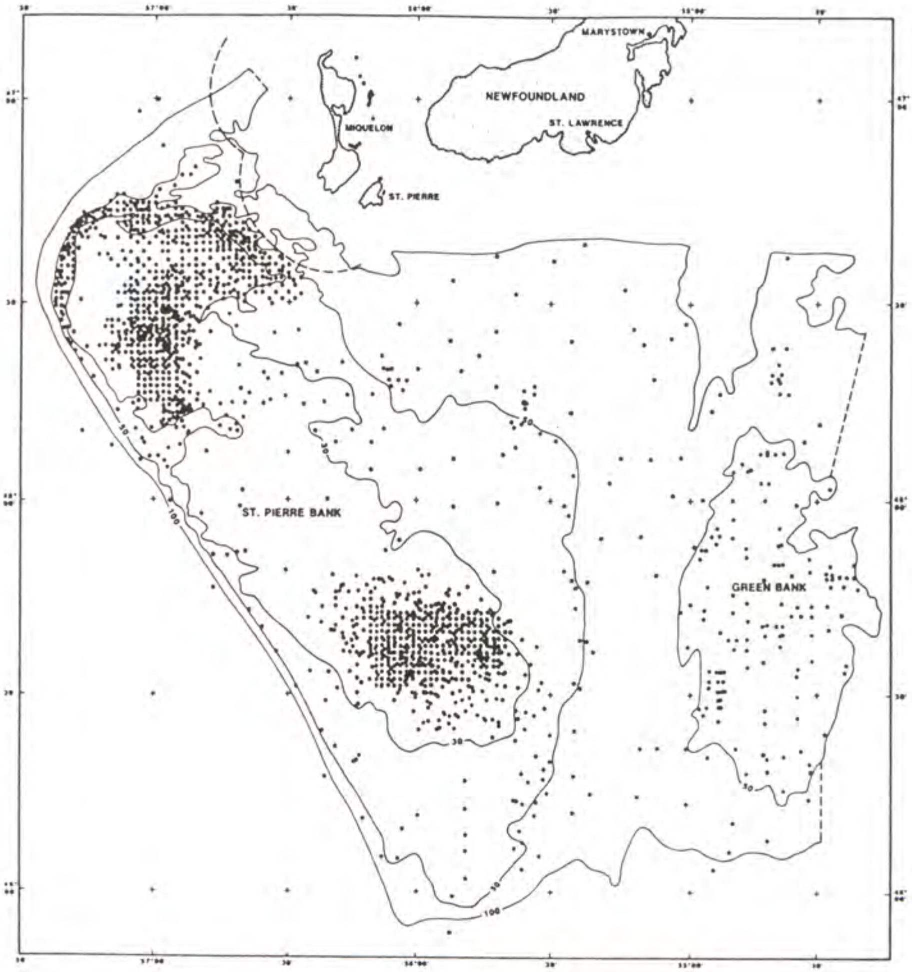

Figure 5. Distribution (composite) of research survey stations in NAFO Div. 3Ps, 1979-91. French territorial waters demarcated by broken line.

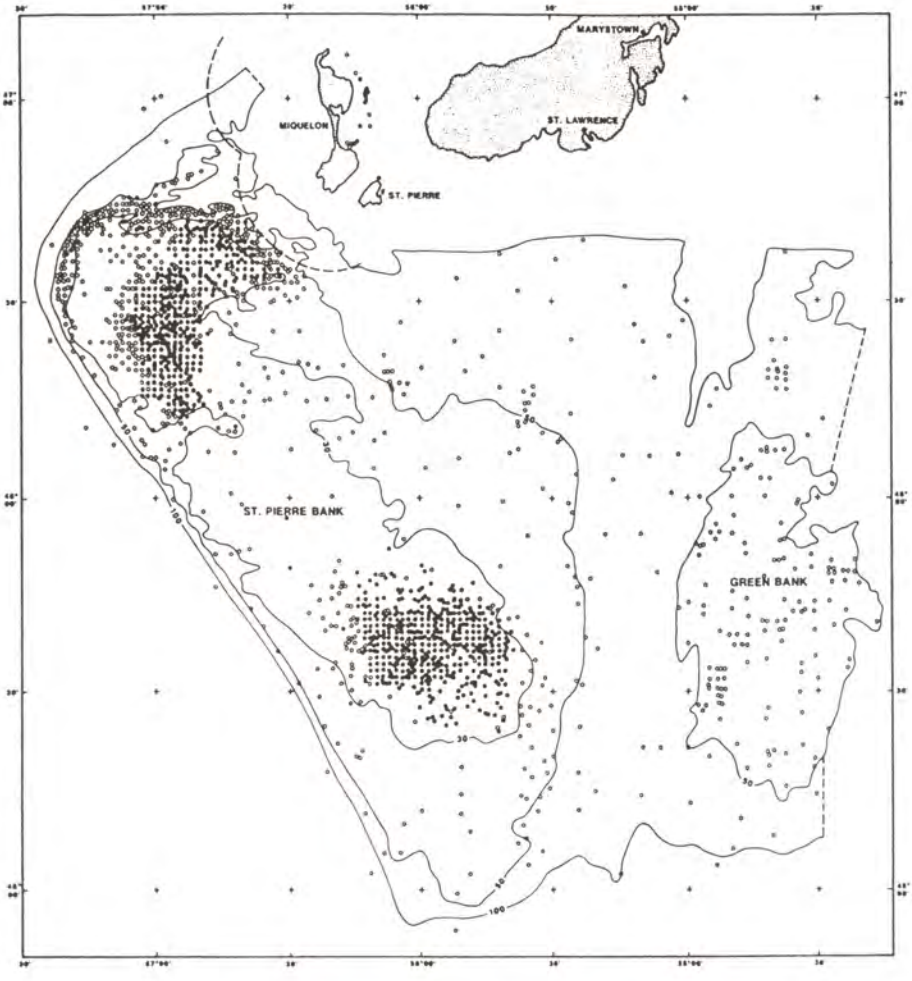

Figure 6. Distribution (composite) of sea scallops in NAFO Div. 3Ps. Each circle represents a research survey station. Closed and open circles represent presence or absence respectively (1979-91).

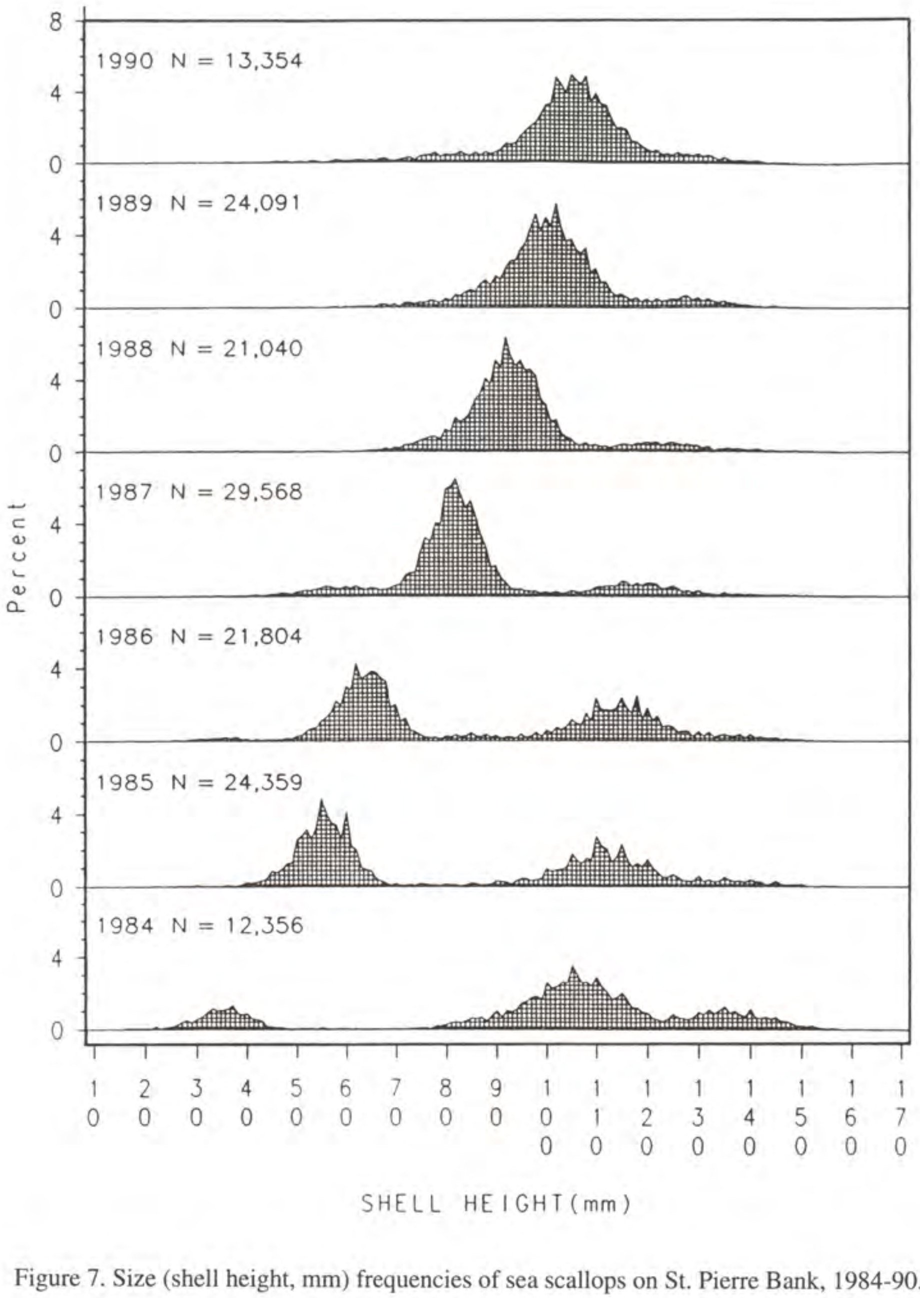

Figure 7. Size (shell height, mm) frequencies of sea scallops on St. Pierre Bank, 1984-90.

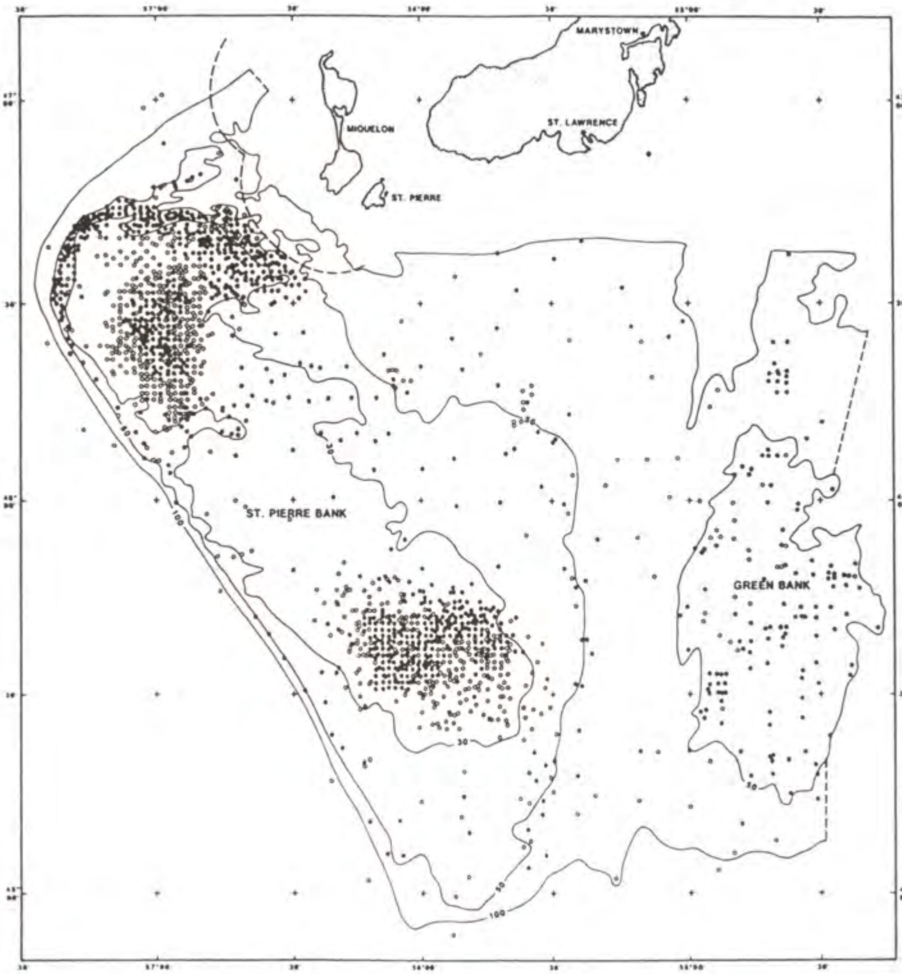

Figure 8. Distribution (composite) of Iceland scallops in NAF0 Div. 3Ps. Each circle represents a research survey station. Closed and open circles represent presence or absence respectively (1979-91).

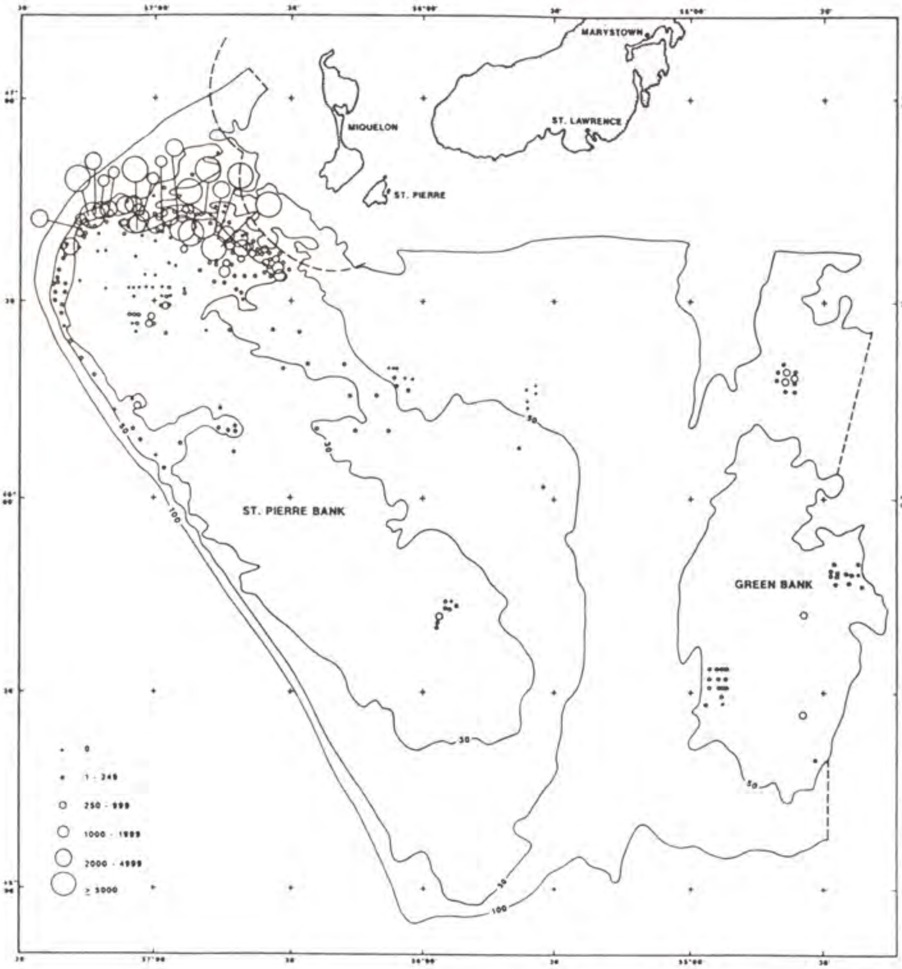

Figure 9. Distribution of Iceland scallops (nos./tow) in NAF0 Div. 3Ps. French territorial waters demarcated by broken line.

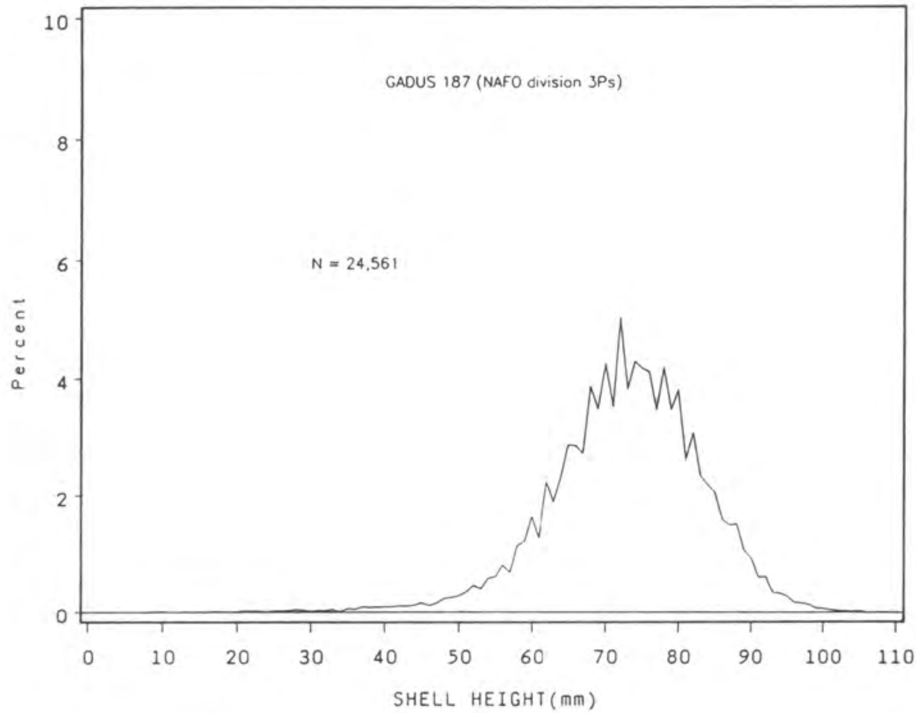

Figure 10. Size (shell height, mm) distribution of Iceland scallops in NAF0 Div. 3Ps, August-September 1990.

8th International Pectinid Workshop. Cherbourg (France) May 22-29, 1991
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GEORGES BANK SCALLOP (*PLACOPECTEN MAGELLANICUS*) POPULATION : DISTRIBUTION, SIZE-STRUCTURE, AND GROWTH

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INTRODUCTION

The sea scallop, *Placopecten magellanicus* (Gmelin 1791), supports a valuable fishery throughout its geographic range along the east coast of North America. Georges Bank (Northwest Atlantic) normally provides more than 50 % of the landings (Serchuk et *al.* 1979). Commercial concentrations generally occur at depths of 40-100 m. As a result of increased fishing effort, the fishery concentrates more on incoming recruitment and the annual harvests fluctuate depending on year-class strength. Establishment of pre-recruit (ages 1-2) indices would improve the Canadian fishery management plan ; stock assessment surveys give relative abundance indices for scallops above 35-40 mm shell height (third year of life) and quantitative data on post-larvae and juveniles prior to age 3 are rare (Larsen and Lee 1978, Thouzeau et *al.* 1991). Settlement patterns, distribution-regulating factors, juvenile growth, and growth-regulating factors have yet to be precised for Georges Bank.

The specific objectives of this study were to locate the distribution areas of ages 1 and 2 (compared to that of the adults), to define growth characteristics and spatial variations within the Bank, and to evaluate the impact of fishing activity on the size structure and growth parameters of the population.

MATERIALS AND METHODS

Three surveys were conducted on Georges Bank in August 1989 and April and August 1990 (fig. 1). Scallops were collected from video-monitored sled-dredge samples. The bottom-sampling gear AQUAREVE III (Thouzeau and Vine 1991, Thouzeau et *al.* 1991) works like an epibenthic sled-dredge sliding on the bottom while its knife slices the upper 5 cm of sediments. The working of the dredge is monitored via an underwater video camera (100° diagonal view field) mounted on the sled and turned toward the opening of the box. The distance travelled on the bottom is measured by an odometric wheel : a proximity sensor is linked to an impulse counter on board.

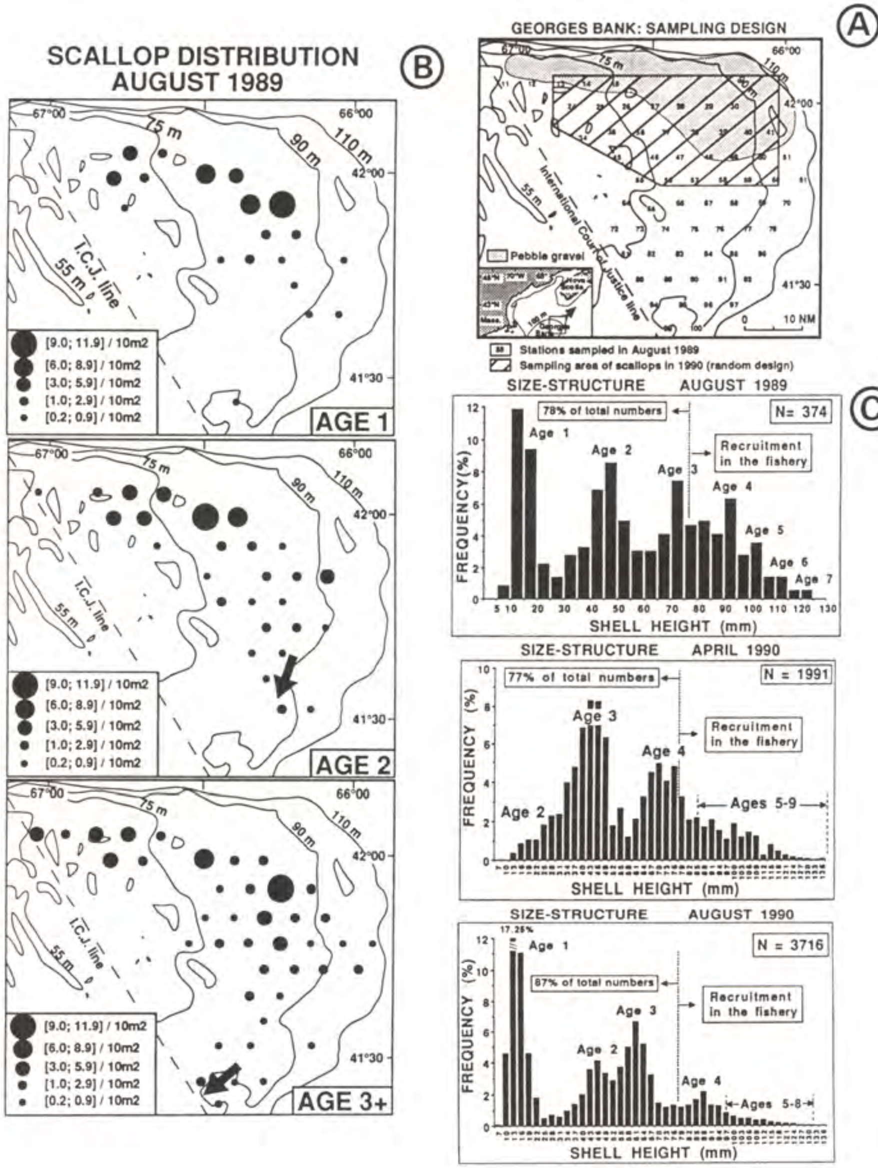

Figure 1 : (A) sampling designs in August 1989 and April and August 1990, on eastern Georges Bank ; (B) distribution of sea scallops, *Placopecten magellanicus* (ages 1, 2, and 3 to 7), in August 1989 (*in* Thouzeau et *al.* 1991) ; (C) size-structure (shell height distribution) of the scallop population sampled with the AQUAREVE III, in August 1989 and April and August 1990.

The collecting box (1.0 m wide x 0.4 m high) is a rectangular steel box drilled with regularly spaced holes of 10 mm diameter ; a box closing device (Aldred et *al.* 1976) triggers when the sled leaves the bottom. The sled is towed by an electromechanical cable. Once on board, the samples were washed, sorted (mechanical sorting table ; grid with 10 mm diameter holes) and preserved in 70 % ethanol (juveniles) or frozen.

Megabenthic animals retained by the 10 mm holed grid, specifically 1 year old *Placopecten magellanicus* were the targeted fauna. In August, Georges Bank age 1 scallops were expected to measure about 15 mm in shell height (Serchuk et *al.* 1979, Mohn et *al.* 1988).

A two dimensional systematic sampling was used in August 1989 (figure 1a), because little was known about the distribution and behaviour of sea scallop post-larvae and juveniles (Larsen and Lee 1978, Melvin et *al.* 1985). A total area of 1776 m^2 was sampled and mean sample size was 25.1 m^2 (SD = 9.4 m^2). Several samples of age 2 sea scallops were also collected in the northern part of the bank during the annual stock assessment survey (17 to 22 August 1989), to determine spatial variability in juvenile growth.

In 1990, the northern half of the bank was targeted to collect scallops (figure 1a), according to the juvenile distribution in 1989 (Thouzeau et *al.* 1991). Total areas of 2504 and 2980 m^2 were sampled in April and August 1990 (stratified random sampling); the mean sample size was 28.8 ($\pm$ 10.2) and 34.6 ($\pm$ 15.2) m^2, respectively.

The effect of sediment type on spatial distribution of scallops was investigated using the methods discussed in McCullagh and Nelder (1989). A preliminary plot of the total number of scallops per m^2 indicated that the mean number for each sediment type was proportionate to the associated variance, implying that the Poisson distribution would be a reasonable model for the random effects in the data. The equality of means across sediment type was tested using an analysis of deviance (McCullagh and Nelder 1989) and parameter estimates were obtained using GLIM (Generalized Linear Interactive Modelling) software (Payne 1985).

Shell height of sea scallops was recorded to the nearest 0.1 mm using vernier calipers. Individual ages were estimated by interpreting external growth rings on the shells, after removing epibionts (Merrill et *al.* 1966). The von Bertalanffy function was fitted to the 1989 shell growth data according to Gaschütz et *al.* (1980). This allows weighting of the data according to the number of individuals per age-class, and estimation of the coefficient of determination. Sea scallops were assigned a biological birth date of October 1st of the year in which they were born (Posgay 1959). Thus, 12-month old juveniles are referred to age 1 individuals in this study ; spat were assigned a settlement date of December 1st. The depth-related size frequency distributions of age 2 juveniles were compared using a 1-way analysis of variance (unbalanced designs ; SYSTAT package).

RESULTS

Spatial distribution

Maximum densities of 1 and 2 year old individuals, as well as of adults, were recorded in the northern area of the study, in August 1989 (fig. 1b). Abundance of scallops was significantly higher on gravel than on any other sediment types. Scallops appeared to exhibit a Poisson distribution within sediment type (Thouzeau et *al.* 1991).

Distribution of juveniles only partly matched that of adults ; ages 1 were less dispersed than 2 year old and adults, and were mainly located on a gravel-pebble deposit in the northern half of the Bank, at depths from 62 to 91 m (fig. 1b). Low densities of age 1 juveniles were found at rocky (cobbles and boulders) stations, but not on biogenic bottom (mixture of gravel, sand, and bryozoan debris).

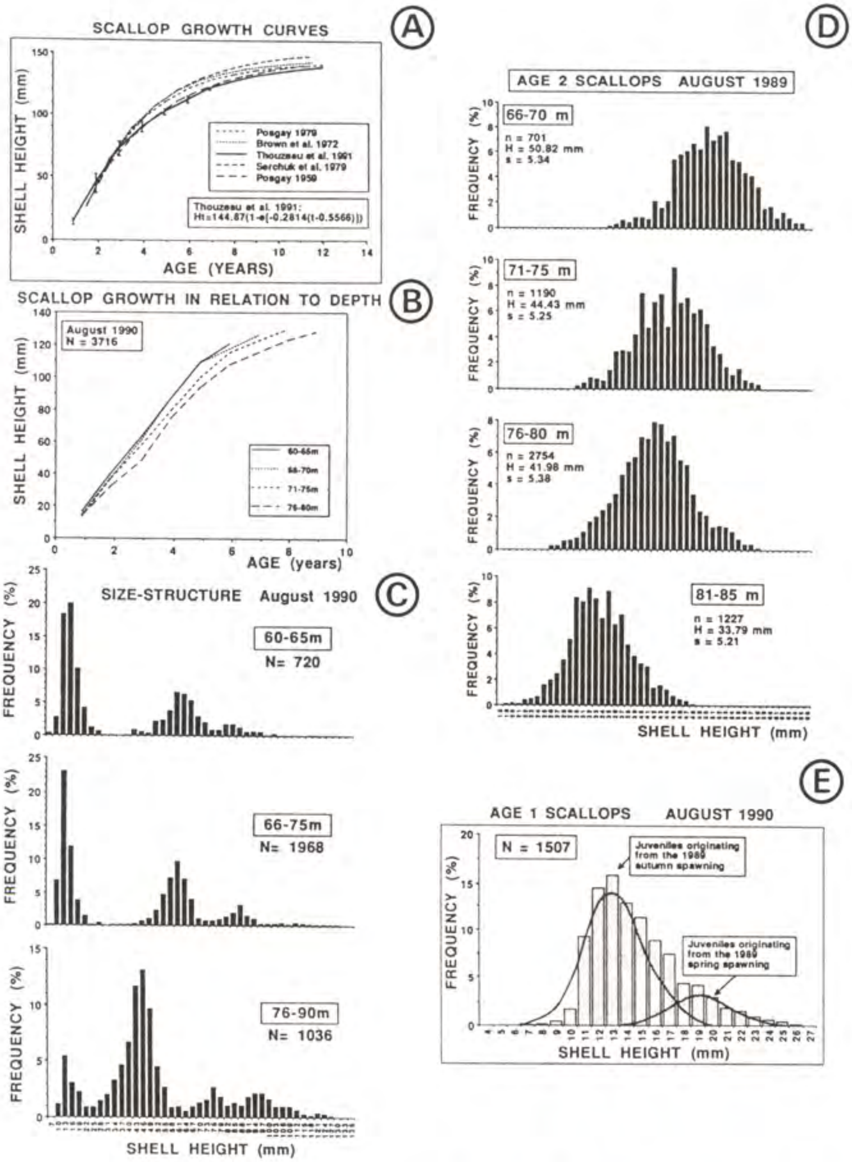

Figure 2 *Placopecten magellanicus*. (A) age-specific shell heights fitted to von Bertalanffy equations for sea scallop populations from Georges Bank, according to different studies (*in* Thouzeau et *al.* 1991) ; (B) age-specific shell heights (mean values) with respect to depth, in August 1990 ; (C) size-frequency distribution of scallops, with respect to depth, in August 1990 ; (D) size-frequency distribution of 2 year old sea scallops with respect to depth, in August 1989 (*in* Thouzeau et *al.* 1991) ; (E) size-frequency distribution of 1 year old sea scallops sampled on the northern half of eastern Georges Bank, in August 1990.

Results of the analysis of deviance indicated that sediment type explained a significant portion of the deviance (Chi-2 test ; Thouzeau et *al.* 1991). The sediment effect was mainly due to more scallops being found on gravel than on coarse-grain sand.
In 1990, ages 1 (in August) and 2 (in April and August) were also less dispersed than 3 and 4 year old, within the northern half of the Bank. The spread of individuals was most obvious for 4 year old, i. e. for scallops fully recruited in the fishery (Thouzeau et *al.* in prep). In August, ages 1 were mainly distributed in the northwestern part of the study area (one main patch), on gravel and pebbles. Their abundance decreased when the rocky fraction increased, within a given area. Neither ages 1 were found on muddy bottoms (several mud patches were located in the 1990 study area), nor on biogenic bottoms. Few individuals were sampled on sandy bottoms from the study area.

Size-frequency distribution and shell growth rate

Scallop size ranged from 7 to 135 mm in shell height (fig. 1c), for individuals collected during the 3 surveys ; this corresponded to 7 to 9 age-classes of which pre-recruits (< 76 mm) made up 77 to 87 % of the tot*al.* Age 1 scallops accounted for 26.2 and 39.8 % of total numbers in August 1989 and 1990, respectively. The higher relative abundance of age 1 individuals in 1990, compared to 1989, was related to much higher total densities of 1 year old on the bottom in 1990.
Few juveniles originating from the 1988 spawning were sampled within the northern half of the bank in April 1990 (age 2 in fig. 1c) ; this may indicate high winter mortality rate or individual migrations.
Mean shell height of 1 year old in August 1990 was 14.7 ± 3.1 mm. However, the size-structure of age 1 juveniles in August 1990 was clearly bimodal (Fig. 2e), which is evidence for spring and autumn spawnings in 1989. The spring spawning could have provided up to 20 % of the 1989 year-class. Mean shell height was 18.8 ± 2.5 and 13.3 ± 1.8 mm for juveniles originating from the spring and autumn spawnings, respectively. The latter may have been overestimated since most of the smallest individuals (< 10 mm) were not sampled.
At the Bank scale, growth parameters of the von Bertalanffy function, calculated from the 1989 data (Fig. 2a ; in Thouzeau et *al.* 1991), were $H\infty$ = 144.87 mm, k = 0.2814 and t_0 = 0.5566 (r^2= 0.998). However, these mean values may not have any significance since strong depth-related growth variations occur on the Bank (Fig. 2b, August 1990 data).

Spatial growth variations

The 2 year old juveniles collected during the 1989 stock assessment survey showed a strong decrease in growth with depth (Fig. 2d ; in Thouzeau et *al.* 1991). A mean size reduction of 33.3 % was observed between 65-69 and 81-85 m. Variations of shell height were significant (99 % c. l.) with depth (Thouzeau et *al.* 1991).
The size-distribution (Figure 2c) and mean growth (Figure 2b) of scallops with depth, also showed depth-related variations, in August 1990. The decrease of mean growth with depth was significant from 71 m on (Thouzeau et *al.* in prep).

DISCUSSION

Distribution patterns

The main features of scallop distribution in August 1989 were the concentration of scallops in the northern half of the Bank and the dispersion of individuals as they grow older. Physical aggregation at the larval stage, substrate selection at settlement, post-larval differential mortality, or juvenile movement (broader initial distribution and migration to the most suitable areas for survival and growth) may explain these patterns (Thouzeau et *al.* 1991). In contrast to other pectinid post-larvae, it seems unlikely that

Placopecten magellanicus has an obligatory settlement substrate or an obvious preference, but sea scallops occur at lower densities on mud than on sand (Caddy 1970, Langton and Robinson 1990, Thouzeau et *al.* 1991, present study). Experiments on settlement behaviour suggest a general thigmotactic response in pediveligers (Caddy 1972, Culliney 1974). The attachment of post-larvae to various substrates in nature supports this view ; sea scallop spat have been found attached to shells of live *Placopecten* and *red algae* (Naidu 1970), shell fragments (Caddy 1968), bryozoans (Caddy 1972), hydrozoans, amphipod tubes and sand grains (Larsen and Lee 1978), and metal and wooden navigation buoys (Naidu 1970, Merrill and Edwards 1976). This study and that of Thouzeau et *al.* (1991) only partially support this generalization : 76.5 % of 1 year old were located on gravel and pebbles and the remainder on sand-shell in August 1989 ; more than 50 % of 19-month old individuals were found attached to gravel and pebbles in late April 1990 ; finally, 92.1 % of 1 year old were found on gravel and pebbles in August 1990.

Several inshore studies indicated an absence of directed population movements or seasonal migrations in adult sea scallops (Dickie 1955, Posgay 1963, Krantz et *al.* 1984). However, localized movements were recorded on Georges Bank (8-10 km $year^{-1}$ on average), their direction corresponding with bottom-water residual currents (Melvin et *al.* 1985). Age-classes showed different distribution patterns in 1989, with a clear drift to the south (age 2) and southwest (age 3^+) as the individuals grow older. It was concluded that the dispersion with age (in an arc, oriented northwest-southeast) supports the hypothesis of current-related dispersion (on a small scale) during the benthic phase (Thouzeau et *al.* 1991). The more localized distribution of age 1 juveniles (observed in 1989 and 1990) would be partly explained by their sedentary behaviour (byssal attachment), while the spread of older individuals corresponds to the motile phase (30-100 mm shell height ; Caddy 1968) with optimal hydrodynamic characteristics (Dadswell and Weihs 1990).
The 1990 results (within the heavily fished northern half of eastern Georges Bank) show the impact of fishing activity on sea scallop dispersion. The clear spread of scallops from the time they start to be caught by the dredges (mainly ages 4, plus some ages 3), suggests that dredging activity through the capture and release of individuals too small to be commercialized, is a major dispersion factor in fishing areas.

Size structure and growth parameters

Nine age-classes (1-9) were sampled in the surveys, though scallops up to age 12 are caught on Georges Bank. However, few specimens (1.9 % in 1989) over age 7 are caught in commercial scallop dredges (Robert and Black 1990), as for other heavily exploited scallop beds (Langton et *al.* 1987). Compared to that of recruits, pre-recruits abundance (77 to 87 % of total numbers) emphasizes the impact of fishing activity on the size or age structure, even if older individuals might have been underestimated because of their wider dispersion.
On the other hand, the bimodal size-distribution of age 1 juveniles in 1990 agrees with histological studies (Dibacco and Robert unpub.) suggesting the occurrence of a spring spawning on the bank.
Several studies fitting shell growth data to the von Bertalanffy model are available for the Georges Bank area (Posgay 1959, 1979a, Brown et *al.* 1972, Serchuk et *al.* 1979, Thouzeau et *al.* 1991). Asymptotic heights, H_∞, range from 141.8 to 152.46 mm, while k varies from 0.26 to 0.38. Through its geographic range, greater variations are observed for H_∞, from 108.83 mm in the southwestern Gulf of St. Lawrence (Chouinard 1984) to 207 mm on the northeastern coast of Maine (Langton et *al.* 1987). Thouzeau et *al.* (1991) suggested that "Rosa Lee's phenomenon" (Ricker 1975) may act on the exploited scallop population on Georges Bank, i. e. heavy fishing would lead the stocks to be mainly composed of slower-growing individuals, due to size-selectivity of the gear. Indeed, the k parameter was much lower in 1989 (0.2814) than in 1972 (0.38 ;

comparisons made for 2 sets of data presenting the same H∞). The strong growth variations observed with respect to depth in 1990 (Figure 2b) imply growth comparisons to be made for the same depth range within the same geographic area (mean temperature and food resources may vary between different locations) to be valid. Since sampling locations in the 2 studies were different (South Channel and southeastern part of the Bank in Brown et *al.* 1972, Northeast Peak in Thouzeau et *al.* 1991), it cannot be concluded from these data if there is a decrease in scallop growth rate, due to fishing activities.

Scallops 2 year old (Fig. 2d, Thouzeau et *al.* 1991) and older (fig. 2b, c, present study) exhibited significant variations in shell growth with respect to depth, on the Bank. In particular, the decrease in growth appeared to be more pronounced from 76 m on (fig. 2b). Decreasing shell growth with increasing water depth has been previously reported on Georges Bank (Posgay 1979b) and elsewhere (Caddy 1970, MacDonald and Thompson 1985, 1988). The latter showed that growth variations along a depth gradient on a micro-geographical scale were equal to or greater than variations on a latitudinal scale. Growth differences on Georges Bank have been related to food and temperature conditions (Thouzeau et *al.* 1991).

Early growth of sea scallops

The first shell ring of scallops on Georges Bank is formed in March-April (Merrill et *al.* 1966, Posgay 1979a), at about 6-8 mm, although it may form at a smaller size (0.2-2.8 mm, Larsen and Lee 1978). Mean sizes at the 2nd and 3rd rings range from 18 to 25 mm and from 48 to 63 mm, respectively (Posgay 1979a, Serchuck et *al.* 1979, Mohn et *al.* 1988). Mean shell height in August 1990 of ages 1 originating from the 1989 fall spawning, was slightly lower than that reported in 1989 (14.4 ± 2.7 mm; Thouzeau et *al.* 1991). Both mean sizes agree with values found on the Northern Edge and Peak region of the Bank (Serchuk and Wigley unpub), but are lower than that recorded in the shallower waters (23 m) of Cape Cod Bay, Mass. (mean height 17-18 mm, following fall settlements). Faster growth rates are usually recorded for spat held in suspended culture (MacDonald 1986, Dadswell 1989). A mean shell height of ca 22 mm by late August was regularly obtained in Passamaquoddy Bay (New Brunswick), following fall settlements (Dadswell 1989). An average growth rate of 51.5 µm day^{-1} during the first year of life was found on Georges Bank (Thouzeau et *al.* 1991), compared to 60-65 µm day^{-1} in Passamaquoddy Bay (Dadswell 1989).

With respect to the spring spawning, individuals with doubtful age and shell size in the range 18-28 mm had been sampled in August 1989 (Thouzeau et *al.* 1991); the small amount of juveniles collected at that time did not allow the identification of a second mode on the size-frequency histogram. These juveniles could have originated from a 1988 spring spawning; with this assumption, growth of the 1989 year-class was lower than that of the 1988 year-class (during the first year) for both the spring and fall spawnings. Whether these interannual variations were related to temperature or food availability cannot be determined from the present study.

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ABSTRACTS

PREDATION ON JUVENILE SEA SCALLOPS, *Placopecten magellanicus*, EFFECTS OF PREDATOR AND PREY SIZES.

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***Abstract** - Predation upon different size classes of juveniles scallops (small: 5-8, medium: 10-15, large : 20-25mm) by different size classes of predatory seastars (*Astrerias vulgaris*, diameter range: 50-150mm) and crabs (*Cancer irroratus*, carapace width range: 45-130mm) were examined by factorial and choice laboratory experiments. In the factorial experiments (in which only one scallop size class is offered to a predator), predator and prey size had significant effects on predation rates. All seastar sizes consumed more small than larger scallops and the predation rate increased with seastar size. Conversely, crabs consumed more of the larger scallops and small crabs were the more voracious. The choice experiments (in which a choice of three scallop sizes was available to the predator) had similar results: small scallops were consumed more frequently than other scallop sizes by the seastars and large scallops were chosen and consumed first by the crabs. Probabilities of capture upon encounter were low (<10%) for seastars preying on all scallop sizes and high (>50%) for crabs preying on medium-size and large juvenil scallops. Scallops show different behavioural responses to seastars and crab predators: upon encountering a seastar, the scallop would be in a ready-to-swim position, with its valves wide open, its mantle closed and its tentacles fully extended, whereas the scallop would usually close up if a crab walked by.*

SCALLOP FISHING FLEET ANALYSIS IN THE SAINT-BRIEUC BAY.

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***Abstract** - In these paper, we attempt to place scallop dredging on the whole fishery of bay of Saint-Brieuc, and to take stock of the main management problem in these area.*
This work takes into account the study of the strategies of fishermen and the first results of the study on the effects of bottom fishing gears in the bay.

AN EMPIRICAL CATCHABILITY MODEL FOR THE SCALLOP STOCK, *Pecten maximus* (L.), IN THE SAINT-BRIEUC BAY (English Channel, France).

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***Abstract** - This paper proposes catchability models for the scallop stock (Pecten maximus, L.) of the bay of Saint-Brieuc (Western English Channel, France). he fishing pattern has evolued year after year going through several stages characterized by fishing gear modifications (use of the dredge with a diving plate, introduction of heavy tooth bars), by the elaboration of a resource management system based on a total allowed catch and by the increase of the fishing vessels horse power. The purpose of this fishing planning is maximizing catch rate by concentration or dispersion of the fleet in regard to the annual state of two age groups. These principles have been taken into account to set catchability models for age-groups 2 and 3 which are the most abundant in the fishery. The models use two independent variables: abundance and mean power of the fleet. Validity of the models must be tested in the future. In so far as the models are valid, they will be useful to estimate the state of the stock several years before cohort analysis could do so.*
***Keywords** : scallop, bay of Saint-Brieuc, catchability, cohort analysis, fishing fleet, dredge, diving plate, tooth bar, fishing pattern, horse power, abundance.*

SIMULATION OF THE NON-DIRECT FISHING MORTALITY FOR THE SCALLOP STOCK (*Pecten maximus, L.*) IN THE SAINT-BRIEUC BAY (English Channel, France).

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Abstract *- This paper studies the non-direct mortality induced by the exploitation of the scallop stock (**Pecten maximus, L.**) of the Saint-Brieuc bay (Western English Channel, France).*
The referenced fishery is exploited by only one standardized fishing gear (dredge with a diving plate). Consequently, a vector of fishing mortality at age (F) should be sufficient in order to describe the fishing pattern of the stock. Nevertheless, a certain amount of fished scallops is not recorded. Between these fished scallop groups, two of them are interesting. They are constituted by the scallops (I) fished and non declared (smuggling) and (II) discarded. This study does not dissociate the two kinds of mortality. It is limited to the 2-age group scallops during the period of the authorized fishing activity (winter). A relationship is carried on between the number of smuggled scallops and the one landed at auction. The simulation introduces a constant parameter of proportionnality between theses two quantities. The 2-age group is decomposed to three length classes concerned by different kinds of fishing mortality. The transition from a length class to another one defines the minimum length in auction and of smuggled scallops one. The calculation uses probability principles. The calculation of probabilities is based on length frequency data of the 2-age group scallops. These scallops are sampled on seven areas of the Saint-Brieuc bay and their distributions are tested comparatively to normal ones. The final simulation needs the introduction of the values of (I) a constant parameter of proportionnality between the number of smuggled scallops and the one landed at auction, (II) the discarding rate and (III) the survival rate of discards. It is possible to estimate the survival rate, but the values of the two other parameters can only be assumed. Consequently, it is impossible to know the actual value of the studied estimator and a great interval of its values is finally obtained.
Keywords : *fishing mortality, auction, smuggling, discards, selectivity.*

THE SCALLOP FISHERIES IN CHILE

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Abstract *- In Chile exist only two commercial species of scallops, the North Scallop Argopecten purpuratus and the South Scallop Chlamys patagonica or C.vitrea. Actually only the south species is under fishery, in the XII Region (Magellan Province) wich is around 40 % of the total landings of Chile. The rest of the landings, 60 %, coming from the north species, which includes scallops coming from fisheries until 1984, and those coming from aquaculture, starting from that year when fisheries were forbiden because overfishing. In the present, the whole production of the north species from I to V Regions, comes from aquaculture.*
In the last ten years, aquaculture of the north scallop has increased very much, from few culture centers in 1981 to more of 106 centers in 1990, and from 1 hatchery mainly dedicated to oysters, to 6 hatcheries specifically dedicated to scallops production. At present, almost all the production coming from aquaculture is exported mainly to USA, France and Australia. In the near future, the production of scallops from aquaculture will be more than the production by fisheries.
The production of scallops seed, which was difficult to obtain at the beginning, now does'nt represent a big problem, being obtained as well as from hatcheries or from natural beds. Finally, the legal problems, the marine concessions, and some biological and technological problems must be solved in the near future to continuing the growth of this activity.

CHAPTER 2.

AQUACULTURE

AQUACULTURE

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THE POTENTIAL FOR SCALLOP CULTURE IN BRITISH COLUMBIA, CANADA

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Abstract : *Scallop resources in British Columbia are too small to support a large sustainable fishery or supply a reliable source of large quantities of seed for culture. A research program at the Pacific Biological Station investigated the feasibility of culturing two species of scallops in British Columbia, the native rock scallop,* ***Crassadoma gigantea****, and the exotic Japanese scallop,* ***Patinopecten yessoensis****, using hatchery technology to produce juveniles. Based on results of this research, a private company, Island Scallops Ltd., built a hatchery to produce Japanese scallops in 1989 and in 1991 began full commercial operations.*

Key Words : *scallop, culture,* ***Patinopecten yessoensis****, British Columbia*

INTRODUCTION

Thirteen species of scallops have been recorded in British Columbia waters but most are small or rare (Bernard, 1983). Four species have been harvested in commercial fisheries : weathervane *Patinopecten caurinus* ; rock, *Crassadoma gigantea* ; pink, *Chlamys rubida* ; and spiny, *C. hastata* (Bourne, 1991). Populations of all four species are too small to support a large sustainable fishery and total annual landings from them will probably never exceed 300 t. If a significant scallop industry is to develop in British Columbia it will have to rely on culture operations.

EXPERIMENTAL SCALLOP CULTURE

In 1981, a joint Federal (Department of Fisheries and Oceans) and Provincial (Ministry of Agriculture and Fisheries) began to investigate the feasibility of scallop culture in British Columbia (Bourne *et al,* 1989). An initial consideration was a suitable species for culture. Pink and spiny scallops were considered unsuitable due to their small size and slow growth rate. Attempts were made to collect natural sets of the two larger species, rock and weathervane scallops, but juveniles of neither species were caught consistently in large numbers. Research concentrated on developing hatchery and nursery technology, with the primary focus on the native rock scallop and the exotic Japanese scallop, *Patinopecten yessoensis*, which is a large, fast growing species, similar to the weathervane scallop, that is cultured extensively in northern Japan (Ito, 1991). Most experimental work and all commercial development in British Columbia has been with this species and it is the only scallop described here.

HATCHERY STAGE

Initially, Japanese scallops with ripe gonads were imported from Japan into the quarantine facility at the Pacific Biological Station. Since 1986 only broodstock raised in British Columbia waters has been used in the experimental work. Sexually mature animals are brought into the hatchery in January and February and conditioned by regulating temperature and feeding regimes (Bourne *et al,* 1989). Spawning is generally achieved by exposing animals to air and fluctuations of water temperature, although injections of serotonin have also been used. It has been possible to spawn Japanese scallops from early February to August although the rate of successful fertilization tends to decline with length of conditioning period.
Larvae are raised in large tanks at densities between 1 - 2 larvae per ml. Water is held at 15 °C and exchanged twice weekly. Larvae mature at a shell length of 260 - 280 um in 20 - 25 days (Bourne *et al,* 1989).
Three species of cultured algae have been the principal larval foods: *Chaetoceros calcitrans*, *Isochrysis galbana* (Tahitian strain), and *Thalassiosira pseudonana* (clone 3H). Considerable work has been devoted to studying the nutrition of scallop larvae and improving their diet (Whyte *et al,* 1987, 1989).

NURSERY STAGE

Various stimuli have been tested to accelerate and increase the success of metamorphosis, including chemicals and physical shock. The neurotransmitter norepinephrine has been found to improve settlement (Kingzett *et al,* 1990) and generally about 25 % of larvae successfully complete metamorphosis.
A variety of material has been tested for cultch. Higher numbers of larvae settle on fibrous material compared to other surfaces. The best experimental cultch found to date is an artificial fibrous material from Japan called "kinran".
Larvae have been set using several methods (Bourne and Hodgson, 1991) but are generally set in tanks with recirculating seawater or tanks supplied with surface seawater until the juveniles are firmly attached to the cultch. Cultch with attached juveniles is placed in spat bags that are suspended in the open environment at a depth of at least 5 m. When the spat measure 5 - 10 mm they are removed and placed in pearl nets, where they remain until they measure 30 - 40 mm shell height.

GROWOUT STAGE

Scallops can be grown to commercial size (10 cm shell height) by different methods: in nets, on the bottom or by earhanging. It is doubtful if the first two methods can be used in British Columbia but earhanging has great potential. Experimental growout has been attempted at depths of 5, 10 and 15 m at selected sites from northern to southern British Columbia. Growth and mortality have been variable, but it is generally possible to culture Japanese scallops to commercial size within two years from the time of spawning. Successful growout of Japanese scallops may be site specific in British Columbia.

COMMERCIAL DEVELOPMENT OF SCALLOP CULTURE

Using technology developed in the experimental hatchery and nursery, a private company, Island Scallops Ltd., constructed a commercial hatchery for culturing the Japanese scallop in 1989. The hatchery is located on the east coast of Vancouver Island near Nanaimo. Now in its second year of production, the hatchery has the capacity to produce over 1000 million mature larvae annually, which will yield 100 million juveniles for culture at up to 45 farms along the British Columbia coast. In 1990 the company produced 160 million mature larvae and to date in 1991 has doubled that production.

Broodstock for commercial operations is obtained from local stock originating at the Pacific Biological Station as well as from stock imported directly from Japan. Larvae are reared in ten 40,000 L indoor tanks, at densities as high as 3 larvae per ml. Each tank can produce 40 million mature larvae in 16 - 23 days. Setting is carried out in eight 40,000 L outdoor nursery tanks using mesh bags stuffed with monofilament netting as cultch. The juveniles are held there for 2.5 - 4 weeks, then transferred to ocean farms for growout. Up to seven species of phytoplankton are cultured for larval, juvenile, and broodstock food, for a total algal culture volume of 120,000 L.

Growout operations are currently carried out at five farms. Scallop spat remain on the setting substrate until they reach 6 mm in size, at which point they are removed, sorted, and transferred to pearl nets. The final growout phase involves earhanging, which occurs when the scallops measure approximately 5 cm shell height. Culture from spawning until marketing will require 18 - 24 months.

With construction of the hatchery and production of juveniles, scallop culture has been successfully initiated in British Columbia. Further research is required to improve the productivity and profitability of hatchery and growout operations, but a significant scallop culture industry should be established in British Columbia by the end of the decade.

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BIOLOGY AND CULTURE OF SCALLOP *Argopecten circularis*

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Abstract : *The production of* ***Argopecten circularis*** *in Northwest of México was increased from 10,940 metric tons in 1988 to 28.325 in 1990. This is the main fishery activity in the state of Baja California Sur. In order to establish the regulation and resource conservatory policy, the SEPESCA (National Fisheries Service of Mexico) grants fishing permission only if scallop aquaculture activities are initiated. Under this scope, the research to develop an aquaculture technique according to the socioeconomic conditions of México is pointed out. This work summarizes the result of biology investigations and efforts on the culture of the "catarina" scallop* ***Argopecten circularis***.
Results of gonadal development and settlement of juveniles using different substrates at different depths and growth of cultured populations are included. Culture methods, comparison between suspended and bottom systems, wild spat collection and hatchery progress in the Northwest of México are discussed.

Key words : ***Argopecten circularis***, *scallop, culture, biology, México.*

INTRODUCTION

The production of *Argopecten circularis* in Baja California Sur, Mexico has been increased through the last decade reaching over 30.000 metric tons of total weight in 1989 (Figure 1). This became the main fishery activity for the state (about 30% of the total fishery production). Nevertheless, the exploitation has not been regulated. Populations that were abundant, presently do not support any fishery efforts, remaining two fisheries areas, the Magdalena and the Concepción Bays (Figure 2).
In order to establish the regulation and resource conservatory policy the National Fisheries Service of Mexico (SEPESCA), gave the fishing grants in 1990 only if a scallop aquaculture program was initiated. Since then, in order to coordinate the aquaculture activities, a general plan was established for natural spat collection in the two Bays. During 1990 about 90 million juveniles were collected using 16.000 artificial collectors, of which 80 million were collected in the Concepción Bay. The spat was sown over natural beds.
This year the program transferred the total aquaculture effort to the Concepción Bay, since January to April 44.000 collectors have been installed in order to continue the sowing program. The high fishery pressure during the end of the last year in Magdalena Bay, resulted in an insufficient yield production to support a commercial activity. Fishery grants were not requested for this area.
Nevertheless, a real commercial aquaculture activity has not been initiated. Under this scope, the research to develop an aquaculture technique according to the socioeconomic conditions of México is pointed out. This work summarizes the results of biology investigations and efforts on culture of the "catarina" scallop *Argopecten circularis*.

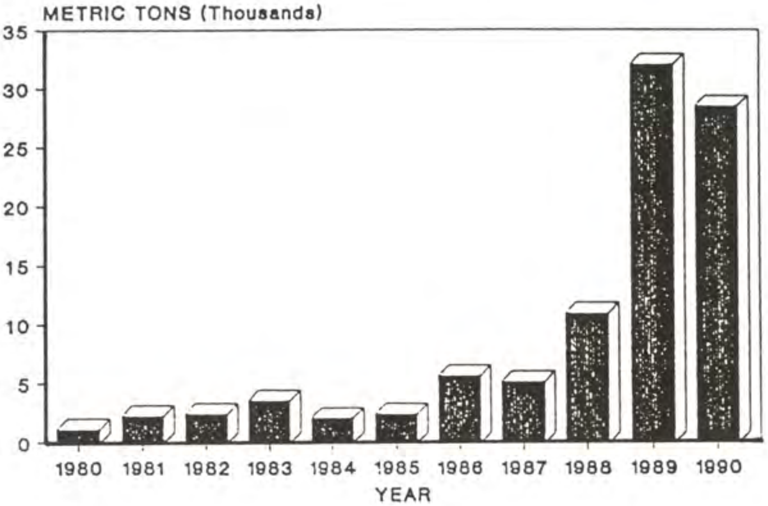

Figure 1 Scallop (*Argopecten circularis*) production in México, from 1980 to 1990

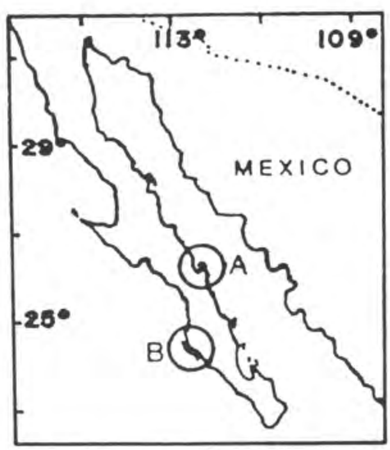

Figure 2 Main fisheries areas of *Argopecten circularis* in México A) Concepción Bay B) Magdalena Bay

BIOLOGY

The scallop *A. circularis* has had a continuous reproductive activity during the year, having two important reproductive periods. The first during winter/spring and the other in early summer (Baqueiro-Cárdenas *et al.*, 1981 ; Villalaz *et al.*, 1989 ; Cáceres-Martínez *et al.*, 1990). During maturity the oocyte diameter is 50-60 m (Avilés-Quevedo and Muciño-Díaz, 1987).

The larvae are present in meroplankton in La Paz Bay, B.C.S., Mexico all year, with a maximum number from June to November when the temperature reaches the highest points (29-30 °C) (Figure 3). In relation to the vertical distribution of larvae, we found a maximum concentration under 11 m of depth (Cortés-Salazar, 1991). The planktonic life lasts for about 15 days when larvae reaches 203-228 m shell height (Avilés-Quevedo and Muciño-Díaz, 1987 ; Ruiz-Verdugo and Cáceres-Martínez, 1989).

Larvae attach to seaweed or other substrates using byssus excreted by the byssal gland which remains functional during their entire life. After attachment the spat shell formation is initiated and the morphology is similar to the adult.

Growth : the growth during the first five weeks after the settlement has been described by the equation Y=0.203+0.337X which is based on the prodisoconch height (Y=mm) and the maximum height of the spat collected on artificial substrates during different times (X=days) (Ruiz-Verdugo and Cáceres-Martínez, 1989).

The growth observed on cultured organisms during seven months can be described by a linear model Y=5.66+0.25X; Y=mm and X=days, r^2=0.998 (Ramírez-Filippini and Cáceres-Martínez, 1991), however, Reyes-Sosa (1987) describes the growth with the Von Bertalanffy model for the same time period $Y=62.36(1-e^{-0.057(t+1.95)})$. A life span period of 2-3 years has been estimated in cultured animals, nevertheless, there is no information available about growth under natural conditions.

EXPERIMENTAL CULTURE

1.- Spat collection : the spat is obtained using artificial collectors similar to those used with the Japanese method, made of onion bags filled with plastic filament (gill-net, 0.55 mm diameter), or natural bushes (*Calliandra* sp.). There are 12 collectors attached in groups of 3 to a 4 m ropes, which are tied-up to long-line systems. The collectors remain in water during 6-8 weeks, then the spat is detached using different methods. The most usual, is shaking the collector content into an aluminium vat where the sort allows the largest spat (10 mm height) to be recovered. The smallest remain attached to the filament or to the onion bag. An other method, is to shake the content of the collector inside a tank filled with flowing seawater. The spat is sorted by sifting the contents of the tank. This method allows the gathering of organisms between 5-10 mm height. Table 1, shows the spat collection number at different localities and seasons.

2.- Hatcheries: the use of Loosanoff and Davis (1963) techniques for bivalve rearing in laboratory conditions permitted the gathering of spat *A. circularis*. Coronel-Solorzano *et al.* (1987) describe the technique for rearing larvae has having 30 % of veliger, 23 % pediveliger and 7 % of fixed juveniles in relation to total fertilized eggs. The graphic description of the larvae external morphology was done by Avilés-Quevedo and Muciño-Díaz (1987). To date there is one experimental hatchery with the capacity of 3 million spat per year (Centro de Investigaciones Biológicas de La Paz, B.C.S.), and there is another under construction in the same center.

3.- Intermediate culture : the intermediate culture is necessary until the spat reachs 20 mm height (6-8 weeks), and is carried out in plastic baskets in a suspended system. The density per basket is 400 scallops (1320 animals/m^2). The average growth is 7 mm/month and the survival is 99 % (Ramírez-Filippini and Cáceres- Martínez, 1991).

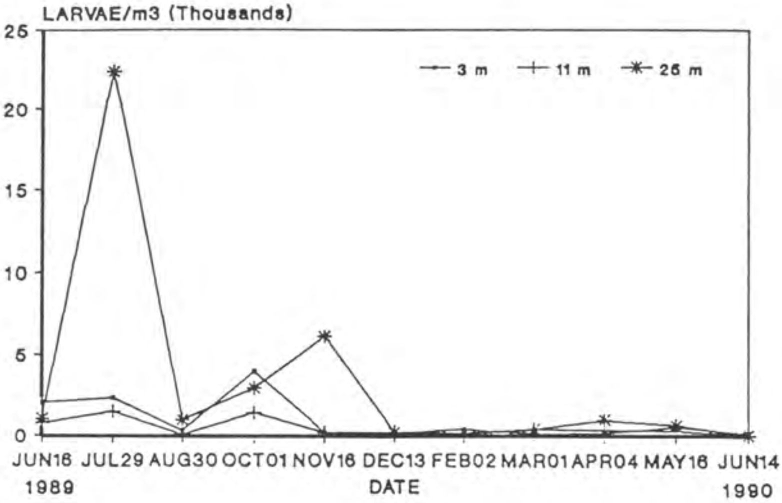

Figure 3. Bivalve larvae abundance in La Paz Bay, from June 1989 to June 1990.

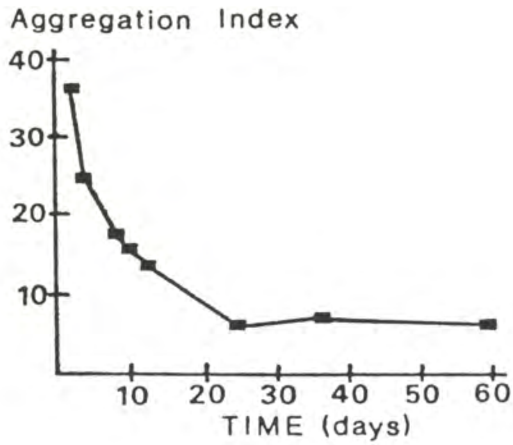

Figure 4. Aggregation Index (S^2/x) for *Argopecten circularis*, during a dispersion experiment in La Paz Bay.

Table 1. Average spat number per collector, in relation to locality and year in Baja California Sur. Mexico.

Locality	Spat number	Year	Source
La Paz Bay	300 (spring)	1988	Own data
La Paz Bay	80 (spring)	1989	Own data
La Paz Bay	91 (summer)	1990	Own data
Magdalena Bay	6819 (spring)	1990	SEPESCA
Magdalena Bay	1223 (spring)	1990	SEPESCA
Magdalena Bay	1000 (summer)	1990	Own data
Magdalena Bay	5733 (summer)	1990	SEPESCA
Magdalena Bay	6200 (summer)	1990	SEPESCA
Concepcion Bay	5040 (spring)	1990	SEPESCA
Magdalena Bay	80 (spring)	1991	Own data

4.- Culture method :

a) Suspended culture : to date there is nobody working with this method. The system uses pile-up plastic baskets forming groups of 7, which are tied-up to a long-line. The basket density is reduced from 400 juveniles every 4 weeks, to 50 scallops at the end of 6 to 7 months of operation. When the animals reach the commercial size, the application of this technique shows a high mortality 43-77 % and an average growth rate of 4 mm/month (Cáceres-Martínez *et al.*, 1987 ; Singh- Cabanillas *et al.*, 1990).

b) Bottom culture

b.1) Enclosures : The juveniles are sowed inside enclosures installed on the sublittoral. The enclosures are of two kinds ; one is made of wood bars and plastic or herring fishing nets (Singh-Cabanillas, 1987 ; Cáceres-Martínez *et al.*, 1987), and the other is a modular design made of corrugated rod and plastic net (Ramírez-Filippini *et al.*, 1990). The juveniles remain inside the enclosure over a sand substrate for 5 to 7 months before harvesting. The average growth obtained is 5.7 to 6.1 mm/month using a density of 100 scallops per m^2 and with a survival of 85 % (Cáceres-Martínez *et al.*, 1987 ; Varela-Correa *et al.*, 1990; Ramírez-Filippini and Cáceres-Martínez, 1991).

b.2) Extensive : This method is in an experimental stage. The results of movement capacity of 2000 scallops with an average height of 35 mm in a experimental sowning protected against predators indicates that the scallops remain in a stationary condition until reaching in 30 days a contagious distribution with 75 animals/m^2 (Figure 4) (López-Contreras and Cáceres- Martínez, 1991). In an other experiment, without protection against predators 3000 scallops of 42.7 mm average height remain in the site where sown even when the predators appeared and in a period of 60 days we obtained a rate of less than 10 % survival.

DISCUSSION

In order to grant fishery permits for *Argopecten circularis*, the state policy of the National Fisheries Service of Mexico forces the fishermen to begin aquaculture activities. However, the technological support for the commercial scallop culture is not available, and the only activity related to the culture is the spat collection and their liberation over natural beds in identified areas. Nevertheless, the ecological impact of this activity is unknown due to lack of information about predation, current dispersion, natural mortality, recruitment, etc... The importance of this activity in the Northwest of Mexico demands the establishment of a research program in order to answer the previous questions.

Even when the basis for hatchery spat production is established, the natural spat collection seems to be enough to support the commercial culture activities. The collector manipulation on large scale operations would be improved in spat sorting and transportation to other Bays. In relation to the collector substrate the use of monofilament gill-nets appears adaptable on larger operations.
The intermediate culture involves several problems, such as excessive fouling (300 % of weight increment during spring), a great number of units and their cost, and finally high cost of human labor. The impossibility of using pearl nets during this phase is due to fish predation (*Diodontidae* and *Tetradontidae*).
An alternative to eliminate the intermediate culture is under investigation. The reduction of the filament collector surface inside the onion bag permits the spat to reach 20 mm height if the collectors remain in the water during 3 months. The consequences of this modification produce a reduction of the total number of the spat collected per unit.
In relation to the suspended culture, the low growth rate, high mortality, high cost of human labor resulted in abandoning this practice.
The enclosure culture method would be a promissing technique, but is necessary to do a pilot-scale culture for cost estimations. Some efforts have been done and experimental cultures of the "catarina" scallop are in progress in La Paz, Bay. These results will give answers for culture feasibilities on projects established near cities. However, we need a pilot-scale culture in Concepción and Magdalena Bays, where there are no urban services.
The extensive method is under experimentation, although the preliminary results are not promissory. A research program for fighting against predators is in progress. It is important to mention that the "catarina" scallop is in movement until a constant aggregation index is attained. Their distribution will be constant if the scallops remain without any movement stimulus. This condition is favorable for a extensive culture over natural beds.

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SEEDING AND RECAPTURE IN THE RADE DE BREST (till 1991)

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***Abstract** : Scallop seeding have been developed in France on the Atlantic coast since 1977, mainly in bay of Brest where research have been regularly conducted. Differents strains, juveniles from natural spat collection and from hatchery, seeding at different sizes and seasons have been experimented.*
Other sites have been used as soon as juvenile production have been controlled. Since 1987, recapture are realized by fishermen by dredging.
Results are highly variable and show the influence of the choice of the seeding site.

***Key words**! seeding, recapture, juvenile, production, hatchery, **Pecten maximus**.*

1 - INTRODUCTION

The first extensive aquaculture of the scallop in France was the re-seeding programme in the Rade de Brest. The juveniles originated from spat which were collected in the Bay of St. Brieuc and then transferred to the Rade de Brest where they were re-laid in an site where fishing was prohibited. Because of the technical success of the first experiment (Buestel and Dao, 1979), this site was subsequently used for different re-seeding trials involving animals of different origins (France, Scotland, Ireland), different sizes (from 10-40mm) and at different times of the year (one per season).
In view of these results it was decided from 1982 to develop a more ambitious research and development programmes and to carry out the operation on a larger scale in order to test the economic feasibility of a scallop culture operation based on hatchery spat (Contrat de Plan Etat/Brittany region).
The first development option of interest to the fishermen (1983-1988) was the re-establishment of a breeding population, that is to revive the natural stock by allowing numbers of animals to build up by a short term ban on fishing. This was feasible because of the longevity of the animal. Because repopulation was not immediately successful (1988-93), the second option was a re-seeding/re-capture programme (until the scallops reached commercial size) while keeping a closed fishery.
The outcomes of this work were technical modifications in spat production in the hatchery and in the nursery and in the choice of site.

2 - METHODOLOGY

Re-seeding is the last stage of rearing and it depends on the precision and the quality of the preceding operations.
The hatchery is the 1st stage and operates for most of the year. However production was uncertain for the first years due to insufficient spawning, uneven gamete quality and husbandry failures (Cochard, 1985 and 1988). Every failure necessitated a replacement batch and the knowledge thus gained allowed a progressive reduction in the number of batches and the reduction of the hatchery procedures down to a few major annual spawnings.

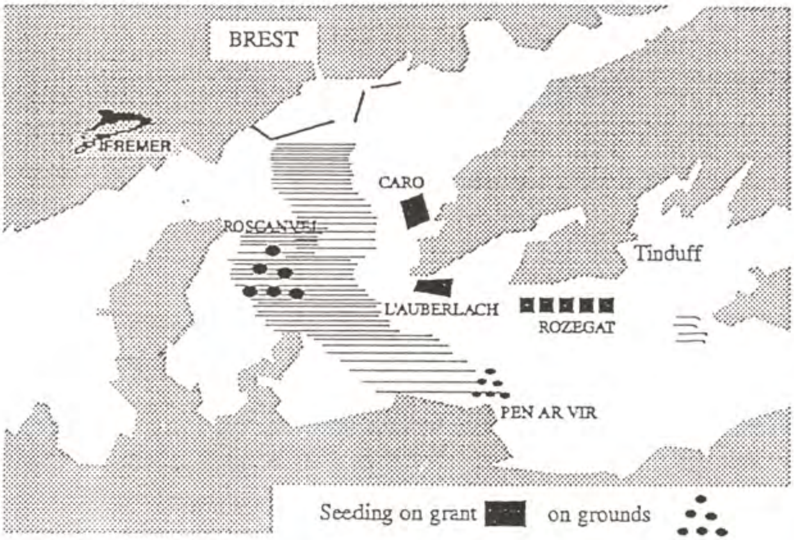

Figure 1. Experimental seedings areas in the Bay of Brest

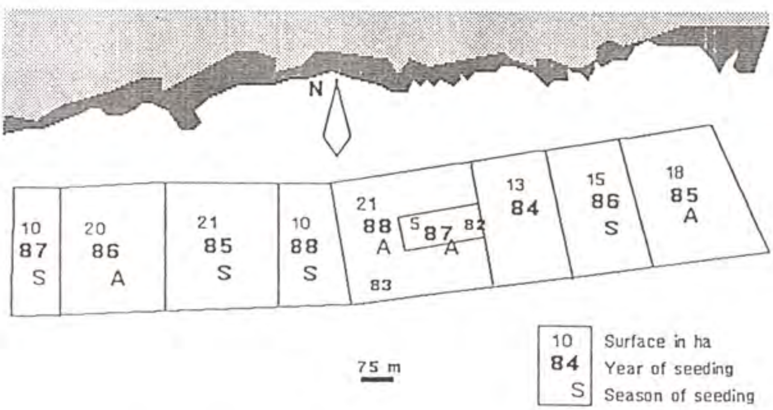

Figure 2. Rozegat : seedings from 1983 to 1988

The nursery is constrained by the limitations of the hatchery since it depends on it for a supply of spat. The length of this operation is directly dependent on the environment, water temperature and availability of algae. It can vary from between 3-5 months (if put in to the sea at the end of spring) to almost a year for the same operation carried out some months later in the year.
The re-seeding operations progress according to the availability of spat from nursery. These followed the specifications worked out progressively during the course of the first ten years, namely a minimum size of 30mm per juvenile and a density of 2-10 individuals /m^2. But they were subject to the effect of new factors listed below:

- the effect of batch quality in the hatchery and nursery.
- stress associated with handling, detachment of the byssus, clumping, stranding, thermal shock, desiccation
- stress associated with the new environment, temperatures (min.10-11^{0}C), salinity, turbidity
- predators and competitors
- possible disturbance from fishing boats
- toxic phytoplankton (*Gyrodinium aureolum*)
- other non-identified factors (pollution...)

Follow-up dives were carried out on the re-seeding areas which had previously been marked out in permanent quadrats. A subsequent sampling programme was based on diver observations and experimental dredging (using an instrument equipped with a video camera, small mesh).
All the desired conditions were rarely met, particularly as the importance of different factors was not identified in the first years. The *Polydora* worm for example had been recognised as a mortality factor in 3-4 year old animals although this only occurred 24 months after its settlement on the valve of the animal. Better re-seeding results were regularly obtained at the Saint-Brieuc nursery site (from 1987) due to the absence of certain pests in the bay (starfish, *Polydora* spp., *G. aureolum*).
Results of re-seeding experiment between 1977 and 1985 had been consistent due to good husbandry. The assessment procedure was therefore simplified which allowed a shift of emphasis onto recapture by the fisherman without the need for an increase in sampling effort. Thus experimentation could now be focused on the nursery. This option led to the identification of two interesting re-seeding periods in the year, one at the end of spring for animals born in the second half of the preceding year, and one in autumn for those born at the end of winter.
From 1988 the recapture programme showed much poorer results. The existing site at ROZEGAT was not used for new re-seeding. CLPM and IFREMER started investigating new sites in a less estuarine zone (fig. 1).

3 - RESULTS

The results can be divided into three groups: (1) the historical experimental re-seeding on a 25 hectare concession between 1977 and 1983; (2) those of the first State-Region contract, from 1983 to 1988, which involved extending the test area to 130 hectares and (3) since 1989, the re-seeding of traditional fishing grounds at sea (fig. 1).

3. 1 - Experimental seeding from 1977 to 1985

The first experiments were carried out in a central part of the ROZEGAT concession and analytical methods were developed to evaluate the behaviour of animals by sampling in a marked-out area (Buestel and Dao, 1979; Buestel, 1985). All the sampling and recapture operations were carried out by diving. Table 1 (Dao, 1985) summarises growth rate and survival. The commercial size of 100mm (height = 86mm) was attained in the third winter, with a survival of about 50%. The source of the animals does not affect these criteria. The movement observed was less than 40 metres from the original site.

Table 1. Growth and survival of scallop in the rade de Brest.

Year of re-seeding	Source	Criteria	Age (in number. of winters)				
			1	2	3	4	5
1977	St-Brieuc	height mm	26	72	90	98	103
		survival %	100		50	4	"40"
1980	Scottland	height mm	36	74	91	98	106
		survival %	100	58	60	46	
1982	Hatchery	height mm	27	65	88	104	
	(Brest)	Survival %	100	60	50	46	

During this time additional re-seeding demonstrated the need to release juveniles with a minimum size of 25mm to enable them to withstand predation, survival being practically nil for sizes less than 15mm. However there was no optimal time of year for this operation (Dao, 1985).

3. 2 - Seeding from 1983-1988

This concerned much larger releases of juveniles (fig. 2). Aquacultural equipment was developed during the first contract period and the size of the re-seeding increased by an order of magnitude up to between 300,000 and 600,000 juveniles. Re-capture was carried out by fishing boats with traditional dredges under the control of the local fishermen's organisation (CLPM, Brest). The fishing effort (in hours) and the landings (in kgs.) were logged. Fishing began in 1988 but the results were much poorer than expected.
Diver observations on the re-seeding area did not resume until the end of the summer of 1989 following the first recapture. The results were qualitative but showed the animals to be in poor condition from the third year: an increased number of animals with poor growth, moribund, poor muscle condition, pitted and intense brown colour on the inside of the shell. Large numbers of adult 'cluckers' were counted on the sea bed.

Table 2. Results of fishing the re-seeding areas from 1983-1988 in the rade de Brest.

Year of hatchery production	Year of recapture	Landings (T)	Recapture rate (%)
1983	1988	10.1	22
1984 (A)	1988/89	19.0	22
1984 (S)	1989	17.0	33
1985	1989/90	19.4	11
1986 (S)	1990	2.8	4
1986 (A)	1991	20.0	20
1987 (S)	1991	35.0	37
1987 (A)			
1988 (S)			
1988 (A)			

(A) = Autumn seeding ; (S) = Spring seeding

From this information we can conclude that:

- Mortality was accompanied by a browning of the shell interior
- It became significant in the third year following re-seeding when the animals were already adult and had attained commercial size.
- Survival rates were particularly poor for batches produced between 1984-1986
- Apart from one result (autumn 1985) survival rates were better on the west side of the concession
- Apart from one result (spring, 1986) survival of those re-seeded in spring was better than that of those re-seeded in autumn.

Even though these results represented only a fraction of the re-seeding, they were the reason for abandoning this concession. The fishermen did not welcome the extension of the concession towards the west and the east side no longer yielded the returns of the first re-seeding. The last re-seeding at this site was the end of 1988.

3. 3 - Seeding after 1988

New re-seeding followed a dredging survey using underwater video (fig. 3). The reasons for choosing this site were a greater depth, a more marine environment with less estuarine influence while conforming with the national marine plan for the bay and the need to keep the main fishing areas open.

In 1989 two areas were developed on a much larger scale at Caro and Roscanvel. The first, of 50 hectares, was marked out and closed for fishing during the growing period of the animals. The second remained a fishing zone but had to be sown in spring so that the juveniles benefited from a good growth during the summer closing of the fishery before commercial fishing recommenced. The object was to provide a boost to fishing fleet during the 1991/92 and 1992/93 seasons. Almost 1.5 million juveniles were sown, representing a potential of 50-100 tonnes. The animals were easily identifiable because of rings linked to stress in the nursery.

In 1990, a third zone was created to replace the Rozegat concession and to assure the self-financing of the Tinduff hatchery. It was also situated in a deeper zone (20-40 metres) off l'Auberlach cove. Almost 3.3 million juveniles were sown there during the two previous years.

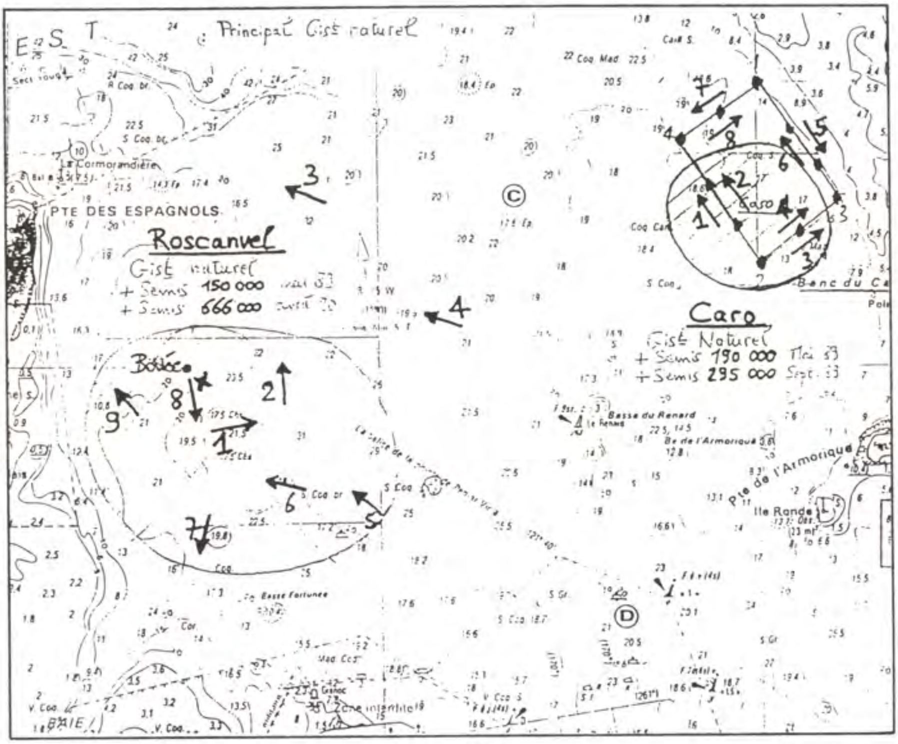

Figure 3. Sample dredging on "Caro" and "Roscanvel" area.

As a consequence of previous results, all the main re-seedings were observed semi-quantitatively in the first days and then at regular intervals in order to describe:

- the behaviour of juveniles going into the sea and the possibility of mortality linked to husbandry
- performance in the first year and the possibility of heavy mortality

Table 3. Cultured scallop and natural population densities in the seeding zones (number per m^2)

	Year class or year production	Date of. seeding	Roscanvel	Caro
Natural production				
	89		0.06	0.12
	88		0.06	0.11
Seedings				
	87		0.02	
	88	june 89		0.40
	89	sept. 89		0.61
	89	may 90	0.34	

A first seasonal sampling programme took place in October 1990 using methods developped for Saint-Brieuc from 1985 (in Fifas, 1989). When dredge selectivity values were applied to the numbers counted before dredging (fig. 3), a first density value on the bottom was obtained (Table 3)

Thus the natural recruitment remained weak, in the order of 6-12 scallops per $100m^2$ in the rade and the provision of cultured animals will be a determining factor in changing the conditions of fishing. The seeding in 1989 and 1990 represent almost 80% of animals on the bottom if the residue in the older age class is taken into account. But because of the inaccuracy caused by the dispersion of the seeded animals, a figure for their survival cannot be given.

4 - DISCUSSION

Two groups of seeding must be identified: those in the shallower estuarine zone at Rozegat and those in the marine zone.

In the first, a progressive deterioration of the animals from the higher rates of survival for the first experiments to the much worse results of 1984-1986 was noted. Different factors contributed to the deterioration in performance:

- a change in the scale of production and handling
- ignorance of the rearing parameter for the subsequent good survival (dirt, *Gyrodinium*, *Polydora*.,..)
- a change in the environmental quality of the bay (river effluent, TBT,...)
- behaviour of stocks for a duration longer than 5 years could provoke an accumulation of sub-lethal effects.

There is unquestionably an improvement in performance in the second group and a response to factors which could challenge the restoration programme in the bed. Survival is good and the quality of the animal is acceptable in the market place. However, it remains to be proven that the husbandry used will lead to good survival and recapture compatible with socio-economic constraints.

One of the spin-offs of the programme has been that of repopulation, i.e. revival of natural settlement arising from an increase in the number of broodstock. The programme has brought about a doubling of biomass of the broodstock in the bay but has not lead to an increase in the fishery.

CONCLUSION

Results from the rade de Brest prove that it is technically feasible to improve the scallop fishery by re-stocking with hatchery-produced juveniles. It is necessary to by-pass the process of natural reproduction and the early stages of development by use of culture techniques. Furthermore similar results were obtained on other French sites while the first experiments were carried out.

Other examples exists around the world on this group of species, in Japan, Australia, Chile, in Europe and North America. Some countries are only at the experimental stage while others have passed into intensive production.

This type of aquaculture however shows the vulnerability of some of the stages to environmental quality. The programme carried out over the last two years (1992-1993) should confirm or deny the results obtained so far. However it is important to take account of economic factors such as the market price, which depends on independent external factors which, in turn, effects what happens in the bay (Dao, Fleury, Paquotte, 1991).

Nevertheless we can be optimistic about this type of development. Similar techniques gave similar results on private oyster farming concessions which is encouraging for the future development of scallop enhancement.

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THE INTERMEDIATE CULTURE OF *Pecten maximus* IN BRITTANY (FRANCE).

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Abstract : Scallop aquaculture is slowly rising in France (over 30 tons in 1990). At the beginning, it was carried out for beds restocking. Now it concerns overall seedings-recaptures of 3-4 years old animals (extensive aquaculture). But one of the problems for this aquaculture expansion is the need of the young (about 3 cm) for the seedings. 3 ways of spat availability have been tried successively : the natural collecting in the wild, the importation of spat and the complete rearing in a hatchery-nursery, the only way carried out since 1984.

Before being seeded in the open sea, the spat has yet to be reared in protected cages. This intermediate culture can be separated in 2 stages :

- "Tiny mesh" cages (500 µ and 1.5 mm) when the spat is still settled and thin.
- "Large mesh" cages (5 mm) when the spat gets detached and thick.

The growth (that involves the rearing duration) and the survival rates of this 2 stages have been studied in the 2 main rearing sites : the Rade de Brest (data 1982-1989) and the Baie de Saint-Brieuc (data 1984-1990).

Rearing lasts 6 to 10 months, according to the date of the transfer to the open sea, and particularly whether there is a winter period or not (growth stops in winter).

Excepted for several trials of winter transfers (which have given very poor results), there is no significative difference (for each site) in the survival rates according to the seasons. For St-Brieuc we get 33 % at the first stage and 95 % at the second one, that means 30 % for the whole intermediate culture. The results are better in Saint-Brieuc, specially with the 2nd stage, for in Brest we have sometimes accidents with toxic phytoplancton (Gyrodinium) or parasites (worm ***Polydora****).*

These results have some variability (standard deviation is around 20-25 %). But they allow to develop quite a regular production. New areas are tested now with fishermen and oysterfarmers.

Key-words *scallop, Pecten maximus, intermediate culture, open sea, frames, France*.

Scallop aquaculture is slowly rising in France (over 30 tons in 1990 overall in Brittany). It is based on an extensive on-bottom ongrowing of *Pecten maximus* (see communication JC. DAO). One problem for this aquaculture expansion is the need of spat in large quantities and big enough for seeding : about 30 mm.

1 - THE FRENCH REARING CYCLE

There are three biological main stages (fig. 1) :

- the pelagic larvae, till 250 µ,
- the settled metamorphosed post-larvae, till 10 mm,
- the bentic young and adult free but sedentary, till 100 mm.

There are also three main stages along the rearing cycle but they do not coincide with the biological ones :

- the hatchery-nursery in tanks on land (intensive), till 2 mm,
- the intermediate culture in open sea with frames and cages (semi-intensive), till 30 mm,
- the on-bottom grow out (extensive), till 100 mm or more.

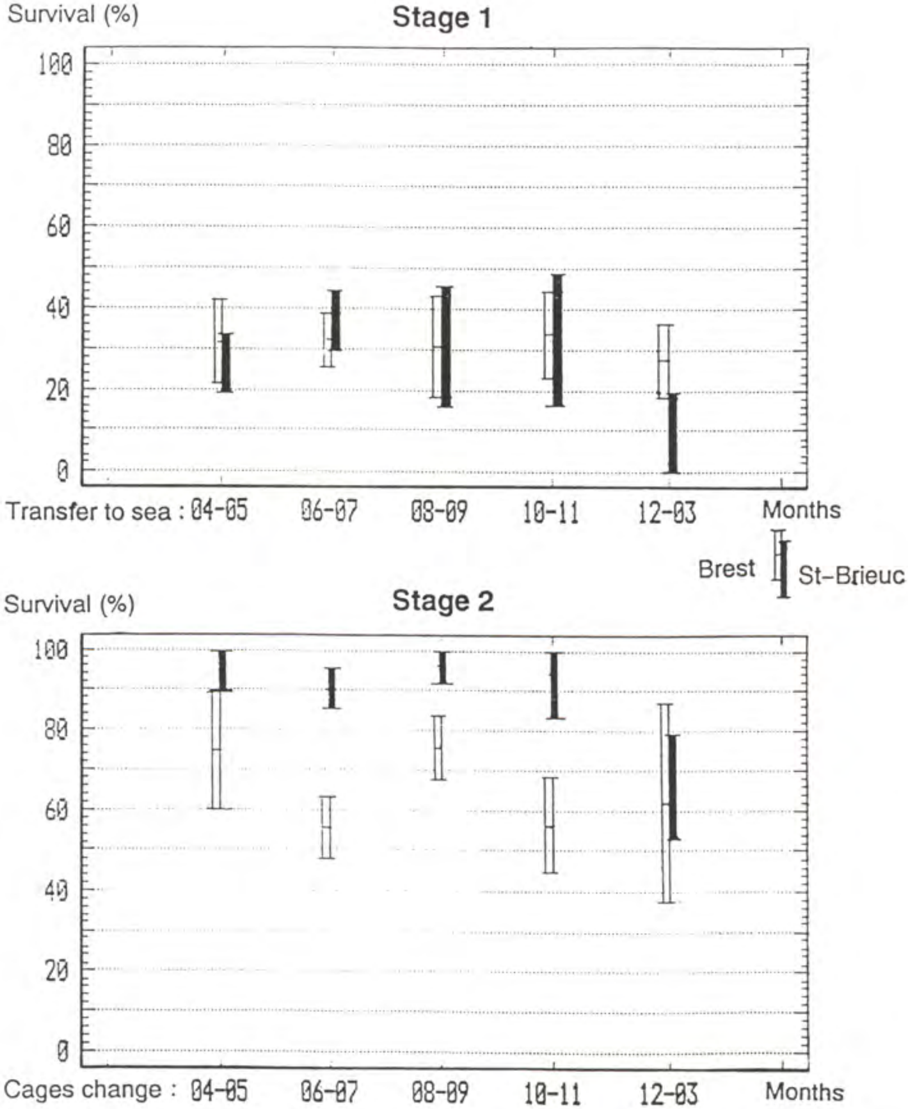

Figure 1. Survival rates - Seasonal variations

2 - THE REARING TECHNIQUES AND THE FEASIBILITY

The intermediate culture in itself has to be dissociated into two stages :

- **stage 1** : from 2 to 10 mm: post-larvaes are thin (translucent) and settled in tiny mesh cages : mesh 500 µ or 1,5 mm ;
- **stage 2** : from 10 to 30 mm: the spat becomes thick (coloured) and detached. It is put in larger mesh cages : mesh 4 or 5 mm ;

When they are 2 mm the post-larvaes are carried out from the nursery in wet filters. They are put in cages on the mesh of which they settle again in a few hours. Because the French rearing sites are not completely protected, the cages have to be made in rigid form with 2 plastic trays tied together ("Colas" trays). They are fixed under the water on metallic tables with divers, or in liftable frames with a manipulation directly from a boat, but with the need of an hydraulic winch. This first stage lasts 2 to 6 months according to the season. The mesh has sometimes to be changed for not being colmated with fouling.

At about 10 mm the spat becomes detached and thick. But it still remains vulnerable with currents or predators. So the intermediate culture goes on with a second stage either in the same "Colas" cages but with larger mesh (5 mm), or in "Northwest" cages. These ones are plastic trays (4 mm mesh) piled up 10 together and either fixed in suspension under main ropes or put in frames. This second stage lasts 3 to 7 months.

The scallops then are 30 mm and about one year old. They are quite too big for being kept longer in cages. They can be seeded on the bottom of the sea in appropriate sites for the extensive grow out.

So, the technique is feasible, but is it reliable ?

3 - THE REARING RESULTS AND THE RELIABILITY

During the intermediate culture, different risks of mortality can induce variability in the results :

- stress of the transfer to the sea : detachment, emersion, shocks, ...
- gales or bad hydrologic conditions such as low salinity, turbidity or chemical pollution
- toxic phytoplancton, parasites or predators.

The survival rate has been regarded for each stage of the intermediate culture, separately in Brest (93 batchs) and in Saint-Brieuc 48 batchs). In Brest we have experimental batchs (IFREMER, from 1982 to '89). In Saint-Brieuc we have pre-development rearings (professionals, 1985-90). The batchs' effectif is very variable (from 10 000 to 1 million)) but the statistical analysis shows no correlation between the batch's effectif and the survival rate. The seasonal variations and the evolution from year to year have both been regarded.

a) The seasonal variations

The results (fig. 2) are presented with a 95% confidence intervalle (2 standard deviations). The survival rate is quite regular along the year excepted in winter (months 12 to 3).

- stage 1 : 20 to 40%
- stage 2 : 90 to 100% in St-Brieuc.
  more variable in Brest where we find some problems with a parasite worm (*Polydora*) and a toxic phytoplancton (*Gyrodinium*).

b) The evolution from year to year

Concerning the evolution of the survival rate, we have different fluctuations for experimental batchs in Brest (according to years with or without *Polydora* and *Gyrodinium*), but quite regular results for the standard production in Saint-Brieuc (fig. 3).

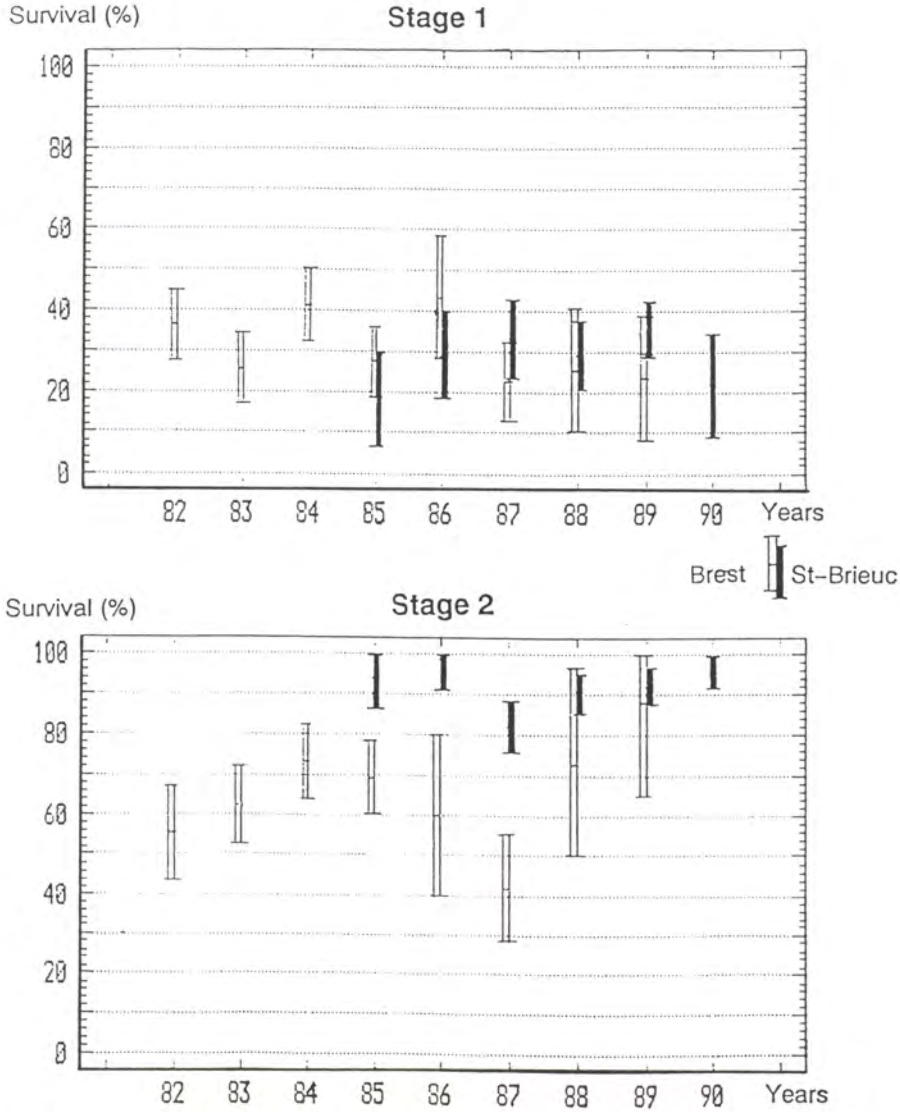

Figure 2. Survival rates - evolution from 1982 to 1990.

4 - THE PERSPECTIVES

From 1982 to '85 French researchers and breeders set-up the techniques. Since 1985 the reliability becomes to be good. It allows quite a regular production : 3 or 4 million juveniles per year. Now we work towards two directions :

- the improvement of the survival, overall during the transfer to the sea. that needs basic data on physiology of the settlement and applied research on transfer techniques ;
- development actions with fishermen and oysterfarmers. That is to say an economical analysis and trials in new areas.

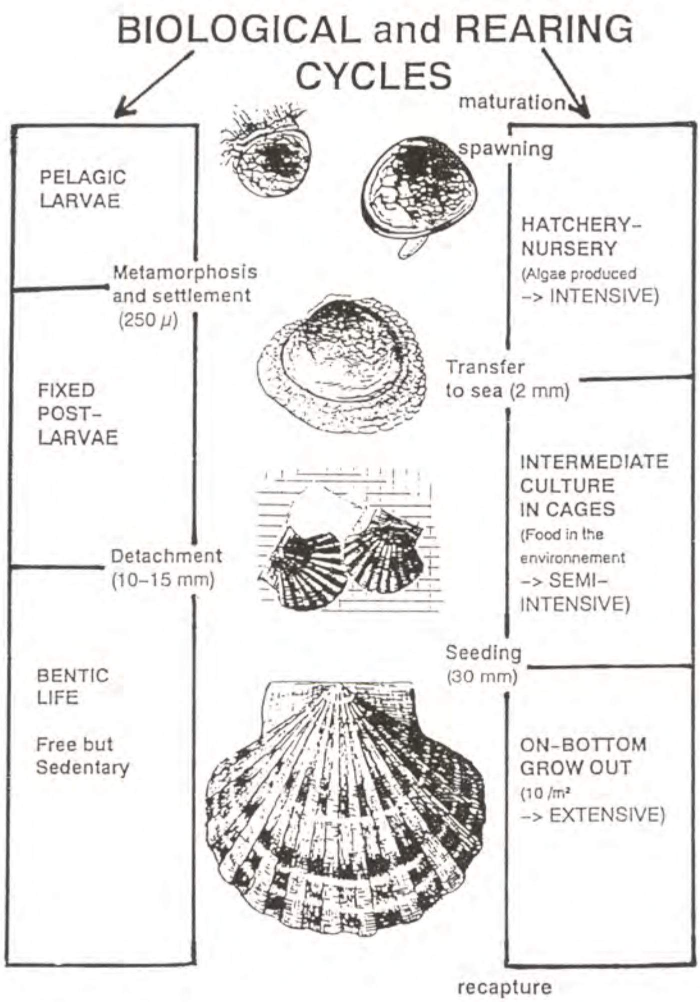

Figure 3. The biological and rearing cycles.

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TESTING OF APPARATUS FOR COLLECTING YOUNG SCALLOP SPECIMENS IN THE NORTH ADRIATIC SEA

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***Abstract** : The increasing demand for fish and molluscs makes the conservation and development of these resources a question of primary importance. This study concerns the Italian scallop fishing industry which until recently succeed in satisfying local demand. A recent heavy drop in the quantity of scallops fished has led to higher prices and first imports. This prompted us to study these molluscs, especially the Mediterranean species **Pecten jacobaeus (L.)**. So far our investigations have concentrated on experimentation with artificial collectors for gathering young specimens during the benthic phase. These are designed to function as substrates for young molluscs, helping maintain natural stoks, and will also facilitate the design of structures suitable for capturing young specimens of Adriatic scallop species. The latter will enable us to evaluate the possibility of farming authoctonous scallops species, as is already done in France, United Kingdom and Japan, without introducing foreign species to the ecosystem which could cause problems of competition between species occupying similar ecological niches.*

***Key Words** : **Pecten jacobaeus**, artificial collectors, young scallops, North Adriatic Sea.*

INTRODUCTION

In the present study, apparatus for collecting young scallop specimens was tested in the North Adriatic Sea, an area heavily exploited for scallops. The study was performed in 1987-88 and was initially concerned with the Mediterranean species, *Pecten jacobaeus* (Linnaeus, 1758), but due to similar reproductive and larval phases, it was impossible to avoid collecting other species as well. Hence the data reported refers to all pectinids collected.
Pecten jacobaeus L. has been heavily exploited in the Adriatic since 1960, leading to a decrease in natural stock, restriction of the area of distribution and scarcity on the market. Until 1987, Italy had a good production of *Pecten jacobaeus*, but overexploitation permitted by non-enforcement of the fishing laws, led to a drop in scallop populations and the need to import from Yugoslavia to meet the demand of the home market. *Pecten jacobaeus* is a highly prized variety but has not been studied to the same extent as the Atlantic species *Pecten maximus* which is cultivated artificially on a large scale.

The aim of the present study was to identify the best material for collecting young scallop specimens in the benthic stage, with a view to scallop farming. A further aim was to begin farming experiments and reproduction of *Pecten jacobaeus*.

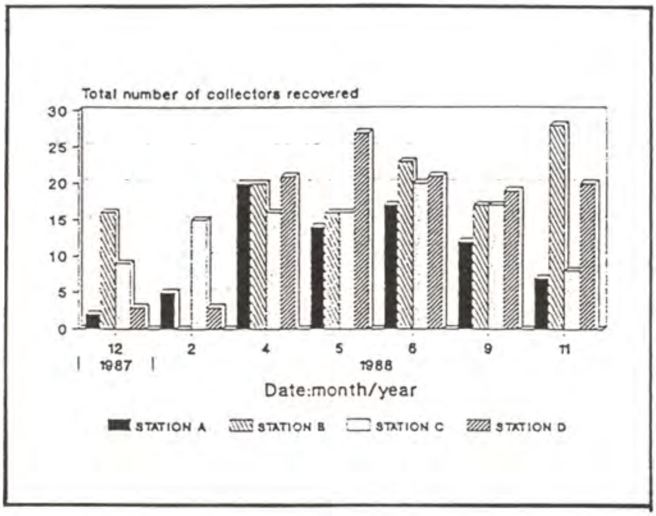

Figure 1 : Recovery of artificial collectors in the single stations of research during the period of study.

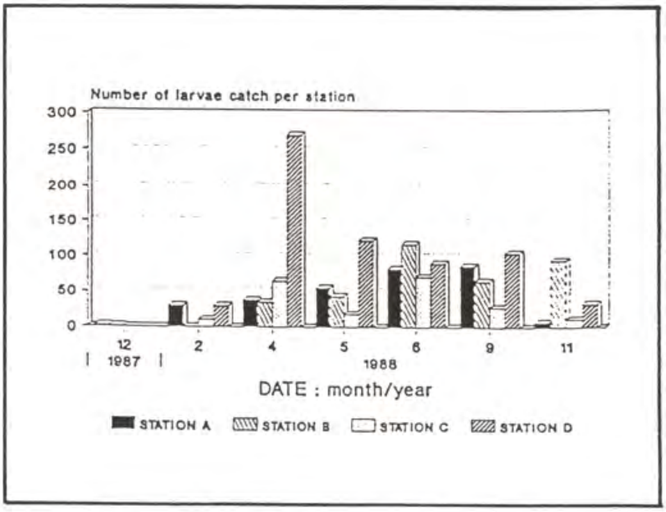

Figure 2 : Total catch of pectinid specimens in the single stations during the period of study.

MATERIALS AND METHODS

The study was performed in the Pesaro area from the port of Fano. The most suitable areas for the release of the collectors were identified by discussion with fishermen. Collectors were released in 4 stations Station A > 20 miles off Pesaro Station B 30 miles off Pesaro Station C 36 miles off Pesaro Station D 30 miles off Rimini. The collectors were released so as to be distributed evenly along the mile and a half of each station.

On the basis of the literature on the subject, we decided to test filamentous nylon material left over from the production of netting and packaging and also vegetable fibre. The plastic threads had a diameter of from 2-3 mm up to 2-3 cm. The collector consisted essentially of a sock of netting filled with the above described material. The sock is the same as that used for muscle farming, with a mesh of 2-4 cm. About a quarter of the socks were of finer mesh, namely that

in which small clams are marketed. In this way it is possible to classify the four types of collectors used as: "coarse" with external socks and internal plastic threads of 2-3 cm of diameter; "fine", with external socks and internal plastic threads of some millimeters of diameter; "bag", with external bag of finer mesh, used to commercialize the clam and with internal plastic threads of about 1 centimeter; "vegetable fibre" with external socks and internal vegetable fibre. They were weighted at one end so as to sit vertically on the bottom. Each sock was marked with the date of release.

The collectors were recovered by trawling twice over the station with the angled net usually used for bottom fishing. Their content was examined using a magnifying glass or stereo microscope when necessary, in order to identify the species collected.

RESULTS

The method was found to be satisfactory for capturing young scallops. Figure 1 shows how it was possible to return precisely to the site of release and recover 2-4 % of the collectors. This would not be an adequate recovery for farming purposes.

For the capture of larvae (fig. 2) the best period was spring-summer which coincides with the reproduction period. The species captured consisted mostly of *Chlamys sp.* This species has a similar reproductive phase to *Pecten jacobaeus*, but spawns all year round (from the study of gonad maturation) where as *Pecten jacobaeus* seems to spawn in winter, with maturation of the gonads in late summer. *Pecten jacobaeus* accounted for only 1-2 % of the scallops caught, testifying to the extremely low level of reproduction in the area. This is in line with the poor catches by fishermen and is further verified by the good catches of *Chlamys sp*. and the corresponding reasonable number of larvae captured. A mean of 300 specimens per station were caught in April, May and June, this trend continuing until September.

As far as the different models of collector were concerned (fig. 3), in all stations socks filled with coarser filaments collected a greater number of specimens. These socks took 49 %, 47 %, 65 % and 56% of the catch in stations A, B, C and D respectively. For the other 3 types of collectors (fine filaments, vegetable fibre, small clam bags) the percentages (10-15 %) were the same for each station, with the only exception of station A which register a 29 % of catch with fine threads. In stations B and D, however, the socks containing vegetable fibre captured a larger proportion, namely 31 % and 29 % of the specimens respectively.

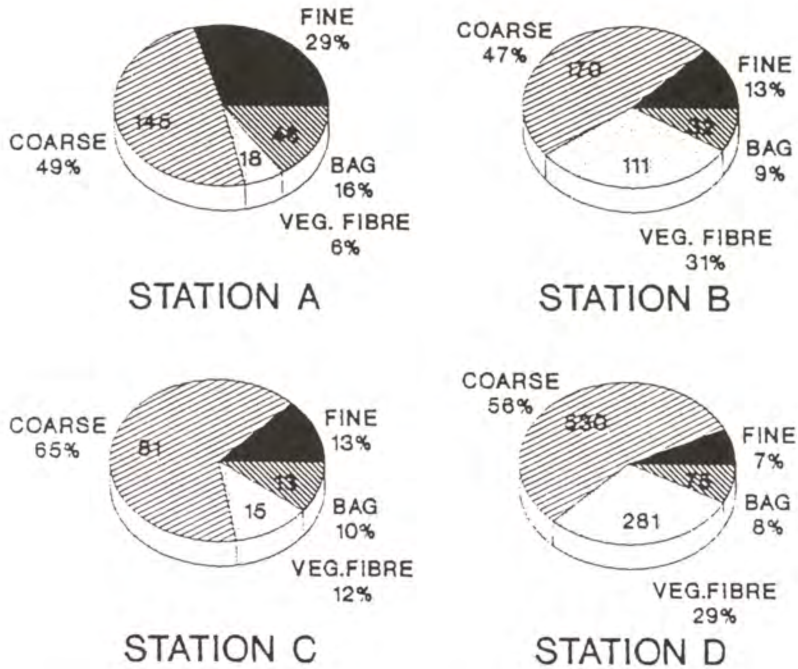

Figure 3 : Ability for the different types of collectors to catch the young pectinids in the four different stations.

CONCLUSION

This first experience has given positive results and will encourage further experimentation of improved collectors and identification of the best season to capture young specimens. As far as the material is concerned, scallops in the benthic phase seem to prefer a substratum consisting of coarser threads (> 1 cm). Threads under 1 cm do not seem to provide a very suitable surface for the filiform bissus of the organisms at this stage of their existence. The vegetable fiber given good results in same stations (B and D) with 31 % and 29 % of the speciments even if this kind of material presents a quick degradation which make the collector unable to collect organisms for a long period. The numbers of larvae captured are not yet sufficient for farming purposes, however in the summer the numbers caught per collector were quite good. In our intention the most important problem is represented by the low percentage of recruitment of collectors. If 20 % of the collectors could be recovered, the number of larvae would be sufficient to consider farming.

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THE LABORATORY CULTURE OF TWO SCALLOP SPECIES FROM THE SEA OF JAPAN : DEVELOPMENT AND INDUCTION OF METAMORPHOSIS

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Abstract *: Two species of scallop* ***Patinopecten yessoensis*** *and* ***Swiftopecten swifti*** *were reared from fertilization to metamorphosis in the laboratory. Data on the development and induction of metamorphosis by various chemical compounds are given. Two chemicals, glycine and theophylline, in a concentration of* 10^{-6} *M, possess considerable activity in the induction of metamorphosis of* ***S. swifti*** *larvae.*

Key Words *: Laboratory culture, scallops,* ***Patinopecten yessoensis***, ***Swiftopecten swifti***, *development, induction of metamorphosis*

INTRODUCTION

The Japanese scallop *Patinopecten yessoensis* Jay and the scallop *Swiftopecten swifti (*Bernardi) occur along the coasts of Primoriye and Hokkaido, South Kurile Islands and in Aniva Bay, Sakhalin Island. *P. yessoensis* is a free-living form, occurs mainly on sandy substrata and attains a size of 180 mm. It is an important item of commercial fishery and culture in Japan and Primoriye. *S. swifti* is an attached organism, up to 100 mm, found on rock substrata. This scallop can be used as food, but it is not commercially exploited (Scarlato, 1976). The development of the Japanese scallop has been adequately studied by Japanese (Maru, 1972; Yamamoto, 1964); Russian (Kasyanov, 1986) and Canadian researchers (Bourne *et al.*, 1989). However, there are practically no studies on the development of *S. swifti*. In the present paper, data on the development, from fertilization to metamorphosis, and induction of metamorphosis of the two scallop species reared in the laboratory are given.

MATERIAL AND METHODS

Larvae were reared in the laboratory at marine stations, (Vityaz Bay, Vostok Bay, and Popov Island) during 1986-1991. Animals were spawned both during the reproductive season (May for *P. yessoensis,* July-August for *S. swifti*) and 1-1,5 months before this season, by acclimating scallops to the spawning temperature. Gametes were obtained by injecting of the gonad or adductor muscle with 0,5-1 ml of 10^{-3} M serotonin diluted in sea water (Gibbon, Castagna, 1984 : Varaksin, Naidenko, 1989). Embryos and larvae were raised in 10-25 l glass vessels with sea water filtered through cotton wadding, and if possible, sterilized by ozonizing or UV irradiation. The author used the method of Loosanoff and Davis (1963) with her own modification being that the culture medium with larvae was mixed with a paddle stirrer at 60 rpm throughout the entire period of larval development, starting with fertilization.

Table 1 : Development of two species of scallop in the laboratory

Developmental stage	*Platinopecten yessoensis*		*Swiftopecten swifti*	
	15-16 °C		18-20 °C	
	Time after fertilization	size m	Time after fertilization	size m
Separation of polar bodies	3-4 min	70	2 min	70
1st cleavage	1-1,5 h	_	50 min	_
2nd cleavage	2-3 h	_	2 h	_
Blastula	14-15 h	_	12 h	_
Trochophore	48 h	_	40 h	_
Early veliger	3 day	112	2,5 day	112
Veliger	4 day	126	3 day	126
Early veliconch	9 day	168	10 day	168
Veliconch	20 day	220	14 day	196
Pediveliger	28 day	250	25 day	230
Spat	30-40 day	280-320	27-30 day	250-320

Table 2 : Induction of metamorphosis of *S. swifti* by chemicals

Chemical	**Concentration M**	**Percent of metamorphosed larvae**
Glycine	$2{,}6\ 10^{-6}$	100
	$1{,}3\ 10^{-4}$	20
	$2{,}7\ 10^{-4}$	0
Theophylline	$0{,}5\ 10^{-6}$	40
	$1{,}1\ 10^{-6}$	80
GABA, GLU, ALA, -aminocaproníc acid, thyroxine, tyramine	10^{-6}	No effect on the metamorphosis of larvae
Control larvae (maintained for 2 weeks)		No spontaneous settlement was observed

Stirring was stopped only during the change of water. Embryos and larvae of *P. yessoensis* were maintained at 15-16 °C and salinity of 32 ppt ; *S. swifti* at 18-20 °C. At the veliger stage larvae began to receive food - a mixture of flagellates *Pavlova lutheri* and *Nephrochloris salina*. Algal density in culture medium ranged from 5000-8000 cells/ml at early larval stages to 15000 cells/ml at later stages. The density of embryos was 20-25 ind/ml, of early veligers 10-15, veliconchs 3-4 and pediveligers 1 ind/ml.
To obtain spat, nylon filaments fastened to holes in the paddle of the stirrer were introduced into culture vessels with competent to metamorphose larvae. In some experiments, the following chemicals were tested for the ability to induce metamorphosis in competent larvae of *S., swifti* : -aminobutyric acid, -aminocapronic acid, glutamic acid, alanine, glycine. theophylline, thyroxine, tyramine. The stock solutions (10^{-3} M) of chemicals in distilled water were diluted with filtered sea water (0,8 m) and used within 1-2 h after preparation. Ten mature larvae of *S.swifti* (252-322

m) were placed in 50 ml Petri dishes. The effect of chemicals showing activity in the induction of metamorphosis was tested at a concentration range of 10^{-4} -10^{-6} M. Metamorphosed larvae (spat) were identified by the reduced velum, initiation of growth of the dissoconch, adhesive response and attachment to the substratum by byssal threads.

RESULTS

Starting with fertilization to metamorphosis, the culture medium with larvae was stirred, except periods of the change of water. According to our many - year observations, stirring by paddle has not any negative effect on the development of embryos and larvae of scallops and other molluscs (Naidenko, in press). The yield of blastulae was 100 %, mortality in the veliger stage was not observed, the survival of veliconchs and pediveligers was 2-3 times that in absence of stirring.

The larval development in the laboratory was 28-30 days for *P. yessoensis* (15-16 °C) and 25-30 days for *S. swifti* (18-20 °C).

The developmental stages and the size of larvae are given in Table 1. Mature larvae of *P. yessoensis* and *S. swifti* have a shell length of 250 m, a distinct eye, a well developed foot, which is from time to time extended beyond the shell. Periodically larvae alternate free swimming with a search for a substratum; the foot in this case lengthens considerably. The larva makes energetic movements with its foot in all directions. But adhesive response is not observed, sticky secretion is not produced. If a suitable substratum or inducer is introduced into a culture vessel, the larvae stop swimming and the process of metamorphosis is started; the velum is reduced, the adhesive response is pronounced. Juvenile is attached to substratum y byssal heads. If the byssal threads get unfastened, juvenile *S. swifti* moves its foot in all directions and surrounds itself within 15 min by fresh byssal threads. The threads of *S. swifti* are much stronger than those of *P. yessoensis.* Two-3 days after the nylon filaments were introduced into culture vessels, they were coated with a bacterial film and up to 30 % of the scallop larvae metamorphosed and settled on them within 1-2 week. In the absence of filaments, a small proportion of metamorphosed larvae were found on the bottom of the vessel. Experiments to test several compounds for the ability to induce metamorphosis of mature larvae *S. swifti* revealed two chemicals, glycine and theophylline, that possess considerable activity at a concentration of 10^{-6} M. With increase in concentration, activity decreased (Table 2). Microscopic observations showed that already within the first hours after the addition of these chemicals, the larvae stopped swimming and the adhesive reaction started, which was evident from the excretion of sticky secretion by glands of the pediveliger foot. Within 12 h metamorphosis was completed and spat was attached to the bottom of dishes. Within 24 h development of the dissoconch commenced. Other compound -GABA, GLU, ALA, -aminocapronic acid, thyroxine, tyramine (10^{-6} M)- had no effect on the metamorphosis of *S. swifti* larvae. No spontaneous settlement was observed in the control larvae which were transferred in microfiltered water on the alternate days during two weeks. Preliminary tests of glycine as a possible inducer of metamorphosis in *P. yessoensis* larvae proved to be successful.

DISCUSSION

In the hatchery of molluscs it is essential that eggs should not be stirred and only monolayer embryos should be in a vessel (Loosanoff and Davis, 1963; Chanley, 1975; Bourne *et al*, 1989). None the less, we do stir the culture medium with embryos and larvae of various molluscs, starting just after fertilization up to metamorphosis, with a paddle at a rate of 60 rpm. Such a Stirling has no negative effect on the development and viability of mollusc's larvae. A merit of this modification is that higher densities of embryos and larvae can be maintained, especially at earlier stages.

The use of different chemicals for inducing metamorphosis of larvae of marine invertebrates has been extensively studied (Pawlik and Hadflid, 1990). French investigators (Cochard *et al.*, 1989) have isolated from the red alga *Delesseria sanguinea* the inducer of metamorphosis of larvae of *P. Maximus* jacaranone -a derivative of tyrosine. The use of norepinephrine increased the proportion of metamorphosed larvae of *P. yessoensis* (Kingzett *et al.*, 1990). As for *S. swifti* larvae, we revealed two substances possessing considerable activity in the induction of metamorphosis - glycine and theophylline-. Eighty to 100 % of larvae of *S. swifti* were induced to metamorphose within 12 h by the addition of these chemicals. However, a possible mechanism of the induction of metamorphosis of larvae of *S. swifti* by this chemicals is unclear. It is assumed that glycine may act as a transmitter or modulator in marine invertebrates, for instance, Aplysia (Walker, 1984).

I am hopeful that large-scale experiments using the above chemicals will encourage us to make recommendations on their application to commercial scallop's hatchery.

***Acknowledgment** : I would like to thank the Organizing Committee of 8th INTERNATIONAL PECTINID WORKSHOP and Prof. P. Lubet for giving me a possibility to attend this meeting and present my work.*

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PECTINID SETTLEMENT ON ARTIFICIAL COLLECTORS IN CASTELLON, EST SPAIN, IN 1990.

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***Abstract** : Two spat collecting sites were used in the Castellon coast. Maximum settlement occurred in Carrero station and was scarce in Azahar coast with predominance of **C. opercularis** in the first one and **F. flexuosus** in the latter. The number of settled pectinid spats varied with depth. No relationship was found between growth of spats and depths. The mean size of live scallop spats was 15.8 ± 1.24 mm with a range of 4.2 to 22.4 mm. The mean size of **C. opercularis** spats was 8.34 ± 0.416 mm with a range of 2.5 to 15 mm.*

***Key words** : settlement, spat, pectinid, Castellon, Spain.*

INTRODUCTION

The Mediterranean scallop *Pecten jacobaeus L.* is becoming an important species for aquaculture purposes in the east coast of Spain, since 1989, when the Regional Government started their support on the study of its reproductive cycle (Mestre *et al.*, 1990 ; 1991). The catches of scallops on the traditional fishing banks were decreasing year by year, some of these banks have even disappeared in the last years. At present a small population of *P. jacobaeus* is located in front of the Castellon coast, and it is the subject of our study.

The first trial of pectinid spat collection in the Mediterranean coast of Spain was carried out in 1983 and 1985 in Malaga (Roman *et al.*, 1985; Roman and Cano, 1987), but that technique was developed firstly in Japan (Taguchi and Walford, 1976; Kafuku and Ikenoue, 1983). This study attempts to document the presence of pectinid spats in two areas of the Castellon coast, at 20 and 75 m deep around the adult scallop bank.

MATERIAL AND METHODS

In 1990 two scallop collecting sites were tried in front of the Castellon coast (figure 1) : Azahar site (40° 06'N, 0° 11'E) at 20 m deep and Carrero station (40° 02'N, 0° 26'E) at 75 m deep, looking for grounds not used by trawling fishermen, the first one in a forbidden area (depth less than 25 m) and a rocky bottom (Carrero) hazardous for trawling.

From May 19th to August 18th ten lines of collectors were submerged into the sea in the Azahar coast on a sandy bottom. In Carrero station 15 lines of collectors were submerged, on a rocky bottom surrounded by a gravel bottom where adult scallops live, from May 19th to September 11th and 18th.

Each line consisted of seven (Azahar coast) or eight (Carrero) onion bags attached at 1 m intervals, starting 3 m from the seabed, with a subsurface buoy located 15 m from the

seabed that kept the rope with bags in a vertical position. The onion bags (40 x 30 cm) were filled with about 15 g of nylon monofilament gillnetting.
Eight lines from Azahar and nine from Carrero were recovered. The content of each bag was removed by hand and fixed in formalin and transferred to the laboratory where counts of the scallop spat, other bivalves spat and crabs in each bag were made. Each individual was measured with a vernier caliper and a stereomicroscope was used to identify the species.
Temperature data of the bottom water was taken monthly around the Carrero station keeping a temperature range of 13 to 14°C all year long.

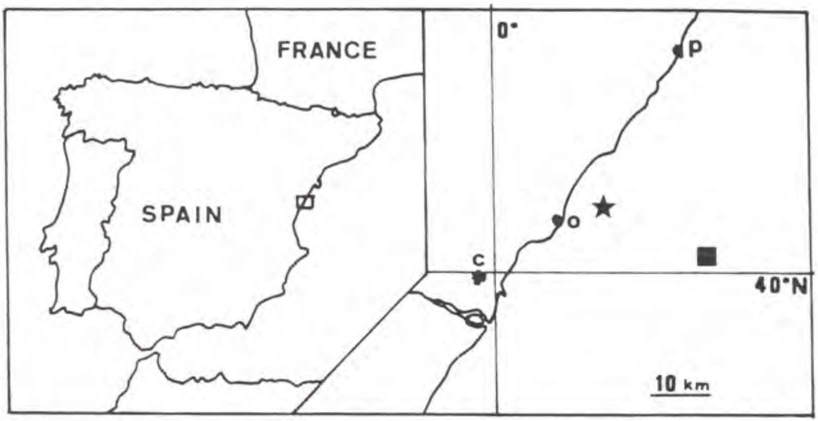

Figure 1 : Map of the spat sampling sites: Azahar (*) and Carrero (¨).
P : Peñiscola, O : Oropesa, C : Castellon.

RESULTS

Four species of pectinid spat were found settled on the nylon monofilament put into the bags: *Pecten jacobaeus L.* and *Chlamys opercularis* of economical value and *Flexopecten flexuosus* and *Palliolum incomparabilis* without commercial value.
The settlement results are very different from one site to the other. In Carrero a great number of pectinid spat was attached, with predominance of *C. opercularis*, however in Azahar it was scarce and no *Pecten* spat was found, only *Chlamys* (a mean of 0.2 per bag) and specially *F. flexuosus* (a mean of 1.1 per bag).
In the Azahar collectors a lot of other bivalve species were found that made up 64.6 % of all spat settled, corresponding a 4.6 % to *C. opercularis* and 30.8 % to *F. flexuosus*. In these collectors some predators (a mean of 0.3 crabs per bag) of the species *Polybius henslowi* and *Liocarcinus vernalis* were recorded. There was a relationship between the presence of crabs and the absence of spat. In the Carrero collectors no crabs were detected.

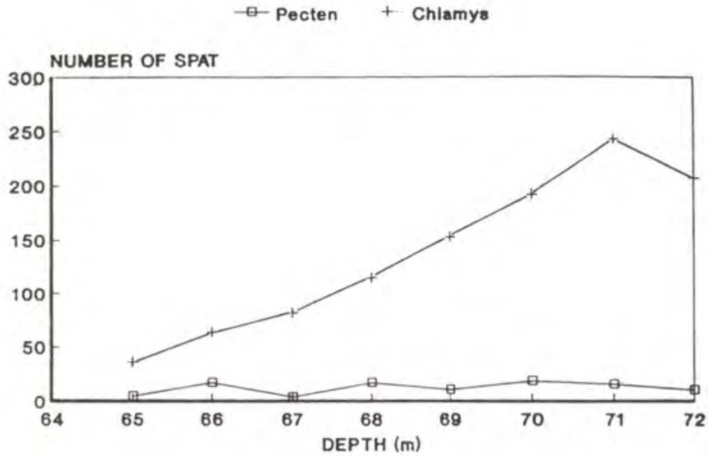

Figure 2 : Variation of number of spat with depth : *C. opercularis* (+) and *P. jacobaeus*

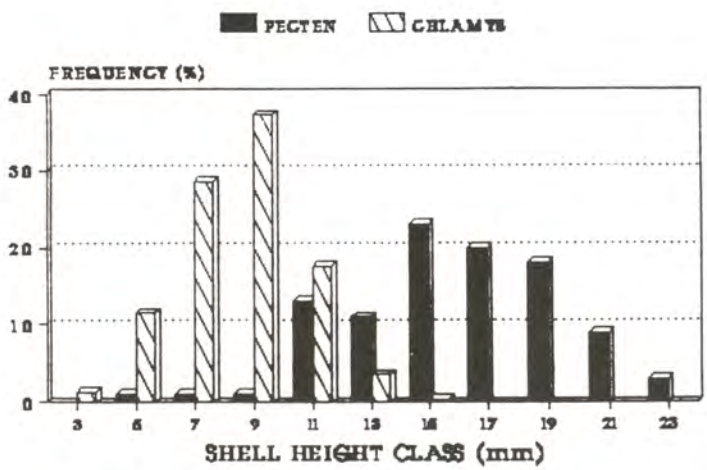

Figure 3 :Size distribution in shell height classes of *Chlamys opercularis* and *P. jacobaeus*.

The relationship between the number of scallop spat settled on collectors placed at different heights from the seabed are shown in figure 2. The number of *C. opercularis* spat settled increased with depth corresponding the maximum at a depth of 71 m (4 m above the seabed). No significant differences between the scallop spat settled and depth was found.

No relationship was found between growth of spats and depths. The mean size of live scallop spats was 15.8 ± 1.24 mm with a range of 4.2 to 22.4 mm in shell height. However the mean size of *Chlamys opercularis* spats was 8.34 ± 0.416 mm with a range of 2.5 to 15 mm in shell height (fig. 3).

DISCUSSION

The results of the first trial of settlement suggest that larvae of *P. jacobaeus* and *C. opercularis* settle near the bottom in the adult habitat and do not migrate to the shallow areas.

In 1990 the spawning season for *P. jacobaeus* was from February to May (Mestre *et al.*, 1991), but for *C. opercularis* it was later, according to the small size of the settled spats. The collectors submerged in Azahar had no scallop spat and a few *Chlamys* spat because predation by crabs and high water temperatures during summer at 20 m depth (between 20 and 26.5 °C) made it impossible for the scallop larvae to develop if any were attached.

The low rate of scallop spat settlement in Carrero suggests that the habitat of adult scallop is in an open area, so larvae are exposed to dispersion by currents, and that the scallop population is not large enough to produce a big amount of larvae, and that the scallop spawning is not synchronic, taking place from early March to mid May, and we only got the last larvae by submerging collectors at the end of the spawning season.

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SCALLOP CULTURE IN BERMUDA: A SAGA

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Abstract *: Populations of the zigzag scallop,* ***Pecten ziczac,*** *declined to near extinction in Bermuda waters over the last 10 years. Efforts were made towards stock enhancement by spat collection in the inshore waters. Growth rate of the latter was monitored in both pearl nets and bottom cages. Spawning was induced in the laboratory by thermal shock, and preliminary larval rearing experiments were performed. The extent to which aquaculture could be performed in Bermuda is discussed with respect to the species potential and environmental capacity, mainly in terms of available surface area and food supply.*

Key words *:* ***Pecten ziczac*** *, Bermuda, spat, enhancement*

INTRODUCTION

The idea of aquaculture in Bermuda has been considered for several years, especially as a tool for stock enhancement of various species. The concluding statements of a workshop hosted by the Bermuda Biological Station for Research (BBSR) in 1983, were that several indigenous finfishes and bivalve species (among which was the zigzag scallop) were excellent candidates for aquaculture (Sleeter, 1983). However, very little was known on the biology, reproduction, growth rate and even abundance of most of these species. It was therefore decided that research programs should be established before the building of pilot-scale hatcheries.

In 1987, a program was developed for the stock enhancement of the zigzag scallop, *Pecten ziczac,* in Bermuda. A dramatic decline in population numbers had been observed over the last 10 years, for many of the bivalve species. The cause of it was uncertain, but coincided with a change in the ecosystem and the proliferation of a green mat-forming algae, *Cladophora prolifera,* on the sandy bottoms of the inshore waters - a preferential habitat of many shellfish species.

Pecten ziczac has a habitat range extending from the coast of Brazil, to Venezuela, where it sustains a commercial fishery; it has not been reported in the Caribbean, but is found occasionally off Cape Canaveral (Creswell, 1987) In Bermuda, P. *ziczac* was found at depths ranging from 2-7 m, occurring in sandy areas, lying underneath the sand with the rim of its outer left valve showing. It will swim when disturbed, but does not cover greater distances than a few meters. Potential predators in Bermuda, would be crabs feeding on juveniles, hogfish *(Lachnolaimus maximus),* octopus *(Octopus vulgaris),* spiny lobsters *(Panulirus* argus) and spotted eagle rays *(Aeteobatus narinari),* preying on larger individuals. Numbers of zigzag scallops during years previous to the decline, were sufficient for recreational harvesting, but were never recorded to be high enough for a commercial operation.

Several questions were put forth considering aquaculture in Bermuda; among the most immediate were the following:

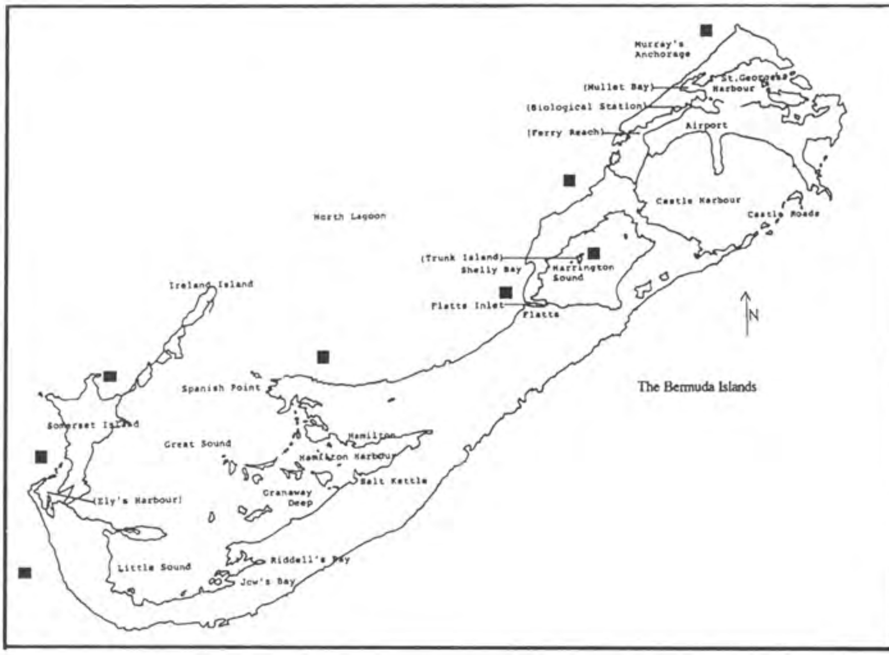

Figure 1. Collectors sites tested for *Pecten zigzag* and *Arca zebra* spat.

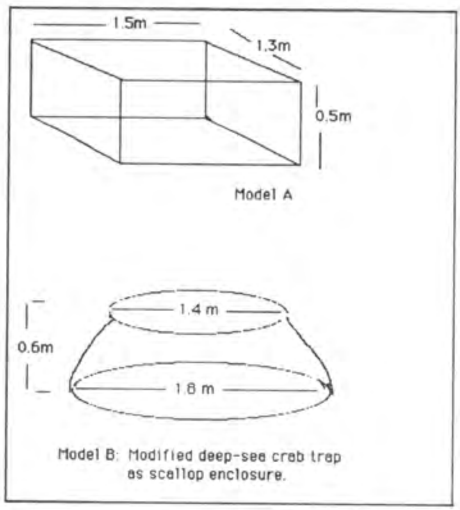

Figure 2. Culture cages experimented upon a scallop growth on the bottom

- Was there a sufficient natural stock in 1987 for the set-up of a stock enhancement program - i.e. for the obtention of a broodstock and subsequent larval and spat production?

- Was the cause of the population decline in bivalves, a factor inherent to water or sediment water quality, and thus be detrimental to future growth and survival rates and consequent culture efforts?
- Was the zigzag scallop an adequate species to culture, in terms of growth, reproductive and survival rates?

The first step undertaken, was aimed at determining the exact abundance of the zigzag scallop in Bermuda. Thereafter, the obtention of spat, via a collector program and their growth and survival rates to adulthood in the field was monitored. Once the reproductive cycle was assessed, preliminary larval rearing under controlled conditions were conducted.

MATERIALS AND METHODS

Population assessment, performed by SCUBA surveys were unsuccessful; only two adult scallops were recorded over a period of 8 months. A second approach was therefore taken and a collector program developed. The type of collector used, was the classic onion-bag type with an available surface area for spat settlement of 0.2 m^2. Collectors were suspended on a sub-surface line (ranging from 0.5m to 7m below the surface).

Eight sites were chosen along the North Shore of Bermuda as well as one in Harrington Sound (Fig. 1). Results of spat collection were also pooled with those obtained separately by the Department of Agriculture and Fisheries.

Growth rates were monitored by shell length, taken from the hinge to the mantle edge. Two grow-out methods were tested: Japanese pearl nets suspended in the water column, or direct growth on sand enclosed for protection. Densities of scallops in pearl nets ranged from approximately 100 spat/net- at 7 mm shell length- to 8 scallops/net - at 50 mm-. Cages offered a surface area of 2.0 m^2 (model A) and 2.5 m^2 (model B) illustrated in Fig. 2; and juveniles of mean shell length equal to 30.7 mm were placed at a density of 15-18 individuals.m^2

Larval culture

From previous field observations, it was concluded that P. *ziczac* spawns through the winter months from January to approximately mid-August; i.e. the first spawn occurred approximately 3 months after the phytoplankton bloom, assessed in terms of chl a (Fig. 3). Laboratory spawning was induced by a thermal shock of approximately 10 °C, on a sample of 20 individuals.

Preliminary experiments were conducted on larval rearing; these were not successful to the point of metamorphosis. Procedures were standard; eggs and larvae were grown in a closed, aerated, and sterile system. Chloramphenicol (4 $mg.l^{-1}$) was added to prevent bacterial contamination, in the holding chambers, during water change.

Larval growth was monitored by shell length and survival rate. *Isochrysis galbana* and *Chaetoceros gracilis* were given at 3 densities: A. 20 $cells.ul^{-1}$, B. 40 cells.ul-l, and C. 60 $cells.ul^{-1}$. A second batch of larvae was reared at 2 temperatures, the ambient temperature (T=19°C), and the maximal summer temperature of 30°C (Fig. 4).

RESULTS

Results on preliminary grow-out experiments in the field, and bottom cage experiments were given in an earlier paper (Sarkis, 1990) In summary, the first collection of *Pecten ziczac* spat occurred in May 1989 in Harrington Sound, when 250 spat of an average shell length of 7.2mm were collected. Spat appeared to remain attached for less than one month. Growth rate was illustrated in Fig. 5. Adult size of 52mm was attained 9 months after collection. Spat collection increased in 1990 to over 800 individuals.

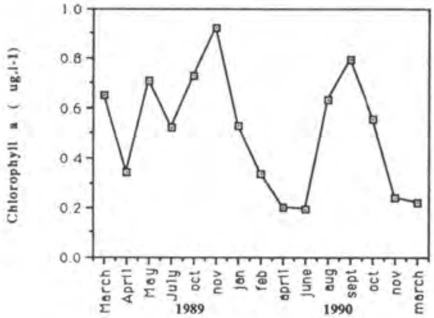

Figure 3.
Seasonal variations in Chlorophyll a,

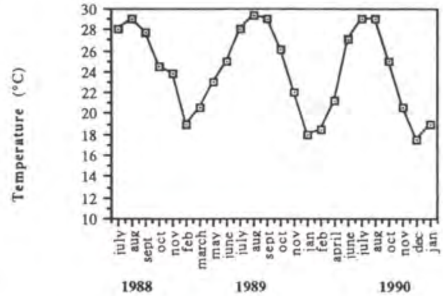

Figure 4.
Sea surface temperatures in Harrington Sound, Bermuda.

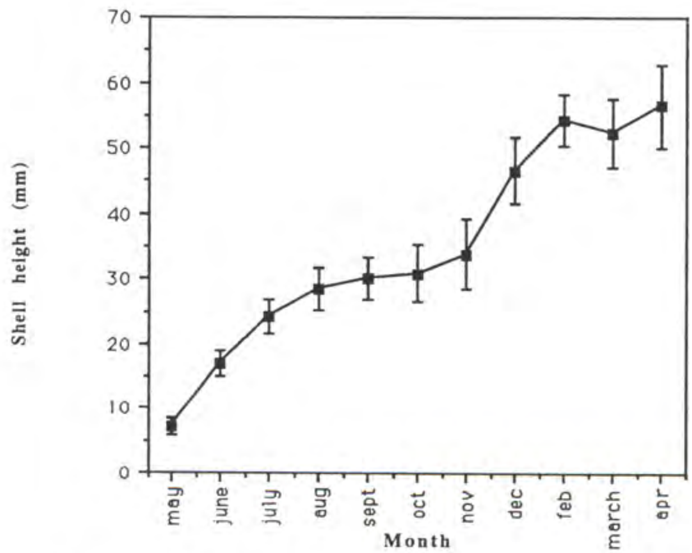

Figure 5. Shell growth of the zigzag scallop in the field.

There was no observed difference in the number of spat collected at various depths in the water column, or suspended at various depths.

The comparison between scallops growth in pearl nets and bottom cages was illustrated in Figure .6 Growth in the bottom cages was much more rapid. Survival rate was high in both cases; however spat grown in pearl nets became very fouled, and required a monthly cleaning, unlike those in bottom cages. Moreover, mortalities of scallops in pearl nets increased after the first year; multiple perforations were noted on the shells, probably caused by a boring polychaete species. Gonads appeared to be at an equivalent developmental stage for suspended cultured scallop, and bottom cultured scallops, despite the shell length difference. Predation appeared to be a problem in those pearl nets suspended off the bottom (0.5 m); a near 100 % mortality was assessed; scallops were crushed in several pieces, yet the nets were intact, without any sign of tear.

Three spawnings were attempted; January 22, February 12 and March Ist; in terms of egg fertilisation and viability, it was deduced that approximately 1 month of recovery appeared necessary for P. *ziczac*. The response to thermal induction was rapid; gamete release began 15 minutes after immersion in a warm water bath. There did not seem to be a trend as to whether sperm or eggs were released first. The average fecundity was of 3.39 million eggs per female; eggs had a mean diameter of 64.6 um. Development followed that of other pectinids (Buestel, 1981).
High mortalities occurred in the first 48h (>90%). The slow growth rate, and lack of metamorphosis throughout the experimental period, may be largely due to the quality of algal diets. However, some conclusions may be drawn from these studies, in that an algal density of 40 cell.ul^{-1} may be sufficient and that higher temperature may increase shell growth rate (Fig. 7); 2-week old larvae reached a maximum shell length of 172 um when grown at a temperature of 30°C. Survival rate decreased dramatically after day 14, without the occurrence of metamorphosis; this suggests larval life to be approximately 15 days, and high mortality follows the inability to settle. However techniques need to be refined for successful rearing.

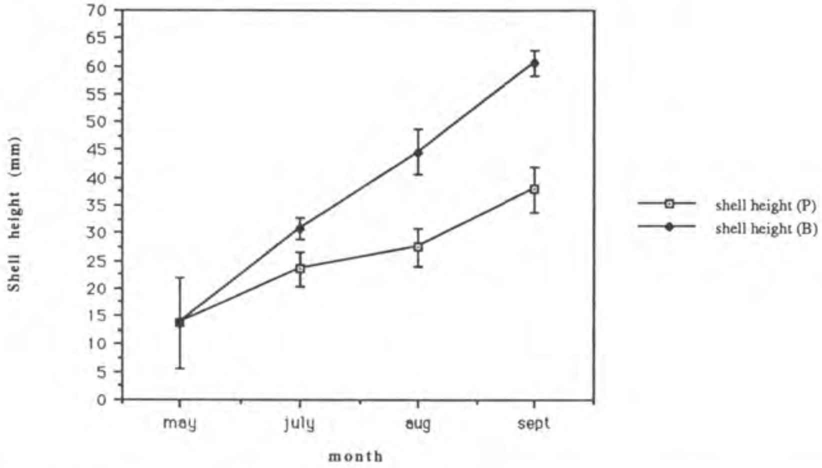

Figure 6. Comparative shell growth between pearl net cultures and bottom cultures.

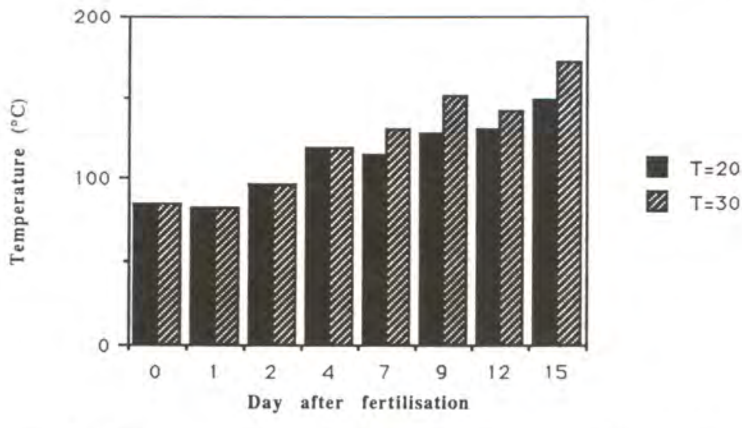

Figure 7. Shell growth of zigzag scallop larvae, grown at two temperatures.

DISCUSSION

Much of the work conducted in the last few years has simply been an attempt at obtaining a substantial broodstock size for future reproduction, larval rearing and spat growth. The first question was the existence of a P. *ziczac* stock in Bermudian waters. The first collection of spat evidently indicated the presence of some healthy individuals. The high survival rates of spat both in the water column, by pearl nets, and directly on the sand, enclosed by cages, was a positive answer to the concern of water and sediment quality. It can be therefore concluded that there does not seem to be any chemical or biological component, present in the water column and/or sediment, inhibiting the shell growth or sexual maturation of this species. The increased numbers of spat collected in Harrington Sound since 1989, indicated a growing population; sightings by locals of juveniles in various parts of the Sound confirm these results.

However, the one foreseeable potential problem in the future efforts of stock enhancement is that of predation. The high mortalities (100%) of scallops grown in pearl nets off the bottom suggest one of the probable causes of the previous decline. It is a must to identify the specific predator(s) in future work; at this point, it is not known whether a specific size class only is preyed upon; it was believed by (Schweimmans, 1979) that fish grazing on the benthos accounted for the low molluscan numbers in Harrington Sound. However, any of the predators, mentioned earlier, exist in abundance in Bermuda in many of the areas which should be potentially good scallop sites. Such that, future work on stock enhancement will have to involve the growth of scallops to sexual maturity in enclosures.

The second point to be taken in consideration is that most grow-out should be performed directly on the sandy bottom, if possible. The slower growth rate, and fouling of the shell do not make pearl net culture very appealing. The former proves more adequate to Bermuda's limited inshore bodies of waters used mainly for recreation and tourism.

The questions to be considered in the future involve the capacity of Bermuda's islands in term of available culture surface area with an adequate food supply. Bermuda consists of 7 major islands linked by bridges; this configuration results in several semi-enclosed inshore bodies of water. The shelf in Bermuda extends to the north, to approximately 10 miles wide, with a 50% coverage of reefs, and to the south to mile only.

Bermuda, situated in the North Atlantic, in the middle of the Sargasso Sea (34°N, 64°W), is considered a nutrient-poor environment. The most productive areas in Bermuda are the inshore waters; of which Harrington Sound is second to Hamilton Harbour (Von Bodungen *et al*, 1982). Maximum chla level reach a maximum of 1.6 ug chla.l^{-1} in later summer/ early fall (Connelly, 1991). This explains the relative abundance of many species - i.e. calico clams, scallops, mussels, conchs etc. Although Harrington Sound is a relatively large body of water, with potentially 0.8 km^2 of cultured bottom (Ward, 1982), it may not sustain a substantial culture operation. Moreover, should an ecological imbalance occur in the future as it has in the past, it would be advisable to consider other sites. Transplant studies are at present being implemented, and other sites, for example Port Royal Bay (Fig l) considered. In terms of surface area, the North Lagoon will also be taken into account; however production levels, in terms of Chlorophyll a, are low (.04-0.3 ug chla.l^{-1}) (Connelly, 1991), and may be insufficient; larval retention may also be less than in the inshore waters, due to the shorter residence time of 4 days, as opposed to 140 days in Harrington Sound (Jickells, 1982).

The fast growth rate, frequent spawning and high survival rate of P. *ziczac* render it a very good candidate for aquaculture. Larval rearing has not yet been optimized, however, this should prove feasible; the only other known attempts at hatchery work of the zigzag scallop was performed in Venezuela (Velez, 1988).

Considering Bermuda's surface area, and human impact on water uses, the most realistic prediction which can be made, with respect to scallop culture operation, is the grow-out of juveniles by individuals for recreational harvesting; the seed for which could be supplied either by natural collection or by hatchery production, performed by an institution, i.e. BBSR or the Department of Fisheries.
In conclusion, it can be said that the last few years have proved the feasibility of scallop growth and culture in Bermuda waters; the next few should demonstrate its possibility of expansion into either a stock enhancement to recreational fishery, or even perhaps a small local commercial operation. With 60,000 residents, 1/2 a million tourists a years, and 90 % of imported seafood, the demand for local seafood is present. Whether the environment can supply it, is not so certain.

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SEEDING TRIAL OF THE GIANT SCALLOP (*Placopecten magellanicus*) IN NOVA SCOTIA

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Abstract : *The viability of direct bottom seeding of the giant scallop,* ***Placopecten magellanicus****, is being assessed in a shallow channel in Lunenburg Bay, Nova Scotia, where a natural population of scallops occurs. A release of 10.220 juvenile scallops within a 40 m^2 area in November 1990 is being monitored using SCUBA. Dispersion of seeded scallops into a hydrodynamically defined area >1200 m^2 took place within 128 days of release. Survivorship of scallops decreased to ≈ 30 % by 16 days and then stabilized. Sea star predation appeared to be the major cause of scallop mortality. Concurrent experiments with tethered scallops showed that predation rates decreased markedly as sea water temperatures dropped below 5 °C in winter. The density of seeded scallops in the study area was ≈ 4 individuals m^{-2} after 128 days, which is 4 times that of the natural population in this area.*

Key Words : ***Placopecten magellanicus****, juveniles, seeding, predation, dispersion, temperature.*

INTRODUCTION

The giant scallop, *Placopecten magellanicus*, inhabits coastal and shelf waters in the Northwest Atlantic from Newfoundland to Virginia (Posgay, 1957). Extensive aggregations of giant scallops in some areas (e.g., Georges Bank) support valuable commercial fisheries (Caddy, 1975). *Placopecten magellanicus* is also a promising species for aquaculture, although development of giant scallop aquaculture in Eastern Canada has been slow (Dadswell and Parsons, 1989). In Newfoundland, giant scallops are cultured by suspending them in pearl nets or by "ear hanging" (Naidu and Cahill, 1986; Young-Lai and Aiken, 1986). An alternative method (bottom culture), practised in Japan, France, and New Zealand, is to seed the sea bed with spat for eventual harvest by conventional techniques (Ventilla, 1982 ; Bull 1986). Cost-benefit analyses indicate that bottom culture of giant scallops may be more economic than suspended culture, since bottom culture is less labour intensive (Tremblay, 1988). A major problem in bottom culture, however, is the low survival rate of juveniles after seeding. Heavy losses may occur due to predation, although the importance of various invertebrate and fish predators in limiting survival of juvenile scallops in the wild is unknown. Another important consideration in bottom culture is the propensity of juvenile scallops for swimming (Caddy, 1972) which may cause them to disperse some distance from a release site, particularly in areas with strong currents.

In this paper, we present preliminary results of a seeding experiment with juveniles of *Placopecten magellanicus* in an embayment on the Atlantic coast of Nova Scotia, Canada. This study is part of a broader program of research aimed at evaluating the potential of bottom culture of giant scallops in Eastern Canada.

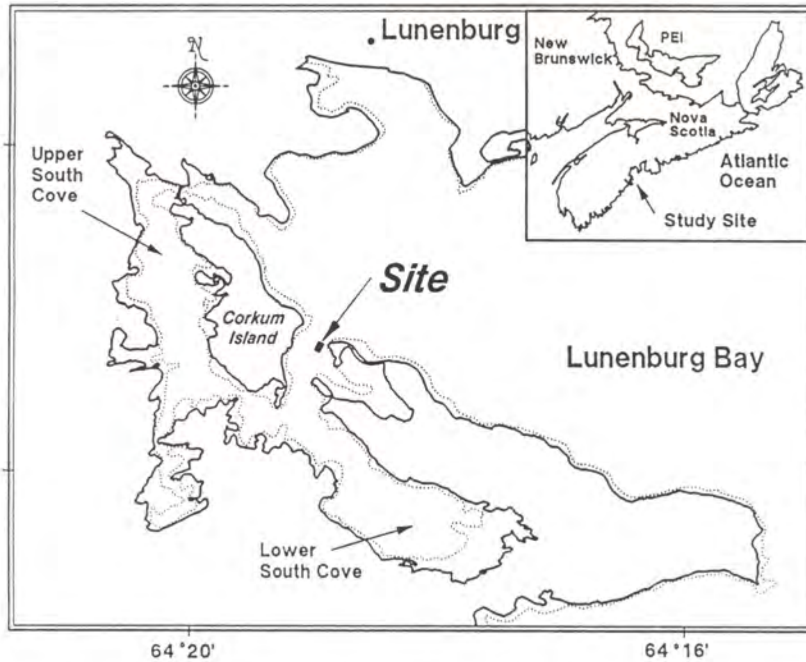

Figure 1. Map of the study area showing location of release site in Lunenburg Bay, Nova Scotia, Canada.

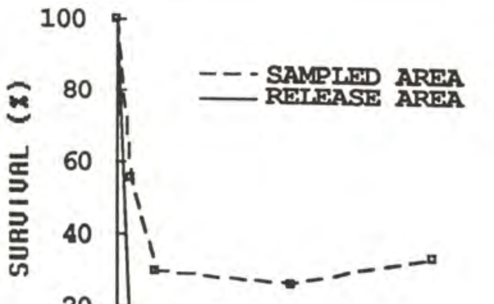

Figure 2. Percentage survival of 10.220 seeded juveniles of *Placopecten magellanicus* in a 40 m^2 release area and in the total area sampled (up to 950 m^2) at various times during the first 128 days after seeding (20 Nov. 1990 to 28 March 1991). Note : The decline in "survival" is due to mortality and dispersion.

MATERIALS AND METHODS

The study site is located within a tidal channel off Corkum's Island in Lunenburg Bay, Nova Scotia (fig. 1). The substratum consists of coralline-encrusted cobbles on mixed silt/sand sediment at a mean depth of 6.9 m below chart datum. Tides are semidiurnal with an amplitude of 1.7 m, and tidally-driven, along-channel currents reach velocities of 0.6 m s^{-1}.

Seawater temperature ranged from 14.4 to -1.4°C, and salinity from 29.7 to 31.5 ppt, during the study (October 1990 to May 1991). *Placopecten magellanicus* naturally occurs in this area.

Hatchery-reared juveniles of *Placopecten magellanicus*, ranging from 5 to 20 mm in shell height, were obtained on 19 November 1990 from a holding facility of National Sea Products Research Development Laboratory. The scallops were transported in coolers to the site, where they were counted and placed in groups of 400 in pearl nets suspended in the channel. On 20 November 1990, 10,220 juvenile scallops were placed in plastic buckets and released by divers within a 4 x 10 m area of bottom. Four groups of 60 scallops were suspended in pearl nets to serve as controls for mortality. The pearl nets were attached to a mooring at one end of the release area.

The density of released scallops was quantitatively monitored in a grid delineated by 20 to 50 m transect lines running parallel to the main axis of the release area and spaced at 5 m intervals. Live scallops, intact scallop valves and valve fragments, and potential predators (sea stars, crabs) were counted in series of contiguous 0.25 m^2 quadrats. The position of the first quadrat in a series was randomly located along one or the other side of a transect line. Successive quadrats (at 0.5 m intervals) were located by flipping the 0.25 m^2 quadrat perpendicular to the transect line, usually until at least 3 successive quadrats gave zero counts of live scallops or scallop valves. Thus, the sampling grid was continually expanded as the released scallops dispersed across the bottom.

The grid was initially sampled on 21 November 1990 (≈ 16 h after scallops were released) and then at weekly (first 2 weeks) or monthly intervals; scallops in pearl nets were sampled concurrently. At each sampling period, density distributions of scallops and their predators were mapped using SYGRAPH (Wilkinson, 1988). The number of surviving scallops was estimated by multiplying the mean density in quadrats in a given region of the grid by the area of that region and then summing the resultant counts over all regions of the grid.

Mortality rates of juveniles of *Placopecten magellanicus* were measured in three experiments using tethered animals (Experiment 1: 20 October to 15 November 1990, Experiment 2: 26 November to 6 December 1990, Experiment 3: 29 January to 26 April 1991). Scallops from the same source as in the release experiment were measured and individually tethered on 15 cm monofilament lines to numbered stainless steel rods. The tethers were affixed with fast-set epoxy glue to the upper valve (after air drying) either in the field (first experiment) or in the laboratory. Twenty-five tethered scallops were placed at 30 cm intervals in a circular array (3 m radius) by driving the rods into the substratum about a fixed location marker. Two to three arrays, spaced at 20 m intervals, were located immediately adjacent to the release area. An additional eight tethered scallops were placed inside a cylindrical, plastic mesh (Vexar) cage to exclude predators. The cage (100 cm diam., 50 cm height, 15 mm mesh aperture) was placed over the natural bottom within 3 m of the middle array, and weighted down with iron chain.

Tethered scallops in the arrays and cages were sampled at daily (first week) to weekly intervals to record individual mortality.

RESULTS

The abundance of seeded scallops decreased sharply to 56 % of the initial number within 6 days after seeding, and then stabilized at ≈ 30% of the initial number between

16 and 128 days (fig. 2). Only 6 % of scallops remained in the 40 m^2 release area 6 days after seeding, as they dispersed in a southerly and easterly direction in accordance with the tidal inflow through the channel (fig. 3). After 128 days, the seeded scallops had dispersed into an area >1200 m^2; a few individuals were found up to 55 m (SSE) from the initial release area. During November 1990, when seawater temperature was > 6 °C, many of the scallops swam when approached by divers, some as far as 12 m on a single excursion. Swimming was not observed in January and February, when seawater temperatures were ≈ 0 °C, but began again as temperature increased to 5 °C in March.

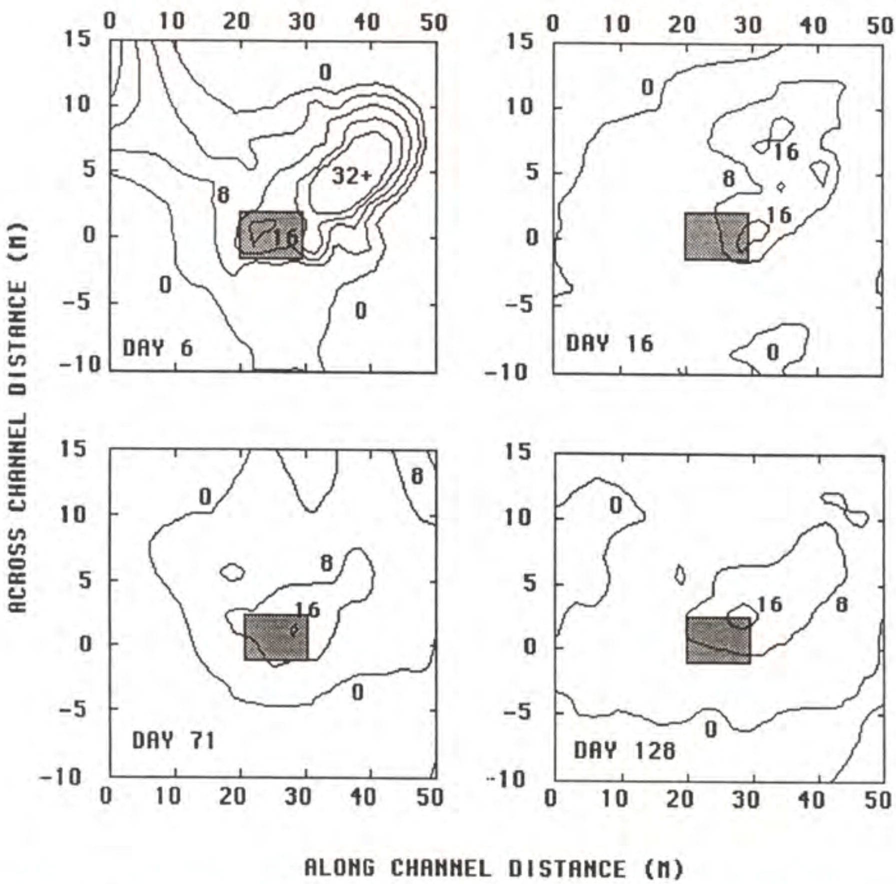

Figure 3. Density distribution of seeded juveniles of *Placopecten magellanicus* at various times during the first 128 days after seeding. Contours are density increments of 8 individuals m^{-2}. Shaded box is the release area.

The mean density of seeded scallops decreased markedly due to dispersal and mortality, from 255.5 individuals m^{-2} at release to 12.5 individuals m^{-2} within 6 days after seeding, but then was constant at 4.0 to 4.6 individuals m^{-2} for the rest of the 128 days of observation. The mean density of the natural scallop population also was relatively constant over the study period, ranging from 0.6 to 1.0 individuals m^{-2}. The natural population was composed mainly of adults with some juveniles that were larger than the seeded scallops, enabling the two groups to be differentiated.

The distribution pattern of dead scallops (intact valves or valve fragments; not shown) was roughly similar to that of live scallops. No attempt was made to estimate mortality from counts of intact or fragmented valves since these may be advected from the study area by tidal currents, buried in the sediments, or recounted in successive samples. There was no mortality of scallops in pearl nets.

Scallop predators did not increase in abundance in the study area after seeding. The mean density of sea stars (*Asterias vulgaris, A. forbesii*) ranged from 3.2 to 4.8 individuals m/m^2 and the mean density of crabs (*Cancer irroratus, C. borealis*) ranged from 0.1 to 0.2 individuals m/m^2 during the study. Sea stars and crabs were dispersed throughout the study area and their distribution showed no relationship to the distribution of seeded scallops. Sea stars and crabs exhibited seasonal variation in foraging activity, which appeared to be mediated by temperature. The activity of these predators decreased as sea water temperature dropped below 5°C in December, and most were quiescent in January and February. Predatory activity increased again in late April and May as temperature rose above 5°C.

Scallop mortality rate was high in the first two tethering experiments, with only about 25 % of scallops surviving after 10 days (fig. 4). Mortality rate was much lower in the third experiment, with about 25 % of scallops surviving beyond 50 days. Again, mortality rate appeared to be related to sea water temperature, which ranged from 14 to 7 °C in the first experiment, from 7 to 5°C in the second, and from -1 to 5 °C in the third. Sea stars were the major cause of scallop mortality: intact valves ("clunkers"), indicative of sea star predation, accounted for 60 to 81 % of scallop losses in tethering experiments. Between 2 and 6 sea stars were observed feeding on tethered scallops during each experiment. In a few instances, a sea star was observed pursuing a tethered scallop which was attempting to escape by swimming. No other predators were observed feeding on tethered scallops, although ≈ 3 % of scallop losses were characterized by valve fragments indicative of crab predation.

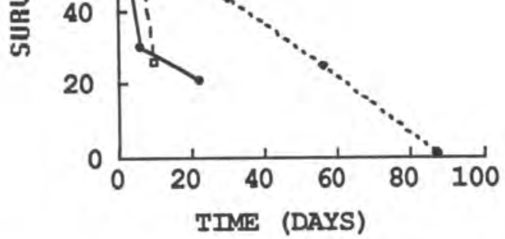

Figure 4. Percentage survival of 50-75 tethered juveniles of *Placopecten magellanicus* in three experiments : 1) 20 Oct. to 15 Nov. 1990; 2) 26 Nov. to 6 Dec. 1990 ; 3) 29 Jan. to 26 April 1991.

DISCUSSION

Within 16 days of seeding, the survival rate of juvenile *Placopecten magellanicus* stabilized at ≈ 30% of the number released. This is similar to survival rates of *Patinopectin yessoensis* (25 to 30 %) in commercial seeding operations in Japan (Ventilla, 1982), and higher than survival rates of *Pecten novaezelandiae* (generally < 5 %) in large-scale seeding trials in New Zealand (Bull, 1986). The density of seeded *P. magellanicus* was consistently highest around the release site, although the population gradually spread over an area exceeding 1200 m^2 during the 128 day study. Average density remained relatively constant after 16 days at ≈ 4 individuals m^{-2}. This was 4 times higher than the density of naturally occurring *P. magellanicus* in this area, and approximates the maximum density of this species on the major scallop fishing grounds on Georges Bank (Caddy, 1975).

The rapid decrease in scallop density in the release area was due largely to dispersal. Our laboratory observations indicate that juvenile scallops placed in dense aggregations in aquaria will disperse along the bottom by short bursts of clapping movements of their valves. Scallops also will undertake longer swimming excursions when approached by predatory sea stars. Swimming scallops may be advected by currents, which could account for the gradual spread of the seeded population in the direction of tidal currents through the channel. Thus, predator abundance and activity patterns may interact with the local hydrodynamic regime to determine the rate of dispersal of seeded scallops from a release site. In a similar experiment with *Patinopectin yessoensis* in the Sea of Japan, Volkov *et al.* (1983) also suggested that swimming activity induced by sea stars contributed to the rapid decline in the density of seeded juveniles.

Sea star predation appeared to be the major cause of mortality among seeded scallops, as indicated by the abundance of clunkers on the sea bed and in the tethering experiments. In laboratory experiments, *Asterias vulgaris* consumed about one juvenile *Placopecten magellanicus* per day (Barbeau, unpub. data). Rock crabs (*Cancer irroratus*) also have been shown to be important predators of juvenile scallops in laboratory studies, but crabs were much less abundant than sea stars in the study area. Mortality rates in the first two tethering experiments were similar to that estimated for recently seeded scallops around the same time (November/December). The markedly lower mortality rate in the third tethering experiment is consistent with the levelling off of the survivorship curve for seeded scallops in winter, and appears to be related to a decrease in sea water temperature. Although tethered scallops were observed attempting to escape from foraging sea stars by swimming, they probably were more vulnerable to predation than naturally occurring ones.

There was no numerical response of sea stars or crabs to the massive increase in juvenile scallop abundance after seeding, nor did these predators aggregate in areas of high scallop concentration. In contrast, Volkov *et al.* (1983) observed marked aggregation of sea stars at their scallop seeding sites within a few weeks.

The success of this seeding trial will depend largely on whether mortality rates of juvenile scallops increase substantially with increased predator activity as sea water temperature rises in summer and fall. Also, as swimming activity of scallops increases with temperature and predator activity, the seeded population may become increasingly more dispersed, resulting in much lower densities of scallops spread over a larger area. Since *Placopecten magellanicus* requires about three to four years to reach harvestable size (Caddy, 1975), the seeded population will need to be monitored for at least another two years before an assessment of yield can be made.

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THE RISE OF THE BAY SCALLOP CULTURE INDUSTRY IN CHINA

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Abstract : *the basic similarity in water temperature conditions of the coastal regions of the Yellow Sea and East China Sea with those of the central coastal regions of north America makes these regions amenable to the mariculture of the bay scallop* ***Argopecten irradians.*** *The successful results of many years combined indoor and field culture using temperature control in regulating the breeding period, substantiated the biological and economic feasibility of bay scallop mariculture in China. The rotative culture of the bay scallop and the kelp,* ***Laminaria japonica*** *and the mixed culture of the scallop and the shrimp,* ***Penaeus chinensis*** *have been proved to be economically feasible. Mariculture areas have been fully used for the production of the bay scallop, making China the number one bay scallop producing country in the world.*

Key words : *bay scallop, temperature control, biological feasibility, gonad maturation control,* ***Laminaria japonica*** *rotative culture, mixed culture,* ***Penaeus chinensis***

The bay scallop, as a fishery shellfish, is a wild species of bivalve mollusc distributed along the Atlantic coast of North America. It has a relatively short life span of 12-16 months. Only in very rare cases can it survive up to 24 months (Castagna, 1975). It exhibits great fluctuation in population abundance, so in commercial fishery for the species, there is the problem of unstable catch (Castagna and Duggan, 1971). However, it has good characteristics of growing fast and having a short life cycle which prompted us to consider its introduction to China with the hope that we can harvest it within a year, thus reducing production cost and increasing production efficiency. The culture of the local scallop, *Chlamys farreri* takes two years before a crop can be harvested.

There is a basic similarity in water temperature conditions of the coastal region of the Yellow Sea and east China sea with those of the central coastal region of northern America. For example, the coastal regions of Wachapreague in Virginia where the scallop thrives well, have water temperatures in the range of -1.1-29.8 °C (Castagna and Duggan, 1971). The coastal areas of Jiaozhou Bay in the Yellow Sea have water temperatures ranging from 1-27 °C. In the Luoyan Bay in the East China Sea coast, the range is 9-30 °C (Zhang et *al*, 1987).

The scallop has long been considered a gourmet seafood not only in China but also in the U.S. and other countries where it commands high prices (Castagna, 1971). So there is biological and economic feasibility in introducing this species into our waters. In December 1982, through the help of Prof. K. Chew, Dr. M. Castagna, and Dr. R. Mann, etc..., the scallop was first introduced into Qingdao, Shandong Province.

Figure 1. Seasonal variation of index of dried viscera (circle) of bay scallop in Jiiaozhau Bay, Shandong province

Figure 2. Nursery rearing of the bay scallop spats in shrimp pond

Basing our work on information contained in the many authors' works dealing with gonad maturation control, larval rearing, growth, mortality, depth distribution, etc... (Castagna Duggan, 1971; Castagna, 1975; Duggan, 1973; Loosanoff and Davis, 1963; Sastry, 1966; Wells, 1927), which laid the foundation for the development of technology for small scale rearing of scallops, we have now developed our own technology which is applicable to our specific culture conditions. We are finally able to establish a bay scallop mariculture industry characterized by completely artificial propagation.

The bay scallop exhibits two spawning periods during each calendar year. The first major spawn occurs in spring, beginning in mid-May and extending to mid-July, with a peak in June. The second minor spawn occurs in autumn, from September to October, with a peak in September (fig. 1). The fecundity of the autumn spawn is half that of the first spawn (Zhang, et *al*, 1991). During the low temperature period of winter, lasting for about 4 months, the scallops stop growing. Spat production for growing out is usually conducted in spring. After its introduction into China, if we produce the spats under natural water temperature, we have to begin egg collection and larval rearing at the end of May or at the beginning of June. It is mid or late June before spats can be moved out for rearing in the sea. Spats produced under natural water temperature conditions cannot grow into the ideal market size by the end of the year. As remedial measures, we resorted to controlled temperature rearing of the adult spawners. The indoor sea water temperature is gradually increased about one degree centigrade each day until it reaches 22-23 °C. There is simultaneous gradual addition of food algae (on an average of $1.2x10^9$ - $4.8x10^9$ cells/day for each scallop). Under such culture conditions, the gonads become matured in about 20 days, after which eggs and sperm are released. In about one day, fertilized eggs hatch into D larvae which have eye spot at about the 10th day. Spat collection then begins at about the 20th to the 25th day. When the shell height reaches 300-500 micra, the spats are ready to be transferred to the sea for nursery (sea water temperature is more or less 10 °C at this time). By early June, when the spats grow to an average shell height of about 5 mm, they are ready to be sold to farmers.

In order to start seed scallop production still earlier, since 1989, we have made use of shrimp ponds as nursery beds which have water temperatures about 5 °C higher than that in the sea (fig. 2). Thus parent scallops can begin to breed in March under controlled water temperature. In late April to early May, spats produced can be transferred to shrimp ponds and grown until early or mid-June when they can reach commercial spat size (with average shell height of 5 mm).

The significance of spat rearing under controlled temperature is that this can lengthen the growing out period of the scallop in the sea 1-2 months so that there is sufficient time for them to reach ideal commercial size at the end of the same year (fig. 3). After he feasibility of rearing spats under controlled water temperature on a productive scale has been established (Zhang, et *al*, 1991), we introduced it to the coastal regions of Shandong, as a result of which 4 $x10^8$ seed scallops were produced in 1985. In 1986, it was introduced into Liaoning, Hebei, and Zhejiang provinces. Pilot culture projects were then extended to Fujian, Guangdong, Jiangsu, and Hainan provinces. The bay scallop is latitudinally the most extensively cultured shallow sea bivalve mollusc in China (fig. 4).

Up to 1988, in Shandong, Liaoning, and Hebei province, 2 x 10^4 mu (15 mu = 1 ha) allocated for the culture of bay scallop were seeded with 2.5 x 10^9 to 3.0 x 10^9 seed scallops (with average shell height of 5 mm) as a result of which over 50.000 tons of live commercial bay scallops were harvested (fig. 5) putting China into the world's number one bay scallop producing country. Processed frozen scallop meat are mainly exported to the U.S. and Canada at about $2 per pound. Rotative Culture of the Bay Scallop and the Kelp *Laminaria japonica*

The kelp, a cold water seaweed, has been an important mariculture species in China since the 1960s. Its annual output is 20-25 thousand tons (1977-1986) (Tseng, 1988). The bay scallop, a warm water species, is fast growing and has short life cycle. Taking into consideration the contrasting temperature requirements of these two species and the existence of warm and cold seasons in a calendar year in our waters, the idea of rotative culture of these two species to make full use of culture equipments prompted us to initiate pilot culture projects. Both the bay scallop spats and the kelp seedlings were produced under temperature controlled indoor conditions and then raft-cultured for a shorter growing out period. After about 7-8 months, they were ready for harvest. The spat-rearing of the bay scallop begins in early spring under raised temperature control conditions. It grows out in the sea mainly during the high temperature periods of summer and autumn. The production of kelp seedling is done in summer under low temperature controlled conditions. They are put out for growing out in the sea during the low temperature periods of winter and spring. Results of many years of field experiments substantiated the feasibility of rotative culture of the bay scallop and the kelp. The two species can be rotatively cultured in the same culture area using the same culture rafts, thus resulting in much higher economic returns than just culturing one species(Zhang, et *al*, 1989). In recent years, there are more and more areas practising rotative culture of bay scallop and kelp.

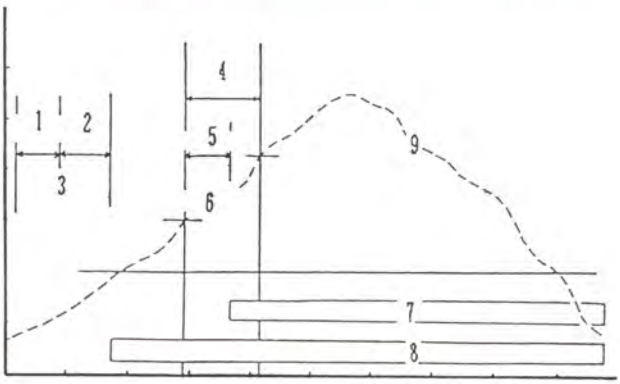

Figure 3. Comparison of growing duration of bay scallop in the sea between the spats reared in controlled temperature and that in natural temperature.

1 parent bay scallop rearing
2,5 egg-collecting and spat-rearing period
3 spat-rearing in controlled temperature
4 spring, reproductive period
6 spat-rearing in natural temperature
7 growing duration in the sea of spats reared in natural temperature
8 growing duration in the sea of spats reared in controlled temperature
9 water temperature

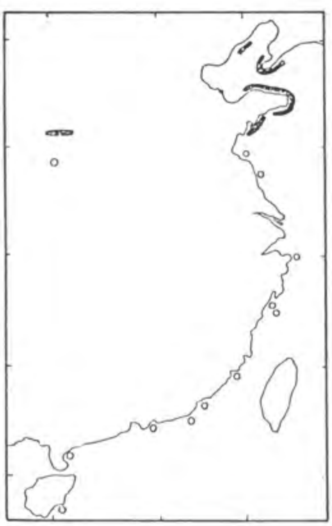

Figure 4. Culture area (black path) and experimental culture site (circle) of bay scallop along China coast

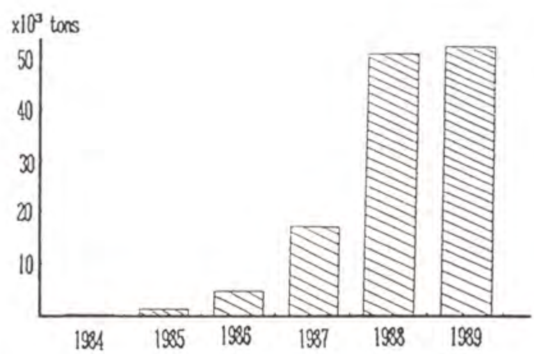

Figure 5. Annual production of bay scallop cultured in China

Mixed Culture of the Bay Scallop and the Shrimp, *Penaeus chinensis*

China is one of the main shrimp producing countries in the world, with annual output amounting to 1/3 of the total world output. The main culture species is *Penaeus chinensis* which grows well at water temperature of from 13-28 °C (optimum, 25 °C). The temperature suitable for reproduction is 14-18 °C. Larvae production usually begins in April and the post larvae are moved to shrimp ponds for growing ou at the end of April or the beginning of May. Shrimps are harvested from the beginning of October when the water temperature in the pond drops to 15-16 °C. The technique of mixed culture of bay scallop and shrimp has been developed since the successful culture of the bay scallop on the bottom of shrimp ponds. Ponds with sandy bottom and salinity higher than 18 %. are chosen and seed scallop density for the bay scallop was 10-15/m^2 pond bottom. The average output can reach 500-700 g/m^2 pond bottom when harvested during October to December of the same year. Scallops cultured in shrimp ponds are bigger and more fleshy especially at their meat part. The scallop can improve the water quality in the shrimp pond and to some extent increases the output of shrimps. The mixed culture of bay scallop and shrimps are now being introduced and intensively practised and developed in the coastal regions of northern China and is taken as a successful model of mixed culture.

That the bay scallop is an excellent culture species has been proved by years of its successful culture in many parts of China. Because of its eurythermal nature, there may be bright prospects for its introduction and culture in the coastal regions of South America, western Europe, Africa, and Australia.

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CHAPTER 3.

REPRODUCTION

REPRODUCTION

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SCALLOP SPAT COLLECTION AND ONGROWING TRIALS IN SOUTH-WEST IRELAND

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Abstract : *Twelve sites were chosen around Whiddy Island in Bantry Bay to study scallop spat collection. These sites were close to, or on, commercially dredged scallop beds. Only four of the studied sites yielded promising results. These were North-East Gearanes, South Gearanes, Whiddy Point East and Trawclona.*
The maximum number of scallops ***Pecten maximus*** *collected in a bag was 60, at the North-East Gearanes. This site consistently collected two to three times more scallops than the other sites. The date of the peak settlement of scallops (**P. maximus**) varied slightly from site to site but generally took place from 15th June to the 18th July 1990. The scallops also settled best in a zone between two and eight metres above the sea-bed. Ongrowing trials with 40mm* ***P. maximus*** *spat showed no significant difference in growth between Walford lantern nets and ear-hanging. However heavy fouling by the tube worm* ***Pomatoceros triqueter*** *caused a 65 % mortality of ear-hung scallops.*

Key Words : *scallop, spat, artificial collectors, ear-hanging, Walford lanterns.*

INTRODUCTION

In order to have a stable scallop culturing industry, Ireland needs a predictable source of seed and a reliable ongrowing method. There are three ways to obtain scallop spat for ongrowing: hatchery, collection of wild juveniles and settlement on artificial collectors. Because of biological and economic constraints on hatcheries and legal prohibition on removing sub-market size (< 100mm) scallops by dredging or diving, the artificial collector is still a viable alternative in Ireland. Mulroy Bay in Co. Donegal has been shown to have a very predictable but variable settlement (Minchin *et al.*, 1987) and in addition there are other bays such as Kilkieran Bay in Co. Galway (Wilson, 1987) and Bantry Bay in Co. Cork (Minchin, in prep.) which have also recorded some settlement.
In 1990 a study on the potential of Bantry Bay, Co. Cork for scallop culture was initiated by the Bantry Bay Fish Farming Cooperative with technical and financial assistance from Bord Iascaigh Mhara (The Irish Sea Fisheries Board). This took the form of an extensive scallop collector programme to establish the best sites for settlement and comparative ongrowing trials at several sites. This paper considers part of that trial at four sites.
Bantry Bay is located in the south west corner of Ireland (fig. 1). Its entrance lies at the south western end and has direct exposure to the north eastern Atlantic. The Bay is 34 km long and its width varies from 8 km at the entrance to about 5 km at the head of the Bay. Water depths vary between 50-60 m at the entrance and gradually decrease to between 30-25 m north of Whiddy Island. Between Whiddy Island and Bantry town, a large sheltered harbour is formed where depths are generally 6-8 m.

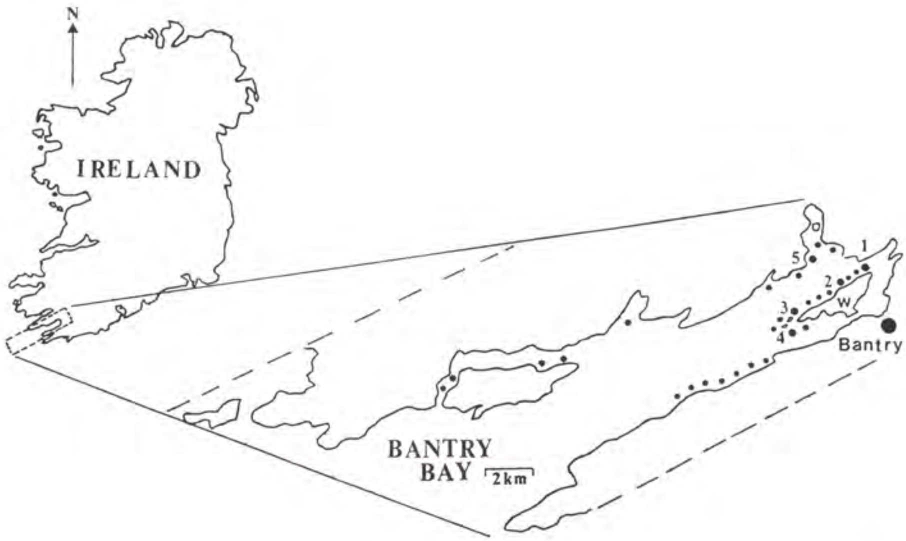

Figure 1. Map of Bantry Bay, S.W. Ireland, showing the spat collection sites (1 = Whiddy Point East , 2 = Trawclona, 3 = North East Gearanes, 4 = South Gearanes) and the ongrowing site (5 = Four Heads). Also marked are Whiddy Island (W) and the major scallop (*P. maximus*) dredging areas (*).

MATERIALS AND METHODS

Collector Programme. The collector bags were set at a number of sites around Whiddy Island (fig. 1). Each collector line consisted of a concrete block anchor with collectors spaced at 1 metre intervals from the sea bed, terminating in a sub-surface buoy which was always submerged. A surface marker buoy was then attached for location and identification. The collector bag unit consisted of a heavy duty monofilament mussel bag (600 x 425 mm: Cean Mara Plastics, Kenmare, Co. Kerry) with a 3 x 3 mm lockstitched mesh, filled with 0.5 m^2 of 5 x 5 mm blue mesh filler (as used by Deegagh Point Shellfish, Co. Donegal). Each week from 15/6/90 to 24/8/90, a collector line was placed at each of twelve sites around Whiddy Island. However for a variety of reasons only four areas gave a relatively complete data set. These were : 1. Whiddy Point East, 2. Trawclona, 3. North East Geranes and 4. South Geranes (fig. 1). The collectors were left *in situ* until the beginning of October 1990, when they were moved to the relative shelter and safety of Trawclona (Site 2) away from active dredging areas.
Ongrowing Trials for *P. maximus*. Scallop seed (shell height 20.26, S.D.= 4.60 mm, n=213) was purchased from Deegagh Point Shellfish, Mulroy Bay, Co. Donegal in May 1990. They were used in a comparative growth trial at Four Heads (fig. 1, site 5). In this experiment ear-hanging was compared with the "Walford lantern net" as a method for ongrowing. The spat were initially held in Walford lantern nets which consist of 700mm diameter plastic discs set at intervals of 350 mm in a cylindrical sleeve of heavy duty monofilament mesh (10x10 mm). In August, 560 spat which had reached 40 mm were selected for the comparative growth trial. Those chosen for ear-hanging were drilled with a standard 1mm bit set on a stand. They were attached singly about 150-200 mm apart, onto 12 mm polyproplene rope using plastic coated wire. The lines were attached to a sub-surface longline from 4 m below surface down to 20 m below the surface. The spat ongrown in Walford lantern nets were stocked at a density of 40 per

disc (10 discs per net.) and suspended at a depth of 5 m below the surface on the sub-surface longline. The trial lasted from the beginning of August 1990 to end of April 1991.

RESULTS

Spat Settlement. Only four sites collected significant quantities of scallop spat and had reasonably complete data sets. These were : North East Gearanes, South Gearanes, Whiddy Point East (missing data for 10th and 24th August) and Trawclona (missing data for 24th June). All sites collected two species of scallop, *P. maximus* and *Chlamys opercularis*. The performance of the collectors at each of these sites is summarised in table 1 and figure 2. At most sites there were two peaks of *P. maximus* settlement, one on collectors set on 15th /29th June and the other around the 18th July. Similarly there was an early settlement of *C. opercularis* (15th and 29th June) with a second settlement in August (10th and 24th). Generally speaking the best *P. maximus* settlement was in midwater, whereas *C. opercularis* was found in higher concentrations towards the sea bed.

Table 1. Sites, dates and depths (off sea bed) of peak settlement for (A) *Pecten maximus* and (B) *Chlamys opercularis* in Bantry Bay in 1990.

A	N.E Gearanes	South Gearanes	Whiddy Point East	Trawclona
Peak settlement (max. no./bag)	18 July 60	29 June 24	29 June 36	15 June 9
2nd highest settlement (max. no./bag)	15 June 30	18 July 19	18 July 15	18/07-10//08 10
Depth (m) of best settlement (> 20/bag)	2 - 7	4 - 7	3 - 9	
B				
Peak settlement (max. no./bag)	15 June 62	24 August 48	29 June 29	10 August 45
2nd highest settlement (max. no./bag)	24 August 30	29 June 15	15 June 12	24 August 30
Depth (m) of best settlement (>20/bag)	1 - 6	1 - 5	7	2 - 5

Ongrowing Trials. There was no significant difference in growth rate (Students t-test, $P < 0.05$) between the ear hung and lantern net spat (table 2). However survival was twice as high in the lantern nets. Only ear-hung scallops on the last 3 m of rope survived an overwhelming settlement of the tube worm, *Pomatoceros triqueter*.

Table 2. The final mean shell height (mm) and cummulative mortality of *P. maximus* ongrown in suspended culture at Four Heads, Bantry Bay (Site 5).

Method of culture	Cummulative mortality (%)	Shell height (mm)	Standard deviation	Sample number
Earhanging	65	57.94	6.05	32
Walford lantern	29	55.08	9.95	209

DISCUSSION

Collector Programme. The results from the twelve collector stations were severely affected by dredging activity around the Gearanes (fig. 1, sites 3 and 4) at the west end of Whiddy and by boat traffic around the south west corner of Whiddy Island. Altogether five stations were lost because of interference with collectors. The best site for *P. maximus* settlement was North East Gearanes (fig. 2) and the highest settlement of 50-60 *P. maximus* per bag on collectors deployed on July 18th, is approaching levels considered economic in Mulroy Bay, Co. Donegal (Slater, pers. comm.) and in Scotland (Walford, pers comm.). The Queenie (*C. opercularis*) settlement was also highest at North East and South Gearanes with levels of 50 per bag on collectors set on August 24th 1990. A similar settlement pattern had been noted by Paul (1981) for *C. opercularis* around the Isle of Man (U.K.) where there was a minor summer spawning (June-July) and a more intensive autumn spawning (September-October). Settlement for both species was greatest in midwater, a phenomenon which has been noted by various authors (Ventilla, 1977, Brand *et al*., 1980) and may reflect the cleaner surface available away from bottom sediments and surface fouling organisms. However there is some evidence, for Australian pectinids, that it may also arise from an uneven distribution of larvae (Young, pers comm.).
If a commercial collection develops for either species this separation in time of peak settlements could be very useful in maximising their respective collection. Local scallop (*P. maximus*) fishermen reported a sudden loss of gonad weight in the first week of April 1990 which resulted in their catch being rejected by the markets. If one allows a 30-40 day larval period at spring water temperatures then the start of the collector programmes (June 15th) was probably too late to catch the resulting settlement. The 1991 programme will be ready to start much earlier should spawning occur at the same time again. Whether the settlement of either species will ever be predictable by monitoring gonad condition or larval concentrations is uncertain as Brand *et al*. (1980) have shown that the intensity of spawning for both species does not necessarily correlate with settlement intensity in a particular area.

The most important features for optimising scallop spat collection have been summarised by Tremblay (1987) and are : (1) site selection, (2) timing of deployment and (3) depth of the collector units. Good sites tend to be small bays containing scallop beds with narrow sill entrances but with adequate inflow. Also if a "gyre" exists the larvae may be retained leading to higher settlement rates. The best settlement tends to be midwater and, for *Pecten maximus*, the immersion or soaking period prior to settlement should certainly not exceed one month (Wilson, 1987). There are a number of small but "healthy" scallop beds in Bantry Bay (fig. 1) which could be managed and act as a broodstock for the Bay. In addition a very detailed hydrographic study of Bantry Bay (Barry, 1988) has identified a number of wind-driven, anti-clockwise gyres including one around the western end of Whiddy Island. This bodes well for developing commercial scallop spat collection in the Bay. There is however a large long-line mussel cultivation industry (circa 2,000 tonnes per annum) already operating in the Bay and the competition for space, and primary productivity may well be a problem in the future. Other biological considerations include the difficulty of identifying scallop larvae due to the preponderance of mussel (*Mytilus edulis*) larvae in the plankton and also the problem of mussel settlement fouling scallop ongrowing structures.

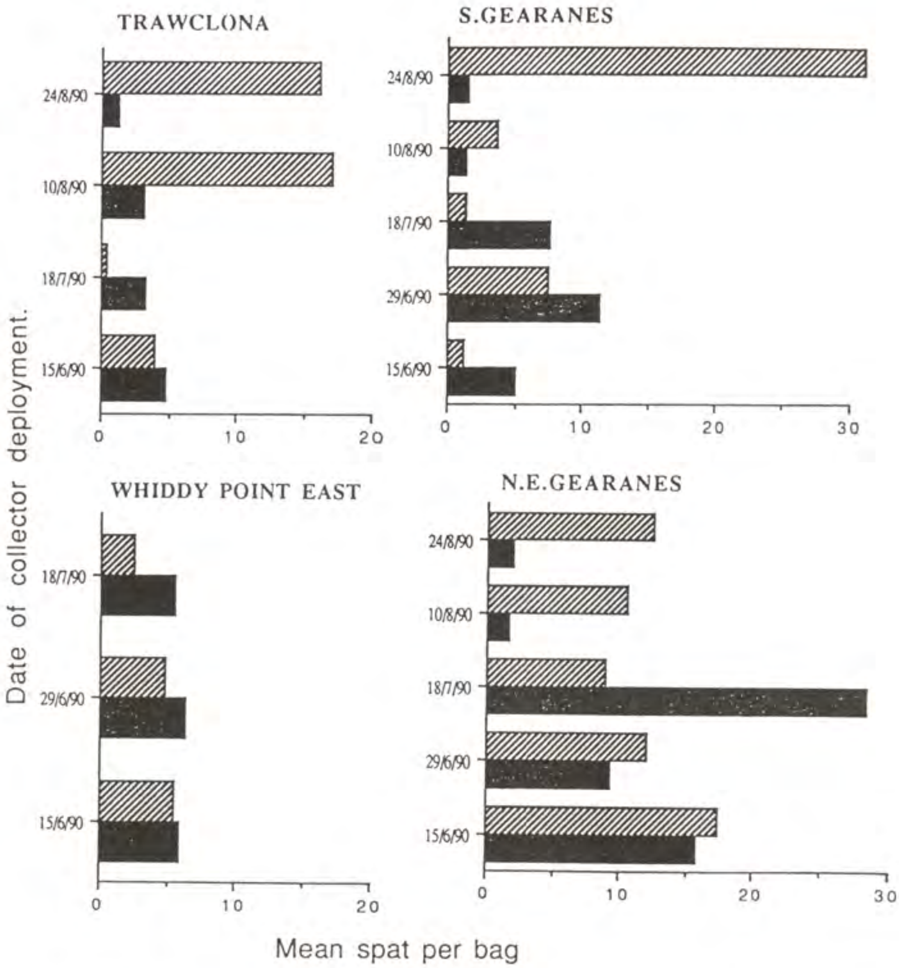

Figure 2. Mean number of *Pecten maximus* (black) and *Chlamys opercularis* (cross hatched) spat settled per collector bag in Bantry Bay.

Ongrowing Trials. A major problem with ear-hanging in Bantry Bay would appear to be fouling by the tube worm, *P. triqueter*. The experience of mussel farmers would suggest that most inner areas of the bay would be subject to this type of fouling. The Walford lantern nets gave better survival but it was very difficult to maintain the disc insets in a horizontal position. If the discs were sloped, scallops became bunched to one side resulting in mortality from the inter-locking of shells.

The growth rate for both ongrowing methods was encouraging with an increase from 40-60 mm in 8 months. In Scottish earhanging trials it took scallops 14 months to grow the same amount (Paul, 1988). There is no doubt that given the right kind of equipment ear-hanging of *P. maximus* gives good growth and survival (Paul, 1988). However it is difficult to see how any midwater, suspended culture can succeed in Bantry Bay. There are limited options for "ranching" on the sea bed at sites like Trawclona (fig. 1) but the best scenario would appear to be the use of rigid, stand-on-seabed containers like the French "Conteneur M1 120" currently being tested in the Bay.

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INTERANNUAL VARIATIONS OF THE BIANNUAL SPAWNING EVENT OF THE SEA SCALLOP, *Placopecten magellanicus* IN THE MID-ATLANTIC REGION

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***Abstract** : Interannual variations of the biannual spawning event of the sea scallop, **Placopecten magellanicus**, in the mid-Atlantic region were documented using gonad weights for the period April 1987 through April 1991. The spring spawning event was the most dominant and consistent feature of the annual gametogenic cycle. Fall spawning events were irregular in magnitude; in addition, data analysis indicated a failure of the gametogenic cycle in the fall of 1989. Gonadal weights provide a relatively accurate indication of trends in the gametogenic cycle.*
***Key Words** : Giant sea scallop, gonadal cycle, interannual variation, biannual spawning.*

INTRODUCTION

The gametogenic cycle of the giant sea scallop, *PlacoPecten maaellanicus* has been the focus of several recent studies relative to biannual spawning (Dupaul *et al*. 1989, Schmitzer *et al*. 1991), bioenergetics (MacDonald and Thompson 1986, Barber *et al*. 1988) and latitudinal variation (MacDonald and Thompson 1988). A causal relationship between the sea scallop reproductive cycle and various environmental parameters, including the physiological condition of the animal, has been difficult to establish. Naidu (1970) rightfully concluded that the strength and duration of the spawning event varies within a breeding season and from year-to-year.
The mid-Atlantic region (fig. l) is a major resource area for sea scallops with landings averaging 14,183 mt over the past five years. The mid-Atlantic fishery is characterized by large cyclic changes in commercial landings; however, consistently strong year class recruitment has been documented since 1985 (Northeast Fisheries Center, NMFS, 1990). The identification of a biannual gametogenic cycle for sea scallops in the mid-Atlantic region (Dupaul *et al.* 1989, Schmitzer *et al.* 1991) raises several important questions. Foremost is the uncertainty that biannual spawning is a consistent feature within the mid-Atlantic. In addition, it is unknown whether or not recruitment is primarily associated with the spring or fall spawn.
The present paper documents the gonadal cycle of sea scallops in the mid-Atlantic region from 1987 through 1990 and quantifies the relative strength of the spring and fall spawning events during this period.

MATERIALS AND METHODS

Whole unshucked sea scallops were obtained from commercial fishing vessels operating in the mid-Atlantic region. Each sample consisted of approximately one bushel of scallops from which 100 individuals were randomly selected for shell-height measurements and gonad weight determination. The net weights of the gonad were measured to the nearest 0.1 g and the maximum distance between the dorsal and ventral margins (shell height) was measured to the nearest millimeter.

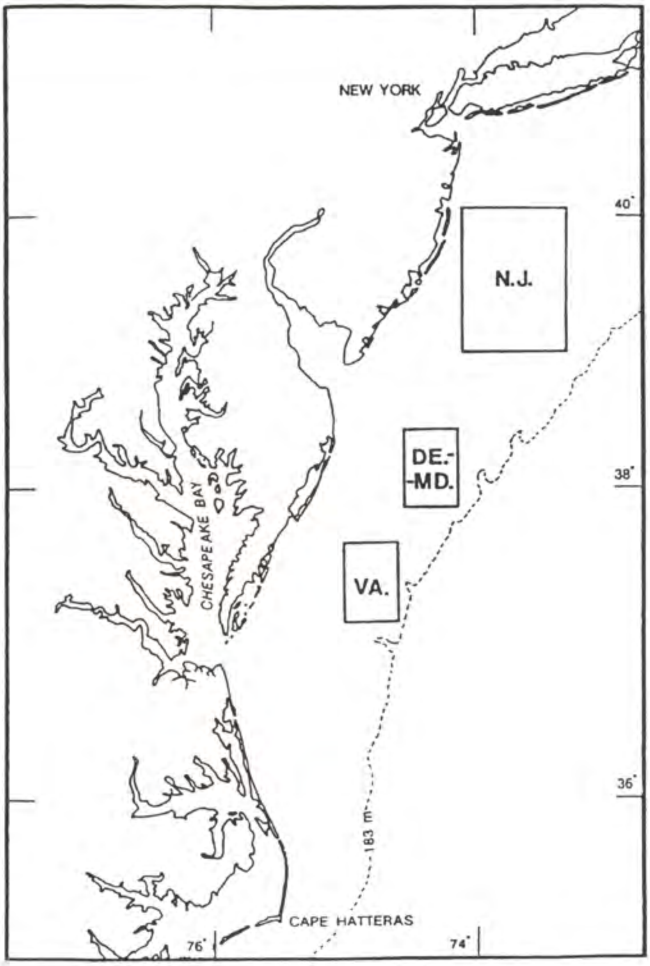

Figure 1. Mid-Atlantic region

Sample collections covered the period from April 1987 through December 1990. Sample locations ranged from south of Long Island (40° 00'N-73° 00'W) to north of Cape Hatteras (37° 30'N-74° 30'W). The coordinates incorporate a rectangular area of approximately 28,000 km^2 with water depths of 40-74 m. Each sample was processed within 48 hours of collection and correlary data relating to date and time of collection, Loran C coordinates, surface water temperature (°C) and water depth were recorded.
For the present study, data from 449 samples consisting of 42,809 scallops were segregated according to shell height groupings of 85-89 mm (N=5698), 90-94 mm (N=6145) and 100-104 mm (N=4463) and 110-114 mm (N=3045). Data for both sexes and all areas were combined to calculate monthly mean gonad weights for each shell size interval. Long-term or year-to-year differences of the mean gonad weights associated with specific seasonal spawning events were examined by one-way analysis of variance (ANOVA).

RESULTS

Patterns of average monthly gonad weights for the selected shell height intervals from 1987 to 1991 indicate regularly occurring cycles of gonadal development and spawning in the spring of each year (Figure 2). Gonad weights for all shell sizes are maximal from February through April and followed by a rapid decline associated with the spawning event. Cumulative average gonad weights for the four shell size groups (during the spring spawning event) were highest in 1987 (44.60 g) and 1990 (43.23 g) compared to 1988 (32.95 g), 1989 (36.03 g) and 1991 (33.93 g). Maximum gonad weights in the fall were highest for 1987 and 1990 with cumulative averages of 30.43 g and 26.38 g respectively. During the fall of 1988 and 1989, however, maximum values were lower with 18.97 g and 15.36 g, respectively.

Table 1. Maximum and Minimum Seasonal Gonad Weights (g) 100-104mm Shell Height 1987-1990

	N	$x \pm a$	$N > x$	%
1987				
Spring Max	6	12.05 ± 2.87	3	50.00
Summer Min	40	4.00 ± 0.99	23	57.50
Fall Max	45	8.07 ± 3.86	24	53.33
1988				
Spring Max	128	9.37 ± 3.37	63	49.22
Summer Min	290	3.45 ± 1.73	116	40.00
Fall Max	104	6.21 ± 3.78	40	38.46
1989				
Spring Max	100	10.57 ± 3.35	51	51.00
Summer Min	99	4.17 ± 2.26	38	38.38
Fall Max	94	3.02 ± 1.69	33	35.11
1990				
Spring Max	108	13.00 ± 3.63	51	47.22
Summer Min	83	2.72 ± 1.21	33	39.76
Fall Max	52	7.70 ± 2.59	26	50.00

Maximum and minimal gonad weights for the 100-104 mm shell height grouping for the 1987-90 time period are presented in Table 1 and Figure 3. Mean spring maximum values ranged from 9.37 to 13.00 g with 1990 values statistically different than values from 1988 and 1989. Mean fall maximum values ranged from 8.07 to 3.02 g with values for 1989 statistically different than those for 1987, 1988 and 1990. For both spring and fall, values for 1987 and 1990 were statistically the same. Mean gonad weights for fall 1989 were similar to values noted for the summer minimum of each year.

DISCUSSION

The biannual gametogenic cycle for *Placopecten magellanicus* in the mid-Atlantic region reported by Dupaul *et al*. (1989) and Schmitzer *et al*. (1991) is relatively stable with the spring cycle being the dominant event. The single discrete reproductive cycle in the fall described by MacDonald and Thompson (1988), Posgay and Norman (1958) and others does not characterize the mid-Atlantic resource area. Current data suggest that the fall reproductive cycle is erratic in the mid-Atlantic.

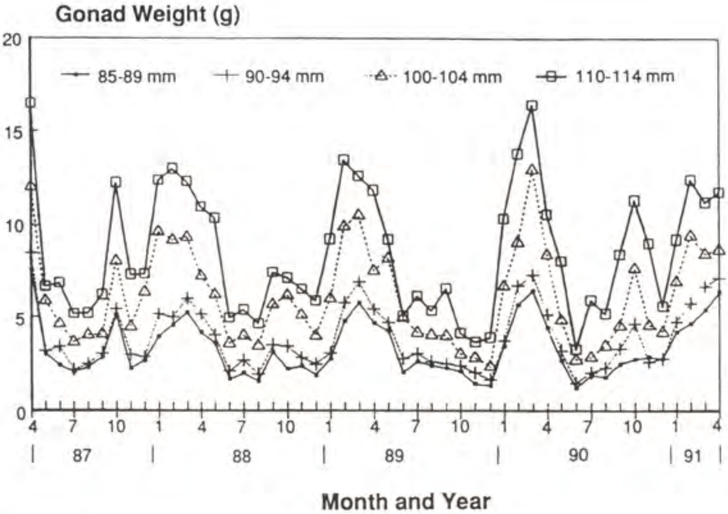

Figure 2. Gonad weight of sea scallops in the mid-Atlantic resource area, April 87-April 91.

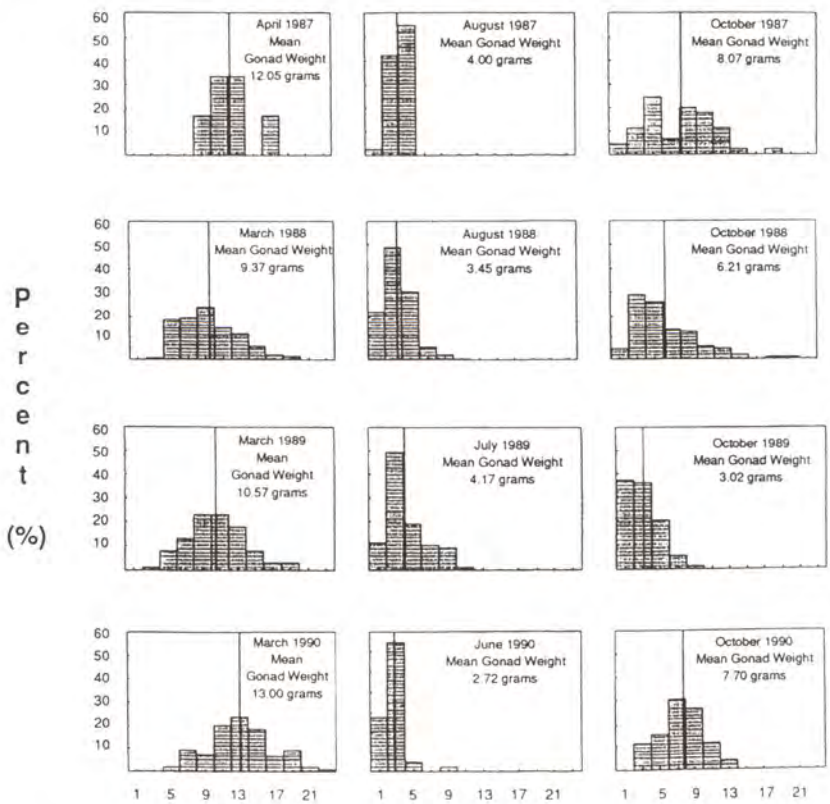

Figure 3. Percent distribution of seasonal maximum and minimum gonad weight, during annual gametogenic cycle, 1987-1990, 100-104 mm shell height.

Mean gonad weights for the fall of 1989 are comparable with values for June, July and August, which are associated with a reproductive condition described as spent or spent and recovering (Schmitzer *et al.* 1991). Data analysis indicates relatively little gonal development occurred during the fall of 1989. Correlation of gonad weights with histologically verified changes in gametogenic cycle was documented by Schmitzer *et al.* (1991), Barber *et al.* (1988), Langton *et al.* (1987) and Thompson (1977). We therefore feel confident that the cycles of gonadal development documented here are indicative of periods gametogenesis and spawning.

In the present case, the use of gross changes in gonad weights over an extended period of time and over a large resource area involving numerous samples is an effective and inexpensive monitoring tool to document trends in gametogenic cycles and potential reproductive success. The method has verified a consistently strong spawning event in the spring preceded by an extensive process of gonadal maturation. Approximately 50 % of the individual gonad weights exceeded mean values during the spring cycle for all years. In contrast, approximately 35-40 % of the individual gonad weights exceed mean values in the fall of 1988 and 1989 when weaker spawning events occurred. Although 1988 values for the 100-104 mm size group were not statistically different from 1987 and 1990, the fall gonadal cycle was characterized by a significantly lower average total for all shell sizes (18.97 g vs. 30.82 g in 1987 and 26.38 g in 1990). Consequently, in two of the four years included in this study, the fall spawning event can be considered as minor or a failure. The relationship of gametogenic cycles to recruitment in the mid-Atlantic region has not been established. Considerable speculation exists as to the importance of the spring spawning event relative to the continued year class success documented by the Northeast Fisheries Center, NMFS (1990).

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REPRODUCTIVE CYCLE OF *Argopecten circularis* IN MAGDALENA BAY, B.C.S., MEXICO.

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Abstract : *Histological and gravimetric gonad indices were used to assess the gametogenic cycle of* ***Argopecten circularis*** *(Sowerby, 1835) in Magdalena Bay, B.C.S.; this natural population was sampled monthly beginning in February 1989 and finally in October 1990. The catarina scallop is hermaphrodite with well differentiated male and female gonadal areas. It reproduces all year round, but two major spawning periods occurred; one in spring and one in summer, during March-April when the bottom water temperature reaches 15.0°C-17.5°C; the secondary spawning takes place in July-August. Larval settlement was detected in the bay following in the summer spawning in September 1989 and in the spring spawning in May 1990. This paper presents the preliminary results on the study of the seasonal behaviour of gonadal development.*

Key Words : ***Argopecten circularis***, *Eastern Central Pacific, Mexico, reproduction, adults, gonadal index, temperature.*

INTRODUCTION

The observations of gonads of the Catarina Scallop, *Argopecten circularis* (Sowerby, 1835), presented in this article describe the gonadal changes that occur at certain seasons of the year in the scallop population of Magdalena Bay, B.C.S. Catarina Scallop is a functional hermaphroditic organism and generally protandrous and with two spawning periods during the year. Little information is available on the spawning period, gametogenesis and gonadal index of the Magdalena Bay Catarina Scallop. It is difficult to obtain biological material from this location, because the commercial exploitation has been very irregular in the last 20 years. In the last two years the commercial landings produced 50.000 t of whole scallop. Which makes it imperative that government officials take steps in the light of these data in order to produce an adequate ruling that will eventually prevent this fishery form collapse.

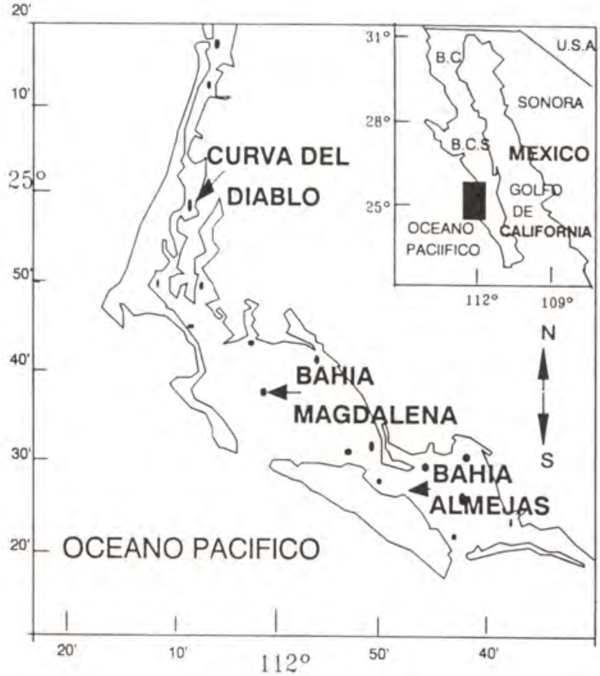

Figure 1. Location of the principal scallop grounds in Magdalena Bay, B.C.S., Mexico.

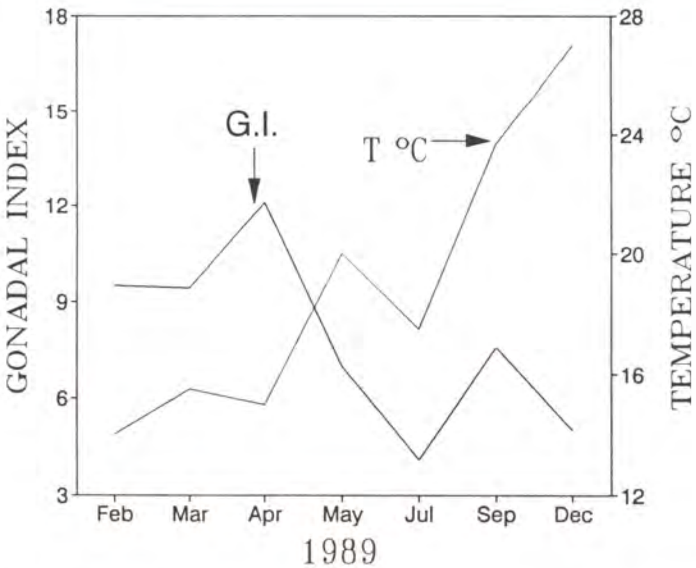

Figure 2. Seasonal variations of gonadal index of *Argopecten circularis* and relationship with the bottom water temperature from the central area of Magdalena Bay, during February-December 1989.

MATERIALS AND METHODS

The bulk of material used in these studies was collected from the scallop beds in the central area of Magdalena Bay (fig. 1). These beds were located at different depths ranging from 8 to 20 m. Samples were collected over a period of two years at monthly intervals. In all cases the scallops comprising the samples ranged from 8 months to one year old.
Soon after the collection of samples, the scallops were opened and pieces of the gonadal tissue were placed in 10% formalin solution, and later prepared for histological examination with the hematoxylin-eosin technic (Humason, 1979).

RESULTS

Gonadal index.

The analysis of the gonadal index (G.I.) shows significant differences along the year (see fig. 2) ; during the month of February, the gonadal index increased from 9.5 to a maximum value of 12.1 in April, to decrease to a minimum of 4.1 in July, and continued ascending to 7.5 in September, and stabilized between medium values until the end of the year. In the following year, the G.I. showed a similar pattern. Figure 3 shows the gonadal index during 1990. High values at the beginning (March-April) and an increment during July; after that, a constant decline toward the end of October was observed.
Bottom water temperatures of Bay Magdalena (the zone of Catarina Scallop concentrations) were obtained; the records (fig. 2 and 3) suggest that during the major gonadal index season, February to may 1990, bottom water temperature at depths from 8 to 20 m ranged from 15.0°C to 18.0°C. The maximum values of temperature show concomitant low values of gonadal index and vice versa.

Ovarian developmental stages.

The developmental stages of Catarina scallop ovaries from the Magdalena Bay grounds were distinguished primarily by colour from February 1989 to October 1990. The spawning period was indicated by the occurrence of ripe (March-May) and partially spent (June-July) ovaries. The ripe gonad is the largest, brightly coloured ovary usually vermilion; the testis is cream coloured. The spent gonadal stage may be partial or complete ; it shows a flabby appearance of dull orange and the testis is yellowish white.
The histological observations were made during March to October 1990. The adult ovary shows gametogenic (stage II) cells strongly defined, and, was found to occur in most individuals. The principal spawning (stage IV) of the adult scallops was found to occur in April and May.
The first recognizable stage in recovery was stage II; gametogenesis continued throughout the summer months, and predominating in June and August (fig. 4), so that by July most adult scallops had attained again full gonadal development (Mature, stage III).
The spring spawning (stage IV) was followed at once by recovery, and, consequently resulted in partially spent gonads (stage V). A few adult scallops spawned in August (the summer spawning period) and the stage V was still evident in October.

Spat abundance.

Catarina Scallop spat were monitored in Magdalena Bay by means of onions bags based on seasonal abundance of spat from July 1989 to October 1990. This resulted in a high spawning intensity in May 1990, and lower spawning intensity continued through August and September 1989 and 1990.

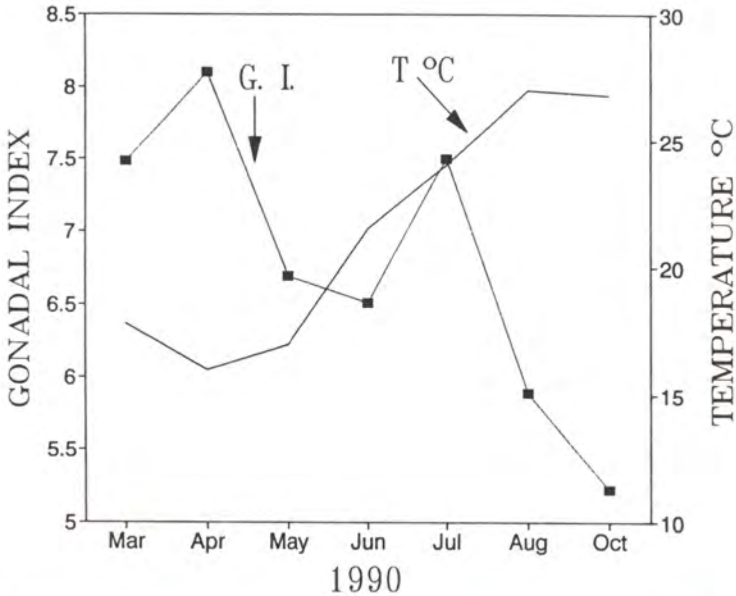

Figure 3. Seasonal variations of gonadal index of *Argopecten circularis* and relationship with the bottom water temperature from the central area of Magdalena Bay, during March-October 1990.

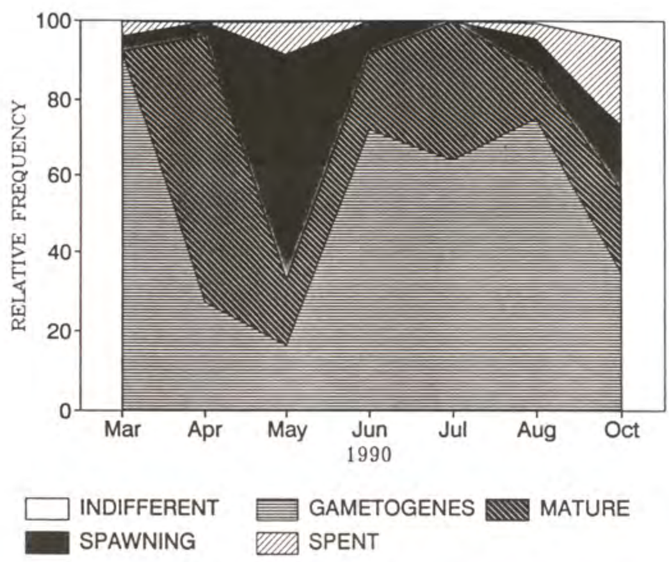

Figure 4. Reproductive cycle of *Argopecten circularis* from Magdalena Bay grounds, during March-October 1990.

DISCUSSION

The majority of adult scallops spawn together twice during each annual breeding cycle: completely in April-May (spring spawning) and partially in August-September (summer spawning).

Spawning intensity in 1989 and 1990 can be correlated with bottom water temperatures. High Spawning intensity occurred from April to May when temperatures were below 15.0 °C. From July to August, the temperature records increased from 21° to 25 °C (fig. 2 and 3). During this period the Catarina Scallops apparently spawned as indicated by the repeated high percentage of ripe scallop ovaries. According to Broom (1976) and Miller *et al*. (1981), the spawning season of the Calico scallop (parallel species) also occurred from early December to May and a minor spawning period was detected in August to December. The effect of the temperature has been correlated with ripening of other pectinid species and found a similar pattern Lubet (1981) and Mason (1983).

Tripp-Quezada (1985) found a main spawning period in spring and summer in the scallop of La Curva del Diablo areas (fig. 1). Baqueiro-Cárdenas *et al.* (1981) and Cáceres-Martínez *et al.*, (1990) found a main spawning period in spring in the Ensenada de La Paz. The colour of the ovaries was used to determine the degree of maturation and the gonadal index by wet weight.

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REPRODUCTION OF PECTEN MAXIMUS FROM DIFFERENT FISHERIES AREAS : RADE DE BREST, BAIE DE SAINT-BRIEUC, BAIE DE SEINE

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Abstract : *The baie de Seine, the baie de Saint-Brieuc and the rade de Brest are the three main fisheries in France. Measurements made on spawners issues from these areas allow now to consider two separate reproductive strategies, in these populations. Scallops from the baie de Saint-Brieuc spawn during a short period (july-august), a sexual rest stage being observed in autumn and winter and recovery occurring in spring. This seasonal recruitment is strongly dependant of external factors and remains aleatory.*

Populations from the rade de Brest and from the baie de Seine show similar reproductive cycle with a permanent annual sexual activity spawning being scattered from early spring to autumn. This reproductive strategy, more opportunistic and flexible could explain that recruitment in these fisheries are better than in the Baie of Saint-Brieuc.

The origin of such differences is discussed, on the basis of transplantation experiments and genetic investigations.

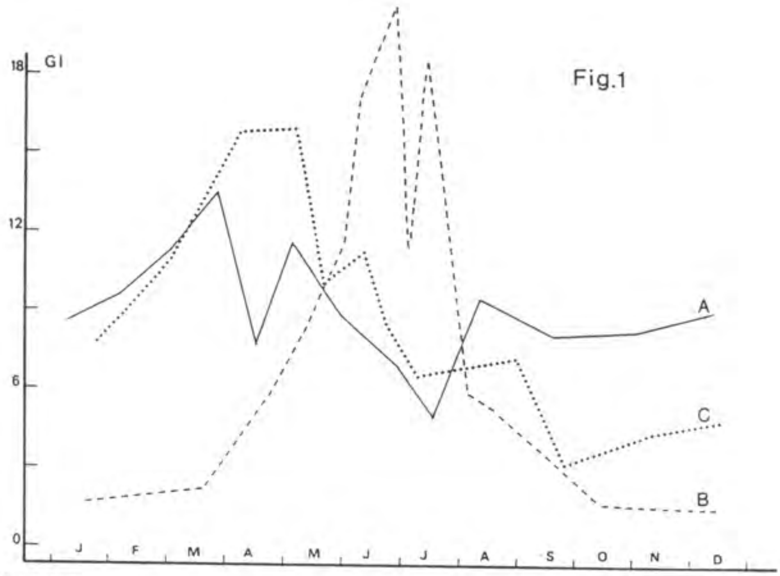
In all populations, the variations of the muscle and gonad index are opposite, the muscle acting as a storage organ releasing metabolites to cover the energy requirements for growth and reproduction. The contribution of the muscle glycogen content is discussed.

Keywords : *Pectinids, Scallops, Reproduction.*

The aim of this work is to compare the reproductive strategies of scallop populations from the three main fisheries in France : rade de Brest, (Atlantic), baie de Saint-Brieuc et baie de Seine (Channel), in order to explain the differences in recruitment. This knowledge is important for managing the different stocks and establishing the legal ryles of exploitation.

MATERIAL AND METHODS

All these populations growth is shallow waters (10-35 m depth), the annual range of temperature and salinities being nearly similar for the three areas. Monthly samples have been dredged (and weekly during the period of reproduction) from october 1985 to june 1989 (baie de Seine), november 1984 to december 1987 (baie de Saint-Brieuc) and april 1989 to may 1991 (rade de Brest).



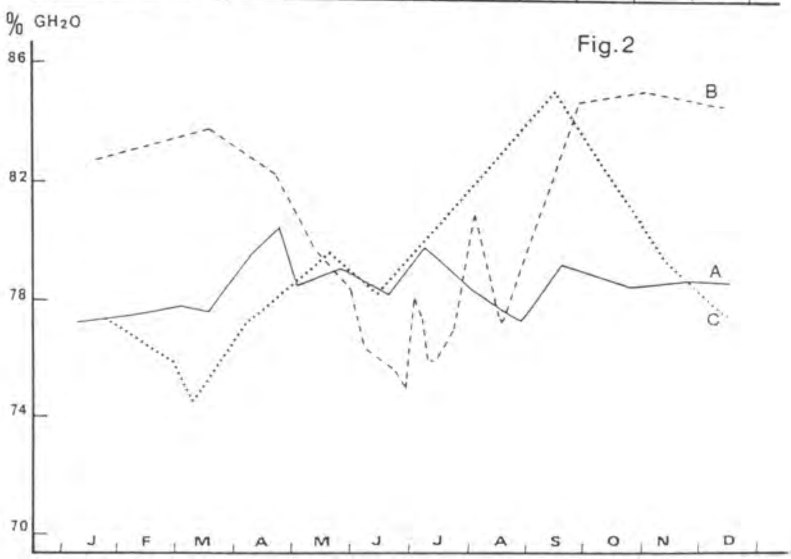


Figure 1. Annual variations of the gonad index (GI)

Figure 2. Annual variations of the gonad water content (% of the dry weight)
-A : rade de Brest, -B : baie de Saint-Brieuc, -C : baie de Seine

Animals of the 3 age group (3 winter rings) were selected for examinations. The sizes attained by the animals from the baie of Seine (10-11 cm height) are greater than those from other areas. For each measurement, 10 scallops or more have been studied (baie de Seine), 20 (rade de Brest) and 30 (baie de Saint-Brieuc).
The shells are measured (height from the umbo to the ventral area). After opening and dissection it has been calculated the following indexes.

- *Gonad index :* gonad wet weight x 100/height 3
The interindividual variancy at the same time of this index gives a good estimation of the synchronism or asynchronism of the sexual stages especially for spawning in each fisherie.
- *Muscle index :* muscle wet weight x 100/Height 3
The muscle or gonad water content has been calculated after drying (48-96 h at 100 °C), the glycogen content estimated by the method of Gilbert and Bourdon (1968). The results are expressed as a percentage of the dry weight of the organ. For each parameter, the graphs are established as means of the results during the studied period because the variations in each fisheries are nearly similar from one year to another. It has been possible to draw a probable annual variation for each parameter.

Annual variations of the gonad index and the reproductive cycle (fig. 1)

Each area exhibits similar variations of the gonad index from one year to another, but differences appears between the different main fisheries.

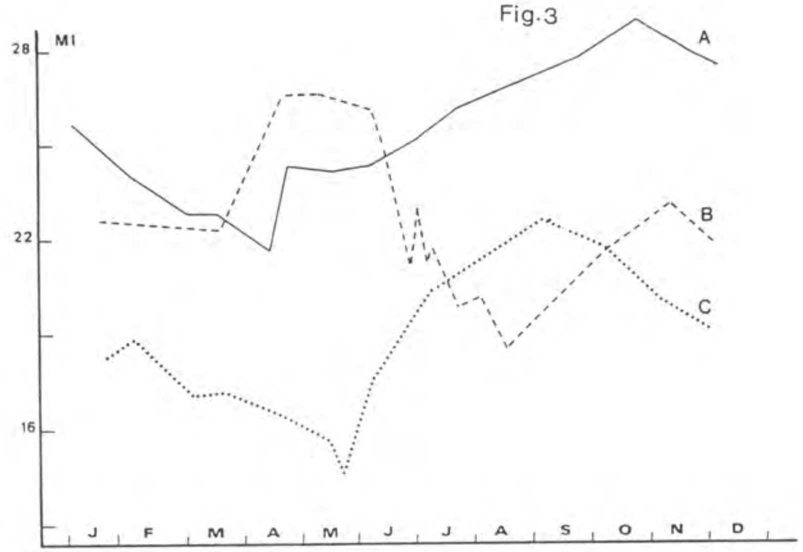
Baie de Saint-Brieuc : the annual variations of the G.I. are very important. This population shows a rest sexual stage (minimal values of the GI) from october to the next march recovery in april corresponds to a sudden increase of the G.I., the maximum values being observed each year at the end of june. Two successive and synchronic spawnings are generally observed in july.

Rade de Brest : the reproductive activity is permanent throughout the year but the variations of the GI are irregular from one year to another. Nevertheless, it appears that the sexual rest stage seems absent and the maximal production of gametes attained during winter (G.I. maximum in march). Three main periods of spawning have been identified, on at the beginning of spring (march - april), very important and synchronic in the whole population, a second from may to the end of july (minimal values for the G.I.) and depending on the year, the last one during autumn. After the first spawning individual asynchronism increases gradually in the population.

Baie de Seine : the annual sexual cycle is continuous, but some years a short rest stage appears in october. A strong gametogenesis takes place in autumn and winter and the maximal values of the GI are observed in mars or april. Spawnings are scattered from may to the next september or october, the main ones occurring in july and august. According to the year synchronism or asynchronism have been noticed. Minimal values of the G.I. correspond to the end of the reproductive season.

Annual variations of the water content of the gonad (fig. 2)

A gross and synchronic spawning is followed by a sudden increase of this index. haemolymph taking the place of oocytes or sperm in the gonad tubules. A decrease indicates restoration, lower values being founded when animals are mature.



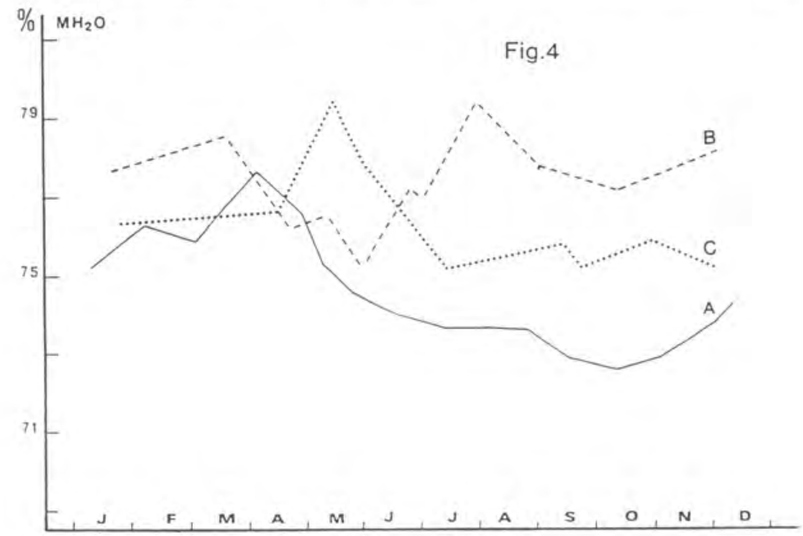


Figure 3. Annual variation of the muscle index (MI)

Figure 4. Annual variation of the muscle water content (% of the dry weight)
-A : rade de Brest, -B : baie de Saint Brieuc, -C : baie de Seine

The populations from the baie de Saint-Brieuc show two major periods of synchronic spawnings in july and august, maximal values of the gonad water content being observed during the winter rest stage.

The gonad water content of scallops from the rade de Brest shows low annual variations indicating asynchronic spawning scattered from spring to autumn. In the baie de Seine, the increase of the water content in september-october might indicate a short sexual rest period.

Annual variations of the muscle index (M1) (fig. 3)

Baie de Saint-Brieuc : the maximal values are observed in april-may during the first phytoplancton bloom and when the gonad recovers (low values of the G.I.). The minimal values correspond to the end of the spawning season, the muscle weight increasing in autumn.

Rade de Brest and Baie de Seine : the annual variations are similar, the index values being lower in the populations from the baie de Seine. The minimal values have been noticed after winter, the muscular index increasing in spring and summer to maximal values in autumn.

Annual variations of the muscle water content (fig. 4)

In the rade de Brest and the baie de Saint-Brieuc, the variations of the muscle water content are opposite to those of the muscle index. In the baie de Seine, the water content increases after winter but remains nearly constant, throughout spring, summer and autumn.

Annual variations of the muscle glycogen content (fig. 5)

In the baie de Seine, estimations of glycogen muscle content carried out during three years have shown that glycogen decreases in autumn and winter but recovers in spring, maximal values being observed in autumn.
These variations are similar to those of the muscle index and in spite of a restricted number of measurements it would be probable that in the rade de Brest and in the baie de Saint-Brieuc, the same relationship could be demonstrated.

DISCUSSION

• In the three populations, the variations of the gonad and muscle index are opposite. The adductor muscle could play an important role as storage tissue in Pectinids (Ansell, 1974 ; Barber, 1983 ; Lubet *et al.*, 1987-1989). The high values of the muscle index is depending on an increase of muscle protein and lipid content (Faveris and Lubet, 1989). On the contrary the increase of the muscle water content would be the traduction of release periods of metabolites by the muscle.
It is important to notice that in the same time, it has been found the lower values of the muscle glycogen content, as observed by EPP (1988) in Argopecten irradians for which the higher water content is linked with the degradation of glycogen liberation high quantities of water. Faveris and Lubet (1989) have shown that the variations of muscle glycogen content are similar to those of lipids and proteins muscle content.
The contribution of glycogen catabolism for reproduction and growth energy could be less important than it has been found in oysters and muscles ; fatty and amino-acids could play an important role in the needs requirements as it has been suggested by EPP (1988).

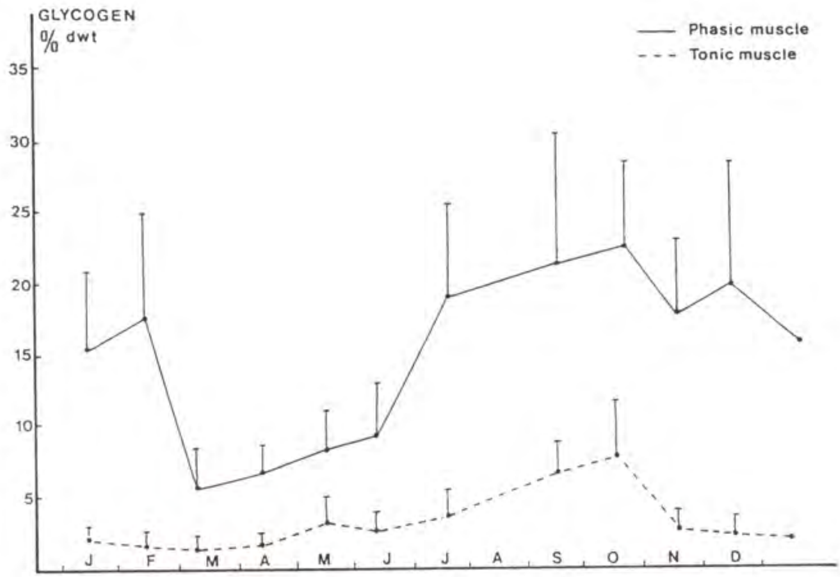


Figure 5. Annual variations of the adductor muscle glycogen content (baie de Seine)

The derease of glycogen could be in connection with the energy requirements involved in lipid and protein metabolism in the adductor muscle, amino and fatty acids being certainly an energy substrate in pectinids (Lubet et al., 1989).

• The sexual cycle of the scallops from the rade de Brest and the baie de Seine shows great similarities : i) it is continuous throughout the year, ii) the maximum of the gonad index is observed at he beginning of the spring, iii) the spawning period lasts from spring to the end of summer. The same pattern has been described in all populations from Scotland, Ireland and Wales (rev. in Mason, 1983). However, the synchronic emissions of the end of spring seem to be the more favourable for a good recruitment. This "spreading out of the risks", obtained by numerous spawnings during the course of the year, will tend to diminish the probability of very low recruitments. This strategy must be considered as an opportunistic one.

Population from the bay of Saint-Brieuc being the exception (Paulet *et al.*, 1988), the gonad activity remains very low during autumn and winter, recovery occurring from march and maximum values of the gonad index being observed before the spawning period in july. The population spawns during a period which lasts from a few days up to three weeks. This "single trial" reproduction may lead to a highly variable recruitment. A similar annual sexual cycle has been described (Lubet, 1959) for *Chlamys varial L.*

The differences in reproductive activities can be the adaptive responses to different environmental factors and (or) the expression of genetic patterns.

Transplantation experiments of spat from rade de Brest to baie of Saint-Brieuc (Bueste et al., 1987) have shown that scallops when mature have the same reproductive cycle as found on the original site, that may be the expression of genetic differences. Moreover, Huelvan (1985) working on enzymatic polymorphism in *Pecten maximus* showed some characteristics specific to each population. Nevertheless, the maximal values of the gonad index of transplanted scallops are lower than those of animals from rade de Brest (Ansell *et al.,* 1988). These differences observed in this paper appeared to be a combination of genetic characteristics and of responses to environmental parameters, principally trophic ones. Such features might be taken in account in fishery management and aquaculture development strategy ; for example, the choice of strains for a restocking program would prefer animal with an opportunistic reproductive type to ensure the most regular recruitment, also the analysis of the reproductive behaviour of experimental transplants can be an accurate source of information for the qualification of potential sites for aquaculture.

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ADENYLATE CYCLASE ACTIVITY IN THE GONAD OF *Pecten maximus* L.

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Abstract : *Regulation of pectinid bivalves reproductive cycle represents an interesting physiological process from the point of view of its applications in Aquaculture. To this Workshop, we present preliminary results about an aspect of the regulatory mechanism: the existence of a cellular signalling system in the gonad of* ***Pecten maximus.***

Key words : *Pecten gonad adenylate cyclase cellular signalling mechanisms*

INTRODUCTION

Pectinid bivalves are a group of molluscs that due to their great economic value and working possibilities arouse the interest of researchers and official organisms. In Galicia, scallops (*Pecten maximus*) are being considered as good candidates for their cultivation in rafts, alternatively to mussels. However, the biological knowledge of this species in Galicia is scarce. Roman *et al.* have performed several experiences on cultivation (1989), growth (1990) and reproduction (1990); the results support the interest of the scallops in the Galician coasts. In France, Lubet *et al.* have studied the reproductive cycle of *Pecten maximus* and the energetic requirements of reproduction (1987).

Studies on cellular physiology and the regulation of the reproductive cycle are our main goal ; the presence of adenylate cyclase activity in both gonads of *Pecten maximus* give us expectations for further studies regarding to the physiological role of the adenylate cyclase as a transmembrane signalling system.

MATERIAL AND METHODS

Adult *Pecten maximus* from Ria de Arosa were used. Two sets of experiments were performed in January 1991.

Enzymatic activity was assayed in male and female gonad particulate fractions as described by Mancebo *et al.* (1991). The assay medium contained, in a final volume of 50 µl, 25 mM Tris-HCI pH 7.5, 1 mM EDTA, 3-5 x 10^6 dpm of (-^{32}P)-ATP, 25,000 dpm of (^{3}H)-cAMP, 0.2 mg/ml creatine-phosphokinase (150-250 U/mg), 0.02 mg/ml myokinase (1,000-1,500 U/mg), 10 mM creatine phosphate. Membrane preparations contained 70-90 µg protein. Incubation was carried out at 20 °C for 40 min. Variable concentrations of enzyme substrate, divalent cations, guanine nucleotides and effectors were tested in dose-response experiments.

(^{32}P)-cAMP formed was chromatographically isolated by the method of Salomon *et al.* (1974) as modified by Bockaert *et al.* (1976).

Protein content was measured according to the method of Lowry *et al.* (1951) using bovine serum albumin as standard.

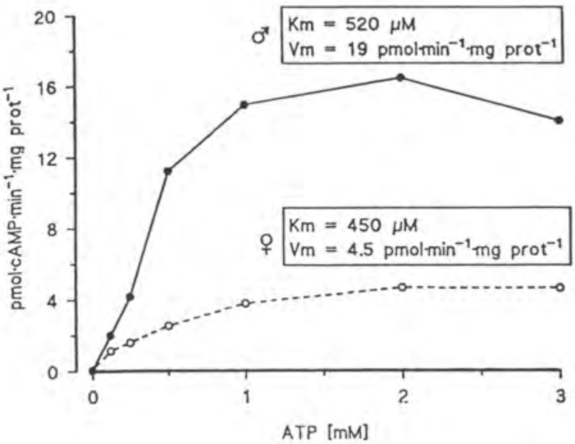

Figure 1. Dose-response to substrate concentration

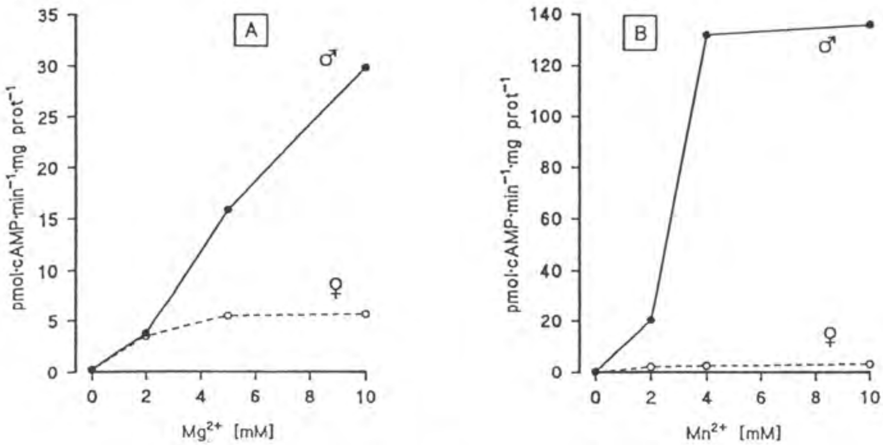

Figure 2. Dose-response to divalent cations : Mg^{2+} and Mn^{2+}

RESULTS

The effect of substrate concentration on the adenylate cyclase activity is shown in figure 1. The dose-response curves exhibited a Michaelis-Menten kinetics. Using the Lineweaver-Burk plot, Km and Vm values were calculated. A 2 mM ATP concentration was chosen for standard experiments.

Different concentrations of divalent cations Mg^{2+} and Mn^{2+} were assayed (fig. 2). In the absence of Mg^{2+} or Mn^{2+} the adenylate cyclase activity was undetectable. The addition of increasing concentrations of Mg^{2+} caused a rise in activity, more drastic in the male gonad. Whereas the adenylate cyclase activity of the female gonad reached saturation at 5 mM Mg^{2+}, it did not happen the same in the other tissue and, surprisingly, only the male gonad adenylate cyclase responded to Mn^{2+}.

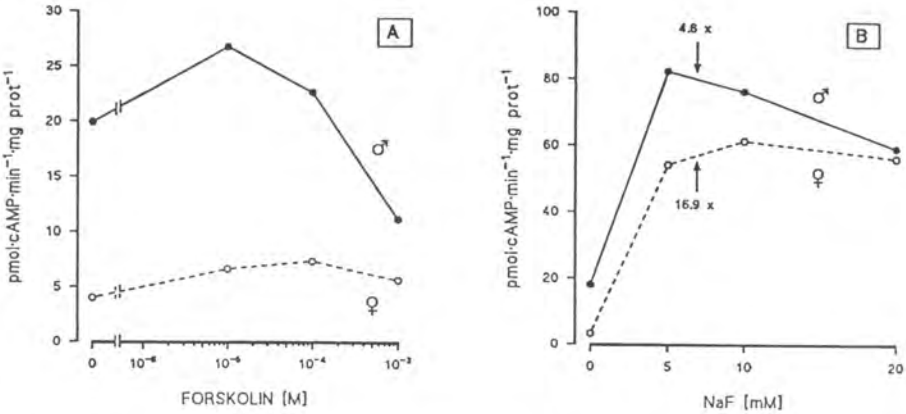

Figure 3. Effect of forskolin and NaF on the adenylate cyclase activity

In figure 3, the responses to forskolin (3A) and NaF (3B) are shown ; specific assay conditions were 2 mM ATP, 5 mM Mg^{2+} and 10 µM GTP. Forskolin did not increase significantly the basal adenylate cyclase activity either in the male or the female gonad. NaF produced a stimulation of the enzyme activity in a concentration-dependent manner ; the action of this effector seem to be different in both tissues : at 5 mM NaF there was a 17-fold increase in female gonad and a 5-fold increase in the male gonad.
The dose-response to guanine nucleotides is represented in figure 4 (4A female gonad, 4B male gonad). In both cases, there was a response to GTP and to non-hydrolizable GTP analogs. GTPS increased the enzyme activity more than GMPpNHp and, both respect to GTP.

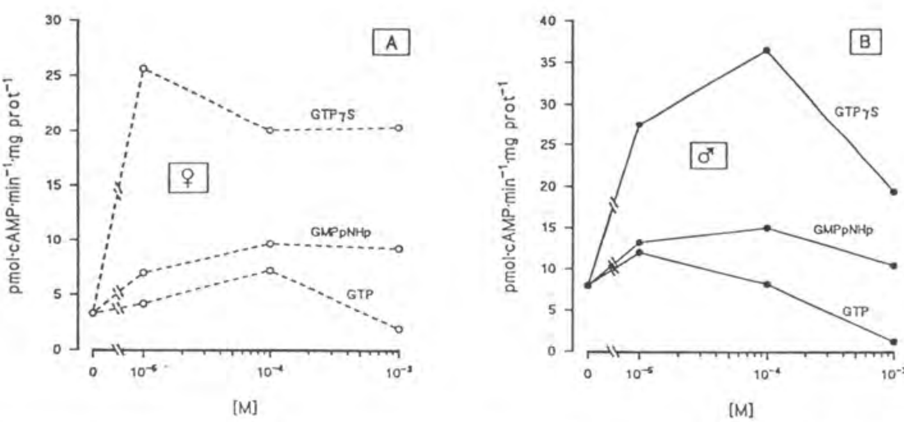

Figure 4. Dose-response to guanine nucleotides : GTP and non-hydrolyzable GTP analogues

DISCUSSION

From the results obtained in our experiments on adenylate cyclase activity, we can speak about an adenylate cyclase system in both the female and the male gonad of *Pecten maximus*. Although the general characteristics of the enzymatic systems are common : substrate saturation, presence of a G protein with GTPase activity and response to NaF, the particular properties of each system seem to be different as shown by the Vm values, the response to divalent cations or the response to a fixed concentration of NaF. These observations evidence a cellular signalling mechanism in the scallop's gonad and, therefore, the possibility of studying regulatory mechanisms is open as well as the regulation by external signals (e.g. neuropeptides, neurotransmitters) and the physiological processes involved in each part of the gonad.
The fact of finding different characteristics depending on the gonad's sex is very interesting and the scallop is offered as an animal model for endocrinological experiences due to its hermaphrotidism and single genetic endowment. Several possibilities could be discussed : e.g. sexual differentiation processes give different adenylate cyclase systems or distinct endogenous regulation in the male and female gonad.

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IN VITRO EFFECTS OF INHIBITORS OF CALCIUM ACTION ON SEROTONIN INDUCED EGG RELEASE IN THE SCALLOP *Patinipecten yessoensis.*

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***Abstract** : The addition of EGTA in media completely blocked serotonin (5-HT) - induced egg release from ovarian pieces of **Patinopecten yessoensis**. Verapamil, a Ca^{2+} channel blocker, however, strongly enhanced the 5-HT effect. Verapamil alone did not induce the in vitro egg release. Other Ca^{2+} channel blockers and calmodulin antagonists used, as compared with verapamil, showed a weak effect on the 5-HT effect. The effect of verapamil was not significantly reduced by high concentrations of Ca^{2+} in the medium. Although it is not clear whether or not verapamil enhances the 5-HT effect via Ca^{2+} action, these results indicate that verapamil-sensitive molecules are involved in the enhancement of egg release triggered by 5-HT in the scallop.*
Key words** : serotonin, verapamil, spawning, eggs, scallop, **Patinopecten yessoensis.

INTRODUCTION

In a number of marine bivalve species, including *Patinopecten yessoensis,* an injection of serotonin (5-HT) has been reported to induce spawning (Matsutani and Nomura, 1982; Gibbons and Castagna, 1984; Braley, 1985). Furthermore, 5-HT was shown to have a direct action on oocytes to induce germinal vesicle breakdown (GVBD) in the surf clam *Spisura solidissima* (Hirai *et al.,* 1988) and the oyster *Crassostrea gigas* (Osanai, 1985). In *P. yessoensis,* 5-HT has shown to induce the release of eggs which underwent GVBD *in vitro* (Matsutani and Nomura, 1987). Thus, the induction of GVBD is one of the important actions of 5-HT in the process of spawning in these bivalves. On the other hand, in some bivalves, the oocyte maturation induced by sperm, 5-HT, or KCl has been reported to require Ca^{2+} influx (Dubé and Guerrier, 1982; Dubé, 1988).
In this study, the effects of inhibitors of Ca^{2+} action on the egg release from ovarian pieces were tested in *P. yessoensis.*

MATERIAL AND METHODS

P. yessoensis were collected from the hanging cultures in Onagawa bay, Miyagi Pref., Japan, during their breeding season and maintained at 7-8°C in a recirculating seawater system. The mean shell length of the animals used was 10.6 cm.
The ovary was removed and cut into small pieces (10-30 mg wet weight) with razor blade. Ovarian pieces dissected from one animal were used in each of the experiments. The pieces were rinsed several times with buffered artificial seawater (TBASW ; modified Herbst's artificial seawater containing 10 mM Tris, adjusted to pH 8.2 with HCl) and incubated for 3 or 5 hours at 10°C in one ml of TBASW containing the test chemicals. The effect of the test chemicals was determined by the number of mature eggs released from each ovarian piece.

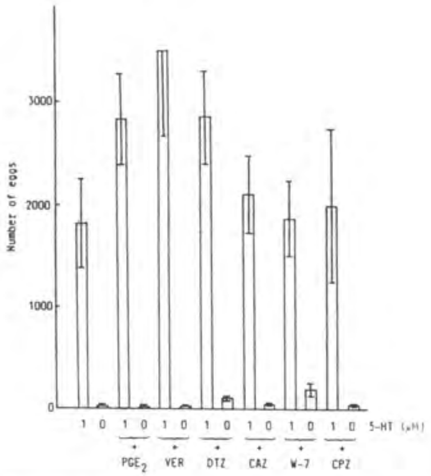

Figure 1. Effects of Ca^{2+} channel blockers and calmodulin antagonists on 5-HT-induced egg release in *P. yessoensis.* Each ovarian piece was incubated in 10^{-6}M PGE_2, 10^{-4}M verapamil (VER), 10^{-4}M diltiazem (DTZ), 10^{-5}M calmidazolium (CAZ), 10^{-4}M W-7, or 10^{-4} M chlorpromazin (CPZ). The values represent the mean ± SE of six ovarian pieces.

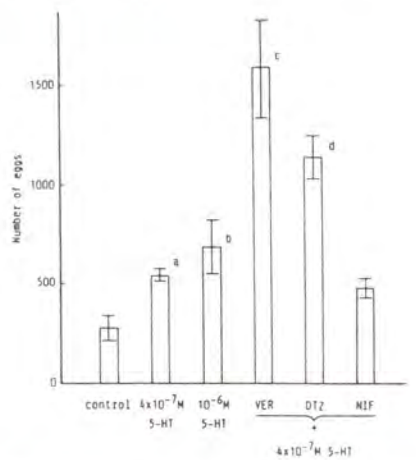

Figure 2. Effects of Ca^{2+} channel blockers on 5-HT-induced egg release in *P. yessoensis.* Verapamil (VER), diltiazem (DTZ), and nifedipine (NIF) were applied at 10^{-4}M. The values represent the mean ± SE of six ovarian pieces.

[c] $P < 0.01$: significantly different from subscripts a and b.
[d] $P < 0.005$ significantly different from subscript a.
[d] $P < 0.05$: significantly different from subscript a.

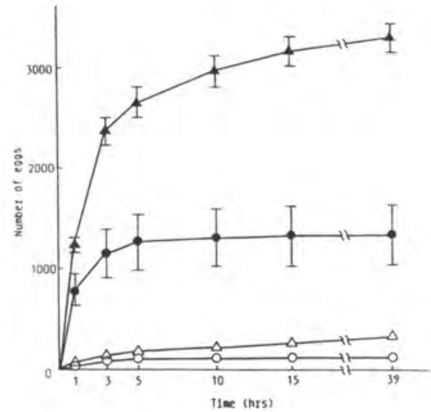

Figure 3. Time-course change in total number of eggs released from ovarian pieces of *P. yessoensis.* Each ovarian piece was incubated in 10^{-6}M 5-HT and/or 10^{-4}M verapamil. The points represent the mean ± SE of six ovarian pieces. SE is not represented when smaller than the point diameter. ●, 5-HT ; Δ, verapamil ; Δ, 5-HT and verapamil ; O, control.

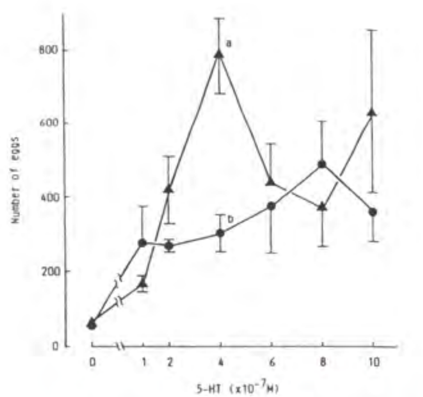

Figure 4. Effect of verapamil on 5-HT-induced egg release in *P. yessoensis.* Each ovarian piece was incubated in 10^{-4}M verapamil and various concentrations of 5-HT. The points represent the mean ± SE of six ovarian pieces. SE is not represented when smaller than the point diameter. ●, 5-HT ; Δ, 5-HT and verapamil.

[a] $P < 0.05$: significantly different from subscript b

The following chemicals were used (unless otherwise indicated, all chemicals were from Sigma) : serotonin creatinin sulfate, verapamil hydrochloride, diltiazem hydrochloride (a gift from Tanabe), nifedipine, N-(6-aminohexyl)-5-chloro-1-napthalenesulfonamide (W7), chlorpromazine, calmidazo- lium, Ca^{2+} ionophore A23187, ethylene glycol bis (ß-aminoethyl ether) N,N'-tetraacetic acid (EGTA), prostaglandin E_2 (PGE_2, Funakoshi). The chemicals were dissolved in a small amount of dimethyl sulfoxide. In each experiment, the final concentration of the solvents in each medium was adjusted to that of the medium containing the highest concentration.

RESULTS

Effects of inhibitors of Ca^{2+} action on the release of eggs from the ovarian pieces were examined. Neither the Ca^{2+} channel blockers and calmodulin antagonists used prevented the 5-HT-induced egg release (fig. 1), but, unexpectedly, verapamil and diltiazem tended to augment the stimulatory effect of 5-HT as in the case of PGE_2 (Matsutani and Nomura, 1987). However varapamil alone had no effect on the egg release. Of Ca^{2+} channel blockers used, the strongest stimulator of the 5-HT effect proved to be verapamil, followed by diltiazem (fig. 2). In most cases, nifedipin and calmodulin antagonists did not affect the 5-HT effect.
The time-course experiment showed that when the medium contained 5-HT alone, release of eggs almost stopped in five hours. When the medium contained 5-HT and verapamil, on the other hand, it continued over five hours, though the number of eggs released was small (fig. 3).
In the subsequent experiments, the most effective concentrations of 5-HT and verapamil for the egg release were examined. When 0.1 mM verapamil existed in the medium, a maximal effect of 5-HT on the egg release was obtained at a concentration of 0.4 µM (fig. 4). Verapamil enhanced notably the 5-HT effect on the egg release only at high concentrations ($\approx$ 0.1 mM) (fig. 5).
The number of released eggs in the control decreased with a decrease in Ca^{2+} concentration (fig. 6). The stimulatory effect of 5-HT was slightly enhanced in the ovarian pieces incubated in the medium containing 1 mM Ca^{2+}. However, the addition of EGTA to the medium completely inhibited the 5-HT-induced egg release.
In addition, the stimulatory effect of verapamil on the 5-HT induced egg release was not reduced by the high concentrations of Ca^{2+} ranging from 20 to 80 mM, and Ca^{2+} ionophore A 23187 (2.5 µM) did not affect the 5-HT effect (data not shown).

DISCUSSION

Verapamil enhanced the 5-HT effect on the egg release by about 2.5 times. This effect of verapamil is considerably great as compared with that of PGE_2 which has been demonstrated to be indispensable for the egg release, or to be a factor enhancing the 5-HT effect (Matsutani and Nomura, 1987). This result strongly suggests that verapamil-sensitive molecules are involved in the enhancement of egg release triggered by 5-HT in the scallop, *P. yessoensis.*
Three important processes, oocyte maturation, detachment of oocytes from germinal epithelia and discharge of oocyte from ovarian pieces, are involved in the 5-HT-induced egg release in *P. yessoensis.* It has been already reported that a Ca^{2+} influx is the key factor for activation of bivalve oocytes (Dubé and Guerrier, 1982 ; Dubé, 1988). In the present study, EGTA completely inhibited the 5-HT-induced egg release, suggesting that Ca^{2+} plays an important role in the egg release also in *P. yessoensis.* According to Carrol and Eckberg (1986), the inhibition of GVBD and induction of ameboid contractions of the *S. solidissima* oocytes by calmodulin antagonists took place via different system, respectively. Therefore, the effect of verapamil on the egg release in the present study may not be implicated in the oocyte maturation, and verapamil may

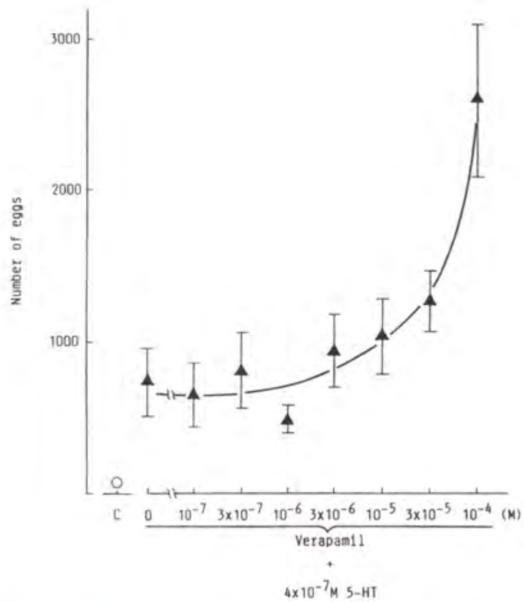

Figure 5. Effect of verapamil concentration on 5-HT-induced egg release in *P. yessoensis.* The media except that of the control (C, O) contain verapamil and $4x10^{-7}$M 5-HT (▲). The points represent the mean ± SE of six ovarian pieces. SE is not represented when smaller than the point diameter.

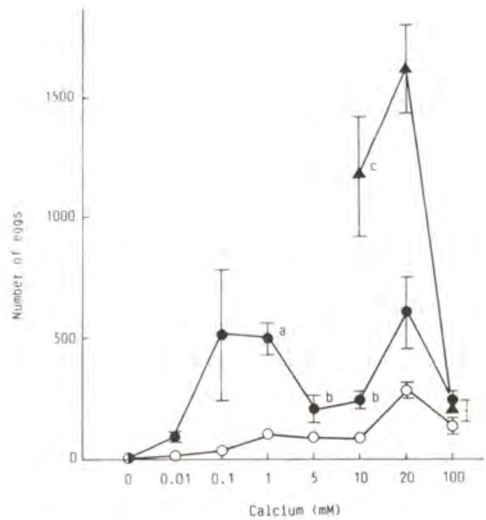

Figure 6. Effect of Calcium on 5-HT-induced egg release in *P. yessoensis.* Each ovarian piece was incubated in the presence (●) or absence (○) of 4 x 10^{-7}M 5-HT, or in 4 x 10^{-7}M 5-HT plus 10^{-4}M verapamil (▲). The points represent the mean + SE of six ovarian pieces. SE is not represented when smaller than the point diameter. [a] $P < 0$ 05, [c] $P < 0.001$: significantly different from subscript b

strengthen the 5-HT effect by promoting the discharge of eggs from ovran pieces. Since the *in vitro* egg release is accompanied by several processes, the detailed investigation of the verapamil action seems to help to clarify the mechanism of the female spawning in *P. yessoensis.*.

Acknowledgements : *I wish to express many thanks to Prof. Tadashi Nomura for his valuable advices, and to Prof. Katsuyoshi Mori for his valuable criticism during the preparation of the manuscript.*

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OPTIMISING SCALLOP SOWINGS FOR THE RESTOCKING OF AN ADULT POPULATION IN MULROY BAY, IRELAND.

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Abstract : *Optimising scallop sowings for the restocking of an adult population in Mulroy Bay, Ireland. Mulroy Bay is a deep-water partially enclosed sea lough on the north coast of Ireland. Within the innermost sea basin, the North Water, commercial quantities of scallop,* ***Pecten maximus****, spat can be obtained from collectors. Settlements are assumed to depend on the adult population within this basin. This population decreased as a result of poor settlements or settlement failures over the period 1981-1985, possibly due to the use of organotins at this time. Settlements have taken place annually since 1986 and future settlements will be dependent on these year classes as older individuals in the population expire. Sowings of scallops within the North Water took place to enhance the biomass of the adult population and thereby promote increased settlements. This paper describes optimum areas for sowing and expectations based on population data collected in 1980, 1984 and 1985.*

The scallop population in Mulroy Bay on the north coast of Ireland has been under study since 1978 (Minchin, 1981 ; 1983). The significant settlements within the innermost basin, the North Water, (fig. 1) may well be due to the high retention of the contained sea water mass. It has been assumed that the adult population within this basin is responsible for spat settlements there. The adult population was studied by diving in 1980, 1984 and 1985 to estimate population size and study growth and mortality. Settlements have been highly variable, nevertheless this did not explain the complete settlement failure for 1983-5 and very poor settlement in 1982. The use of organotins used as antifouling agents coincided with this period and moderate settlements returned once the use of organotins ceased (Minchin et al, 1987). During this time adult population numbers decreased and with them the biomass of reproductive material. Since 1986 there have been annual settlements and it will take some years before a significant natural increase of the reproductive biomass takes place. It is assumed that the greatest settlement intensity possible is dependent on the reproductive output of the adult population. The production of this biomass varies according to growth and so estimates of reproductive output have been calculated for 5m intervals of depth and area. Sea-star and scallop densities were also calculated in this account.

METHODS

Scallop populations over the period 1978-90 were investigated using standard SCUBA equipment. Transects from deep to shallow water were made using a compass in the direction of known points on the shore of the North Water in 1980, 1984 and 1985.

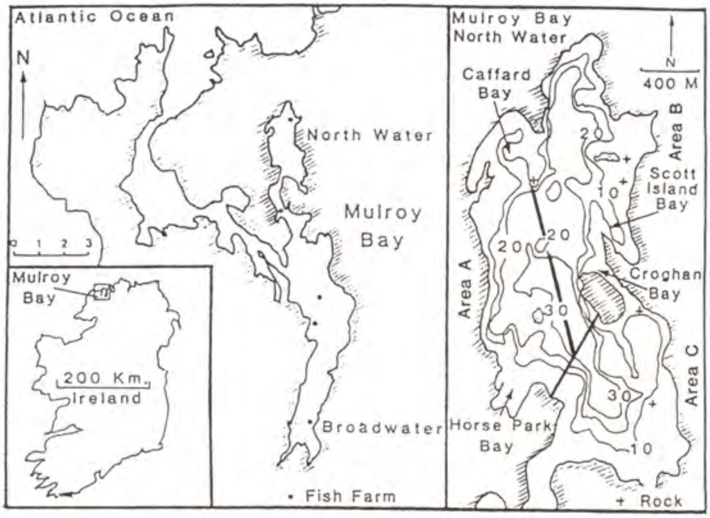

Figure 1. Mulroy Bay on the North coast of Ireland. Inset shows depths (m) within the North Water rand division of areas, A - west, B - east and C - south.

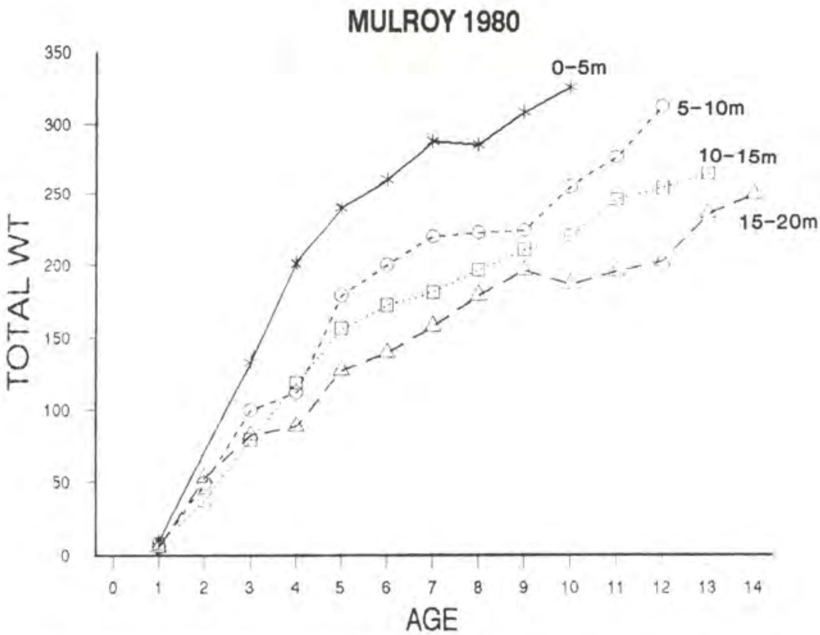

Figure 2. Mean total weight (g) for all scallops from each of the four sampled depth zones.

The area covered within each depth zone was calculated by using a depth gauge and a detailed chart of the area. Scallops that appeared beneath a 1.5 m rod held in front of the diver close to the sediment surface were counted for each 5 m depth interval. Each survey was conducted within a ten day period (30 July - 8 August 1980, 40 transects; 5 - 9 August 1984, 19 transects; 1 - 6 July 1985, 9 transects). A second diver sampled scallops, for growth and tissue measurements, from the same depth intervals alongside each transect. Scallops were sampled from each of the three areas at the beginning and end of the sampling period to determine change in gonadal index. The North Water was divided into three areas (fig. 1). Divisions of depth are referred to as zones and by region as areas.

Tissue weights (total wet weight of soft tissues, muscle and gonad) were measured for 1980 collected scallops (sample size was 1356) using a balance to the nearest 0.1 g. Ageing was by the method of Mason (1957) supplemented with age estimations from ligament scar tissue. Measurements of growth were made of shell height to each annular ring on the left valve. The first ring of some scallops was not easily determined and was aided by Ring II to Ring I relationships from scallops with clear growth rings for each depth interval.

Growth data collected in 1980 were used in the following calculations, because this preceded the use by fish farms of organotins which may have had some influence on growth. Scallops sown in 1983 and 1988/89 had previously been collected and on-grown within the North Water.

RESULTS

Scallop total weight varied with depth. Those in the shallowest zone, 0-5 m, grew the fastest and growth at 15-20 m was least (fig. 2). A similar trend was found for adductor tissue. However, shell growth although greater in the shallowest zone was found to be identical below 10 m. Gonadal weight increased rapidly from ages 2 to 6 but slowly thereafter. Gonad weight at each age decreased with depth, gonad weights at 5-10 m and 10-15 m were similar and those obtained at 15-20 m were approximately half the weights at 510 m (fig. 3). Gonadal indices for stations within each area were similar at the beginning and end of the sampling period.

Table 1. Numbers of scallops estimated at each depth zone for years 1980, 1984 and 1985 as calculated by diver sampling.

DEPTH INTERVAL	YEAR OF SAMPLING		
	1 980	1 984	1 985
0-5 m	55 392	49 087	2 675
5-10 m	99 706	30 071	29 428
10-15 m	308 979	74 072	86 395
15-20 m	57 053	46 876	38 712
20 m +	33 789	21 006	-

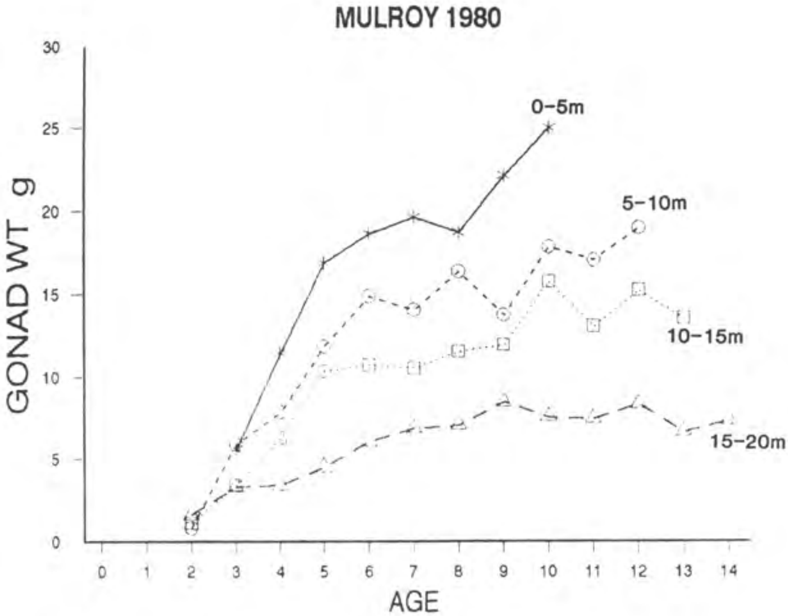

Figure 3. Mean gonadal weight by age for each of four depth zones sampled.

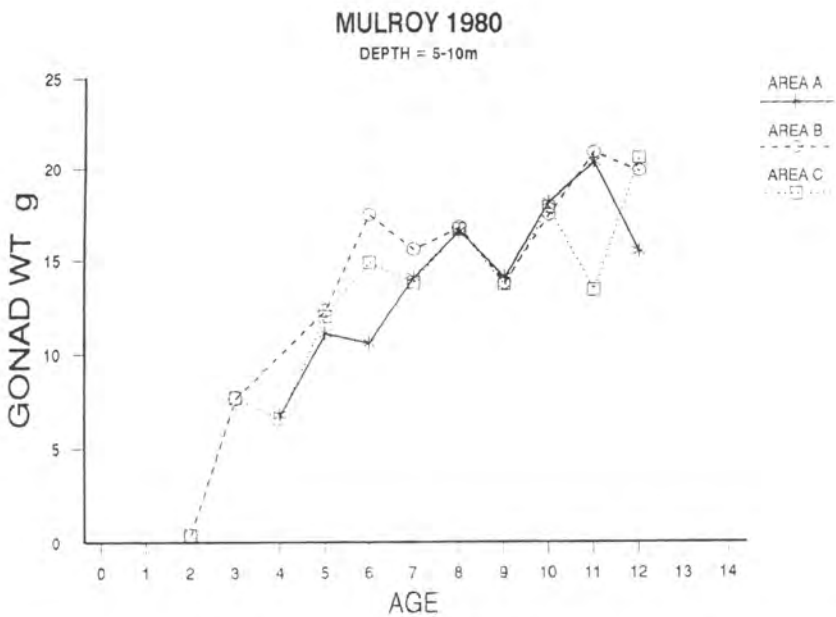

Figure 4. Mean gonadal weight of scallops at 5-10 m for the tree sampled areas of the North Water.

Scallops were most frequent at 5-15 m (table 1), these two zones produced the greatest output of reproductive material. The gonadal biomass at each age within each of these zones for the three areas of the North Water A, B and C, was obtained (fig. 4 and 5). Gonadal indices and biomass at age at 5-10 m were similar for all three areas, at 10-15m biomass varied with least growth in area B.

Two sea-star species predominated throughout the North Water, *Asterias rubens* and *Marthasterias glacialis*, a further species, *Solaster papposus*, most frequent at 5-10 m, formed only 3.8 % of those collected. The size distribution of seastars overlapped, *A. rubens* ranged from 1-10 cm arm radius with a mode at 5 cm and *M. glacialis* 1-21 cm and a mode of 11cm. Area C had the highest density for both species ; this ranged from 0.61-1.08/m2 for *A. rubens* and 0.24-0.29/m2 for *M. glacialis.* However densities of scallop in this area were also greater than in other areas, 0.20-0.37/m2.

Scallop distribution and density varied according to the topography within each area. Area A consisted mainly of slopes of sediment interspersed with rock fields. Area B was principally rock and scree to 10 m+ to meet a sediment slope and also muddy sediments made up of shallow embayments. In Area C there were slopes of sediment but also many rock ledges and drops. Scallops were principally confined to sediments on slopes, they were seldom seen on the muddy hillocks which occupied most of the almost level expanse of mud in deep water.

DISCUSSION

The North Water of Mulroy Bay is presently the only location producing naturally settled spat for culture in Ireland. It has a low rate of exchange of water. This is because it is deep and has a small tidal amplitude, approximately 1m, due to a series of narrow and shallows sills leading into it. Larval production is assumed to be dependent on the resident population and the majority of these remain in this basin to the time of settlement. However, some larval transfer with the adjacent Broad Water and loss to it must take place. Larvae prior to settlement become concentrated within Area B, the main spat collection region.

There can be great variability in scallop settlement between years. In 1979 there was an exceptional settlement and it may be of some consequence there was a poor settlement the preceding year. During 1882 scallop settlement was poor and from 1983-85 it was absent, this corresponded with the usage of organotins by fish farms to control fouling on cage netting (Minchin *et al,* 1987). When the use of organotins ceased settlements returned. By 1986 the estimated population had decreased to 21 % of the population calculated in 1980. Scallops that settled in 1986 would not contribute significantly to the spawning biomass until 1989, by which time the resident, now elderly, adult population would have further decreased to an estimated 7% of the 1980 population.

Projections and backcalculations of population numbers are based on two calculations of instantaneous natural mortality (M) for years 1980-84 and 1984-85, estimated as 0.30 and 0.31 respectively. Backcalculations indicate population numbers prior to 1978 exceeded 1,000,000 individuals. Scallops present in these numbers may have been subject to densitydependent effects, and so could explain the comparatively poor recruitment of scallops since the mid-1970's. However, a related expansion of sea-star numbers with their subsequent predation on pre-recruits could result with the same effect. Intensive predation by sea-stars was noted following the intense settlement of 1979, this was followed by only moderate numbers recruiting as adults.

Annual monitoring of spat settlements in September aid in prediction of the population structure from 1986, from which it was possible to calculate the overall biomass of reproductive material. Gonadal biomass has decreased from the estimated 7.6 mt in 1979 to 0.4 mt in 1991. By sowing scallops the reproductive output can be increased.

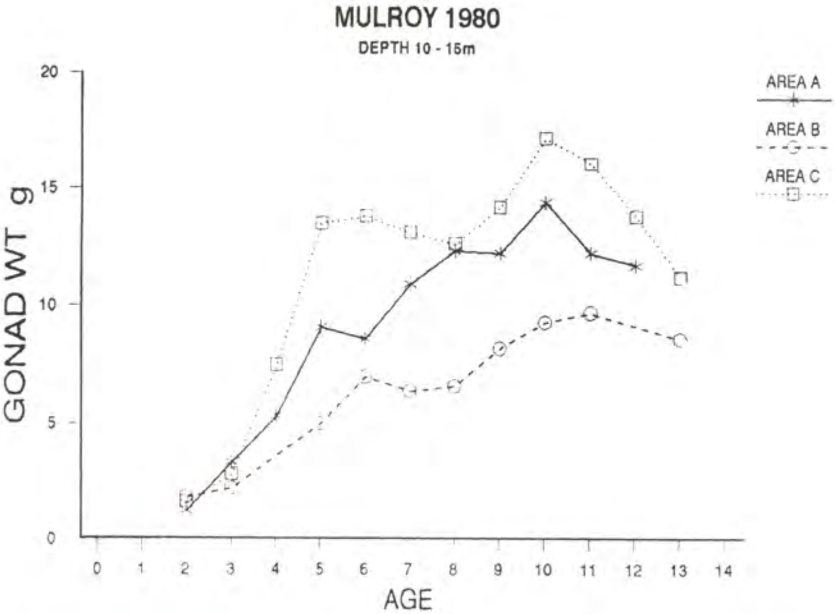

Figure 5. Mean gonadal weight of scallops at 10-15 m for the three sampled areas of the North Water.

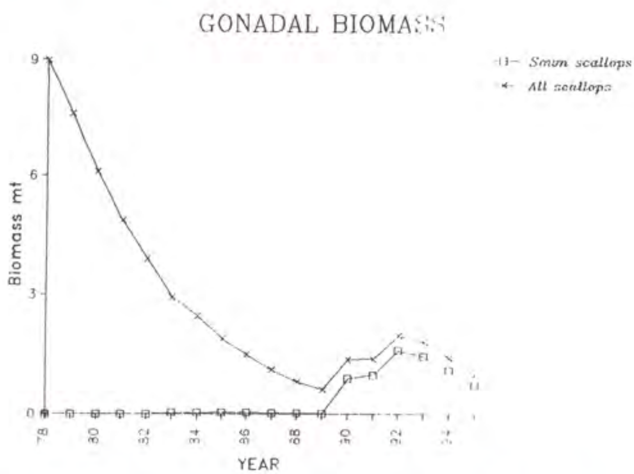

Figure 6. Total estimated biomass of scallop gonads for the natural population and for sown scallops for the period 1978 to 1995 in the North Water of Mulroy Bay.

In 1983 6,000 were sown in area C but larger numbers were sown more recently (200,000 in 1989, 28,500 in 1990 and 100,000 in 1991 within all three areas). This is expected to have promoted the reproductive biomass by 1.0 mt in 1991, more than twice that produced naturally (fig. 6).

Scallops in Mulroy have partial spawnings as indicated by a small drop in gonadal index. For this reason gonadal biomass represents only an index of gamete availability. The survey on gonadal weights took place in August 1980, and would have followed the main spawning from which spat for commercial collections would have been obtained, nevertheless these indices are similar to those found in June.

In order to maximise gonadal output, areas to be sown should take advantage of the zones where optimal growth can be found. It is assumed that all ages from each zone and area produce equally viable gametes, and sown scallops are subjected to the same mortality rate as the undisturbed population. Sowings at 0-5m are not thought to be suitable because of a loss from fishing. Estimates based on a low instantaneous fishing mortality of F = 0.1, result in less gonadal biomass being produced than those that are undisturbed at 5-10m (table 2). Although in the 1970's some dredging took place in the North Water, this has not happened since 1980. A bye-law (Anon, 1982) prevents dredging in order to conserve the adult stock. However, it is permitted to remove scallops in shallow water by means of a hoop-net on a pole. It is this form of fishing pressure that is likely should sowings take place at 0-5m.

Table 2. Production of gonadal biomass summed for a ten year period resulting from the sowing of 1000 scallops for different depth zones. An instantaneous fishing mortality of M = 0.3 has been used. Fishing mortality of 0.1 to 0.3 for the depth zone 0-5 m indicates lower values than at 5-10 m where no fishing is expected (see text for explanation). Scallops are assumed to be sown at 40-50 mm.

						DEPTH 0-5 m					
Year		**0-5 m**	**5-10 m**	**10-15 m**	**15-20 m**	**F = 0.1**		**F = 0.2**		**F = 0.3**	
1	-	-	-	-	-	-	-	-	-	-	-
2	1000	-	-	-	-	1000	-	1000	-	1000	-
3	740	4.14	4.514	2.516	2.442	670	(3.752)	606	(3.393)	549	(3.074
4	549	6.31	4.337	3.459	1.867	449	(5.163)	368	(4.232)	301	(3.461)
5	406	6.86	4.831	4.222	1.827	301	(5.086)	223	(3.769)	165	(2.788)
6	301	5.63	4.485	3.251	1.836	201	(3.758)	135	(2.524)	90	(1.683)
7	223	4.39	3.144	2.363	1.539	135	(2.659)	82	(1.615)	49	(0.965)
8	165	3.1	2.706	1.914	1.171	90	(1.692)	55	(1.034)	27	(0.507)
9	122	2.71	1.683	1.464	1.037	60	(1.332)	33	(0.733)	14	(0.310)
10	90	2.26	1.611	1.422	0.684	40	(1.004)	20	(0.502)	8	(0.201)
		35.4	27.31	20.61	12.4	24.5		17.8		12.9	

Should the cumulative gonadal biomass to ten years of age be considered, a greater output at 5-10 m of 24.4-28.6 kg per 1000 scallops sown is obtained for all areas. At 10-15 m only in area C are the levels comparable, 24.5 kg per 1000 sown scallops (table 3) Growth data suggest little or no movement between depth zones. Should sown scallops behave in the same way, these predictions should ensure that sowings in the most suitable areas will maximise production of reproductive biomass. Suitable sowing area are found on the slopes surrounding the North Basin where sediments have a component of shell sand.

Table 3. Production of gonadal biomass summed for a ten year period for each area for two depth zones. Scallop gonadal production is similar for all areas at 5-10 m but at 10-15 m only area C should be considered for sowing.

DEPTH 5-10 m

Year	Numbers	Area A	Area B	Area C
1	-	-	-	-
2	1000	-	-	-
3	740	3.996	4.514	4.514
4	549	3.733	4.337	3.623
5	406	4.507	4.994	4.872
6	301	3.190	5.267	4.484
7	223	3.144	3.479	3.077
8	165	2.739	2.772	2.755
9	122	1.720	1.683	1.671
10	90	1.638	1.575	1.611
		24.670	28.620	26.610

DEPTH 10-15 m

Year	Numbers	Area A	Area B	Area C
1	-	-	-	-
2	1000	-	-	-
3	740	2.442	1.628	2.072
4	549	2.909	1.976	4.282
5	406	3.695	2.030	5.481
6	301	2.588	2.107	4.154
7	223	2.431	1.427	2.921
8	165	2.029	1.089	2.079
9	122	1.488	1.000	1.732
10	90	1.296	0.837	1.764
		18.880	12.090	24.490

CONCLUSION

Scallop growth in the North Water of Mulroy Bay is highly dependent on depth. The main part of the population appears at 5-15 m. Population numbers and total gonadal biomass are thought to have decreased considerably. This population could benefit from planned sowings. Sowings at 0-5 m where growth is greatest, are likely to be fished and so spawning production may be considerably reduced. Scallop sowings at 5-10 m in all areas may optimise gonadal production from reduced mortality although growth rates are lower than at 0-5 m. Should additional sowing space be required, sowing in area C at a depth of 10-15m could be considered. Higher densities of seastars appear within depths 5-15 m and in Area C. Control of sea-stars prior to sowing is recommended.

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REPRODUCTIVE AND RESERVE STORAGE CYCLES IN *Pecten maximus* REARED IN SUSPENSION.
I: SOFT TISSUE GROWTH AND REPRODUCTION.

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***Abstract** : Reared 1 1/2 years old **Pecten maximus** earhung on rafts for one year showed simultaneous dry weight growth in striated adductor muscle and digestive gland while gametogenesis and spawning were proceeding. Spawning, and a subsequent decrease in gonad dry weight, started in June, and went on till September. By September, a decrease in the digestive gland dry weight had started, related to gonad recovery. High percentages of atretic oocites were recorded most of the year, which were related to the high temperatures recorded in the environment.*
***Key words** : reproduction, **Pecten maximus**, dry weight, gonad, reserve.*

INTRODUCTION

The scallop, *Pecten maximus*, is a commercially important species actively fished in Galicia (NW Spain), where catches have decreased drastically owing to overfishing. The recent development of small-scale farming of young scallops in suspension will reinforce the wild breeding stock as well as provide an easily accessible source of parent stock for hatchery larval rearing. Knowledge of the reproductive cycle of this cultivated population is thought to be paramount in order to assess the feasibility of increasing production both by natural settlement or by hatchery-rearing techniques.

MATERIAL AND METHODS

1 1/2 year old scallops were fished in early winter and earhung in mid January on a raft situated in O Grove (Ria de Arousa, NW Spain). The scallops were placed 4 to 10 m below the surface. Monthly, 30 scallops were brought to the laboratory and placed in plastic tanks with flowing seawater until the next day, when they were dissected. Total length and disturbance ring length (Roman and Fernandez, 1989) were previously measured with a vernier caliper to the nearest mm. Individual fresh weight of striated and smooth adductor muscles, digestive gland, gonad (both testis and ovary separately) and remaining tissues (foot included) were recorded. Pooled tissues were homogenized for 24 h at 95°C for the determination of the dry weight. A further 6-10 scallops were sampled, and a small piece of the ovary dissected and fixed in Davidson's fluid and finally stained with hematoxilin-eosin. The gametogenic cycle was monitored with a Weibel graticule, considering the following cellular categories : oogonias and previtelogenic oocites (< 60 μm), vitelogenic oocites (> 60 μm), atretic oocites, non germinal tissues and intrafollicular space. In each ovary 25 areas were analyzed. Temperature was recorded by means of Aanderaa temperature sensors placed on the raft. Chlorophyl a analysis was carried out on 4 samples of seawater (1 l) filtered through a Whatman GF/C filter paper after extracting in 90 % acetone.

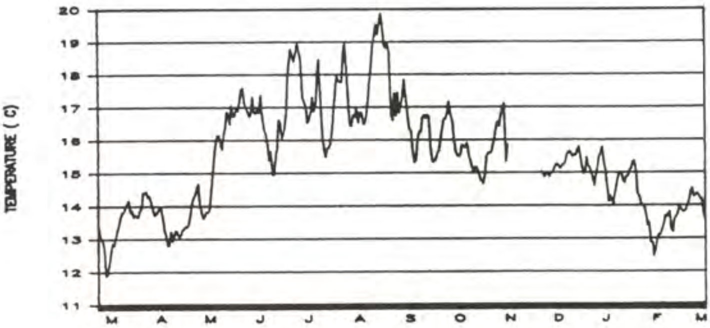

Figure 1. Seasonal changes in temperature

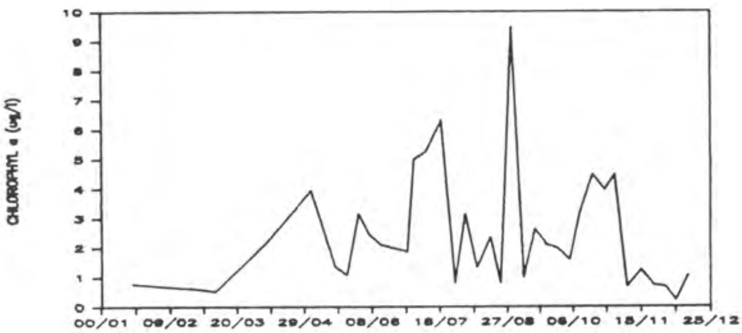

Figure 2. Seasonal changes in chlorophyl a (ug/l)

RESULTS

The initial length of the seed and its standard deviation (SD) was 100.7 ± 4.8 mm. After hanging in January, scallops deposited a ring of disturbance, and new growth was visible by March. The highest growth rates took place in spring and in autumn ; a lower growth rate was recorded in summer. By December the scallops stopped growing, after reaching a final length ± SD of 129.2 ± 8.5 mm (Roman and Acosta, 1990).
Minimum water temperatures were recorded from March-April (12-14 °C). Then temperature increased rapidly, reaching 17 °C by mid-May. Through the summer, values ranged between 15 and 20 °C. During autumn, the temperature decreased slowly (17.0-14.5 °C), and in winter the temperature again reached minimum values (12.5-14.5 °C) (fig. 1). Chlorophyl a (fig. 2) showed peaks in spring (3-4 μg/l), summer (7-9 μg/l) and autumn (5 μg/l). Minimum values (< 1 μg/l) were recorded in winter.
Neither the smooth adductor muscle nor the remaining tissues showed seasonal patterns of variation which could be related to energy reserve storage. No further analyses were performed on these tissues.
Striated adductor muscle (SAM) dry weight showed a continuous increase through most of the year, from 3.0 g in March to 9.8 g in November, then decreased to a minimum in February (7.5 g). Digestive gland (DG) dry weight increased continuously from April (1.1 g) to August (2.1 g), then decreased steadily, reaching a minimum by February (1.3 g).

No significant differences were found between testis and ovary dry weight (one way ANOVA, $p < 0.05$), so both tissues were pooled. Gonad dry weight increased more than thrice from March (0.7 g) to May (2.4 g). A decline was recorded by June, after water temperatures reached 17.5°C. Minimum values were recorded in July and August (1.2 g), increasing again till a highest maximum was reached in December (4.2 g). Subsequently a decrease was recorded, with significantly lower (one way ANOVA, $p < 0.018$) mean values in January and February. From March to May there was a simultaneous growth of gonadal and reserve storage tissues (SAM and DG). Spawning started after May, as indicated by the sharp decline in gonad dry weight, but reserve storage tissues continued growing, until August (DG) and December (SAM). When gonad dry weight started recovering in September a decrease in DG dry weight started simultaneously. After December, when both gonad and SAM reached maximum values, a decline in the dry weight of both tissues was observed.

Reproductive cycle (fig. 4)

The percentage of gonad occupied by apparently ripe ovocites (> 60 µm) increased from the initial value in March (19.8 %) to a maximum in April (47.5 %), followed by an initially slow (37.9 % in June), and subsequently rapid decrease, reaching minimum values by August-September (≈ 2.0 %). By October, the ovary started to recover. The percentage of germinal cells smaller than 60 µm decreased continuously from its initial March value (31.5 %) to a minimum in June (9.0 %), then increased again and remained constant (≈ 20 %) from July to October, decreasing again in November (5.9 %). A rapid increase in the percentage of atretic ovocites was recorded from March (2.0 %) to June (52.6 %), when values stabilized (≈ 53 %) till August. A decrease was observed in September, mainly owing to the high percentage of cell free space. The cell free space was a maximum in March when gametogenesis was taking place, but decreased rapidly, reaching a minimum just before spawning. Then, by June, when the first spawning took place, the cell free space increased, but decreased again owing to the start of a second gametogenic cycle. By September, it had risen to a maximum as a consequence of the almost complete evacuation of gametes.

DISCUSSION

Scallop farming dictates animal size, initial reproductive stage and sampling period. Animals employed as seed were about 1 1/2 year old and bore a small gonad when caught in the winter. By this date, scallop seed hanging takes place. Fishing, handling and adverse environmental conditions occurring during this period of the year prevented or delayed growth when culture started. In March, when sampling started, slight new growth was apparent on the shell edge.

Continuous growth of the somatic tissues was recorded through most of the year, although slight decreases were recorded in September and mainly in July, both in SAM and in DG dry weight, probably related to the reproductive activity. In July the second spawning apparently started, and by September the spawning-season had ended and gonadal recovery started. The decline in DG dry weight observed from September to February, related to the increase in gonad dry weight agrees with the results of Sastry and Blake (1971), which indicated that gonad and digestive gland showed a reciprocal relationship through the reproductive cycle. The decline in gonad and SAM dry weight recorded from December to February could be related also to metabolic maintenance expenses.

Mason (1958) described the scallop breeding in Manx waters in relation to age, the first spawning taking place in autumn in animals just two years old. The same pattern is followed by 3 years old scallops, while both spring and autumn spawning were recorded in older animals. However, populations of *P. maximus* from different areas show variations in the seasonal pattern of gonadal development (Ansell *et al.,* 1991).

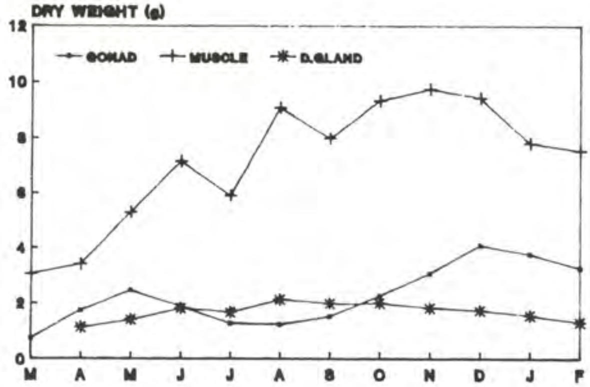

Figure 3. Seasonal changes in mean dry weights of striated adductor muscle, digestive gland and gonad.

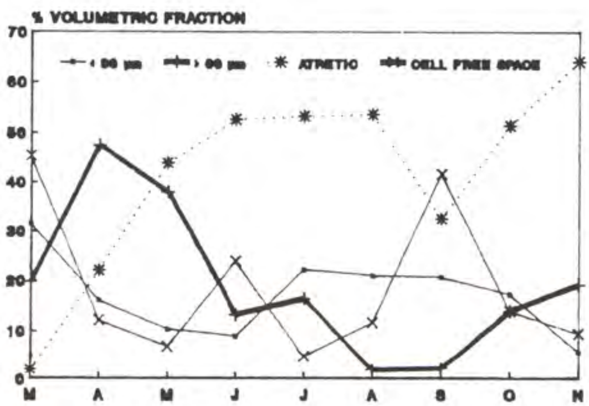

Figure 4. Seasonal changes in ovary tissues

In this area, no data are available on the reproductive behaviour of wild scallops younger than 1 1/2 year old. A long period of spawning always was recorded starting in spring when they were just two years old, followed by an autumnal gonad recovery which could result in a new spawning by the end of winter. However, by this time farmed scallops no longer remain in the sea since most are marketed between summer and autumn. For farmed scallops, the only chance of participating as breeding stock, thus reinforcing natural recruitment is in spring to summer spawning period. However during most of this period, most of the oocytes appear to be of bad quality. In the Bay of Brest repeated cycles of maturation of cohorts of gametes have been described throughout the year, with many of those produced during the winter months becoming atretic. As a consequence, there is a considerable seasonal variation in the quality of the gametes produced (Cochard, 1985). We recorded a high proportion of atretic oocites most of the year. Unfortunately, the histological samples from December to February were damaged. Trials for hatchery larval rearing employing cultivated scallops as breeding stock resulted in consistent failure in summer, and only in winter could spawning and settlement be achieved

The high sea temperatures recorded during the summer would explain the high proportion of atretic oocytes, which seems particularly characteristic of populations of *P. maximus* from shallow, warmer waters in the more southerly parts of the geographic range (Ansell *et al*., 1991).

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REPRODUCTIVE AND RESERVE STORAGE CYCLES IN *Pecten maximus* REARED IN SUSPENSION. II : ENERGY STORAGE CYCLE.

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***Abstract** : Reared 1 1/2 years old **Pecten maximus** ear-hung on rafts for one year showed specific reserve storag in striated adductor muscle (glycogen and protein) and digestive gland (lipids) from March to October. Gametogenesis and a subsequent increase in total ovary lipid were recorded from March to June. Spawning took place from June to September. The gonad recovery after spawning involved a loss of digestive gland lipids and muscle glycogen reserves, apparently expended to fuel gametogenesis. In January and February metabolic maintenance involved a loss of muscle proteins. The highest percentage of lipids in the ovary was recorded while spawning went on.*

This is a continuation of a previous paper (Roman and Acosta, 1991) describing the growth of the soft tissues and the reproduction of young 1 1/2 year old cultivated scallops ear-hung on a raft for one year. According to Giese and Pearse (1974), the relationship between the buildup and utilization of energy reserves and the annual cycle of gametogenesis and spawning should be investigated as an initial step toward a better understanding of reproductive success.

In pectinids, the digestive gland and the adductor muscle are the main body components where energy is stored, as lipids in the digestive gland and as glycogen and proteins in the muscle.

Mori (1971) in *Patinopecten yessoensis*, Barber and Blake (1981) in *Argopecten irradians*, and Robinson *et al* (1981) in *Placopecten magellanicus* reported losses of lipids in the digestive gland in conjunction with the gametogenesis.

The adductor muscle is an important site of energy storage and the use of reserves associated with the reproductive development has been reported in *Chlamys septemradiata* (Ansell, 1974), *C. opercularis* (Taylor and Venn 1979), *P. maximus* (Comely 1974), (Lubet *et al* 1987), *A. irradians* (Barber and Blake 1981) and *P. magellanicus* (Robinson *et al* 1981), with a loss of carbohidrates through the cycle.

This study was perfomed to monitor the levels of main specific reserves in *Pecten maximus* grown on rafts within each storage tissue trying to relate these changes to the reproductive cycle.

MATERIAL AND METHODS

Sampling schedules, seasonal variations of temperature and chlorophyl a, soft tissue growth and reproductive cycle were described in the preceding paper (Roman and Acosta, 1991). Pooled tissues of ovary, digestive gland and striated adductor muscle were homogenized and frozen before the biochemical analyses were carried out.

The total lipid content of the ovary and digestive gland was determined by gravimetry, after extracting in Soxhlet with chloroform : methanol (2 : 1).

The glycogen in the striated adductor muscle was determined by modified GLUCINET (Crespo and Espinosa, 1990).

The protein content in muscle was estimated as N in the elemental analyzor.

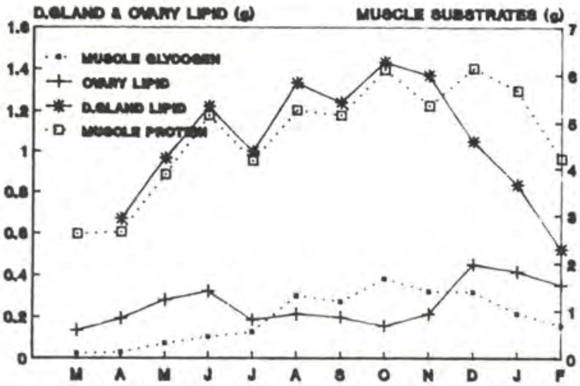

Figure 1. Total biochemical content of soft body components

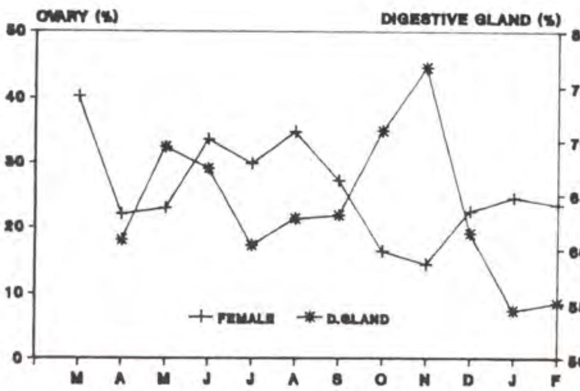

Figure 2. Percentage of lipid content (dry weight) of ovary and digestive gland.

RESULTS

The main component of the striated adductor muscle (SAM) was protein, which increased from 2,5 g in March to 6,1 g in December. It then decreased sharply, with minimum values in February (4,2 g). The total glycogen in SAM increased from 0,1 g in May to a maximum of 1,7 g by October. It continued to decrease until it reaches a minimun value in February (0,7 g). The total lipid of the digestive gland (DG) showed a similar pattern, going from 0,65 g in April to 1,4 g in October, then decreasing sharply, with minimum values recorded in February (0,5 g). The total lipid content of the female gonad closely followed the seasonal pattern of gonad dry weight as described in the previous paper, although the first peak was changed to June. Minimum values in March (0,14 g) were followed by a first maximum in June (0,33 g), a decrease between July and October (0,15-0,21 g) and a sharp increase reaching a second maximum in December (0,45 g) followed by a decrease. Similar to the seasonal variation of dry weight, there was a simultaneous growth of total metabolic reserves both in ovary and in reserve storage tissues. When the total lipids in the ovary decreased as a consequence of spawning, both total glycogen and protein in SAM and lipid in DG went on increasing until October. From this date total lipids increased in the ovary and simultaneously the lipid in DG and the glycogen in SAM decreased. (fig. 1). In winter, both the lipid in gonads and protein in SAM decreased simultaneously.

The mean lipid content (% dry weight) of the digestive gland showed a peak in spring (≈ 68-70 %), low values in summer (≈ 60-63 %), and another peak in autumn with a maximum in November (76 %), followed by lower values in winter (≈ 57 %). The mean lipid content of the female gonad showed a high value in March (40 %), then a decrease between April-May (≈ 23 %), a peak between June-September (29-35 %), then a sharp decrease (14 % by November), and a new and smaller peak between December-February. The seasonal variation of the percentage of lipids in DG closely followed the pattern of variation of gonad dry weight and total lipids in the ovary, suggesting a relationship between both organs. Moreover, the percentage of lipids in the digestive gland and ovary showed an inverse relationship where the lower levels of percentage of lipids in the digestive gland in summer cioincide with the higher levels of ovary while spawnings took place. In spite of the low dry weight and low lipid total content of ovary between July and September, the percentage of lipids reached the highest values in these months as well as in June, suggesting the presence in the ovary of ripe oocytes rich in lipids. (fig. 2)

The mean glycogen (% dry weight) in SAM followed the same pattern as the total glycogen content, going from 3,8 % in March to 18,5 % in October and then decreasing to a minimum in February (12,5 %). The mean protein (% DW) in SAM showed a reciprocal relationship with the mean glycogen content. Although minimum values where recorded in mean protein (% DW) between August and December, by this time the total content reached maximum values (fig. 3).

DISCUSSION

Gametogenesis in *P.maximus* takes place in winter at the expense of reserves stored previously (Comely, 1974). This would explain the low initial level of metabolic reserves in the energy storage tissues, as scallops had gonads when fished in December. When environmental conditions became favourable in spring after an increase both in sea water temperature and in concentration of chlorophyl a, there was a simultaneous growth in resserve storage tissue dry weight and their specific reserve substrates as well as in the gonad. Through spring and summer conditions were apparently good enough to support the gonadal maturation and spawning at the same time as to allow a rapid somatic growth and storage of reserves, although slight decreases were recorded in July and September both in the digestive gland and adductor muscle. This would agree with the results of Ansell *et al* (1991) which found reductions of reserves of glycogen coinciding with the main spawning period. However, the high temperature recorded in summer could also be considered as a stres factor, unfavourably affecting the scallops which would lose part of their metabolic reserves. From autumn on the energy required for gonad recupération cannot be covered only by the food present in the environment, so the stored energy in SAM (glycogen) and DG (lipid) is used. In winter, when the food level is minimum, a decrease was recorded in Sam protein content which could be related to metabolic maintenance expenses.

The lipid content recorded (% DW) both in the digestive gland (54-76 %) and ovary (15-40 %) is higher than what is usually found in the literature. Mori (1975) reported a lipid content in the digestive gland reaching 70 % in *P. yessoensis* cultivated in suspension. The culture conditions may allow for a greater contribution of food, and thus a higher buildup of reserves, when compared to scallops living on the bottoms.

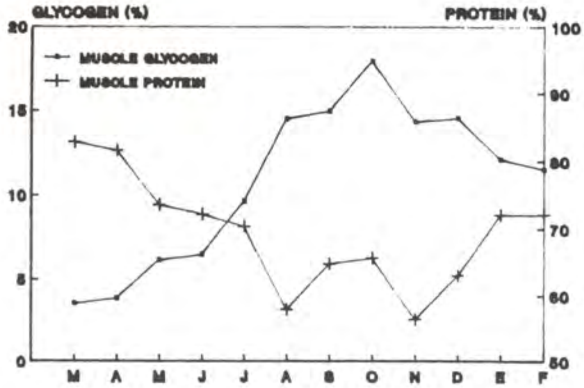

Figure 3. Percentage of glycogen and protein content of striated adductor muscle.

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THE REPRODUCTIVE CYCLE OF THE SCALLOP *Chalmys farreri* IN THE SEA OF JAPAN

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Abstract : *Seasonal gonadal changes and the time of spawning were studied for the most northern population of the scallop Chlamys farreri. It was shown that spawning in late June -early July at t° = 18°C- and ended in August. From late July to late September, the scallop was in a spent condition. Reduction stage when gonads had minimal size and sexes were difficult to distinguish extended from late September to the middle of May. Gonad development and sex cell maturation take place during winter and spring months. In April and May, growth and maturation process are more active which results in pre-spawning condition of the majority of population in June.*
Key words : *reproductive cycle, spawing, sex ratio, Chlamys farreri.*

INTRODUCTION

Rather many works are devoted to reproductive cycle of scallops. At the same time information about scallop reproduction in various regions of their area is mostly insufficient. First of all it concerns the time and duration of spawning of scallops from various populations in latitudinal direction. From this point of view, investigation of reproductive cycle of the scallop *Ch. farreri* is rather interesting.
On the Asiatic coast northern boundary of the area of the scallop *Ch. farreri* Jones, Preston, 1904 passes through the Bay of Possjet, the Sea of Japan (42°N), and southern boundary -along the coast of the East China Sea (25°N)(Scarlato, 1981; Yousheng, 1991). It dwells near the Japanese Islands as well (Waller, 1991).
In China *Ch. farreri* is caught and cultivated in considerable amounts which has aroused an intense interest to its reproduction biology.
We studied reproductive cycle of the scallop *Ch. farreri* from the northern habitats. In the Bay of Possjet density of its accumulations makes from 4 to 100 specimens per sq. m(Afeichuk et *al.*, 1988). Scallop populations locte mainly at oyster banks and stony fields of shallow creeks of the Bay. Despite the fact that cultivation of this species in Primorye can be very profitable (Bregman, 1982) its reproduction biology has been studied rather poorly.

MATERIALS AND METHODS

The scallop *Ch. farreri* was collected during 1990 in creeks of the Bay of Possjet (Peter the Great Bay, the Sea of Japan). Total amount of collected scallops was 436 specimens of the age from 1 to 8 years and shell size from 20 to 105 mm.

From May to August, frequency of collection was several days in the rest of the time the scallop was collected monthly as far as possible. Molluscs were kept for up to a week in aquarium flow through systems at the temperature of their habitat.

Water temperature was measured at the surface and at the bottom at 3 m depth in sites of sampling. Fragments of gonads from 15 specimens were fixed in Bouin's solution every month as far as possible. Out of these fragments we prepared paraffin sections 7 mkm thick and stained them with Karrachi's hematoxylin using standard methods (Merkulov, 1969).

Gonad index was calculated on the basis of percental ratio of fresh gonad weight to fresh body weight (of soft tissues). Results of the study were processed by IBM PS personal computer using "statgraphics" program. Selections of males and females including such parameters as shell diameter (height), total weight and weight of a muscle and gonads were examined with the help of discriminant analysis.

RESULTS

Mature male individuals had white gonads, and female ones -orange gonads. Examination of gonadal smears and histological preparations from 436 individuals did not reveal the presence of hermaphrodites. Sex ratio in the population was male/female 1/1.36. Examination of gonads showed that scallops from the Bay of Possjet became mature on the second year.

While making distinction between sexes by weight of body, muscle and gonads and shell diameter, it appeared that the obtained value of canonical correlation coefficient (0.497) and x-criterion (6.24 with df=57) showed the absence of such distinction between males and females (table 1).

Table 1 : Sex comparison for some biological characteristics.

Variables	Females	Males	Average	Difference between 2 & 3 %
1	2	3	4	5
WT, g	78.14	72.40	74.70	7.4
WM, g	31.80	30.60	21.10	3.7
WC, g	39.70	35.60	37.20	10.3
WMU, g	9.40	9.94	9.72	8.4
WG, g	4.04	3.90	3.95	4.0
H, mm	93.40	90.50	91.70	3.0
Quantity	252	184	436	6.1

WT : total body weight WM: fresh body weight WC : weight of the shell
WMU : weight of the muscle WG : fresh gonad weight H : height of the shell

Five typical stages of reproductive cycle were revealed on the basis of the analysis of histological changes in scallop gonads during a year.

Pre-spawning stage (late May - July) is characterised by maximal development of acinar system and by small amount of megacinar connective tissue (fig. 1a). Female acini contain freelaying oocytes 60 mkm in diameter. They have rather thick membrane (fig. 1b). Male acini are filled with spermatozoa. Their ends from strands directed to acinus aperture (fig. 2a). Spermatogenetic layer is very thin at this stage (fig. 2b).

During spawning, which occurs from early June to August, oocytes and spermatozoa are discharged into water. Spawning takes place at water temperature of 16-18°C. Spawning is begun by males who stimulate females.

Individuals in spent condition begin to appear in late July, and are observed to late September. Remained gametes are found in their gonads (fig. 1c). In the end of September, this stage smoothly changes into reduction stage when sexes cannot be distinguished because of complete resorption of retained gametes and absence of new generation of sex cells (fig. 1d). Acini become smaller in size and in number. This stage lasts to November.

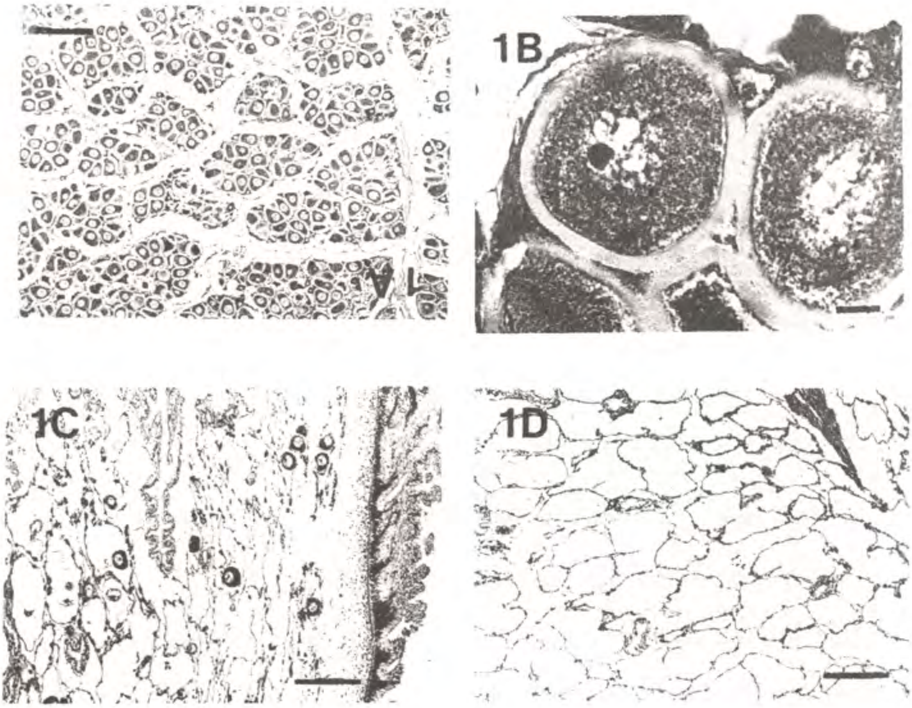
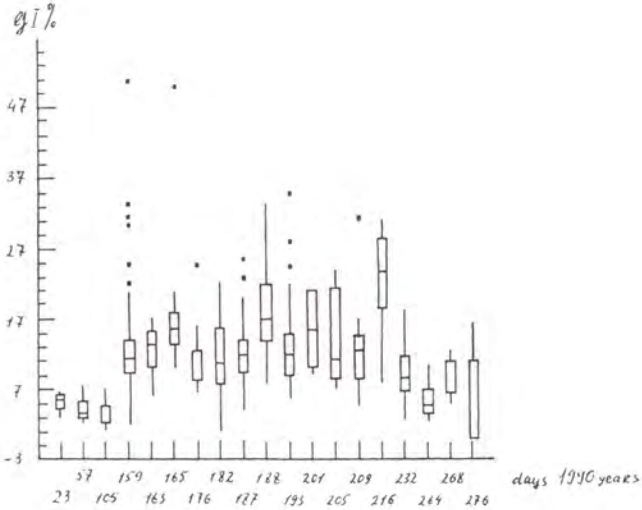
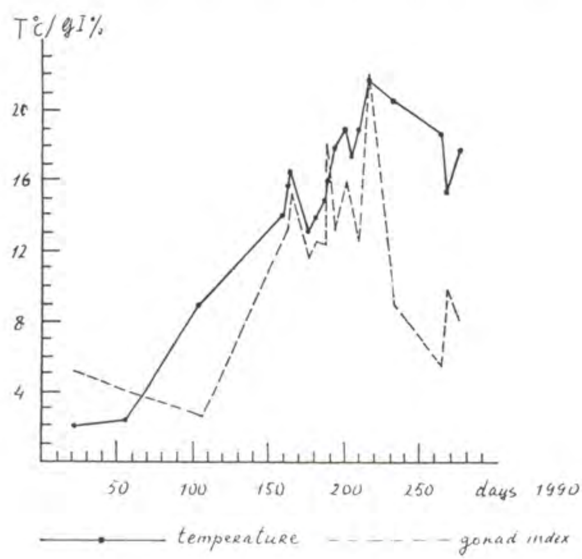


Figure 1. Photomicrographs of some gonadal stages of female *Ch. farreri*.
a) prespawning stage. Scale 200 mkm b) oocytes. Scale 10 mkm
c) spen condition. Scale 200 mkm d) reduction stage. Scale 200 mkm

Figure 2. Photomicrographs of some gonadal stages of male *Ch. farreri*
a) prespawning stage. Scale 200 mkm
b) Part of acini near digestive tract. Scale 25 mkm
c) stage of development and maturation. Scale 50 mkm



a) means of gonadal index. Multiple box and whisker plot



b) display of connection course of temperature to value of gonadal index

Figure 3. Gonadal index and course of temperature in habitat of *Ch. farreri* in 1990 year

The stage of development and maturation of new generation of sex cells is observed during winter and spring months up to late May -early June. In spring, in April, gametogenetic processes of this stage accelerate. For females the diameter of oocytes and number of Freelaying oocytes increase. For males, a great number of spermatozoa appears in acini (fig. 2c). The value of gonad index of the scallop *Ch. farreri* reflects gametogenetic processes in gonads (fig. 3a, b). Its values, being low in winter, reach maximum in summer. Sharp drop of gonad index value occurs to the end of September.

DISCUSSION

Judging by the data on reproduction of *Ch. farreri* from the Yellow Sea (the region of Qingdao, China) (Liao et *al.*, 1983), reproduction of this species in Primorye (Maritime Territori) has some peculiarities which are probably connected with more severe temperature conditions of this habitats. Unlike the scallop from Primorye, China scallop reaches maturity not in the second but in the first year. To our opinion the fact that in spawning period which is more prolonged in the Yellow Sea (from May to October) there are two spawning peaks, is of great interest. The first peak takes place from the middle of May to June, the second one -from late September to October. A gonad is completely released from sex cells in November -December (Liao et *al.*, 1983).

In Dalian (Dairen), situated in the northern China, gonad index grows from late April and reaches its peak in the middle of June (T°C 16-19). After the first drop in late July -August the index rises to the middle of September, and drops again in early October (Yousheng, 1991). It means that in Dalian, spawning also occurs twice a year : the first one in late June, the second in late September -early October.

In Primorye in 1990 *Ch. farreri*, spawned from the middle of July to September. From August gonad index sharply dropped and to 19 August it had very low values. From the middle of September to October, a certain increase of gonad index can be observed but its values grew not very much. In this period, histological examination of male and female gonads showed the absence of sex cells. All that conforms to the suggestion concerning reproduction of mussels in the Peter the Great Bay, the Sea of Japan, when the second gametogenetic cycle of mussels is depressed by low temperature in autumn (Yakovlev, 1986)

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VERTICAL DISTRIBUTION OF LARVAE AND SPAT OF THE COMMERCIAL SCALLOP, *Pecten fumatus.*

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Abstract : *The larval dynamics of* ***Pecten fumatus*** *were examined by determining the vertical distribution of larvae by pump sampling, and that of settling-stage pediveligers by vertically arrayed spat bags. The larvae did not show a consistent diel pattern of distribution and most were found between 18 and 25 m above the seabed while the number of pediveligers settling in bags progressively increased towards the seabed, reaching a maximum between 2 - 14 m above the bottom. These results suggest that scallop larvae may act as relatively passive particles, with only a weak depth regulation but as they approach settling size they sink to the relatively still bottom waters for settlement and metamorphosis.*

Key words : *larvae, spat, settlement, advection, vertical distribution.*

INTRODUCTION

Fluctuating annual recruitment is a widely described feature of most scallop fisheries, including those in south-east Australia (Caddy, 1989 ; Young and Martin, 1989). Whilst many mechanisms have been proposed to account for this fluctuation, the crucial period between gamete release and subsequent settlement to a suitable substrate the larval phase and its dynamics has not been rigorously examined. It has usually been assumed that the adaptive function of the planktonic larval phase of scallops is dispersion (Sinclair *et al.* 1985), with recruitment variability a function of such factors as larval predation (Morgan *et al.* 1980), substrate suitability (Culliney, 1974), hydrodynamics (Butman, 1987), hydrology (Trembly and Sinclair, 1990) and post-settlement mortality (Young *et al.* in prep).

Knowledge of recruitment in scallop populations is fundamental to the understanding of scallop stock dynamics (Darby and Durance, 1989), particularly as the importance of a stock-recruitment relationship in scallops is becoming increasingly clear (Sinclair et *al.* 1985 ; Caddy, 1989 ; Young and Martin, 1989). A critical link in this process is the larval phase, where dispersion by currents has a potentially major effect on subsequent recruitment. This is likely to be controlled by hydrodynamic advection of the larvae from their position of release. The advection path itself is also affected by the position of larvae in the water column where hydrological conditions such as stratification and current flow may vary.

The behaviour of larvae and the effects of water flow on settlement processes are yet to be fully described. Butman (1986), in an analysis of velocity profiles on soft substrate has reported that the speed of horizontal flow, even to within one body diameter of most larvae above the bottom is greater than their maximum observed swimming speeds. Mann (1986) has also reported that bivalve larvae are, in general, heavier than water (specific gravity 1.3). These observations suggest that larvae may act passively in the horizontal plane, but to remain in the water column for the normal duration of their larval phase they must either be subjected to constant vertical mixing processes in the water column, or regulate their depth by active swimming.

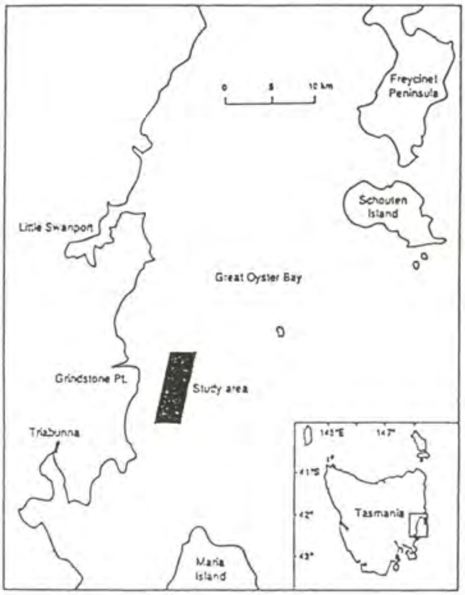

Figure 1. Map of Great Oyster Bay and the sampling area. Both larval pumping stations and deployment of spat lines was carried out in the shaded region.

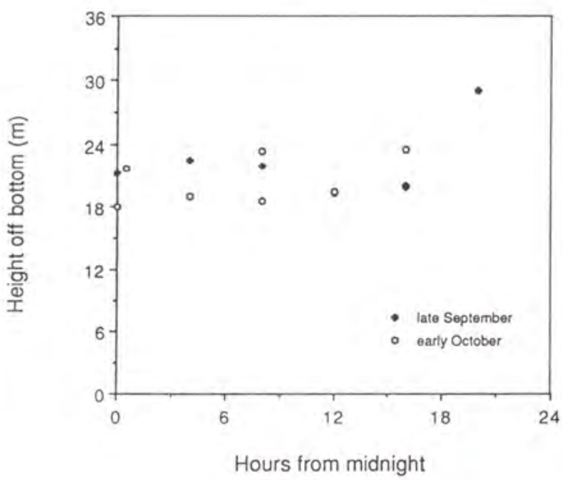

Figure 2. Hours from midnight versus larval height above the bottom (Zcm) for the two 24 hour samplings, in late September and early October.

In this paper we describe field observations we have made to : 1) determine the position of larvae in the water column, and 2) to see if patterns of vertical distribution of spat in collectors was related to the vertical concentration of larvae and the amount of water flowing through the spat bags.

METHODS

Adult scallops were collected each week from 17 July to 28 August 1990 from Great Oyster Bay, a marine embayment on the Tasmanian east coast (fig. 1), and assessed for gonadal condition. After spawning was detected, the distribution of larvae in the water column was examined in samples collected on two occasions in late September and early October 1989, at 4 hourly intervals for 28 hours each time. Additional samples were collected at midday and midnight in middle and late October and early November 1989.

The larvae were sampled with a diaphragm pump. A "Platypus" conductivity, temperature and depth logger was attached to the hose intake which recorded the sample depth, salinity and temperature. The position of maximum larval abundance in the bay was determined before sampling by weekly larval surveys using drop nets during the preceding weeks. On each sampling occasion, the procedure was to deploy a drogued buoy at mid-water depth, and take all samples within 50 m of the buoy to sample from the same water mass. Larvae were collected by pumping water and filtering it at a constant rate for ten minutes at each 5 m depth interval from 35 m to 5 m below the surface (the depth of the study area ranged from 35-42 m). This produced a sample from a total filtered volume of 1.5 m^3 for each depth. Filtration was achieved by directing the outflow from the pump into a 100 µm mesh net, and the larvae then preserved in alcohol. In the laboratory, larvae were transferred by pipette into a Sedgewick-Rafter cell, identified (Dix and Sjardin, 1975), and measured by image analysis.

The density of the water (σ_t) was calculated from the conductivity and temperature data for each sampling occasion, and a measure of water column stratification, S, calculated (Fortier and Leggett, 1982), where

$$S = \frac{1}{n} \sum_{i=1}^{7} \Delta \sigma_{ti} \quad \Delta Z_i \qquad (1)$$

where n is the number of pairs of adjacent measurements, $\Delta \sigma_{ti}$ is the difference in σ_t between the i-th pair of measurements, and Δz_i is the depth interval between the pair of measurements. The distribution of larvae in the water column was then described by calculating a centre of mass of the larvae (Z_{cm}) from

$$Z_{cm} = \sum_{i=1}^{7} P_i z_i, \qquad (2)$$

where P_i is the proportion of larvae in the i-th stratum, and z_i is the mean depth of the ith stratum (Fortier and Leggett, 1982).

Spat were collected in Japanese spat bags of 1.5 mm mesh, filled with 3 m^2 of black plastic oyster mesh of 2 cm mesh size. The bags were placed on two vertically buoyed lines adjacent to the area of larval sampling and attached at 2 m intervals from 2-28 m above the bottom.
Indirect measurement of flow through each bag was achieved by placing a ball of "Plaster-of-Paris" ($CaS0_4.2H_20$) in the centre of each spat bag. The rate at which the plaster balls dissolved with water flow had been previously determined, and the loss of weight from each ball was used as a measure of water flow through the bags. Two current meters were also deployed within 50 m of the spat lines, one 5 m above the seabed and the other at 25 meters above, to test the accuracy of the flow rates estimated from the Plaster of Paris balls. The lines were retrieved by divers 18 days after deployment and the spat removed from the bags.

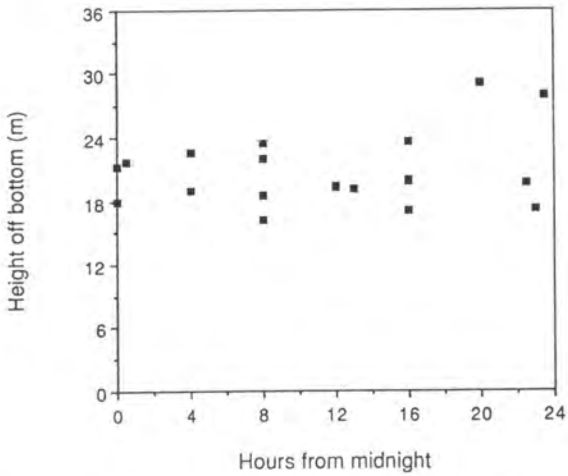

Figure 3. Hours from midnight versus larval height above the bottom (Zcm) for all stations.

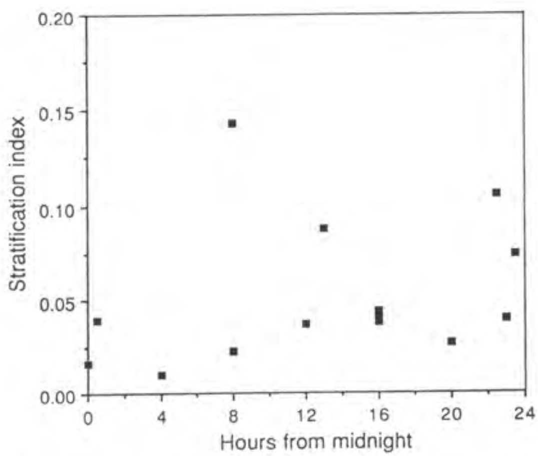

Figure 4. Hours from midnight versus stratification index (S)

RESULTS

The vertical position of the centre of mass, *Zcm,* of larvae sampled during the two 24 hour periods is shown in figure 2. This shows the centre of mass remaining between 18 and 25 metres above the bottom, and with no repeatable diurnal pattern. When the centre of mass of the larvae was examined from all 20 sampling occasions (fig. 3), its depth was again constant and without detectable diurnal cycles. Water column stratification (S) in Great Oyster Bay was weak throughout the larval sampling period, and also showed no detectable diurnal cycle (fig. 4). Analysis of size-frequency data from the first period of 24 hour sampling showed that larval size was uncorrelated with depth ($\underline{n}$ = 1289, R^2 = 0.0002, F = 0.245, p = 0.62).

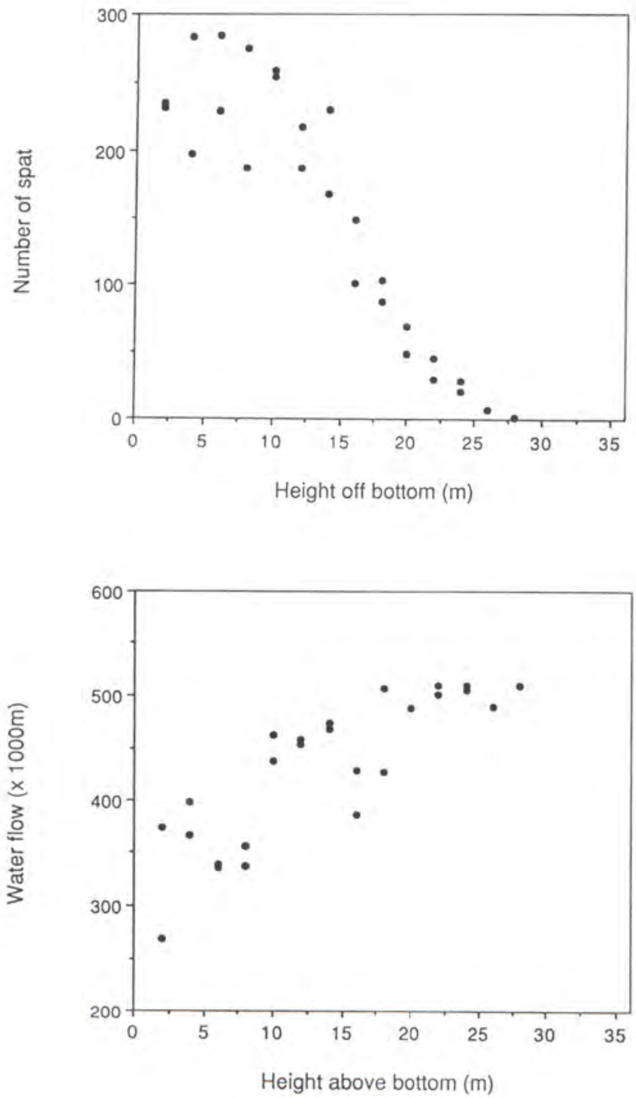

Figure 5. Height above the bottom versus number of spat in collector bags.

Most settled spat were found from 2 - 14 m above the sea bed, thereafter decreasing towards the surface (fig. 5a). The plaster-of-paris balls indicated decreased waterflow with increasing depth (fig. Sb), and the estimated flow rate was significantly negatively correlated with the number of settled spat (n = 26, $R^2 = -0.52$, $p < 0.05$).

DISCUSSION

In a similar study of diel vertical migrations of larval *Placopecten magellanicus,* Tremblay and Sinclair (1990 a) observed small-scale vertical movements of 3 to 4 m towards the surface at night in a shallow embayment of less than 25 m water depth. By contrast, in open oceanic conditions on Georges Bank, the larval distribution of the same species was related to water column stratification (Tremblay and Sinclair, 1990 b). A Phototaxis response was experimentally induced in *Pecten maximus* larvae by Kaartvedt *et al.* (1987) who reported a strong vertical migration in plastic tanks exposed to light. By contrast, Mann (1985) could not positively identify any diurnal migration related to phototactic behaviour or to food levels in bivalve larvae on the New England shelf, concluding that water column stratification might account for most of his observations. Our observations suggest that in *P. fumatus* there is no evidence for mass diurnal vertical migration, as during all sampling periods the centre of mass of the larvae was consistently found between 18 and 25 m above the bottom. This did not coincide with the depth at which most spat settled, which was from 2-14 metres above the bottom where least water flow was observed through spat bags.

These results lead to the conclusion that in this area (Great Oyster Bay) most larvae of *P. fumatus* spend their larvae life disposed between 18 and 25 m above the bottom. However when settling, they sink towards the relatively still bottom water where they preferentially settle and metamorphose into spat.

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ABSTRACTS

LARVAL GROWTH AND BYSSAL DRIFTING OF SCALLOP SPAT

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Abstract. *The duration of larval life of scallops and the potential for secondary dispersal by "bysso-pelagic drifting" are important considerations for management models of scallop fisheries.* ***Pecten maximus*** *veliger larvae were grown at 9, 12, 15 and 18°C to determine the effect of temperature on the duration of the veliger stage. Although growth rates achieved were lower than previous reports in the literature, Q_{10} values over the range 12-18°C were similar to other studies. Based on our data, and data from the literature, we estimate that the length of veliger life may range from 78 days at 9°C to 24 days at 18°C. Both* ***P. maximus*** *(laboratory reared and wild caught) and* ***Aequipecten (Chlamys) opercularis*** *(wild caught) spat exhibited byssal drifting when dropped down a 2.3. m column of water. Only smaller specimens of* ***P. maximus*** *(250-530 µm shell length) demonstrated this behaviour, but A. opercularis spat up to 1.4 mm were able to produce a byssal drifting thread. Dispersal times used in scallop fisheries recruitment and management models can now be adjusted to take into account sea surface temperatures and the potential for byssal drifting (which differs between species). Further studies are clearly needed to determine how frequently, and under what circumstances, byssal drifting behaviour is initiated.*

TROPHIC RELATIONSHIPS BETWEEN THE GONAD INTESTINAL LOOP AND DEVELOPING GAMETES IN *Pecten maximus*

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Abstract. *Ultrastructural, histological and histochemical studies were performed on the gonad and gonad intestinal loop of adult* ***Pecten maximus*** *at various intervals during the reproductive cycle in St Brieuc Bay, France, in order to better understand the sources and transfers of energy to developing gametes in scallops. The epithelium of the gonad intestinal loop of* ***Pecten maximus*** *appears to have a high cell turnover rate, and is capable of both extracellular and intracellular digestion. Anatomical evidence is presented for the direct transfer of metabolites from the gonad intestinal loop to the developing gametes, in particular via vesicular cell-haemocyte couples, which appear to follow fibrous pathways within the loose connective tissue extending from the base of the intestinal epithelium to the acini. Autoradiographic studies are currently in progress to further test this hypothesis.*

THE EMBRYOS DENSITY AS QUALITY INDICATOR IN THE HATCHERIES

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Abstract. *In the hatcheries the embryos produced by the scallop* ***Pecten maximus*** *are highly variable in quality. A test, we have developed, allows the prediction of the embryos capacity to develop in larvae and postlarvae. It is based on the cells separation in relation with their density. We describe here the methodology followed.*

SPERMATOGENESIS OF THE JAPANESE SCALLOP *Mihyzopecten yessoensis* (JAY) AS A MODEL FOR ESTIMATION OF GONADOTROPIC ACTIVITY OF CHEMICAL COMPOUNDS.

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Abstract. *A major indicator of the physilogical activity of test chemical is its possible effect on the reproductive function, spermatogenesis in particular. Morphological methods using traditional laboratory animals have an important part in study of the above properties of chemical compounds. However, the existence approaches do not allow reliable evaluation of the effect of test compounds on selected stages of gametogenesis. This drawback can be avoided by the use of male Japanese scallops as test objects. The main advantage of this mollusc is that its sexual cycle is strictly synchronized, while the spermatogenesis pattern and the composition of spermatogenous cells are the same as in all animals. The development of the sex cells in male Japanese scallops takes a year and proceeds step-wise. After spawning, the proliferation of gonia in gonad is consecutively followed by the maturation of spermatocytes I, spermatocytes II and the formation of spermatides and spermatozoa. Thus, at a definite time of the year, the testis contains spermatogenous cells of one type, which allows differentiated evaluation of the effect of test chemical compounds on selected processes of spermatogenesis. We have used this model for determination of the effect of several groups of chemical compounds. This study provides specific data on the character of the gonadotropic effect of compounds. This encourages us to recommend spermatogenesis of the Japanese scallop as a test process in differentiated evaluation of changes in the proliferative activity of gonia, genesis of spermatocytes I, spermatocytes II, spermatides and spermatozoa under the influence various chemical compounds.*

EFFECT OF PHOTOPERIOD ON THE CONTROLLED REPRODUCTION OF *Pecten maximus*

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Abstract. *This paper shows that the scallop, **Pecten maximus** reproduction is clearly influenced by photoperiod. A long daylight (16 hours) accelerates the gametogenic activity compared to a short one (8 hours). The direct consequence is a higher number of viable larvae produced. As a consequence, the scallops which reproduction normally occurs in July - September may spawn in January - February after 2 months acclimatation under 16 LD. The strain of scallops which are mature all the year round is twice more fecund after such treatment under long daylight. As a consequence whatever the strain considered is, the production in viable larvae may be increased in winter. Such treatments don't alter the survival and growth rates.*

OOCYTIC PATHWAY DURING SPAWNING IN *Pecten maximus* (MOLLUSCA, BIVALVIA).

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Abstract. *The examination of serial sections of overall genital gland-kidneys-digestive gland, from a scallop **Pecten maximus** fixed for histological study at the beginning of spawning, allows to describe the oocytic pathway during spawning. The presence of oocytes in the gonoducts facilitates the reconstitution of the genital tract. According to their localization in the gonad, the oocytes are evacuated from acini into sea water by gonoducts of one of the two oocytic ways. These ways are independent in nearly the whole gonad; each is constituted by two main oocytic collectors in the female gonade and by only one in the male gonad. The two collectors of the male gonad join up at the proximal extremity and form a short gonoduct that discharges all the oocytes into the right kidney. One part of these oocytes is evacuated directly in sea water by the urogenital orifice of this kidney. The other part is propulsed into the left kidney through an inter-renal communication located in front of the digestive gland, then evacuated in sea water.*

CHAPTER 4.

GROWTH - METABOLISM - NUTRITION - GENETIC
CROISSANCE - MÉTABOLISME - NUTRITION - GÉNÉTIQUE

8th International Pectinid Workshop. Cherbourg (France) May 22-29, 1991
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USE OF EXTERNAL SHELL MICROGROWTH PATTERNS FOR DETERMINING GROWTH AND AGE IN THE SCALLOP, *Pecten maximus* (L.)

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Abstract : *Shell growth in* **Pecten maximus** *involves the deposition of microgrowth increments (striae) which form cyclical patterns of width and abundance on the exterior of the flat (left) shell valve. The extent to which striae patterns represent annual growth cycles, and thus also measure age, was confirmed (and local problems highlighted) using 10 shells that had been aged accurately by stable oxygen isotope analysis.*
Striae pattern analysis was then applied to large samples of shells from fisheries in the English Channel and Irish Sea. In the western Channel, where external rings are not reliably interpretable by traditional macroscopic methods, striae analysis provided much more accurate estimates of growth and age parameters by distinguishing between true winter zones (annual growth checks) and supernumerary or spurious rings (disturbance checks). Many shells in each fishery could not be used, however, because striae patterns had been destroyed by shell damage, or obscured by abrasion, fouling organisms or excessive shell thickening.

Key words : *Shell striae, growth, age, scallop, Pecten maximus.*

INTRODUCTION

The determination of age and growth in the European scallop *Pecten maximus* has been based traditionally upon macroscopic interpretation of annual (winter) rings often visible on the external surface of the flat, upper (left) valve. This method is prone to considerable subjective error and bias when applied to this species in British waters, and particularly in the western English Channel where most scallops have indistinct true rings as well as several spurious rings (Dare and Deith, 1989). There, stable oxygen isotope analysis of shell carbonate was found to provide accurate location of winter 'ring' positions (Dare and Deith, 1989).

The high cost and time demands of this technique, however, preclude its wide application. In searching for a cheaper and simpler method for large-scale use, attention focused on the external microgrowth patterns on the flat valve. These patterns are formed from successive minute growth increments laid down as ridges or striae in an annual cycle ; the numbers, widths and frequency of striae produced vary with age and size of scallop and with season (Antoine, 1978 ; Franklin and Pickett, 1980 ; Gruffydd, 1981). This paper reports preliminary results from a study to assess the reliability of this technique, particularly for scallops in the large western English Channel fishery. Isotopic data from the earlier study are used to validate the method and to highlight problems with interpreting microgrowth patterns.

MATERIAL AND METHODS

Initial validation of the method was undertaken using 10 scallop shells from the earlier isotope studies. Subsequently, 1700 specimens (28 samples) were examined from three fishery areas : (i) English Channel, west - between Lizard Point and Plymouth ; (ii) English Channel, east - 25 nautical miles south-west of Beachy Head ; (iii) Irish Sea - 10 mm south of the Isle of Man.
The external surface of the left, upper valve was scrubbed and then examined damp under a binocular microscope using transmitted light at x 20 to x 50 magnifications. Observations were made in the radial grooves along, and close on either side of, the median axis of dorso-ventral (height) growth from the umbo to the growing edge. Linear measurements of growth were confined to the median line.
Interpretation of striae patterns was assisted by the earlier experimental studies (Antoine, 1978 ; Franklin and Pickett, 1980 ; Gruffydd, 1981), and by reference to the analyses of microgrowth bands observed in sectioned shells of other lamellibranchs (e.g. Richardson et al., 1990). The annual cycle of *Pecten* shell formation produces striae that are narrowest and most closely crowded together during the coldest months, when growth is slowest, or ceases. The next annual growth increment then comprises an increasing production and widening of new striae as shell deposition accelerates in spring and summer, followed by progressive narrowing again as the next winter is approached and striae size and production rate decline. Three examples are shown in figure 1.

Table 1. Numbers of *Pecten maximus* shells examined, and the proportions discarded because striae patterns were obscured or disrupted by various factors.

1. damaged shells - broken and repaired frequently ; often at or close to winter striae zones during years 4-10.
2. opaque shells - either too thickened or densely pigmented.
3. fouled shells - by encrusting or boring organisms.
4. faint striae - no discernible winter zonation during one or more winters of years 2-5.

	Average Percent of Unreadable shells per sample					
Area	No. shells (samples)	Total	Damaged	Opaque	Fouled	Faint striae
English Channel (W)	1,160 (16)	36	17	2	0.7	17
English Channel (E)	112 (4)	52	15	7	26	4
Irish Sea	428 (8)	59	37	20	0.5	1
	1,700 (28)					

This sequence of gradually narrowing, and then expanding, striae either side of a winter zone was distinguishable from short-term slowing or interruptions of growth due to extraneous disturbing factors. The latter (Richardson et al., 1990) are characterised by sudden narrowing and recoveries of striae width, sometimes accompanied by visible discontinuities in shell deposition.
Annual growth increments were measured with calipers between the mid-points of successive winter zones of narrow striae, the number of zones thus providing a measure of age.

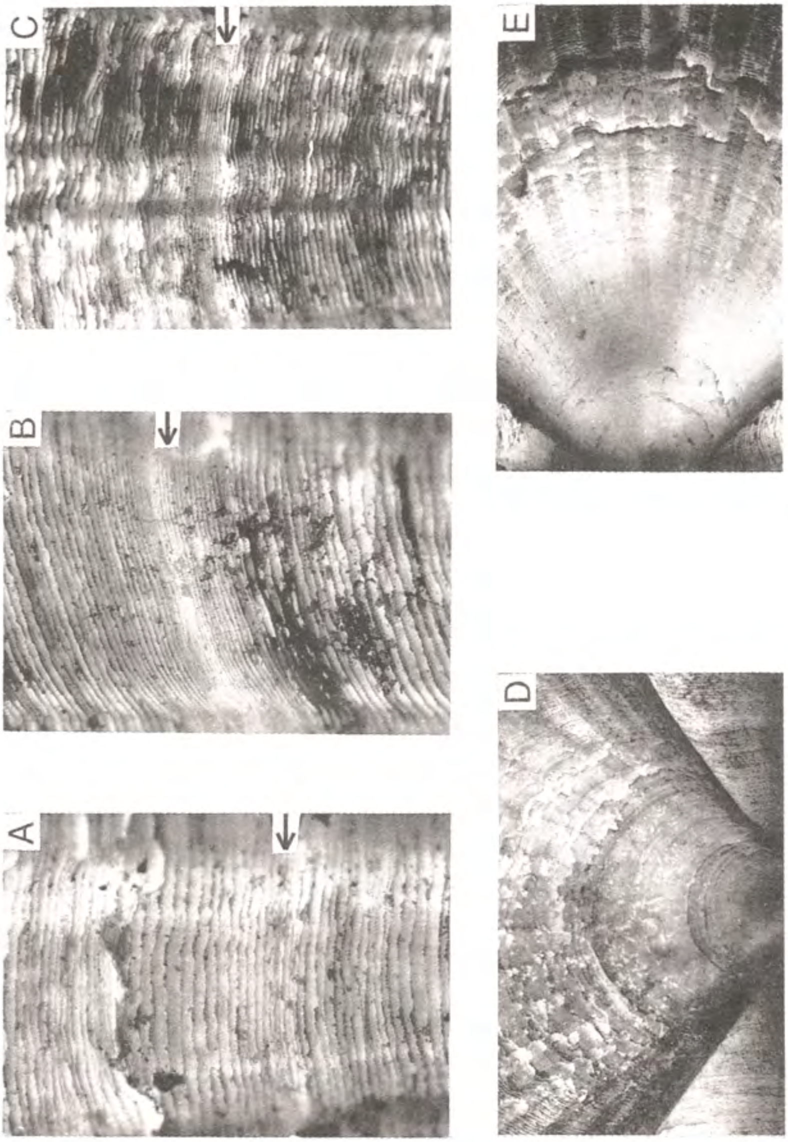

Figure 1. Photomicrographs of 5 left (upper) valves of *Pecten maximus* shells from the western English Channel, showing striae patterns in the median radial grooves (A-C) and damage near the umbonal region (D,E). A. faintly marked 2nd winter striae zone (arrowed) with disturbance distally caused by damage to the growing edge ; B. 3rd winter zone ; C. 4th winter zone ; D,E damage and disturbance to the spat shell. Plates A-C are orientated with the umbonal direction at the bottom (striae laid down from bottom to top).

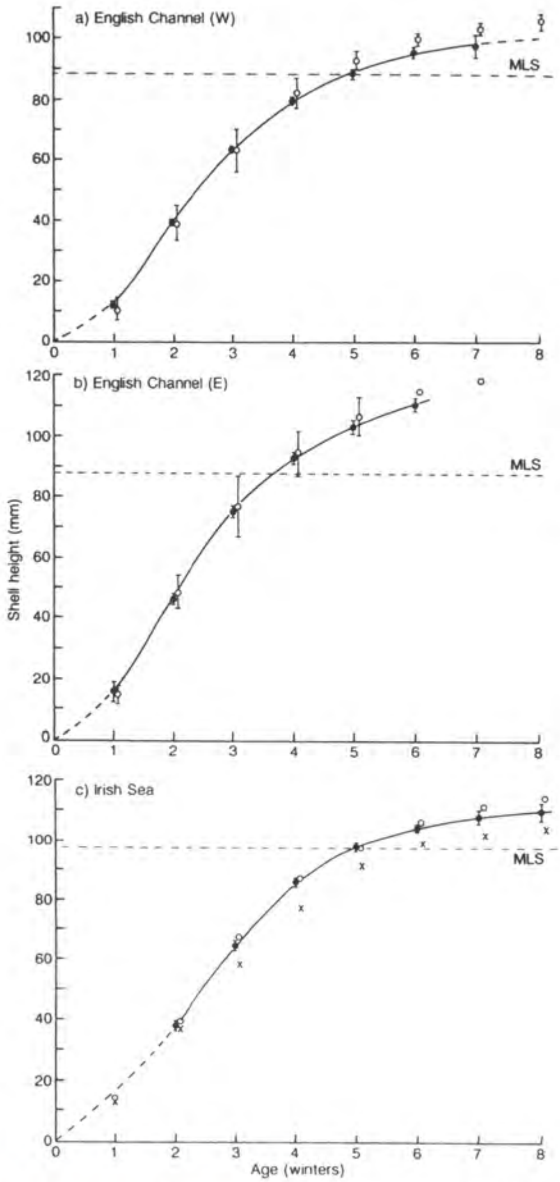

Figure 2. Shell growth curves of *Pecten maximus* derived from striae pattern analysis (•) and from stable oxygen isotope analysis of shell carbonate (○), for scallop stocks in:
(a) English Channel, west, (b) English Channel east, (c) Irish sea

RESULTS

Sampling problems - Striae analysis requires microgrowth patterns not to be obscured or disrupted by shell damage, excessive thickening or abrasion, or by fouling and boring organisms. In fact, high proportions (36-59%) of scallop shells collected from each area had to be discarded, chiefly due to repeated damage - apparently from dredges and beam trawls - and which coincided usually with winter zones (Table 1). In the western Channel, 17% of otherwise intact shells were not interpretable because of indistinct winter zonation, presumably indicating only a gradual reduction of growth during winter.

Isotopic validation - Only 10 of the 22 isotopically aged shells could be used to test the accuracy of striae interpretation ; 12 shells were either too badly scarred by removal of powder samples, were otherwise damaged, or were too densely pigmented and opaque. Two further problems arose during microscopic examinations of the test shells :

(a) 1st winter zone: The isotopic study (Dare and Deith, 1989) had shown that this ring was not reliably detectable on any scallop by the traditional method ; it was always located in the pale, smooth, umbonal depression between 2 mm and 22 mm from the umbo itself. Unfortunately, this region had been destroyed on test shells by the isotopic sampling method.

(b) 2nd winter zone : The isotope study showed that this zone also occurred in the umbonal depression on some shells, in which case it too could escape visual detection.

Excluding the problematic first-winter zone, for which allowance was made, the results from the 10 shells fell into two groups (table 2) according to the concordance between striae patterns and isotopic data.

(A) good agreement : for 6 shells the estimated positions of second to fifth-winter striae zones were within 2 mm of isotopically predicted positions. For sixth and later winters, shell damage obscured the patterns.

(B) poor agreement : for 3 shells (all western Channel) there was a complete mismatch due to the second-winter zones also being overlooked because they were located within the umbonal depression, at 25-27 mm from the umbo according to isotopic data (see also Dare and Deith, 1989). Consequently, true age was under-estimated by two years. Repeated shell damage obscured most striae zones for the sixth and later winters in these three specimens.

Table 2. : The locations of winter ring positions on 10 shells of *Pecten maximus* as determined by stable oxygen isotope analysis (O) and by microscopic examination of striae patterns (S). Locations are distances (mm) from the umbones).

Notes : ? = no data, position destroyed by sample removal for isotope analysis.
* = shell surface too smooth for striae to be visible.
d = striae patterns destroyed or disrupted by repairs to damaged shell.

Area	winter	1		2		3		4		5		6		7		8		9	
	Shell	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
A. Good agreement : English Channel E	A	10.5	?	44.5	48.5	75	76.5	93	93	102	102.5								
English Channal W	G/A	10.0	?	42.0	41.0														
	G/B	15.0	?	44.5	44.5														
	G/C	10.5	?	39.0	39.0	64	61												
Irish Sea	A	13.0	?	37.0	35.0	58	58	77	77	91	92	99	99	102	104	104	d		
	B	14.0	?	39.0	38.0	67	67	87	88	97	98	106	d	11	d		114	d	
B. Poor agreement English Channel W	C	2.0	?	27*	54.0	52	69	75	88	88	d	96	d	99	d	103	d	105	d
	E	2.0	?	27*	44.0	60	72	77	91	92	100	99	d	103	ds	109	d		
	F	1.5	?	25*	44.0	46	67	72	84	86	97	97	101	102	d	107	d		
	3	22.5	?	57.5	52.0														

Growth parameters from striae patterns - The above criteria were applied to interpret striae patterns of the 771 usable shells obtained from the three *Pecten* populations. Few estimates of first winter zone locations were obtained due to polishing or abrasion of the umbo region by sand grains, or to frequent micro-damage (fig. 1, D-E). Derived growth curves and von Bertallanffy parameters for these samples are compared with those calculated from earlier isotopic data in Figure 2 and Table 3. An ANOVA performed on the data plotted in Figure 2 showed that there were no significant differences at the 5% level between the striae and isotopic values of size at age in any sea area. Thus, for the western Channel, $F_{1,1233} = 2.37$; eastern C., $F_{1,178} = 3.42$; Irish Sea, $F_{1,566} = 1.69$. It is concluded, therefore, that striae pattern analysis can provide valid estimates of growth in these three populations.

DISCUSSION

The validation test, using a few isotopically aged shells, indicated inherent problems with interpreting striae patterns. These concerned detecting the true positions of all first and some second winter zones. The former difficulty applied to every stock but it could be obviated by accepting that, in fact, the first detectable winter zone more than 25 mm from the umbo would be the second-winter zone. This assumption did not introduce any major errors, or significant differences between the growth parameters calculated from striae patterns (large samples) and from isotopic analysis (fig. 2, table 3).

Table 3. : Growth parameters for *Pecten maximus* from three fisheries, estimated by analysis of (A) microgrowth patterns, (B) stable oxygen isotopes in shell calcite.

(b) English Channel, east, (c) Irish Sea (isotope data for only 2 shells (O and X)).

Vertical bars denote 95% confidence limits. MLS = minimum legal size.

	A. Microgrowth patterns				B. Isotope analysis			
Fishery Area	L. +/-(s.e.)	K	to	(n)	L +/-(s.c.)	K	to	(n)
English Channel, E	132.4 (7.0)	0.35	0.66	(43)	133.1 (2.9)	0.37	0.70	(6)
English Channel, W	109.0 (3.3)	0.38	0.72	(586)	115.4 (2.9)	0.37	0.78	(15)
Irish Sea	115.1 (1.3)	0.48	1.19	(152)	123.7 (5.0)	0.32	0.69	(2)

Non-detection of the second-winter striae zone could be more serious though likely to occur only on shells where it is located in the smooth umbonal depression. This potential problem appears to be confined to the western Channel scallop stocks, in which an unusually prolonged spawning season results in some spat settling late (in mid-autumn) and then overwintering at very small size; their second-winter ring is then also within the umbonal depression (Dare and Deith, 1989). The scale of this error source will depend upon the proportions of late-settled scallops in samples. In practise, the striae growth data obtained by combining sub-samples of shells from this fishery agreed closely with the isotopic data (fig. 2), suggesting that slow-growing late settlers were probably too few to have much effect on the population mean growth curve. The growth parameters (and age estimates) from these large samples also matched the isotopically derived data far better than did data obtained from traditional reading of macroscopic rings (see data *in* Dare and Deith, 1989). In consequence, striae pattern analysis has now been adopted as the only practicable method for obtaining realistic growth and age data for western Channel scallops. It will be used also in our other English Channel fisheries, as well as the Irish Sea, despite the high discard rates in samples due to various shell defects.

The physical features of macroscopic rings and of striae zonation in this species seem to be influenced by environmental factors. In the western Channel populations, lack of a conspicuous and obviously age-dependent ring pattern reflects the often weak zonation of winter striae, especially in the second and third winters. This is exacerbated by frequent growth checks in later winters, caused apparently by impacts from heavy fishing gears (dredges and beam-trawl chains). In this area, where minimum bottom temperatures seldom fall below 9°C, isotopic data showed that juvenile scallops may scarcely cease growing in winter (Dare and Deith, in prep). Conversely, in the eastern Channel and in the Irish Sea, where average temperature minima are much lower (5.7°C and 7.1°C, respectively, for the coldest months), the isotopic data showed a cessation of growth in winter. In both these areas, scallop shells tend to have a more clearly demarcated winter striae zonation which coincides with generally obvious rings.

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DETERMINATION OF TEMPERATURE CONDITIONS OF GROWTH IN SEA SCALLOPS BY THE CALCIUM-MAGNESIUM METHOD

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Abstract : *Magnesium content and Ca/Mg ratio of shell calcite were studied in four common sea scallops as a function of environmental temperature. It was found that linear relations between temperature and Ca/Mg ratio in shell carbonate differed among different species. Fluctuations of magnesium content in scallop shells were synchronous with changes in sizes of elementary growth layers of the external surface of valves, this observation was useful for determination of seasonal and optimal growth temperatures in sea scallop.*

Key words : *Ca/Mg ratio, sea scallop, growth temperatures.*

INTRODUCTION

Along with isotope-oxygen method, an approach based on linear correlation of the magnesium content and Ca/Mg ratios of shell carbonate and environmental temperature is used for determination of growth temperatures in marine invertebrates (Chare, 1954, Dodd, 1967, Pozdnyakova and Silina, 1985). The study used the scale of recalculation of Ca/Mg ratios to temperatures proposed by Berlin and Khabakov (1966). However, different invertebrate species can accumulate different amounts of magnesium, this makes it impossible to use one scale of reconstruction of growth temperatures from the Ca/Mg ratio.

Correspondingly, we have studied the pattern of the magnesium content and the Ca/Mg ratio in the shell calcite of some common scallop species of commercial value in order to determine seasonal and optimal growth temperatures.

MATERIAL AND METHODS

Four sea scallop species of the family *Pectinidae* have been studied : Mi*zuhopecten yessoensis* and *Swiftopecten swifti* from coastal waters of Primorye, southern Sakhalin (depths of 3-40 m) in the Sea of Japan; *Chlamys albida* from Paramushir Is. in the Sea of Okhotsk and *Chlamys islandica* from the Barents Sea (20-25 m) and the Kara Sea (32 m). To study the dynamics of the magnesium content, Ca/Mg ratio and growth temperature in ontogenesis of the scallops, the shells were divided into concentric portions in accordance with changes in growth rates detected in elementary growth layers (Silina, 1978). Chemical analysis of calcite samples of the separated shell portions of the outer prismatic layer of scallop shells was performed with the use of complexonometric titration and atom-absorption spectrometry (Krasnov and Pozdnyakova, 1982). The relation of oxygen isotopes $^{18}O/^{16}O$ was determined on a mass-spectrometer MI-1309.

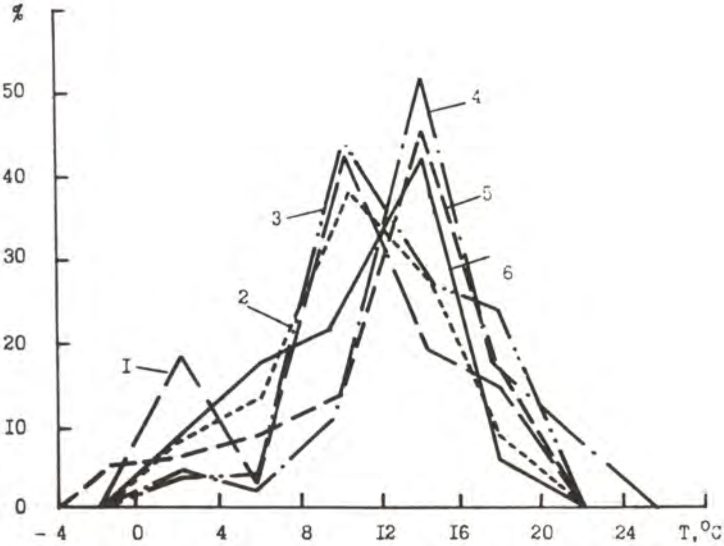

Figure l. Seasonal fluctuations in the width of elementary growth layers (a) and growth temperatures (b) determined by the calcium-magnesium method for shells of *Mizuhopecten yessoensis* from Vladimir Bay (Sea of Japan), depths of 2-3 m. Roman figures used for months.

RESULTS

We found similarity in the ranges of fluctuations in magnesium content and Ca/Mg ratio in the outer calcite layer of shells of the scallops studied : minimal values for Mg content were in the range of 0.08-0.10 % and 90-150 for Ca/Mg, maximal estimates for Mg was 0.28-0.40 % and for Ca/Mg 380-470, although environmental temperatures in habitats of *M. yessoensis* and S. *swifti (*from-2 to +23°C) differed significantly from temperature conditions of *Ch. albida* and *Ch. islandica* (0-8°C). Comparison of magnesium contents and the values of Ca/Mg ratios in carbonate samples of shell edges formed at different temperatures and comparison of the curves of seasonal dynamics of magnesium contents and Ca/Mg ratios with temperature curves plotted by the oxygen isotope relations gave us a linear correlation between the magnesium content, Ca/Mg value and temperature. In all the species studied, Mg content increased and the Ca/Mg ratio decreased with temperature rise; taxonomic differences were evident: for M. y*essoensis* T=27.30-0.0661 Ca/Mg, for S. *swifti* T=26.20-0.0670 Ca/Mg, for *Ch. albida T=*9.73-0.02713 Ca/Mg, and T=8.51-0.0243 Ca/Mg for *Ch. islandica.* Using the equation of linear correlation between Ca/Mg ratio and temperature fluctuations, we calculated seasonal growth temperatures for the scallop : species studied. Growth temperatures of *M. yessoensis* varied from -2 to 22°C, which corresponded to environmental conditions in their habitats and confirmed that the shells grow all the year round. Calcite samples taken from broad seasonal growth layers with minimal Mg contents and highest Ca/Mg values gave low winter temperatures, while samples from narrow daily growth layers forming in summer with maximal Mg contents and minimal Ca/Mg ratios gave maximal temperatures (fig. 1). Collation of temperatures with the widths of elementary growth layers can be used for reconstruction of growth temperatures in any month. The ranges of growth temperatures of -2 to 20°C calculated for *S. swifti* correspond to annual variations in their natural habitat, but maximal values were somewhat lower than in *M. yessoensis.* Maximal temperatures were calculated for samples taken in the basis of the valve ledge, which correspond a renewal of intensive growth of shells in height in August-September. Minimal winter growth temperatures were obtained for the flat portion of shells, nearer to the last ledge. In *Ch. albida,* variations in the width of elementary growth layers, Mg content and Ca/Mg ratio were synchronous, and so were also the calculated values of growth temperatures. Broad growth layers light in colour (in mature individuals they slightly overlap also dark-coloured layers) correspond to minimal values of Ca/Mg ratios and maximal summer temperatures. Linear growth rates in *Ch. albida* are maximal in the period. Narrow growth layers form in winter at minimal environmental temperatures. Similarly, in *Ch. islandica,* broad elementary growth layers form also at maximal summer temperatures of 6-8°C, and narrow layers at -1 to 0°C in winter. In spite of the fact that the range of water temperature fluctuations in *Ch. albida* and *Ch. islandica* habitats was narrow, from -1 to 6-8°C, the calcium-magnesium method revealed seasonal dynamics in their growth temperatures. The amplitude of growth temperature fluctuations faded with molluscan age.

DISCUSSION

Thus, although the ranges of fluctuations in Mg contents and Ca/Mg ratios during ontogenesis were similar for the scallop species studied, the values of their growth temperatures estimated by species scales correspond to environmental annual growth temperatures. The estimated range of growth temperatures for sea scallops is generally narrower than the range of temperature fluctuations, this creates some difficulties in estimating the highest and the lowest values. The width of elementary daily growth layers under extreme conditions is very small, therefore, to obtain a sufficient weight of a sample for chemical assay we have to combine layers formed not only at maximal or minimal but also at moderate temperatures in one sample. With growth of the animal, the growth temperature range becomes narrower, as the number of samples taken for analysis from each annual layer reduces.

The estimated growth temperatures can be represented as variation curves of the values of shell increments as a function of environmental temperatures (fig. 2). An analysis of the curves thus obtained showed that the maximal shell increment corresponds to relatively narrow range of temperatures. In the studied specimens of *M. yessoensis,* 33.3-48.3 % accretion of the shell occurred at 12-16°C, in *S. swifti* -36.8-44.5 % at 8-12°C.

Chlamys albida and *Ch. islandica* show maximal increment at 4-6°C. i.e. in summer months, at maximal water temperature in their habitat. Our observations confirm the suggestion on species-specificity of optimal growth temperatures for carbonate skeletons of marine invertebrates (Zolotarev, 1975).

Study of seasonal dynamics of growth temperatures for scallop shells with respect to sculpture marks on the shell surface opens a possibility to determine exact age of each individual, which is necessary for estimations of linear growth rates of molluscs in different seasons of the year.

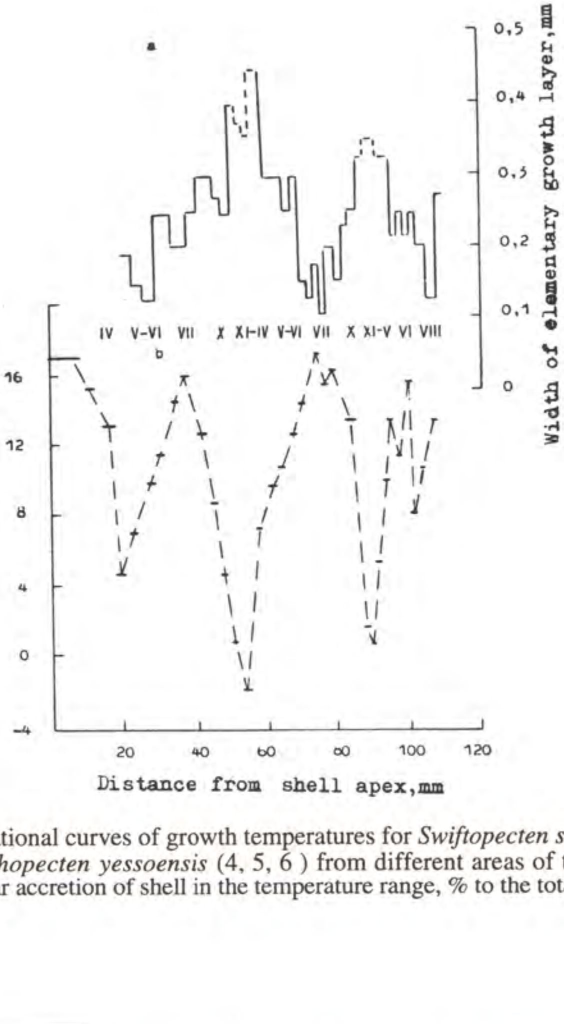

Figure 2. Variational curves of growth temperatures for *Swiftopecten swifti* (1, 2, 3) and *Mizuhopecten yessoensis* (4, 5, 6) from different areas of the Sea of Japan. Linear accretion of shell in the temperature range, % to the total shell length.

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A STUDY 0F THE INDIVIDUAL AGE AND GROWTH IN SEA SCALLOPS BY THE MICROSCULPTURE OF THE OUTER SHELL SURFACE

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Abstract : *Microsculpture of the outer shell surface in different species of the* ***Pectinidae*** *scallops is observed as broad and narrow microrings - elementary growth layers detectable visually or under a binocular microscope. Elementary growth layers are specific for scallop species. They may be one or more types on one valve. The distance between microsculpture elements (the width of elementary growth layers) of all types from umbo towards the shell edge increases and decreases periodically. Annual patterns of the formation of elementary growth layers have been revealed for eight species. They are useful in determination of scallop's age and growth.*

Key words : *Age, growth, microsculpture, scallop, growth layer.*

INTRODUCTION

Knowledge of sea scallop growth rates and size-age characteristics of their populations in different regions is necessary for analysis of production properties of species, for forecast of reproduction of wild, commercially exploited populations and for selecting optimal sites for cultivation. However, there are no sufficient and reliable techniques available for determination of individual age and growth rates in scallops. It is known that longitudinal sections of bivalve mollusc shells reveal growth layers formed under periodical changes of environmental conditions. These layers are used for determination of the age and growth rates in some mollusc species. In scallops of the family *Pectinidae*, such a chronological record is revealed on the outer surface of shells in the shape of microsculpture specific for each scallop species. Therefore, it is necessary to investigate periodicity and regularity in formation of microsculptural elements during the year in order to ascertain possibility of their use for age and growth determinations in different species.

MATERIAL AND METHODS

Swiftopecten swifti, *Chlamys rosealba*, and *Ch. farreri* were collected on the north-western shores of the Sea of Japan, *Mizuhopecten yessoensis* - from Japan and Okhotsk seas, *Ch albida*, *Ch. stratega* and *Ch. behringiana* from the coasts of the Kurile Islands. *Ch. islandica* samples were taken from the Barents and Kara seas and *Patinopecten caurinus* and *Ch. hastata* from the shores of British Columbia (Canada). We counted and measured concentric microrings of the outer sculpture of shells (elementary growth layers) parallel to the growing margin under binocular microscope at 20X magnification. For scallops collected in different year seasons (*M. yessoensis,* and *S. swifti*), we compared the appearance and width of growth layers on the shell edge. For other species which were not sampled seasonally, we used the isotope-oxygen (Epstein et *al*., 1951) or calcium-magnesium (Dodd, 1967) methods of thermometry to determine the season of formation of different shell areas (with specific microsculpture).

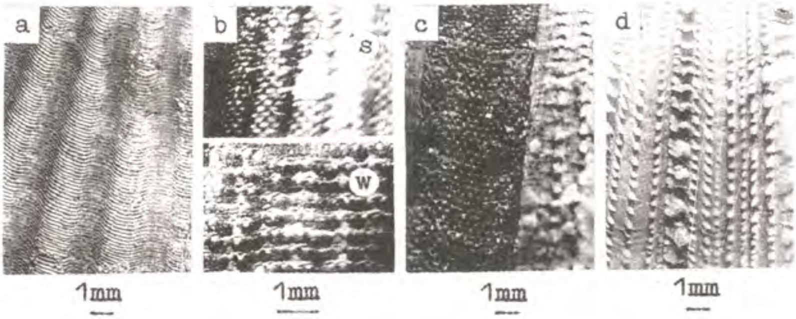

Figure l. Elementary growth layers on the outer surface of the shells
a - *Patinopecten caurinus*, b - *Swiftopecten swifti*, c - *Chlamys stratega*, d - *Ch. hastata* (s - elementary growth layers formed in summer, w - the same, in winter).

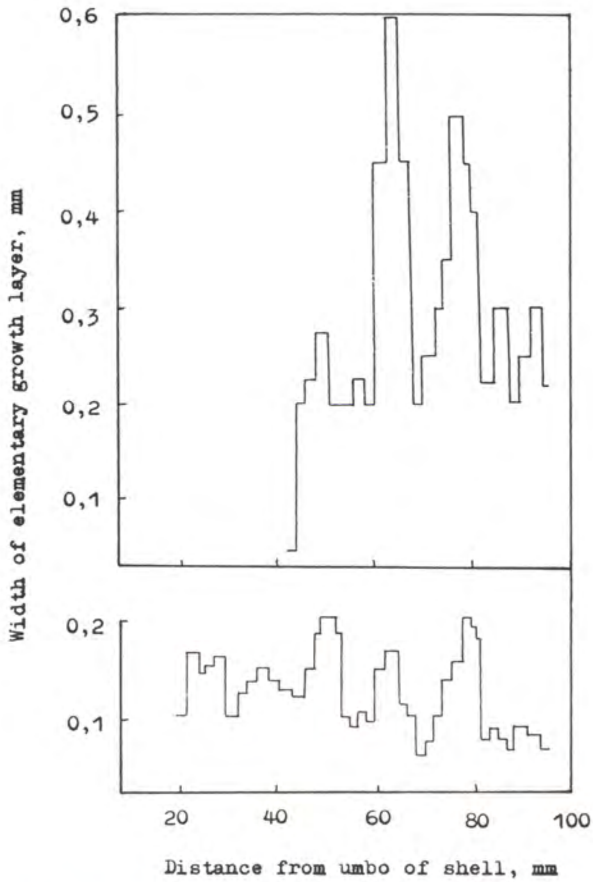

Figure 2 Seasonal changes in width of elementary growth layers of different types on the outer surface of the shell of *Chlamys islandica*

RESULTS

Microsculpture of the outer surface of shells in different scallops species is formed as broad and narrow microrings (elementary growth layers) detectable visually or under a binocular microscope. Microsculptural elements of the borders of these layers are species specific. Moreover, for some species only one type of elementary growth layers was revealed, as for *P. caurinus* (fig. 1a). In the microsculpture of this species, one growth layer forms within about a day, narrow in the cold time of the year and broad in warm months (Silina et *al.*, 1988). Some scallop species have periodical changes in the type of elementary growth layers as the shell grows. For example, *M. yessoensis* and *S. swifti* form one broad elementary growth layer every 5-7 days during November-April when water temperature is below 4-6 °C, and a narrow one nearly every day during the rest of the year. The layers differ in appearance (fig. 1b). It should be noted that *S. swifti* forms also shell macroledges during April-August (Silina, 1978; Ponurovskii, Silina, 1993). In other scallop species, two types of elementary growth layers form on the valve surface simultaneously during the scallop's life. Thug, the shell microsculpture in Ch. islandica, *Ch. albida*, *Ch. behringiana, Ch. stratega* and *Ch. rosealba* is characterized by formation of elementary growth layers of the first type with borders marked by spines on rib surfaces, and those of the second type with thin wavy borders that all together form a small network in the intercoastal spaces (fig. 1c). The network in *Ch. stratega* is formed also on rib surface. The period of formation of layers of the first type is about two weeks. The layers of the second type are formed more often (Silina, Pozdnyakova, 1986, 1990). Growth layers on both types decrease in width simultaneously in the cold year season (fig. 1c, 2). In these scallop species spines are produced simultaneously on the all ribs of the shell, but on *Ch. hastata* and *Ch. farreri* shells spines are formed less often on greater ribs (fig. 1d). However, in both cases the width of growth layers marked by spines on larger or smaller ribs changes simultaneously during the year. This allows us to determine the individual age of the mollusc by counting the number of shell rings, for example, with narrow growth layers (if it's known that they are formed in the definite season of the year). Measuring the height of the shell from the apex to portions of thick growth layers, we can investigate the size-age relationship and linear growth rate of each individual in retrospect.

DISCUSSION

The suggested method for determination of age and growth rate of scallops by the microsculpture of the outer surface of their shells allows us to investigate some developmental problems of biological objects and to use it for applied purposes. Thus, comparison of growth rates in scallops of different species and populations helps to establish species and regions which are prospective for cultivation. Analysis of the age structure of populations is necessary for estimation of a possible level of the scallop catch from sites of its habitat. Comparison of the values of linear increments of scallop shells (width of elementary growth layers) formed for known periods of time in different environmental conditions gives the possibility to reveal optimal and unfavourable parametres of the environment for scallop growth. Specific signs in the microsculpture of cultivated scallops (for example, a sign of shell break at replacement of molluscs from the nurse-cages to the bottom) is useful for distinguishing introduced individuals from resident specimens and for comparison of growth rates in scallops settled in different years or seasons and with various height of the shell.

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SOME ASPECTS OF THE POST HARVEST PHYSIOLOGY OF THE SCALLOP *Pecten maximus* (L.).

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Abstract *: The physiology of the scallop,* ***Pecten maximus*** *during aerial exposure is currently being investigated. Survival in air was found to be temperature dependent; values for EL50 were 118 h at 5°C but this decreased to only 39 h at 20°C. Rates of oxygen consumption in air were reduced by up to 80 % of the rates recorded in water indicating a switch to anaerobic metabolism. A pronounced increase in the number of bacteria in fluid retained within the mantle cavity occurred during aerial exposure. A prerinse in antibiotics, however, controlled bacterial numbers and enhanced scallop survival. When scallops were returned to water, their ability to recovery was dependent on the duration of aerial exposure. Recovery was very poor in scallops which had begun to gape. Shell gaping appears to be related to adductor muscle fatigue, but this does not appear to be caused by substrate (glycogen) depletion.*

Key words *: Scallops,* ***Pecten maximus,*** *aerial exposure, respiration, shell gape.*

INTRODUCTION

The scallop *Pecten maximus* is both fished and cultured on the west coast of Scotland. A premium is paid for the live, in-shell product, at home and abroad, but commercial and physiological constraints make live transportation to distant markets a potential limitation to further development of the trade.

The poor aerial survival of *Pecten maximus* compared with other intertidal bivalves which show a variety of physiological and behavioural adaptations (Coleman and Trueman, 1971; Widdows and Shick, 1985; Seaman, 1991) is well known. This project investigates the differences in physiological responses between *Pecten maximus* and other bivalve molluscs, with the aim of developing post-harvest transport conditions which optimize scallop survival.

The initial areas of investigation concentrated upon determining the duration of survival in air. In order to determine the cause of deterioration and death, an assessment of changes to the respiratory physiology have been carried out. Initial observations showed that the onset of death is associated with the onset of shell gaping. Preliminary results are presented on the causes of shell gape.

MATERIALS AND METHODS

Experiments to study the ability of *Pecten maximus* to survive periods of aerial exposure were carried out at temperatures of 1, 5, 10, 15 and 20°C and 95 % RH. Samples of 24 scallops (shell width 90-110 mm) were used and subsamples removed at intervals of 6 hours. Death was determined by lack of mantle response (Dickie, 1958). Comparisons were made between scallops placed horizontally and those placed vertically (causing mantle water to drain from the shell) and between a sample with the shell valves artificially held closed and those in which the shell valves gapes naturally.

Rates of oxygen consumption (Vo2) in water were measured with a Radiometer E5046 oxygen electrode and Strathkelvin oxygen meter in a closed respirometer chamber at a temperature of 10°C for 60 minutes. Aerial respiration was measured following the determination for aquatic respiration, using a constant pressure respirometer (Davies, 1966). Vo2 was determined for periods of 60 min at intervals of 6 h until the animals died. Respiration measurements were normalized to dry tissue weights.
During the experiments to measure aerial respiration it was noticed that after several days Vo2 began to increase. In order to determine whether this was due to bacterial growth, samples of mantle fluid were taken at daily intervals whilst the scallops were in the respirometers, and plated on to marine agar medium (Difco 2216). Colony counts were made following incubation at 20°C for 48 h and 120 h.
The effect of antibiotics in preventing bacterial growth was determined by exposing the scallops to a 0,06 $g.l^{-1}$ solution of Benzylpenicillin and Streptomycin sulphate for 90 min before measuring aerial respiration rate and survival. Effectiveness of kill of the bacteria was measured by sampling and plating samples of mantle water as before.
The frequency of adduction of the shell valves and the relationship between this and the onset of permanent gaping was measured by connecting the upper valve to an isotonic transducer whose output was displayed on a multichannel oscillograph recorder. Recordings in air at 10°C and 95 % RH. were made continuously for 20 h. To determine whether shell gape was caused by depletion of glycogen substrate within the adductor muscle, 20µm frozen sections were taken and stained with Perodic Acid Schiff's reagent (PAS). Quantitative assays of adductor muscle glycogen were also made using the method of Kepper and Decker (1974).

RESULTS

Typically there is a rapid decline in survival, usually within 24 hours of the first mortality. Survival is strongly temperature dependant (table 1). It improves as the temperature is reduces from 20°C to 5°C, to reach a maximum of 118 hours at 5°C. However, at 1°C survival time is reduced to only 70 hours. There is no significant difference in survival between drained and undrained scallops. Enforced shell closure also produced no significant effect on survival.

Table 1 : Time (h) to 50% mortality for Pecten maximus exposed to air at various temperatures, and 95% Relative Humidity. Undrained and drained scallops are syored with and without mantle cavity water respectively.

Temperature	1	5	10	15	20
Drained	79	118	89	51	40
Undrained	70	117	91	49	39

Respiration : The mean rate of oxygen uptake in water was found to be approximately 130 µl02. g^{-1} h^{-1} in animals of this size . Vo2 decreased during aerial exposure by 60-80 % before it increased again after 4-5 days. This increase was probably caused by bacterial respiration since the Vo2 of scallops treated with antibiotic was reduced throughout much of the exposure period relative to that of the intreated animals.

Microbiology : Bacterial growth within the mantle cavity fluid was exponential during exposure in air. The number of bacteria increased from 104 ml^{-1} to 1012 ml^{-1} after 7 days. The effect of antibiotics was to reduce the initial population. However, the growth rate of the remaining bacteria was no affected, so that the bacterial populations were similar in treated and untreated scallops after about 6 days. Scallops treated with antibiotic, however, showed a significantly improved survival compared to untreated animals. There was a significant increase (by 24 h) in EL50 24 h (Kolgmorov-Smirnoff two sample test, $P<0{,}05$).

Adduction & Gape : The frequency of shell adduction decreased from a peak of 45 h^{-1} in the first hour to less than 4 h^{-1} after 12 h. The degree of shell gape, however, increased during aerial exposure with maximum valve separation being reached after 12h.

Histochemistry : PAS staining demonstrated a decrease in glycogen concentration in the adductor muscles during a 12 h period of aerial exposure. Glycogen stores showed differential distribution in fast/striated muscle and slow/smooth muscle. In the latter, the energy substrate is localized in the myofibril membrane, while in the former tissue, glycogen is diffuse throughout the muscle. Enzymic assays confirmed a glycogen depletion of approximately 25 % following a similar period of aerial exposure.

DISCUSSION

This study has confirmed that *Pecten maximus* has a limited ability to survive periods of aerial exposure. survival in air is, however, temperature dependent; survival is greater at lower temperatures but at very low temperature (1°C) it was found that mortality rates increased. The cause of death is, however, far from clear.

During the first hour of exposure, a high frequency of shell adduction was recorded. This subsequently decreased and was accompanied by an increase in the degree of shell gape. When scallops were returned to water, their ability to recover was dependent on the duration of aerial exposure. The recovery of scallops which had begun to gape was very poor.

Unlike many sublittoral bivalves, *Pecten maximus* is unable to keep the shell closed for long periods during aerial exposure. Desiccation may therefore be an important factor in causing death. It is interesting to note, however, that enforced shell closure, which was likely to have reduced water loss from the tissues, did not result in a significant increase in survival.

Rates of oxygen consumption decreased markedly during aerial exposure. This may result from an overall reduction in activity despite the high frequency of adductions during the first hour or it may result from a inability to obtain sufficient oxygen from the air. Even though the gills may collapse during exposure and therefore function less efficiently, the tissues lining the mantle cavity still provide a large surface area for gas exchange. Oxygen uptake by both the gills and these other tissue may be inhibited, however, as water is lost from their surfaces and by the proliferation of bacteria.

Some bivalves such as *Mytilus edulis* and *Modiolus demissus* are known to be able to control the degree of shell gape during aerial exposure and to use air as a source of oxygen (Lent, 1968; Coleman; 1973; Widdows and Shick, 1985). Although scallops may be able to obtain oxygen from air, it appears that the rate of uptake is insufficient to meet their respiratory requirements and that they must rely, at least partially, on anaerobic metabolism.

undertaken to determine the rate of accumulation of end-products. These and other studies in progress will attempt to establish the primary cause(s) of death during aerial exposure.

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SOME BIOCHEMICAL AND NUTRITIONAL ASPECTS OF THE METAMORPHOSIS IN *Pecten maximus* (Mollusca, Bivalvia)

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***Abstract** : The biochemical composition and the nutrition rate of **Pecten maximus** (L.) have been studied during metamorphosis. Protein was the major constituant followed by lipids and carbohydrates. Both individual level and proportion of neutral lipid decreased at metamorphosis (25th day) while the first settlement was observed on 23 days old larvae. An important decline of total Organic matter/Dry weight ratio between 25th and 35th day indicated the postlarval shell formation. Nutritional experiment with 14C-labelled algae showed that in a mixture of three algal species, **Pavlova lutheri** and **Isochrysis galbana** (T-iso clone) were preferred to **Skeletonema costatum** by 23 and 28 days old animals. The feeding rate decreased strongly at day 23 and remained very low during metamorphosis.*

***Key Words:** **Pecten maximus,** larvae, metamorphosis, biochemistry, feeding.*

INTRODUCTION

Metamorphosis is a critical period where the locomotory and feeding organ of the larvae, the velum, disappeared while the gills were not yet sufficiently developped. It is believed that there is no feeding activity, at least during first days of metamorphosis (Gruffydd and Beaumont 1972, Lucas 1982) and thus the animals have to rely on their energy reserve to maintain their metabolism activity.
Although many works were made on biochemical composition of invertebrate larvae (see review by Holland 1978), the studies on metamorphosing larvae are scarce. Among the last we can mention the studies made on *Ostrea edulis* (Holland and Spencer 1973, Ferreiro *et al.* 1990. In our knowledge no such work has been made on scallop *Pecten maximus* (L.).

MATERIAL AND METHODS

The artificial spawning, larval and postlarval cultures were conducted at experimental hatchery of Argenton according to the method described by Buestel *et al.* (1982) .

Biochemical analysis

The samples for biochemical analysis were prepared according to Holland and Hannant (1973). Because of its advantage, dichloromethane-methanol solutions were used inætead of chloroform-ethanol in lipids extraction (Beninger 1982). Lipid fractions were obtained by adding activated silisic acid (Holland and Hannant 1973) and determined gravimetrically.

Total carbohydrates and glycogen were measured by colorimetric method described by Dubois et al. (1956) with D-glucose as standard. Free sugar was obtained by difference. Total protein was analysed following Lowry et al. (1951) with Bovin Serum Albumin in 0.01 NaOH as standard.

Nutritional experiment with labelled algae.

Three species of algae were used: *Pavlova l~theri, Isochrysis galbana (T*iso clone) and *Skeletonema costatum.* They were cultured in erlenmeyer containing 250 ml of filtered sea water completed with 0.25 ml of Conway medium and 4 MBq of radio-element (~laHI4C03). Algal growth and its radioactivity were evaluated regularly.
In order to know if the animals show any preference to the given algal species and if there is any decrease on nutritional activity during metamorphosis, two experiments were held. In the first experiment, the animals were fed on three algal species but only one of them was labelled algae. The second experiment consisted to feed the animals by a mixture of labelled algae. The final concentration of each algae was 20 cells/larva while the density was 3 animals/ml.
The radioactivity of algae and animals was measured in liquid scintillation counter Packard Tricarb 3000.
The experimentæ were based on a simple model of three compartments i.e.: algae, herbivorous animals and medium (Samain *et al*. 1986). The nutritional parameters were determined graphically. The error of this method is estimated to about 5 percent.

RESULTS

In hatcheries, the artificial spawning of *Pecten maximus* could be made easily, but the larval and postlarval growth rates vary considerably along the year. In the present study, the settlement was first observed at 23th day of larval life while the velum disappeared between days 24 and 25 indicating the beginning of metamorphosis.
Of different growth parameters, the relation between total length and either individual dry weight (DW = 0.00896 TL Z.197) or organic matter content (TL = 0.02470 TL 1-429) were better explained by a multiplicative function of simple regression (r = 0.991 and 0.988, respectively), while a linear regression was fitted well the relation between individual dry weight and organic matter content (MO = 640.486 + 0.1648 DW; r = 0.999). Thus, each parameter could be used as an estimation for the others.
The daily growth rate in length were not constant during metamorphosis and postlarval life. Two important declines were observed, i.e. at day 25 and 32. Both organic and inorganic matter contents increased slowly during larval life. A rapid increase of inorganic matter content was observed at the moment of metamorphosis (day 25 of larval life), while that of organic matter took place only after metamorphosis.
The Organic matter/dry weight ratio decreased from 43 % at day 18 to 27 % at day 28 and then continued to decrease slowly with age.
Protein is the major constituant of organic matter, following by carbohydrates and lipid. The evolution of the proportion of protein to total organic matter were similar to that of carbohydrates, while the lipid/total organic matter ratio varied inversely.
The slow growing of 23 days old larvae showed the low levels in all biochemical constituants comparing to that of normal larvae. Its neutral lipids proportion was very low and comparable to that of 18 days old. Meanwhile, the slow growing of 25 days old larvae had lower proportion of neutral lipid as well but still sufficiently high levels of organic matter constituants comparing to those of normal larvae.
The preference proportion of 23 days old larvae on different labelled algae were 0.44, 0.37 and 0.19, while those of 28 days old postlarvae were 0.40, 0.29 and 0.31 for *P. lutheri, I. galbana* and S. *costatum* respectively.
The feeding activity (Ingestion) reached a highest level at day 22 (3730 Cells larva -l day -l), a day prior to settlement. This activity decreased and remained low during

metamorphosis. In non-settled of 25 days old animals, the nutritional activity remained high and was comparable to those of 23 days old.

DISCUSSION

Although the protein is the major constituant of the pediveliger, it seems that the lipid reserve, especially neutral lipid, are used to supply the energy demand during metamorphosis. This result is in accord with those found earlier (Holland and Spencer 1973, Holland 1978, Gallager and Mann 1981, Gallager et al. 1986, Ferreiro et al. 1990). Meanwhile, Holland and Spencer 1973 found that besides the neutral lipid, the level of glycogen was decreased as well during metamorphosis of 0. *edulis*. In P. maximus no such phenomenon is observed.

As in 23 days old slow growing larvae, the slow growing of 25 days old animals have a lower level in their biochemical constituants comparing to that of normal larvae of similar age but they will metamorphosis few days after, while the first group will not. This suppose that there is a minimum level of biochemical constituants below which the larvae will not metamorphose. Gallager et al. (1986) have suggested the minimum level of triglycerol to fuel the transition period between velar resorption and gill activation for C. *virginica* and *M. mercenarla.*

The decrease of ingestion rate during metamorphosis is confirmed by 14C labelled algae experiment. This does not mean that no feeding period never occurred since the radioactivities were measured on a group of individuals among which the velum disappearance did not take place at the same moment. The results suggest that while the non feeding period in *P. maximus* occurs less than one day, the low feeding activity last at least until 3 days after metamorphosis.

S. costatum is less ingested by both 23 and 28 days old animals. The experiences made in younger larvae show the similar preferences on *P. Iutheri* and *I. galbana,* while *S. costatum was* less or not ingested at all (Salaun, pers. comm.) . This suppose that the bigger size and the long chains usually formed by this algae were not suitable for larval food.

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THE LEVEL OF GENETIC VARIATION IN *Swiftopecten swifti, Mizuhopecten (Patinopecten) yessoensis*, AND *Chlamys farreri nipponensis* FROM THE SEA OF JAPAN.

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***Abstract** : Genetic variation in three scallop species from the Sea of Japan was studied by starch gel electrophoresis. Eighty four allozyme loci were scored in **Swiftopecten swifti** (Bernardi), eighty two in **Mizuhopecten (Patinopecten) yessoensis** (Jay) and fifty one loci in **Chlamys farreri nipponensis** Kuroda. Percentages of polymorphic loci (P.95) are 16,7 %, 22 % and 46,2 %, observed (and expected) heterozygosities are 0,051 ± 0,012 (0,050 ± 0,012), 0,087 ± 0,019 (0,085 ± 0,018), and 0,225 ± 0,038 (0,221 ± 0,037) for each species, respectively. Observed genotype distribution at the polymorphic loci were in general agreement with Hardy-Weinberg equilibrium expectations. Each scallop species did not exhibit an overall heterozygote deficiency. We suggest that significant differences between the species in amount of genetic variation may be explained by their evolutionary history.*

***Key words** : scallops, allozyme variation, evolutionary history*

INTRODUCTION

There are three scallop species in the Peter the Great Bay (The Sea of Japan) : *Mizuhopecten (patinopecten) yessoensis* (Jay), *Swiftopecten swifti* (Bernardi), and *Chlamys farreri nipponensis* Kuroda. *M. yessoensis* is widely distributed and fished in Primorye. This species is an important object of aquaculture too. Two other scallop species are rare and do not form abundant settlements. Electrophoretic studies have been made of some European scallops; from three Far East species of scallops there are data on allozyme variation in *M. yessoensis* only (see review : Beaumont & Zouros, 1991). The present paper reports an extensive electrophoretic analysis of *M. yessoensis, Swiftopecten swifti,* and *Chlamys farreri nipponensis.*

MATERIAL AND METHODS

Samples of scallops were collected from the Peter the Great Bay, the Sea of Japan, USSR. Adductor muscle and digestive gland tissue were used as protein source for electrophoretic separation. Electrophoresis was carried out on horizontal blocks of starch gel, using two buffer systems : Tris-citrate (pH 8.0) and Tris-EDTA-borate (pH 8.6). Gels are stained following the routine procedures.

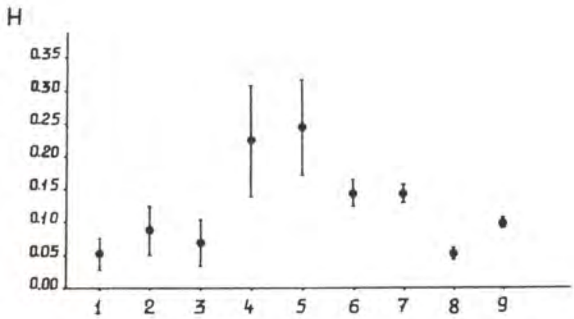

Figure 1. Average observed heterozygosity (Ho) for : 1) *Swiftopecten swifti;* 2) *Mizuhopecten yessoensis*; 3) *M.yessoensis and S swifti;* 4) *Chlamys farreri nipponensis*; 5) four European scallop species (Beaumont and Beveridge, 1984); 6) 23 oyster species, 7) 61 marine bivalve species; 8) vertebrates (551 species, from Nevo et al., 1984); 9) invertebrates (361 species, from Nevo et al., 1984). Vertical lines are 95 % confidence intervals.

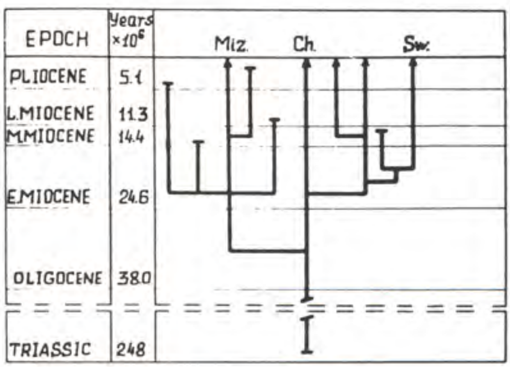

Figure 2. Schematic reconstruction of philogenetic relationships of three scallop genera (after Kafanov, 1986, and Waller, 1991). Miz : *Mizuhopecten*, Sw : *Swiftopecten*, Ch : *Chlamys* genera, respectively.

RESULTS

The amount of allozyme variation in the three scallop species is summarized in the Table. Average values of heterozygosities are presented in fig.1. The parameters of allozyme variation for *C. farreri nipponensis* (Ho = 0,225 ± 0,38) was found to be higher than observed for the other two species. The heterozygosity values in *M. yessoensis and S. swifti* do not differ significantly. Average observed heterozygosity for these two species is 0,069 ± 0,018. Average Selander's coefficients (D) are positive in all three scallop species (see Table), indicating lack of overall deficiency of heterozygotes.

Table. A summary of genetic variation in three scallop species from the Sea of Japan. Ho and He : average observed and expected heterozygosity, respectively. SE : standard error. D : mean value of Sealender's D statistics. Ne : mean effective number of alleles. P.99 and P.95 : the proportion of polymorphic loci with frequency of most common allele $\leq$ 0,99 (P.99), or $\leq$ 0,95 (P.95). Underlined values of heterozygosities were obtained without general protein loci.

Species	Ho ± SE	He ± SE	D	Ne	P.95	P.99
Swiftopecten swifti	0,051 ± 0,012	0,050 ± 0,012 0,050 ± 0,012	0,005	1,07	16,7 %	31,0 %
Mizuhopecten yessoensis	0,087 ± 0,019 0,092 ± 0,020	0,085 ± 0,018 0,090 ± 0,020	0,002	1,15	22,0 %	35,4 %
Chlamys f. nipponensis	0,225 ± 0,034	0,222 ±0,033	0,001	1,52	46,2 %	48,7 %

DISCUSSION

The amount of genetic variability detected in *M. yessoensis* and *S. swifti* is lower than the level of variation in *C. farreri nipponensis* and other scallops (see fig. 1). The relatively low level of genetic variability in *M. yessoensis* and *S. swifti* could be caused by inclusion of general protein loci in survey (as was suggested by Beaumont and Zouros, 1991). However, as follows from Table, these loci reduce average values of heterozygosities only slightly. We believe that significant differences of genetic variation between *M. yessoensis* and *S. swifti,* from one hand and *C. farreri nipponensis*, from the other hand might have arizen from different evolutionary history of these lineages. *C. farreri nipponensis* belong to the ancient genus *Chlamys*, which exists since Triassic (that is at least 200 million years). The *Mizuhopecten* and *Swiftopecten* genera descended from genus *Chlamys* about 20-30 million years ago in Late Oligocene and Early Miocene, respectively (fig. 2). As appears from geological record both genera are relatively young lineages; their geological age is far less than age of genus *Chlamys*. In the Miocene there was intensive speciation in *Mizuhopecten* and *Swiftopecten* lineages (fig. 2). These events are often accompanied by bottleneck effects, which in turn lead to decreasing of genetic variation (Nei et al., 1975). Thus, there seems is direct connection between evolutionary history of the lineage and the level of its genetic variation, as is predicted by neutral evolution theory (Kimura, 1983).

Heterozygote deficiency (HD), was frequently observed in marine invertebrates, and in scallops as well (Beaumont and Zouros, 1991). We did not find any HD for the three scallop species. In those cases when HD is observed it can be explained by some technical reasons, such as :

1) Insufficient resolution of heterozygotes, which are mistaken for homozygotes;
2) Inclusion in the survey of loci with unclear pattern of variation (esterases, for example);
3) Inadequacy of D-statistics, when it is calculated for small samples at low variation loci.

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LACK OF CORRELATION BETWEEN ALLOZYME HETEROZYGOSITY AND SIZE VARIATION IN JUVENILES OF THE SCALLOP *Mizuhopecten yessoensis*.

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Abstract *: Genotypes at 6 allozyme loci were scored in 427 recruits (settled into collector bags) and 200 adults from adjacent natural population of the Japanese scallop in Peter the Great Bay of the Sea of Japan. Each individual was weighted and their valve length measured. The proteins assayed were aspartate aminotransferase, esterase-D, glutathione reductase, glucose-6 phosphate isomerase, octopine dehydrogenase, phosphoglucomutase. All samples proved to be in Hardy-Weinberg equilibrium and there were no differences in allele or genotype frequencies between adults and recruits. We could not reveal any significant correlation between overall heterozygosity of individuals and their size. Neither could we obtain consistent and significant size or weight differences between homozygotes and heterozygotes at any locus considered separately. Thus, we conclude that the relation between heterozygosity and growth rate, shown by Singh and Zouros (1978 and later) in oysters, is not a general rule.*
Key words *: scallops, allozyme, heterozygosity, size-variation.*

INTRODUCTION

Since pioneer work by Singh and Zouros (1978), who reported marked positive correlation between allozyme heterozygosity and growth rate in the American oyster, many vertebrate and invertebrate (mainly mollusc) species were considered in this respect. In some species the correlation was found, in some not. In scallops *Placopecten magellanicus* and *Pecten maximus* such a correlation was not revealed (Beaumont and Zouros, 1991). In the present study we report an attempt to find the correlation in juveniles of the scallop *Mizuhopecten yessoensis*.

MATERIAL AND METHODS

Juvenile scallops were gathered from collectors (bags of nylon meshwork) exposed to spatfall in the middle of July. Removal of juveniles of about 50-60 days old (after settling) was done in September. There were two groups of collectors exposed at different time and for different duration; thus two groups (sl and s2) of recruits were collected and they were considered separately. Besides, a sample of adults was collected at the same locality. .Juveniles removed from collectors were dried with filter paper, weighted and their valve length measured. For electrophoresis whole molluscs were crushed in a drop of extracting solution, the mixture centrifuged and supernatant routinely electrophoresed in 14% starch gel. Slices of gel blocks were stained for 6 proteins: aspartate aminotransferase (Aat), esterase-D (Est-D), glucose-6-phosphate isomerase (Gpi), glutathione reductase (Gr), octopine dehydrogenase (Odh) and phosphoglucomutase (Pgm). In adults small pieces of adductor muscle were cut, frozen and kept at -18 °C until electrophoresis. Glutathione reductase could not be resolved in adults. In addition to 5 enzymes a non-enzymatic protein was stained in adults.

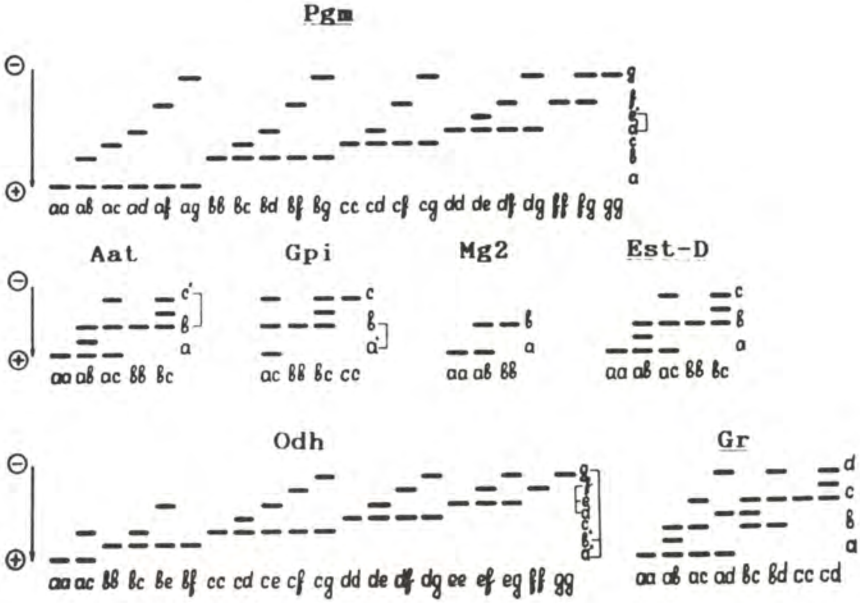

Figure l. Observed allozymic phenotypes. Muscle protein could not be stained in recruits; glutathione reductase was not resolved in adults.

RESULTS

All the observed allozymic phenotypes are shown in Figure 1. One can see the loci we surveyed are quite polymorphic (see values of heterozygosity in the table 1). As allele frequencies an all 6 loci in samples Sl and S2 proved homogeneous (X2=7.71 ; d.f.=13 ; P=.86) they were pooled. Sample sizes, observed and expected numbers of heterozygotes, Selander's D are given in the Table (for the pooled sample). It can be concluded from the Table genotypic proportions are in Hardy-Weinberg equilibrium at all loci. Fig.2A presents means and standard deviations of valve lengths in different heterozygosity classes. It is evident there is no correlation between heterozygosity and valve length, between heterozygosity and variance of valve length; more than that there is no difference at all in these parameters among heterozygosity classes. Fig.2B shows differences in valve length between heterozygotes and homozygotes for each locus separately. Again, there is no significant difference at any locus.

DISCUSSION

In their review Beaumont and Zouros (1991) report data on absence of heterozygosity-growth correlations in two scallop species, *Pecten maximus* and *Placopecten magellanicus*. Our data fully corroborate this information for *Mizuhopecten yessoensis*. There was no negative correlation between heterozygosity and variance in shell size (fig. 2A), demonstrated by Zouros and Singh (1978 and later) in the American oyster. We did not observe any increase of heterozygosity with age from 1 to 7 years old, nor in comparison of recruits and adults ; neither age increase of heterozygosity at Odh locus (fig. 3A,B), which were thought characteristic for mobile scallops (Beaumont and Zouros, 1991). Thus, we could not reveal any correlation between heterozygosity and survival, suggested by these authors. There was no deficit of heterozygotes (estimated with Selander's index D) in either juveniles and adults, nor did we observe any trend of its change with age in a much larger sample of scallops (Pudovkin and Dolganov, 1991).

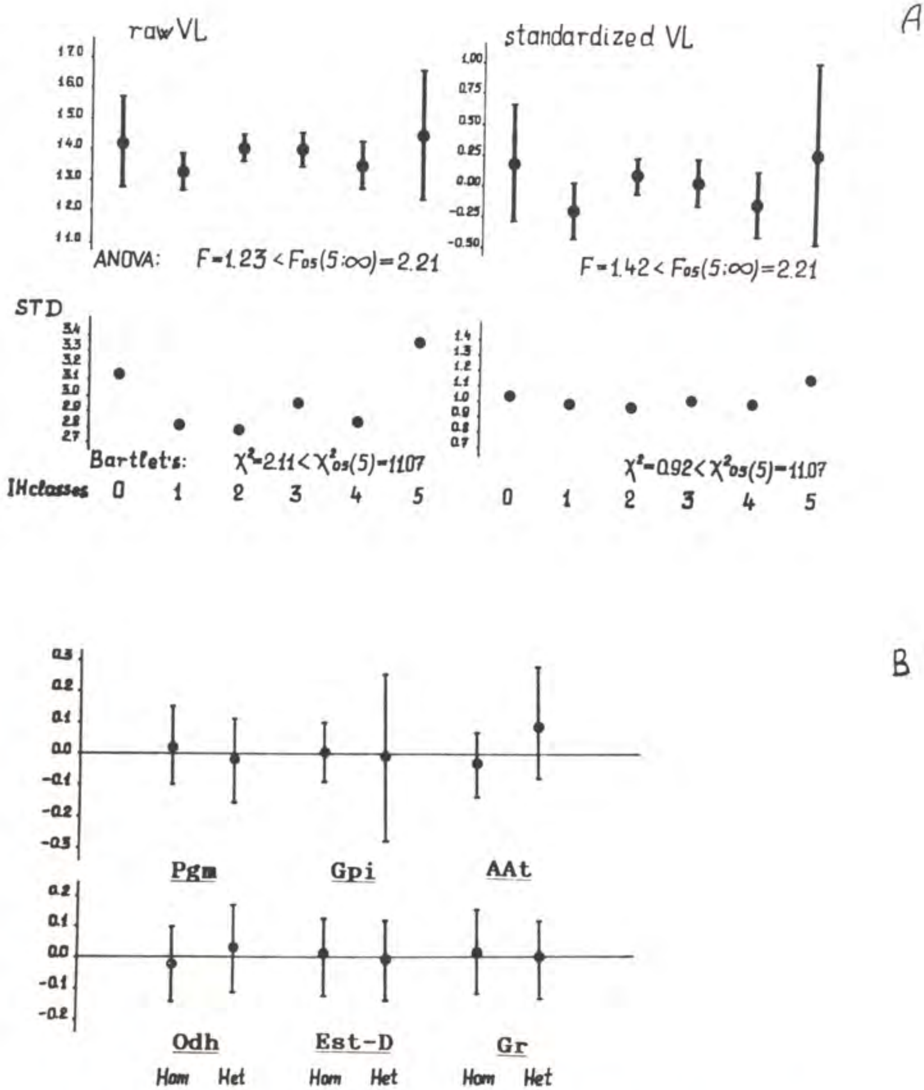

Figure 2. Valve length in juvenile scallop groups differing in heterozygosity.
A. Means and standard deviations of valve length (standardized and nonstandardized) in different heterozygosity classes. Standardization was done in the following way:
Xij = (Yij yi)/si, where Xij and Yij are standardized and nonstandardized valve length in j-th individual in i-th sample (i =1, 2), si standard deviation.
B. Mean valve lengths (standardized) in heterozygotes and homozygotes at different loci.

Table 1 : Sample sizes, observed heterozygosities, and coefficients of heterozygote excess for the pooled sample of juvenile scallops *Mizuhopecten Yessoensis.*

Locus	Number of individuals	Observed heterozygosity	D	X2
Aat	427	.267	.105	4.710
Est-D	427	.475	-.001	.000
Gpi	425	.141	-.114	.083
Gr	426	.549	.027	.311
Odh	425	.379	-.014	.083
Pgm	426	.502	-.014	.083
Total	2556	.384	.011	.311

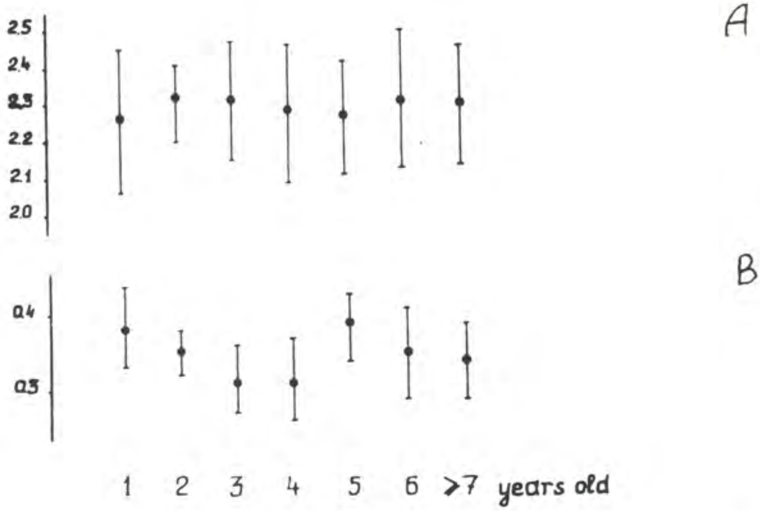

Figure 3. Heterozygosities in different age groups.
A. Mean heterozygosities (number of heterozygous loci per individual).
B. Heterozygosities at Odh locus.

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THE ROLE OF *Gpi* POLYMORPHISM IN GLYCOLYTIC FLUX VARIATIONS AND ITS EFFECT ON GENOTYPE DEPENDENT VIABILITY IN THE BAY SCALLOP

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Abstract : *Virtually every animal and plant species exhibits genetic variation for a variety of enzymes involved in the control of metabolism. Only a few studies have clearly established the relationships among genetic variation for a specific enzyme, the mechanistic, biochemical expression of that variation, and its relevance to the physiology and phenotype of the whole organism. A more integrated approach to examine the biological significance of genetic variation for a single enzyme involves detailing the effects of that variation on the overall rate of flux through the metabolic pathway in which the enzyme is embedded. The research presented uses this approach to attempt to establish a causal explanation for observations of a strong relationship between genotype for the enzyme glucosephosphate isomerase Gpi and production related traits in the bay scallop, Argopecten irradians. The proposed mechanism for selection involves the differential inhibition of Gpi variants by an intermediate of the pentose shunt. The experiments discussed examine the expression of genetic variation at Gpi by using radioisotopes to measure the rates of flux through this enzyme as well as through glycolysis when the enzyme is artificially inhibited with a product from the pentose shunt. The results ultimately address questions regarding the biochemical genetic basis of quantitative variation, and explore the applications of genetic variation to economically important traits in fisheries and aquaculture.*

Key words : *Glucose phosphate isomerase, Argopecten irradians, allozymes, metabolic control*

INTRODUCTION

Evolutionary explanations for the maintenance of genetic variation require an understanding of the functional. biochemical expression of that variation and its relevance to the physiology of the organism. Metabolic control theory predicts that much of the genetic variation at enzymatic loci has evolved to become selectively neutral in natural populations (Hartl et *al.* 1985). The impact of biochemical variation at a single enzyme step on associated metabolic pathways will be diminished through interactions with the substrates and products of other constituent enzymes (Kacser and Burns, 1981). Several authors have recently suggested that the investigation of the selective consequences of enzyme polymorphism should now focus not on the enzyme in isolation, but rather on the relationship of the enzyme to its affiliated metabolic pathway (Watt 1985; Dykhuizen et *al. 1987*).
At metabolic branchpoints where resources are partitioned in response to changing environmental demands, we might predict that genetic variation for enzymes affecting flux and therefore partitioning is potentially adaptive (Watt, 1985; Burton and Place, 1986). This research empirically tests the predictions of Kacser and Burn's model of metabolic control. I present evidence for large genotypic effects of the *Gpi* polymorphism on quantitative characters related to fitness. Preliminary results are then given for experiments which examine the consequences of *Gpi* genotype on associated metabolic flux.
The enzyme glucosephosphate isomerase (Gpi, D-glucose-6-ketol isomerase E.C. 5.3.1.9), strategically located at the branchpoint of glycolysis and the pentose phosphate pathway, catalyzes the reversible isomerization of glucose-6-phosphate and fructose-6-phosphate (Noltmann, 1972). Gpi is generally thought to transmit rather than limit flux through glycolysis based on the agreement between the mass-action ratio and equilibrium constant

(Cameselle et *al.*, 1980). Possible regulatory roles for Gpi involving either the maintenance of hexose phosphate pools, as suggested by Katz and Rognstad (1976), or the partitioning of flux through the pentose shunt modulated by competitive inhibition (Atkinson, 1976; Palumbi et *al.*, 1980; Zamer and Hoffmann, 1989) call into question this characterization.

If Gpi does function strictly as a coupling enzyme, then how do we explain the apparent paradoxical evidence for the operation of natural selection on variants of the *Gpi* locus ? Biochemical differentiation and spatial variation correlated with thermal variation of *Gpi* genotypes has been demonstrated in numerous studies (Hoffmann, 1983; Zamer and Hoffmann, 1989; Watt, 1983 and others). Population genetics studies of the bay scallop, *Argopecten irradians*, also suggest a selective role in the maintenance of the *Gpi* polymorphism. While bay scallop Gpi displays near equilibrium *in vitro* kinetic properties (Chih and Ellington, 1986), preliminary evidence (presented below) leads to the prediction the genetic variation at *Gpi* may exert differential metabolic control on glycolysis which ultimately translates into differential growth. The research presented examines the *in vivo* biochemical expression of genetic variation at he *Gpi* locus of bay scallops in the context of its participation in the glycolytic pathway.

MATERIALS AND METHODS

Scallops for electrophoretic analyses were collected by SCUBA or dredging and returned live to the lab for subsequent lyophilization. Measurements of various quantitative characters, including shell height and length as presented here, were recorded. Dried tissues were homogenized in Tris HCl pH 8.0 buffer for starch gel electrophoresis. Samples were run with a discontinuous lithium hydroxide buffer system and stained for Gpi using standard protocols (Harris and Hopkinson, 1976).

Bay scallops for flux experiments were collected by hand and returned to a recirculating seawater system held at ambient temperature and salinity. Scallops are individually numbered, measured for shell height and thickness, and biopsied and typed for Gpi. Individuals for the experiments are selected to provide approximately equal representation of the nine most common genotypes. Sixty animals are then removed from the system and incubated in 5 mM 6-aminonicotinamide (6-AN) in seawater at ambient salinity and temperature. This analog of NADP competitively inhibits 6-phosphogluconate dehydrogenase, causing the accumulation of 6-phosphogluconate (6PG), a known inhibitor of Gpi (Gaitonde et *al.*, 1987 ; Herken et *al.*, 1969 and others). Scallops are removed from the 6-AN solution and their gills are excides. Both gill are placed individually into incubation salts (Zaba and Davies, 1980), shaken and acclimated for 15 minutes at 15 °C 5mM glucose is then added to each incubation vial. One gill is additionally treated with 3 uCi/5ml [^{3}H]-2-glucose. Gills are then incubated at 15 °C for 75 minutes. At the end of this period, the "cold" gill is plunged into liquid nitrogen and lyophilized for measurement of 6PG by standard fluorometric methods (Lowvry and Passonneau, 1972). Flux is measured in the other gill by measuring the concentration of tritiated water produced at the Gpi reaction using micro vacuum distillation (Winshell and Ertl, 1986). This procedure allows for the estimation of partial carbon flux at Gpi through the loss of label in the proton exchange reaction during the formation of the enediol intermediate (Katz and Rognstad, 1976 ; Zaba and Davies, 1980). The experiment is repeated on alternating days until approximately 180 animals have been measured for flux and 6PG accumulation.

Data are analyzed to partition the effects of genotype on quantitative characters and Gpi flux using SAS (Statistical Analysis Systems, Inc., Cary N.C.). The concentration of the inhibitor, 6PG, is used as a covariate for the analysis of flux.

RESULTS

Repeatable observations of a non-random association between *Gpi* genotypic variation and phenotypic traits are found in the bay scallop. The genotype at *Gpi* explains a significant proportion of the variance in size related characters in populations of *A.i. irradians* from Connecticut (table 1.), and Long Island, as well as *A.i. concentricus* from North Carolina (table 2.).

Table 1. Multivariate Analysis of Variance : Shell height (HT) and thickness (T) of one cohort of scallops from Niantic, Connecticut, were tested for differences among genotypes over seven sampling dates.

Date	Variable	P	r^2
9-86	HT TH overall		
12-86	HT TH overall	 MS	
4-87	HT TH overall	 MS	
5-87	HT TH overall	 MS * *	 0.05
7-87 :TH:*	HT 0.12 overall	* * * *	0.12
10-87	HY TH overall	* * * * * * *	0.12 0.12
4-88	HT TH overall	 *	

Table 2. Multivariate Analysis of Variance : Shell dimensions of adult scallops collected from Long Island (LI) and North Carolina (NC) were tested for differences among individual Gpi genotypes. HT, shell thickness ; TH, shell height.

Sample	Variable	P
1988 NC	HT.ms TH overall	 * ms
1989 *LI*	*HT* *TH* *overall*	* *ms* *ms*
1985 *LI*	*HT* *TH* *overall*	*ms* * *ms*

Multiple samples from a single Connecticut cohort indicate a temporal trend to the relationship between *Gpi* and the quantitative traits. The magnitude of the genotype-specific differences (the proportion of variance in the trait explained by *Gpi*) increases as the cohort ages. The genotype explains up to 14 % of the variation in size of animals entering their second winter. Additional evidence for selective genotype-specific differences in bay scallops is found in preliminary transplant data, clinal data, and concordance of ranks of genotypes with respective to "size" among geographically separated populations (Krause, unpublished data). Only the preliminary results of the first flux experiment can be described here. The work is currently ongoing. The first trial experiment was conducted on juvenile animals in which previous work has indicated that the genotypic effect of *Gpi* on quantitative characters is minimal. No significant effect of genotype on flux was found ; however, because of experimental difficulties, the results from only 70 animals could be used for statistical analysis. In the total sample of 120 animals, no significant statistical association was found among genotype and shell height or thickness.

DISCUSSION

While the correlative evidence between genotype at *Gpi* and quantitative traits is very strong in this species, the mechanism for explaining the effect is not yet known. The proposed mechanism is differential inhibition of *Gpi* genotypes by a compound from the pentose shunt, 6-phosphogluconate. Differential inhibition of Gpi, and resulting inhibition of glycolytic flux, could shunt a greater proportion of carbon flux into the pentose phosphate pathway. This pathway is responsible for producing a large quantity of the NADPH required for lipid biosynthesis. Zamer and Hoffmann (1989) have demonstrated such genotypic differences in the sea anenome, *Metridium*. Their work, however, is complicated by the combined effects of diet and temperature which affect the natural activity of the pentose shunt. My work attempts to circumvent this problem by artificially increasing the levels of the inhibitor, 6PG. Further experiments on animals collected during their spawning period (when lipid synthesis for eggs is important) will attempt to demonstrate genotypic flux differences through this enzyme as well as test for corresponding changes in glycolytic flux. It is not suprising that this first experiment did not yield any significant results because of both sample size and the age of the animals. As mentioned previously, the genotypic associations with quantitative traits increases as the cohort ages. This first experiment was conducted on animals that are only nine months old. If genotypic variation does not correspond to variation in flux, then other explanations will have to account for the observed phenotypic correlations with genotypes. Alternative hypotheses include selection operating on linked loci, or selection operating to maintain constant glycolytic flux by modulating pentose shunt flux. The abundance of observations from a diversity of organisms including the bay scallop strongly suggests that this enzyme locus is the focus of selection. Elucidation of the biochemical mechanism for its action is required to directly implicate *Gpi*. The understanding the mechanisms which control the maintenance of such genetic variation and the biochemical genetic basis of quantitative variation can lead to applications in fields such as aquaculture, where known genotypic effects on production related characters can be exploited to maximize production.

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BIOCHENICAL GENETICS OF THE MEDITERRANEAN SCALLOP *Pecten jacobaeus*

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Abstract : Thirteen enzymatic systems coded by 17 loci were used for polymorphic analysis of a Mediterranean scallop population using horizontal starch gel electrophoresis. At 0.95 criterion, four loci (Aat-2, Mdh-l, Mdh-2 and 6-Pgd) were found to be monomorphic while the others were polymorphic (Aat-l, a-Gpd, Gpi, Idh, Lap-l, Lap-2, Me-l, Me-2, Mpi, Odh, Pgm, Sdh and Sod) which gave 76.47 percent of polymorphism. An average of 3.4 + 0.4 allele per locus and 0.325 + 0.05 of unbiased estimation of heterozygosity were obtained. Most of the studied loci showed an heterozygote deficiency.

***Key words**: Population genetic, electrophoresis, scallops, Mediterranean sea.*

INTRODUCTION

The Mediterranean scallop, *Pecten iacobaeus* L., as other species of pectinids, has a high economical value. Nevertheless, in the spanish Mediterranean coast there are no copious catches of this shellfish since there is no skilled fishing and only some specimens can be caught by trawling nets together with other benthic species. *P. jacobaeus* is principally distributed along the Mediterranean coast, between 25 and 75 m deep which is usually found around some rocky formations that stick up from the sandy and gravel bottoms.
The great economical interest which represent the pectinid scallops has brought in various countries. The setting up of programs for improving knowledge on the biology of the species, specially on the stock management, population structure, reproductive biology and artificial production of young spat in hatchery (Ansell et al., 1988).
In populational genetics, a number of works on the intra and interspecific variation of the pectinid scallops has been investigated previously (Wilkins, 1981; Nikiforov & Dolganov, 1982; Foltz & Zouros, 1984; Kijima et al., 1984; Huelvan, 1985; Beaumont et al., 1985; Woodburn, 1990).
This paper reports the preliminary results on the genetic structure of *P. iacobaeus* in the spanish Mediterranean. The purpose of this study is to gain a better knowledge of the biology of this population on which the only works presently known are those of Mestre et al. (1990; 1991) on the reproductive cycle.

Table 1. Allozyme data for *Pecten jacobaeus.* N: sample number. RM: relative mobility. Ho: observed heterozygosity. He: expected heterozygosity. XZ: goodness-of-fit from Hardy-Weinberg eauilibrium. D: heterozygote deficiency.

Locus	N	RM	Allele Frequen	HO	He	XZ	D
		105	0.067				
Aat-1	30	100	0.833	0.267	0.291	1.267	-0.084
		95	0.100				
Aat-2	77	100	1.000				
		110	0.007				
		105	0.160				
a-Gpd	75	100	0.587	0.293	0.569	35.388	-0.485
		95	0.246				
Idh	52	100	0.856	0.096	0.247	15.302	-0.61
		95	0.144				
		106	0.089				
Lap-1	73	100	0.774	0.315	0.382	2.849	-0.176
		97	0.041				
		94	0.096				
		105	0.361				
Lap-2	61	100	0.566	0.295	0.546	16.307	-0.46
		95	0.016				
		90	0.057				
Mdh-1	77	100	1.000				
		110	0.032				
Mdh-2	77	100	0.968	0.065	0.063	0.001	0.034
		105	0.045				
Me-1	77	100	0.851	0.273	0.264	0.86	0.035
		95	0.104				
		105	0.175				
Me-2	77	100	0.701	0.325	0.402	0.59	-0.298
		95	0.123				
		105	0.104				
		104	0.188				
Mpi	72	100	0.701	0.462	0.361	6.749	0.218
		96	0.007				
		104	0.026				
Odh	77	100	0.76	0.351	0.376	4.109	-0.068
		96	0.214				
		110	0.006				
6 Pgd	77	100	0.968	0.065	0.063	0.001	0.028
		95	0.026				
		102	0.045				
Pgm	77	100	0.877	0.182	0.225	1.479	-0.192
		98	0.065				
		95	0.013				
		120	0.155				
Sdh	29	100	0.793	0.276	0.344	1.306	-0.199
		90	0.052				
		100	0.94				
Sod	67	90	0.045	0.119	0.114	0.001	0.051
		80	0.015				

Locus	N	RM	Allele Frequen	HO	He	XZ	D
Gpi	77	120 115 110 105 100 95 90 85 75	0.047 0.101 0.095 0.189 0.351 0.047 0.101 0.061 0.007	0.608	0.803	49.71	-0.243

MATERIALS AND METHODS

Samples of *P. iacobaeus* were collected by trawling boats from 23 sea miles off Peniscola and 15 sea miles off Oropesa coast (Castellon, Spain). Usually, scallops were held in running sea water on the boat until landing and then transferred to the laboratory, and kept in running filtered sea water for about 14 hours before analysis. Shell length and weight were measured. Adductor muscle and digestive gland were then removed and stored at -70 °C.
Electrophoresis was carried out on standard horizontal starchgel. Adductor muscle and digestive gland were homogenised separately in extraction buffer solution (Tris 0.01 M, EDTA 1.27 mM, NADP 0.03 M, pH 6.8). They were then centrifuged for 20 minutes at 15,000 g and stored at -70 °C. From the supernatants, 17 loci were tested in 13 enzymes. For each scallop, the genotype at 13 polymorphic loci was analysed, as described by Beaumont et al. (1985), Pasteur et al. (1987). The enzymatic systems used are presented as follow: Aspartate aminotransferase (Aat), Glucose phosphate isomerase (Gpi), a-Glycerophosphate dehydrogenase (a Gpd), Isocitrate dehydrogenase (Idh), Leucine aminopeptidase (Lap), Malate dehydrogenase (Mdh), Malic enzyme (Me), Mannose phosphate isomerase (Mpi), Octopine dehydrogenase (Odh), Phosphoglucomutase (Pgm), 6 Phosphogluconate dehydrogenase (6 Pgd), Sorbitol dehydrogenase (Sdh), Superoxide dismutase (Sod).
Electrophoretic data were analysed by Biosys-l Program release 1.7 (Swofford ~ Selander, 1981). Allelic frequency at 17 loci were determined for a sample of 77 individuals from Azahar coast. The proportion of polymorphic loci, mean number of alleles per locus, observed and expected heterozygosities and heterozygote deficiency (Ho-He/He) were calculated. A chi-square test was used for testing to see if they agreed with the Hardy-Weinberg equilibrium. Allele classes were pooled when the observed frequencies were less than 0.05.

RESULTS

Of 17 analysed loci, four were revealed to be monomorph at 5 % of goodness of fit (6 Pgd, Aat-2, Mdh-l and Mdh-2), while the others were polymorphic. The various genetic parameters of *Pecten iacobaeus* are presented in Table 1. It shows a high genetic level in terms of polymorphic rate (76.5), average number of allele per loci (3.4 + 0.4) and heterozygosity (0.325).
The phenotypic distribution observed at each polymorphic locus was found to be in fair agreement with the Hardy-Weinberg equilibrium, except for a-Gpd, Idh and Lap-2 loci.

DISCUSSION

In the present study, the analysed individuals of *P. jacobaeus* showed a high genetic variability, similar results have been reported for other pectinid species by some authors (Beaumont & Beveridge, 1984; Huelvan, 1985; Ansell et al., 1988; Woodburn, 1990)-

Scallops from Oropesa (Spain) showed higher levels of variability than that reported by Huelvan (1985) from the Lion Gulf (France) with Ho values of 0.325 and 0.174 respectively; 76.5 % of loci are polymorphic in our population and only 54 % in that of Huelvan.
This first genetic approach has permitted to know the basic results on the population genetic of *P. iacobaeus* in the Spanish Mediterranean coast, that will serve in the future for the comparative study between two Mediterranean scallop populations and its comparison with *Pecten maximus* from the Atlantic Ocean.

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POPULATION-GENETIC STRUCTURE OF THE SCALLOP *Mizuhopecten yessoensis* IN THE NORTHERN PART OF ITS GEOGRAPHIC AREA.

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***Abstract** : Samples from natural settlements of the Japanese scallop **Mizuhopecten (=Patinopecten) yessoensis** were collected in 24 localities along the 1200 km of Russian coasts of the Sea of Japan (Primorye Region), from near Sakhalin and South Kurile Islands (Sea of Okhotsk). Starch gel electrophoresis was used to score each of over 4300 scallops for 6 highly polymorphic loci. It was revealed that spatial differentiation is very weak, allele frequencies being homogeneous over 1200 km of the continental coastline of the Sea of Japan. These populations exhibit substantial excess of heterozygotes at muscle protein locus. There are statistically significant differences in allele and genotype frequencies when settlements from Primorye are compared with Sakhalin and Kurile ones, but degree of differentiation is again very weak - Nei's indices of standard genetic distance average 0.017. Our results contradict those obtained by Kijima et al. (1984), who reported in the scallop significant differentiation over very short distances.*

***Key words** : allozymes, genetic differentiation, Japanese scallop, population structure.*

INTRODUCTION

Japanese scallop *Mizuhopecten yessoensis* (Jay, 1856) is an important commercial species ; that necessitates research into its population structure. The most detailed study of population genetics of this scallop was done by Japanese authors (Kijima *et al.*, 1984). We present here data on allozyme variation (coded for by 6 highly polymorphic loci) within and between populations of the scallop in the northern and major part of the species geographic area.

MATERIAL AND METHODS

During four monthly trips on board a small ship in 1986-1990 adult scallops were recovered by scubadivers from depths of 3-30 m. Localities of collection are shown in figure 1 and sample sizes are indicated in table 1. In some third of individuals we determined age from outer growth rings. Small pieces of adductor muscle were taken from each individual, frozen and kept under -18°C for several months until electrophoresis in 14 % starch gel.
Full circles marked with letters indicate localities of sampling. In many localities replicate samplings were made 2-4 times in different years. As replicates proved homogeneous in each locality they were pooled in the analysis, results of which are presented in this paper. Circular diagrams present allele frequencies in 6 main groups of settlements. Frequencies are plotted on radii as percentages relative to the maximal frequency of the allele among the 6 populations. Crosses indicate sampling localities in the study by Kijima *et al.* (1984).
Slices of the gel blocks were routinely stained for aspartate aminotransferase (Aat), esteraseD (Est-D), general proteins (Mg2), glucose-6-phosphate isomerase (Gpi), octopine dehydrogenase (Odh), and phosphoglucomutase (Pgm). Staining for Odh was done after Beaumont *et al.* (1980).

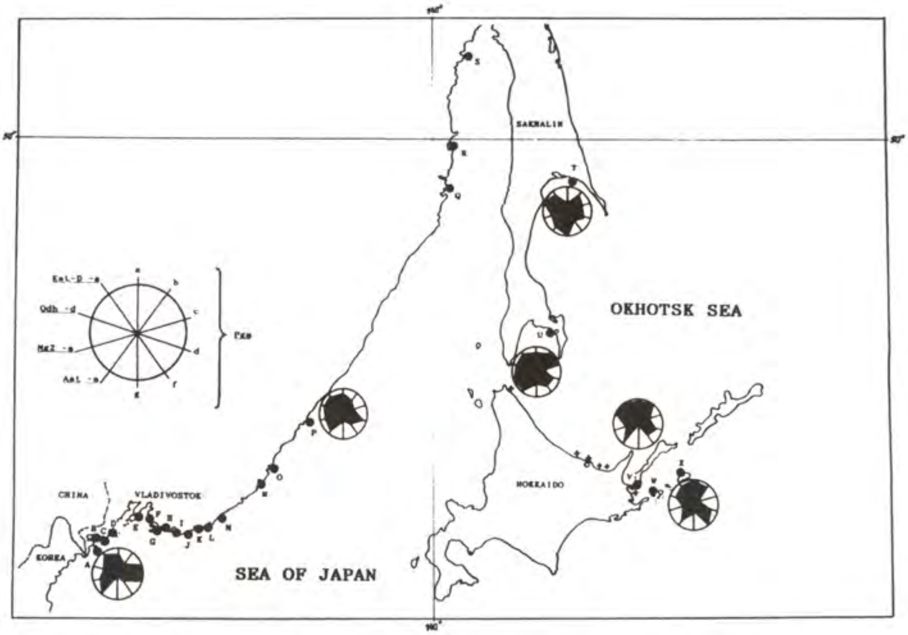

Figure l. Localities of sampling of the scallop *Mizuhopecten yessoensis.*

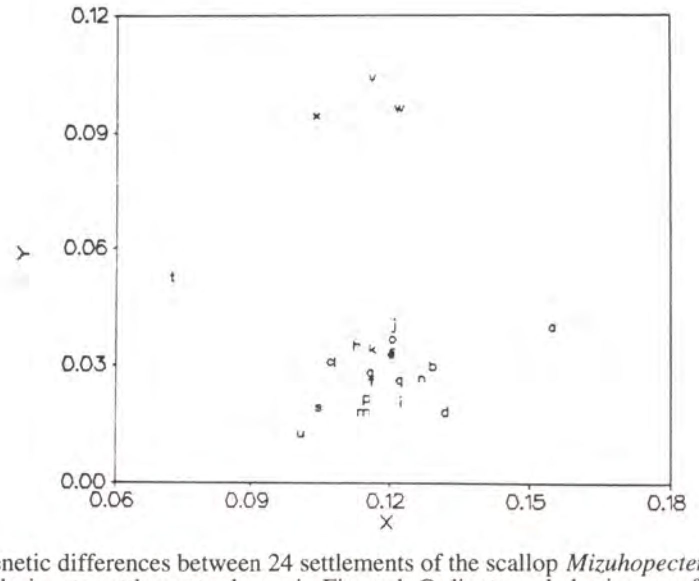

Figure 2. Genetic differences between 24 settlements of the scallop *Mizuhopecten yessoensis.* Letters a-w designate settlements shown in Figure l. Ordinate and abscissa are first principle components axes calculated from correlation matrix of allelic frequencies at 6 allozyme loci.

RESULTS

The loci we surveyed are highly polymorphic (see diagram of observed electrophoretic phenotypes in : Dolganov and Pudovkin, 1991). The table 1 gives a summary of variation : number of alleles range from 2 at Est-D and Mg2 to 7 at Odh and Pgm ; observed heterozygosities vary (in the pooled Primorye sample of 3454 individuals) from 0.155 at Aat to 0.511 at Mg2. Circular diagrams in figure 1 give an idea of variation pattern for 10 more informative alleles (those giving major contributions to the chisquare heterogeneity value) between main geographic populations. It can be seen that each population has its own peculiar "genetic aspect" and differs from other populations in frequencies of specific alleles at different loci. Figure 2 shows an overall pattern of differences in allele frequencies among all the 24 settlement studied. The chart is obtained using principal components analysis operating on allele frequencies at the 6 loci. One can see that settlements designated B-S along the coast line in Figure 1 form a tight cluster. Its tightness is confirmed by chi-square heterogeneity test - there is overall homogeneity of allele frequencies among these 18 settlements at all the 6 loci. Settlements, V and W, show no significant differences either. Three settlement, A, T and X differ both from each other and from first two groups : B-S and V-W.

Table 1 -Sample sizes, observed heterozygosities, F and D statistics, contingency Chi-square analysis for 6 populations of the scallop *Mizuhopecten yessoensis*

					L	o	c	i
Region Localities	Localities in the map	N*	Pgm	Gpi	Aat	Mg2	Odh	Est-D	D**
		Observed heterozygosities							
Primorye	b-s	3454. 00	0.506	0.155	0.273	0.511	0.350	0.485	0.009
Furugelm Island	a	99.80	0.451	0.180	0.210	0.510	0.255	0.545	0.051
Shihatan Island	v-w	240.50	0.566	0.183	0.299	0.465	0.335	0.458	0.002
Proliv Izmeny	x	99.80	0.560	0.091	0.270	0.480	0.320	0.370	-0.027
Zaliv Aniva	u	298.00	0.564	0.155	0.300	0.403	0.340	0.466	-0.020
Zaliv Terpeniya	t	139.00	0.511	0.122	0.406	0.486	0.428	0.557	0.016

No. of alleles	7	3	3	2	7	2
F_{IS}	0.051	0.030	-0.065	-0.017	0.020	-0.030
F_{ST}	0.017	0.006	0.017	0.064	0.007	0.007
Test for heterogeneity of allele frequencies						
Chi-square	164.8	8.6	25.7	202.7	13.8	10.4
d.f.	25	5	5	5	10	5
P	0.000	0.124	0.000	0.000	0.184	0.066

* Numbers of individuals scored for different loci are slightly different,

** Selanser's D computed over all the 6 loci

Thus, among the 24 settlements we reveal 6 different sets of settlements, shown by circular diagrams in figure 1 and characterized in the table 1. It is interesting to note that the genetically homogeneous Primorye settlements stretch over a distance of 1200 km. Settlement A is the southernmost one and situated very close to the other Primorye settlements, nevertheless it differs from them significantly at two loci, Aat and Odh.

In 1563 individuals from the homogeneous Primorye population we determined age. We grouped the scallops into 7 year classes (from 1 to 7 and more years old) and 9 groups according to their year of birth (from 1979 to 1987). We did not reveal any significant differences in allele frequencies between the groups (using chi-square contingency analysis), neither observed we any trend or regular pattern of temporal changes.

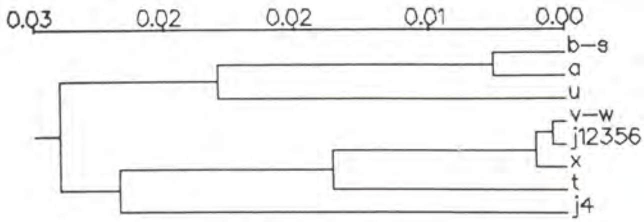

Figure 3. Dendrogram visualizing genetic distances between 8 groups of scallop settlements. The dendrogram is computed from matrix of indices of Nei's standard genetic distance calculated over 4 loci common for our and the Japanese (Kijima *et al.*, 1984) studies ; Hokkaido samples of the Japanese authors are designated j4 and jl2356 ; the latter resulted from pooling of allele frequencies of five samples, which proved homogeneous.

At all the loci except for Mg2, which exhibits excess of heterozygotes, there is good agreement of genotypic proportions with Hardy-Weinberg equilibrium expectations.

DISCUSSION

The scallop populations have potential for gene exchange over considerable distances through dispersal of pelagic larvae, which stay in plankton for 4-5 weeks. This makes understandable homogeneity of Primorye settlements over a distance of 1200 km. The difference of Sakhalin and Kurile settlements from Primorye ones and each other may result from their isolation by long stretches of open sea with colder water, which can constitute an obstacle for larval propagation and gene flow. The situation in the South of Primorye (settlement A) and Kurile Islands (X and V-W), where settlements situated at a distance of some 20-50 km can be genetically different evidences either for a sharp barrier for gene exchange or/and operation of natural selection favouring different alleles in adjacent localities.
Figure 3 gives a dendrogram, calculated from Nei's genetic distances at 4 loci (Aat, Gpi, Mg2 and Pgm), which were common for our study and that by Kijima *et al.* (1984). Recalculation of their data showed that among 6 natural settlements on Okhotsk coast of Hokkaido they surveyed, only one settlement (Notoro Lake, designated j4 in Figure 3) substantially differed from the other five, which were quite homogeneous ; we designated the pooled sample jl2356. One can see this sample cluster with our Kurile settlements (X, V-W).

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ABSTRACTS

GROWTH AND SURVIVAL OF SCALLOP *Pecten maximus* (L.) IN AN ENRICHED, SHALLOW SEAWATER FOND.

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Abstract. *Growth of scallops **Pecten maximus** (L.) at three experimental locations was compared; 1) in a high prospective, high temperature pond; 2) at a fish farm and 3) at an open, unloaded sea station. Shell growth and survival was registered in two seasons, in 1989 and 1990. In 1989 mean shell height of the scallops was 24.0-26.2 mm. In 1990, using the same scallops, mean shell height was 48 mm.*
Both water temperatures and phytoplankton densities were higher at the pond location compared to the other locations. In 1989 total ongrowth varied little between the location (14.0-20.9 mm/ind), although growth rate during spring was significantly lower than total ongrowth of most of the scallops of the other stations (13.6-14.7 mm/ind compared to 18.4-25.3 mm/ind), mostly due to very low growth rate and high mortality (59.1 and 66.7%) in the pond in June. Scallop in the pond seemed more negatively affected by extremely high phytoplankton densities in 1990, compared to 1989.
Correlation between growth rate of each scallop group in 1990 and the different environmental factors was only significant in the case of growth rate at the fish farm and open sea location, and temperature. Considering the scallops in all stations at 2 m depth, a low but significant negative correlation was found between growth rate and POM, and growth rate concentration of unidentified flagellates.
***Key Words** : Scallop, growth, POM, survival.*

ACCELERATED GROWTH, INCREASED MEAT YIELD AND ENHANCED SURVIVAL OF GIANT SCALLOP (*Placopecten magellanicus*) GROWN IN SUSPENDED CULTURE : IMPLICATIONS FOR LARGE-SCALE AQUACULTURE IN ATLANTIC CANADA.

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Abstract. *Giant scallop (**Placopecten magellanicus**) were grown in suspended culture at two sites in the Canadian Maritimes, Passamaquoddy Bay, NB and Mahone Bay, NS. After capture in spat collectors, juveniles at age 4-12 months were transferred to pearl nets at a stocking density of 30-200/net depending on initial juvenile size.*
At 14 months of age, if required stocking density was reduced to 30/net and at 20-24 months, scallops were transferred to ear-hanging lines at 50/5m of line or lantern nets at 10/floor. Harvest of commercial size scallops (15gm meat weight) began at 27 months and was completed by 36 months of age. Meat weights ranged from 15-30% greater than comparable sized bottom grown Placopecten. A survival rate of 85-95% was attained in all grow-out stages providing handling procedures were strictly adhered to.
Availability, growth, yield, survival and high market value of giant scallop in suspended culture make it an attractive candidate for large-scale aquaculture in Atlantic Canada. Currently at least four operations are expanding production and have entered product into the market.

PROBLEMS WITH RECONSTRUCTING SEA-WATER TEMPERATURE RECORDS FROM STABLE OXYGEN ISOTOPIC PROFILES IN SHELLS OF THE SCALLOP *Pecten maximus*.

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Abstract. *Several time series of $g^{18}O$ values from 16 scallop shells were analysed to assess their reliability for reconstructing bottom water temperatures in the English Channel (west and east) and Irish Sea. The data had been obtained primarily to determine scallop age and growth (Dare and Deith, 1989). For each shell (until its sixth year) from 10 to 25 discrete calcite samples were analysed per yearly cycle deposition, depending on the size of annual growth increments. The stable isotopic composition of bottom sea-water from each of the three areas was measured and used to convert $g^{18}O$ shell values to the estimated ambient sea temperature at the time of deposition of each shell sample. Reconstructed 'shell temperatures' showed clear seasonality and could then be compared with recorded bottom temperatures.*

In general, there was poor agreement between derived shell temperatures and actual sea temperatures for both warmest and coldest two months in each sea area. However, a discrepancy of only ~ 1 °C was found in the first two years of life for shells from (a) Western Channel in summer and winter, and (b) eastern Channel during summer. Otherwise, shell temperatures exceeded actual values by from 2-3 °C for immature scallops in winter to 4-6 °C for adults in winter. These positive anomalies increased systematically with age in the Irish Sea and eastern Channel (but not in western Channel). They could result from several processes : (i) cessation of winter shell deposition at different minimum temperatures for immatures and adults, (ii) progressive metabolic changes ('vital effect') in $g^{18}O$ fractionation by adults during summer growth and spawning periods, and (iii) increasing effects of time-averaging or lengthening the integration period of shell samples in later winters.

IMMUNOHISTOCHEMICAL DEMONSTRATION OF VERTEBRATE BIOLOGICALLY ACTIVE PEPTIDES IN THE BIVALVE *Pecten maximus*

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Abstract. *The localisation and distribution of six vertebrate gastro-intestinal and neuropeptides have been searched by an indirect peroxydase-anti-peroxydase technique in* ***Pecten maximus****. Positive reactions were found with antisera directed against glucagon, vasoactive-intestinal peptide, insulin, somatostatin, salmon GH, gastrin : but we failed to detect any related material to substance P. Most of the reactions concerned some pericarya of the central nervous system ; the distribution map of these cells indicates that the peptidergic system is mainly located in definite lobes of the cerebral and visceral ganglia and that it differs from the aminergic system. Supposed endocrine cells were detected in the mid-gut with antisera directed against insulin and vasoactive intestinal peptide.*

GROWTH OF *Placopecten magellanicus* IN CULTURE : EFFECTS OF VERTICAL POSITION AND FOOD QUALITY.

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Abstract. *Researchers at several Canadian universities are involved in a 5 year multidisciplinary study (OPEN - Ocean Production Enhancement Network) of the ecology and culture of the sea scallop* ***Placopecten magellanicus.*** *One component of OPEN concerns environmental factors controlling growth (seston, temperature, water circulation, etc...) and their incorporation into a model of carrying capacity for scallop culture. In a pilot study, we have placed juvenile scallops in cages and ear-hung arrays at 0, 2, 5, 1 and 2 m above a muddy bottom (5 m depth). environmental monitoring of current speed and direction, temperature, salinity, fluorescence, and transmissometry is achieved by continuously recorded instruments and beweekly water sampling. Initial results suggest enhanced shell growth in bottom cages, and higher growth in ear-hanging than in cages. Higher growth rates were also observed following a fall phytoplankton bloom. Final results will include tissue growth measurements, vertical seston profiles, and growth rates through the spring bloom.*

STOCKING DENSITY EFFECT ON THE PRODUCTIVITY OF GIANT SCALLOP (*Placopecten magellanicus*) CULTIVATED IN SUSPENDED CAGES, IN PORT BAY, NEWFOUNDLAND (CANADA).

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Abstract. *An experiment was conducted comparing growth, mortality and yields (total wet weight and adductor muscle wet weight) of giant scallops (****Placopecten magellanicus****) maintained in suspended culture and under different stocking densities. The experiment was conducted in 1989 and 1990 with scallops 21 months and 33 months old respectively. The stocking densities were 25, 50 and 100 scallops/cage in 1989, and 10, 25 and 50 scallops/cage in 1990.*
Results are showing an added variance due to stocking density. The best growth, in shell height, was observed in cages with the lowest densities. Mortality was low, ranging from, 0% to 8% and was not related to stocking density. The total wet weight/shell height and adductor muscle weight/shell height relationships were compared between stocking densities. No significant differences were observed. The information was presented to aquaculturists in the form of production tables, under different scénarios.

A SURVEY OF GROWTH RATES IN THE GIANT SCALLOP, *Placopecten magellanicus*, IN THE BAY OF FUNDY USING THE RNA/DNA RATIO TECHNIQUE.

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Abstract. *Previous studies have indicated that the relative size of the adductor muscle in the giant scallop tends to decrease the further up the Bay of Fundy the scallop are found. The objective of this study was to examine the short-term growth rates of scallops from different parts of the Bay using the RNA/DNA ratio technique which effectively measures the rate of protein synthesis in a tissue over the recent past. Two types of tissues were sampled : the ventral edge of the mantle and the adductor muscle. Results indicated that the RNA/DNA ratio was higher in the muscle tissue than in the mantle by about 20%. There were also spatial differences found from different parts of the Bay of Fundy. Implications of these observations will be discussed.*

WHAT ABOUT GROWTH VARIABILITY FOR *Pecten maximus* LARVAE PRODUCTION ?

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Abstract. *Large variabilities in rearing of* ***P. maximus*** *larvae production were observed in so called "standard" conditions of hatchery technology. Improvement in reliability for bivalve hatcheries is an important aim to sustain industrial development of such activities. A cooperative EEC project is focused on this problem. The different topics investigated will be introduced with some examples.*

- The first evidence was about food quality : large biochemical changes of phytoplankton under culture conditions were incriminated. Fatty acids (Delaunay) and vitamins (Seguineau) were mainly studied. Food composition affects also gonads composition with a possible consequence on larval development.

- Water quality was also demonstrated as a source of variability in larval production, peculiarly the small 1 µm particulate fraction. Bacterial interactions in rearing conditions were evidenced (NICOLAS) as well as the effect of some small phytoplanktonic strains.

- Genetic origin of parents is also probably a source of variability. So basic research projects on growth mechanisms were undertaken on hormonal control of growth (Mathieu et al., Toullec, Van Wormhoudt et al.) as well as studies on digestive processes (Boucaud-Camou, Auffret, Samain).

ENZYME PROFILES IN *Pecten maximus* HEMOLYMPH

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Abstract. *The hemocytes of bivalve molluscs are multifunctional cells involved in various physiological mechanisms, either pathological or not. Their participation in metabolites transfer and in seasonal tissular reorganization, such as oocytic atresy, seems to be naturally linked to the biology of these organisms. These abilities mainly rely on the phagocytic activity of certain hemocyte types, macrophages and granulocytes. It is now assumed that secretion (or excretion) of catabolytic enzymes may occur in the extracellular medium, allowing extracellular enzymatic degradations. Enzyme profiles of hemolymph components, cells and serum, were established in Pecten maximus, by using a semi-quantitative micromethod (APIZYM) over a one-year period.*

The application of this technique brought original results for this species. The presence of several hydrolytic enzymes and peptidases was demonstrated in both components. However, no activity of ß-glucuronidase was detected. A great qualitative resemblance was observed among the activities in serum and cells. This may indicate that physiological secretion or/and release occurred from cells to serum. Conspicuous variations were observed in the activity of several enzymes (esterases, acid phosphatases, ß-galactosidase and N-acetyl-ß glucosaminidase) during the sampling period, which could be related to physiological changes.

SCANNING AND TRANSMISSION ELECTRON MICROSCOPIC STUDY OF THE STOMACH OF *Pecten maximus* (L.) : ultrastructural localization of amylase secreting cells.

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Abstract. *The internal structure of the stomach of* ***Pecten maximus*** *has been first investigated by scanning electron microscope (S.E.M). The wide oesophagus anteriorly opens into a globular space the posterior end of which is reduced, while the conjoined style sac and mid-gut open ventrally. At the end of the oesophagus is a broad principal sorting area. This area, which is entirely composed of numerous ridges and grooves, is devided in two pockets : the right one, the largest, have several embayments receiving ducts from the digestive diverticula. The long regular ridges and grooves stop against the major typhlosole. The minor typhlosole ends on the right gastric wall; the major typhlosole accompanied by the intestinal left posterior side of the stomach there is a crescent shaped pouch : the dorsal hood, extending in an anterior and a posterior pocket. Ventrally to the dorsal hood and posterior to the left pocket is a voluminous crest-like ridge, the gastric shield against which the crystalline style rotates.*

The epithelieum of the stomach has been then studied by transmission electron microscope (T.E.M). It always consists of a single layer of columnar cells united by belt desmosomes followed by septate desmosomes and gap junctions. The cells rest on a basal lamina; underneath are numerous nervous fibers, connective tissue and amoebocytes.

The different part of the stomach wall have their ultrastructural specific features :

- under the gastric shield, the epithelial cells are characterized by long and thin microvilli, numerous large autophagic vacuoles and small secretory granules,

- in the dorsal hood, some cells are ciliated and contain secretory granules; the other cells have cytoplasmic extrusions,

- the main sorting area is composed of two type of cells : A and B. They both possess numerous cilia between microvilli : B cells are characterized by two types of granules, small granules which are electron dense and large clear granules.

A polyclonal serum against amylase of ***Pecten*** *was raised and used to immunolabel Epon embedded sections of the stomach wall by the protein A gold method. The clear secretory granules of the B-cells were immunogold labelled. This result suggests the existence of two different types of secretory granules in the B cells : the unlabelled small dense granules and the labelled large clear granules in which amylase is likely confined.*

AN INTRODUCTION TO THE STUDY OF NUTRITION : ENZYMATIC PROCESSES INVOLVED IN DIGESTION IN THE SCALLOP *Pecten maximus* (L.)

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Abstract. *The complexity and imbrication of the digestive gland, the stomach and the midgut in Bivalvia make difficult to found the actual sources of the digestive enzymes. The histochemical and cytochemical methods (enzymological or immunochemical) and the isolation of the different cell types, allow to precise the localization of enzymes involved in digestion, and help to understand the processes of digestion in the scallop* ***Pecten maximus*** *(L.).*
Most of the extracellular digestive activity occurs in the stomach and in the lumen of the digestive diverticula. The extracellular digestive enzymes are mainly glucanases (-amylase and cellulase, laminarinase) that agrees with the phytoplanktonic diet of the scallop. The cells secreting amylase are the type B cells (secretory cells) of the stomach, the amylase being later transported to the digestive tubules with the food by the inhalent current. The digestive tubules secrete lysozyme, that implies bacteria utilization as food. The digestion is achieved in the digestive cells within lysosomes II containing acid phosphatase and N-acetylglycosaminidase. The proteolytic activity appears very low; which is also characteristic of a phytophagic diet. The cells of the digestive ducts, especially the brush border cells which display the same enzymatic equimement as the intestine cells of vertebrates appear involved in the achievement of peptide digestion and absorption. The intestine could play a complementary role in the digestive absorption.

THE EFFECTS OF SUSPENDED CLAY ON THE GROWTH AND PHYSIOLOGY OF THE SEA SCALLOP (*Placopecten magellanicus*)

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Abstract. *Sources of suspended solids in the marine environment include; land-based erosion, resuspension, seabed dredging, ocean dumping, oil-well drilling and trawling and dredging for fish and shellfish. Once in suspension, fine particles settle slowly and may be transported considerable distances. While contaminants associated with some particle types may exhibit a degree of toxicity to commercially important scallop stocks, most of the solids descarded to the marine environment are biologically inert. The potential impact of bentonite clay on the growth and physiology of adult sea scallops was examined under ecologically revelant sedimentary and current conditions during gametogenesis. A combination of short (one hour) and long term exposures (two months) to concentrations of ventonite less than 10 mg l^{-1} provided information on scallop growth rates, condition reproductive output and physiological functions. Scallops exhibited a low tolerance to suspended clay and demonstrated no apparent physiological acclimation abilities. When added to unfiltered seawater, bentonite levels as low as 1 mg l^{-1} had adverse effects on scallop energetics while 10 mg l^{-1} caused tissue resorption and high mortalities within one month. In contrast, the addition of less than 2 mg l^{-1} to a diet of cultured algae increased ingestion rate and may be beneficial as food supplement for scallop brood stock in hatcheries.*

EFFECT OF DIETARY LIPIDS ON FATTY ACID COMPOSITION OF THE FEMALE GONAD AND LARVAE OF THE SCALLOP *Pecten maximus*.

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Abstract. *Marine animals have low capacities for the bioconservasion of dietary lipids which play therefore an important nutritional role to provide essential fatty acids (EFA), besides their energetic role. In bivalve hatcheries, the supply of EFA may be modified by the choice of microalgae which present a large variability of their fatty acid composition, depending on both species and culture conditions. To obtain informations about the regulation of the fatty acid composition and EFA requirements of scallop, we determined the effect of dietary fatty acids on the lipid composition of animals fed monospecific algal diets during oocyte maturation and larval development.*

After the conditioning of two broodstock batches on the diets ***Isochrysis galbana*** *(high 22:6/20:5 n-3 ratio) and* ***Skeletonema costatum*** *(low 22:6/20:5 n-3 ratio), algal fatty acids were strongly recovered in neutral and also polar lipids of female gonads. This result suggests that the high 20:5 (n-3) level usually found in oocytes spawned by wildor hatchery conditioned animals is rather attributable to the food intake than to a metabolic necessity.*

When larvae were grown on algal diets exhibiting various polyunsaturated fatty acid (PUFA) deficiencies, we observed that dietary fatty acids were accumulated in neutral lipids within few days after the first feeding while fatty acids not supplied by the food were rapidly depleted. In polar lipids of ***Pavlova lutheri*** *and* ***Isochrysis galbana*** *fed larvae, there was a marked preferential incorporation of the 22:6 (n-3) but this fatty acid was partially replaced by the 20:5 (n-3) in larvae grown on* ***Dunaliella tertiolecta*** *which was totally deficient for C20 and C22 PUFA, the 20:5 and 22:6 (n-3) were partially replaced by the major dietary PUFA : 18:3 (n-3).*

These results indicate that no significant elongation and desaturation of dietary fatty acid occurs in ***P. maximus*** *larvae. The control of the fatty acid composition, in polar lipids peculiarly is thus probably done through a selective retention of some dietary fatty acids such as the 22:6 (n-3). When larvae were fed PUFA deficient diets, the missing fatty acid was replaced by the structurally nearest one, available in the food, probably in order to maintain the balance between saturated, monounsaturated, (n-13) and (n-6) PUFA very stable in larvae whatever the diet in the experiment.*

Results are discussed in terms of lipids metabolism and EFA requirements.

Keywords *:* ***Pecten maximus****, larvae, gonad, microalgae, lipids, fatty acids, bioconservation.*

A COMPARISON AND EVALUATION OF LIPID STAINING ASSAYS AS MONITORS OF PHYSIOLOGICAL CONDITION OF SCALLOP LARVAE

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Abstract. *Physiological condition indices provide a valuable indicator of the general "health" or nutritional status of an animal. Lipids, and triacylglycerols in particular, have been identified as the principal energy reserve in bivalve larvae. Adverse conditions such as disease or nutrient stresses can result in the mobilization of these lipid deposits. Assessment of the lipid content of larvae by conventional means involving chemical extraction have proven inadequate in culture operations due to time and cost factors, and do not give much information on individual variability in lipid content within a population. Histochemical techniques using lipid-specific stains have proven to be much more effective and informative. Sudan Black B and Oil Red O have been used for this purpose for some time, and have been found to be invaluable diagnostic tools. Unfortunately, both techniques involve rather lengthy procedures and the sacrifices of the animals. A new method is described that uses the fluorescent hydrophobic lipid probe Bile Red as a vital stain. This stain fluoresces intensely when viewed under UV light, and can be readily quantified. These three staining techniques are evaluated in terms of their applicability to studies of bivalve larvae, using Placopecten magellanicus as a test species.*

SEASONAL VARIATIONS OF ADENYLATE NUCLEOTIDES AND ADENYLATE ENERGY CHARGE (AEC) IN DIFFERENT TISSUES OF JUVENILES OF *Pecten maximus* CULTURED IN THE BAY OF BREST

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Abstract. *A population of* ***Pecten maximus*** *born in hatchery and sowed in September 1989 in the Bay of Brest was followed through an annual cycle for shell growth and nucleotide analysis. The experiment started in March 1990 with 4.5 cm mean longitudinal sized scallops. A monthly sampling was achieved by diving. Twelve individual scallops were analysed at each sampling date. Scallops were processed the more quickly as possible after collection time and different tissues (mantle, gills, digestive gland and muscle) dissected and separately frozen in liquid nitrogen. The shell growth was related to the seasonal temperature cycles and started in spring till late autumn increasing from 4.5 to 7.7 cm longitudinal size. No growth was observed in winter. The mean concentration of adenylate nucleotides and the mean AEC value were different depending on the considered tissue. High value was associated with high adenylate concentration in the muscle. These values were gradually lowered from the muscle, to the mantle, the gills and the digestive gland. Mean adenylate concentrations varied from 100 to 34,25 and 23 µmoles/mg protein and AEC from 0.93 to 0.86, 0.78 and 0.63. However, the seasonal variations of these two parameters were inversely related. AEC seasonal variations were more pronounced for the digestive gland and the gills. The muscle and the mantle exhibited few seasonal AEC variations. In the contrary, variations of adenylate concentrations were only observed for the muscle and the mantle. When observed, AEC variations were characterized by a minimum value in summer. Inversely, minima values of adenylate concentrations were observed in winter.*

AXENIC BIVALVE LARVAE FOR STUDY OF PATHOLOGY AN DEFFECT OF DISSOLVED ORGANIC MATTER

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Abstract. *Oyster (**Crassostrea gigas**) and (**Pecten maximus**) eggs were decontamined by 5 antibiotics (penicillin, streptomycin, oxolinate, erythromycin and kanamycin) during 48h in order to obtain axenic larvae. About 30% of batches were completely decontamined. Their growth rates in 20 ml tubes at 10 larvae* ml^{-1} *did not seem different to the control non axenic larvae in 2l beaker.*

Partial decontamined scallop larvae could grow and survive as well as control larvae (no-decontamined) with antibiotic whereas larvae control without antibiotic systematically died. It is probable that some bacterial strains caused these mortalities although all investigations failed until now to isolate a pathogenic bacteria.

Screening of different dissolved organic matter (DOM) and some bacteria were performed. Although the tests were not always reliable, antibiotics and other substances including some amino-acids and vitamins were tested. Furane affected dramatically the growth of scallop larvae but not the oyster larvae whereas chloramphenicol, oxolinate, gentamycin did not seem detrimental for both species. Thiamin and glycin improved the growth rate of oyster larvae. Aspartate, glucose and biotine did not change the growth rate of these larvae. The response of scallop may be different and will be observed. The responses different between scallop and oyster larvae show the complexity of the problem of sea water quality even in the absence of bacterial flora.

DIGESTIVE ENZYMES DURING DEVELOPMENT OF *Pecten maximus* LARVAE

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Abstract. *Enzymatic properties of amylase, laminarinase and lysozyme activities were determined for quantitative investigations on digestive capacity of Pecten maximus larvae during their larval development. Proteolytic activities on casein and pseudosubstrate for trypsin and chymotrypsin were not detected.*
Specific activities of digestive enzymes were increasing from day after hatching with maximus around the second and third week, and then decreased to very low values during metamorphosis. Differences were observed depending on :
- activity considered : laminarinase and lysozyme were detectable at day two, but amylase appeared after day five,
*- large fluctuations were observed in standard conditions of rearing with three algae (**Pavlova lutheri, T. isochrysis, Skeletonema costatum**) depending probably on food quality and ingestion behaviour,*
- experiments with monospecific diets of the same algal species demonstrated corresponding specific enzymatic patterns, but growth rates were also lower,
- a sudden starvation on day 2, 9, 16, 23 diet not affect activities in a 48 hours survey but some decrease observed at 48 hours suggested to investigate on longer starvation periods,
- a monomodal amylase and laminarinase rhythm was evidenced with a major amplitude around the third week and a maximum 2-3 hours after feeding time. A possible bimodal or more complex rhythm was evidenced for lysozyme. These rhythms were lower before metamorphosis and continued in starvation conditions with a progressively decreasing amplitude. Relationship between digestive enzyme levels, ingestion, absorption were studied using C14 labelled algae. Result are under study. All these results will be discussed.

VITAMINS IN DIET AND LARVAE OF *Pecten maximus* (L.).

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Abstract. *Successful growth and development of cultured species depend to a large extent of the nature and content of biochemical constiruents in the feed provided.*
Vitamins compared to the major components protein, carbohydrates and lipid comprise only a minor fraction of the diet but are critical for the maintenance of normal metabolic and physiological functions.
BIOCHEMICAL QUALITY OF ALGAE
*The vitamin content of phytoplancton fed to **Pecten maximus** larvae was determined. Vitamin composition of the species **Isochrysis galbana** (clone T-Iso), **Pavlova lutheri**, and **Skeletonema costatum** was performed during different phases (stationaly or exponential) of growth.*
*The temporal variations of vitamins B_1 (thiamin) and E (tocopherol) were as important as the interspecific differences. Thiamin is added to culture medium, then the level was higher on the beginning of the culture and varied from 27 to 137 µg/g. Tocopherol increased with ageing culture from 147 to 284 µg/g for the species **Isochrysis galbana** for example.*
*Vitamins B_2 (riboflavin) and C (ascorbic acid) remained constant during the different phases of growth. For riboflavin no significant differences between the species were observed (0.4 µg/g), however **Isochysis galbana** and **Skeletonema costatum** exhibited higher vitamin C level (1500 µg/g) than **Pavlova lutheri** (152 µg/g).*
LARVAE DEVELOPMENT AND VITAMINS
*The vitamin content of **Pecten maximus** larvae was analysed from J2 to the metamorphosis.*
Preliminary studies showed that from J2 to the metamorphosis, the level of ascorbic acid increased and riboflavin content decreased.

PRELIMINARY STUDY OF PARTICLE SELECTION BY JUVENILE SCALLOPS.

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Abstract : *Juvenile scallops (<2 mm shell height) of three species (**Placopecten magellanicus, Patinopecten yessoensis, Argopecten irradians**) were fed mixed, unialgal cultures. A total of six algal clones were fed simultaneously and clearance rates monitored using flow cytometric techniques. In addition, scallops were presented with natural assemblages of particulate matter as a food source. Data are presented on differences in clearance rates for the individual algal species as well as size-related differences and uptake of chlorophyll vs. non-chlorophyll cells both within and between scallop species. Significant differences in clearance rates of individual species have been found within and between scallop species. Particle selection does not appear to be based upon size alone and is apparently based on other characteristics of the algae as well. Pre-ingestive sorting of particles by juvenile scallops is also a possibility.*

Key words : *scallops, feeding, selection, **Placopecten, Patinopecten, Argopecten.***

CAROTENOID PIGMENTS VARIATIONS DURING SEXUAL DEVELOPMENT IN *Pecten maximus.*

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Abstract. *Carotenoid pigments were investigated in **Pecten maximus** during sexual development, using thin layer chromatography method. Their individual variations were mesured in four organs : mantle, digestive gland, male and female gonads. If the range of identified pigments was characteristic, the results showed the important role of the Zeaxantin/Pectenoxanthin complex. During the sexual development, there is successively an increase of the relative concentration of this complex in the four studied organs.*

Just before reproduction time, this complex was the most important in the female gonade. The role of esterified forms, and the transfer of carotenoid pigements from all other organs to ovaries, during ovogenesis are discussed.

STIMULATORY EFFECTS OF MICROALGAL CHEMICAL CUES ON THE CLEARANCE AND INGESTION RATES OF *Placopecten magelllanicus.*

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Abstract. *The feeding activity of bivalve molluscs is a dynamic process which is influenced by various physical and chemical factors in the environment, as well as the quantity and quality of particles in the surrounding media. Many previous workers have shown that changes in temperatures, salinity, pH, particulate load, particle size, and perhaps particles shape can affect pumping, clearance, and ingestion rates. Few workers, however, have considered chemical signals as important factors in mediating bivalve feeding, even though chemically mediated feeding behaviour in another class of molluscs, the Gastropoda, has been shown to be very important. In this study we demonstrate that the giant scallop,* ***Placopecten magellanicus****, increases its clearance, and digestion rates in response to metabolites from the diatom* ***Chaetoceros muelleri.*** *On average, clearance rates were 44% higher and ingestion rates 46% higher when scallops were exposed to soluble metabolites than when they were exposed to control media. Dose response curves indicate that the stimulation saturates at a low concentration of diatom extract (eq. to 5,000 cells ml^{-1}). To our knowledge, this is the first time that this phenomenon has been demonstrated in a marine bivalve, and we suggest that chemical cues from microalgae are important factors which allow scallops to adjust feeding rates in nature.*

THE POTENTIAL VALUE OF PLOIDY MANIPULATION IN SCALLOP

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Abstract. *The theory and practice of the production of triploids, tetraploids and diploid gynogenomes, using physical or chemical potential value of triploidy induction for production sterile animals, with higher overall heterozygosity, is discussed in relation to scallop growth and marketing. Sterile scallops are also ideal where non-indigenous species are used for aquaculture since naturalisation will not occur. All triploid offspring could be produced by crossing a tetraploid with a diploid. However, viable tetraploid induction has yet to be successful in bivalves. Diploid gynogenetic scallops will show reduced heterozygosity and may provide a method for rapid inbreeding. Crossing between inbred lines can be expected to produce offspring with hybrid vigour, and this may become an important and valuable technique in future scallop aquaculture programmes.*

MITOCHONDRIAL DNA POLYMORPHISM IN THE SCALLOP *Pecten maximus*

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Abstract. *Two scallop populations localized, on one hand, in Brest area and on the other hand, in Saint-Brieuc bay, display two different reproductive behaviours. As the studies of enzymatic polymorphism did not show differences discriminating the two populations, we have started the characterization of mitochondrial DNA of the scallop* ***Pecten maximus.***

The obtained restriction profiles, for a certain number of individuals from each of these two populations, report a very high level of polymorphism regarding the number of DNA fragments and also the size of the entire mitochondrial genome. Facing this high level of individual polymorphism, it is not possible to propose a "type" profile for each of these populations. It seems that a variable part of the mitochondrial DNA exists with a certain number of copies giving rise to different genome size between 19.500 and 25.500 base pairs. These particularities were only found for this mollusc. A control experiment done on five individuals of another bivalve mollusc : the oyster ***Crassostrea gigas*** *shows homogeneity in size and restriction maps. The size of the oyster mitochondrial DNA is around 17.500 base pairs as it was usually observed in metozoa.*

We are currently working to determine "type" profiles for unmixed populations and populations representing the limits of geographical repartition of this species along the Atlantic coast. On another side, we are searching for "signature" sequence in order to discriminate between these two populations and to establish the phylogeny of these molluscs.

So, managing scallops populations for optimum yields requires that each stock be identified separately in regard to its genetic structure, provided by mitochondrial DNA analysis which is a new and powerful tool in the study of animal populations.

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Spatial and temporal variations of the sea scallop (*Placopecten magellanicus*) in the Magdalen islands (Quebec. Canada).
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M. Frechette.
Min Pêches et Océans. Institut M. Lamontagne. Quebec. Canada.

Analysis of scallop swimming using high speed video recording.
A. Ansell
Dunstaffnage Marine Lab. Argyll Scottland. U.K.

Swimming behaviour of the giant scallop *Placopecten magellanicus*.
G.J. Parsons and M.J. Dadswell
Dept. Fish Oceans. Biology station. St-Andrews. N.B. Canada

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Marine Farming unit. Argyll. Scottland. U.K.

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P.E. Dabinett
Ocean Sciences Center. Memorial Univ. of Newfoundland. Canada

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C. Couturier
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C. Couturier
Biol. St Andrews. N.B. Canada

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Dept. Biology. Univ. Moncton. N.B. Canada

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J.E. Ward, P.G. Beninger, B.A. MacDonald and R.J. Thompson
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Release of large numbers of small symbiotic cells by the giant scallop Placopecten magellanicus in Newfoundland.
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Recent advances in scallop genetics.
E. Kenchington
Dept. of Fisheries and Oceans. Halifax. N.S. Canada

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