Scallops - *Pecten maximus* and *P. jacobaeus*

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Biology, ecology and genetics

Distribution

P. maximus is distributed from northern Norway down to North Africa (Fig.1 – inset). Extensive fisheries exist for this species around the coasts of France and UK (Fig.1). *P. jacobaeus* is present within the Mediterranean and the Adriatic Sea and has been extensively exploited by local fisheries. The distributions of the two species are not thought to overlap at the entrance to the Mediterranean (1).

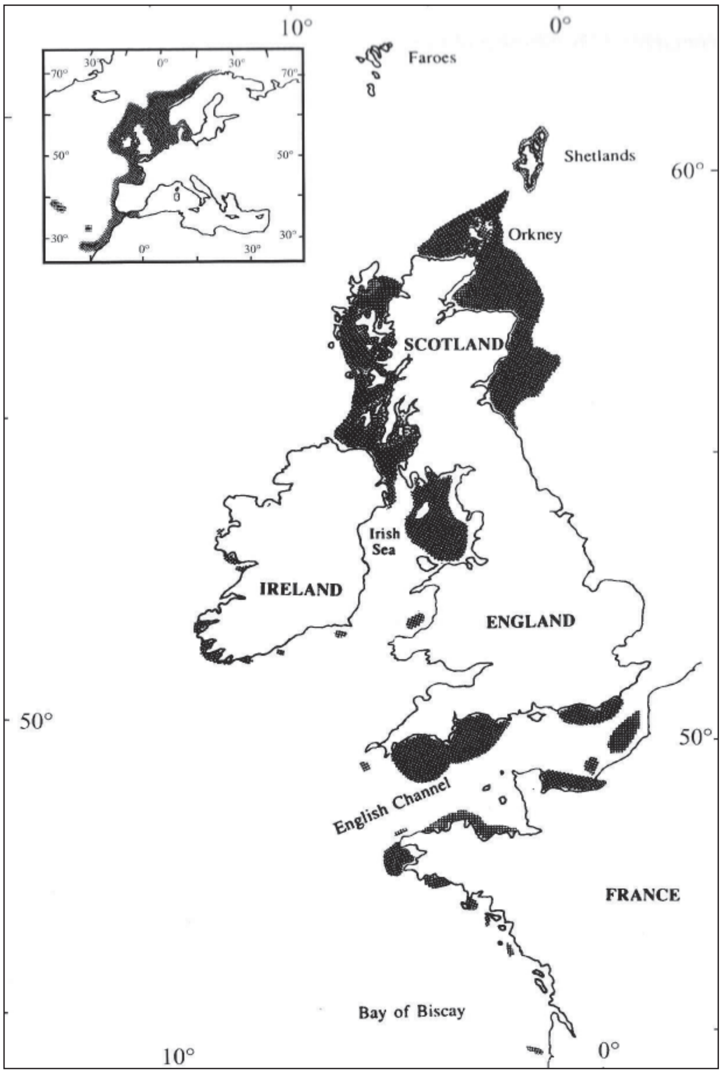

***Fig. 1.** Main fishing grounds for* P. maximus *around the UK, Ireland and France. Inset shows range of the species - from (1)*

Capture

Significant dredge fishery for scallops in Europe began in the 1950s around the coasts of UK and France and tonnages are given in Fig.2, with landings by country in Fig.3.

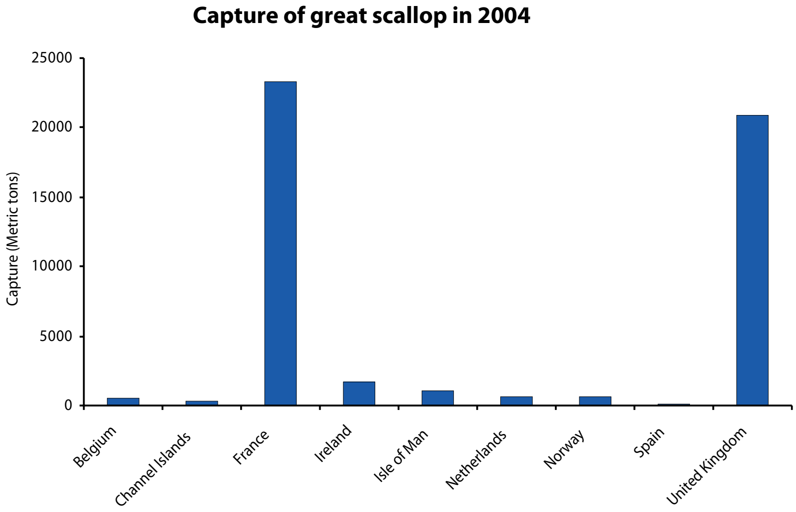

Fig. 2. *Landings of capture fishery of* P. maximus *in Europe, 1950-2004 (2)*

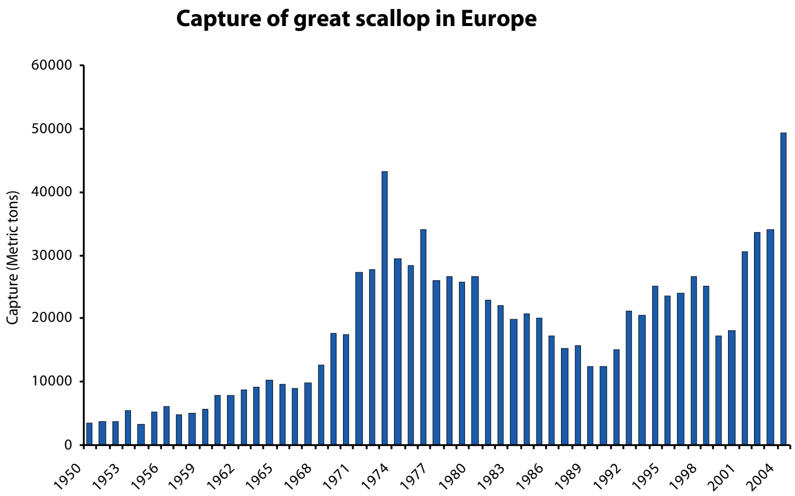

Fig. 3. *Landings of capture fishery of* P. maximus *in European countries during 2004 (2).*

Biology

Pecten spp. are bivalve molluscs in the family Pectinidae. They are filter feeders extracting particulate matter from the surrounding water via a feeding current drawn across the gills by cilia. Food material is trapped on the gills and carried to the mouth in mucous streams. The gills also act as the respiratory organ for the scallop. The shell is secreted by the mantle as the scallop grows. The upper (left) valve is flat and usually reddish brown while the lower (right) valve is convex and paler cream or brown in colour. Both valves can be marked with spots or zigzags of red, pink or yellow. There are prominent ears occupying about half the width of the shell. There is a sculpture of 12-14 broad radiating ribs on the upper valve (slightly differently shaped in the two *Pecten* species) and concentric annual growth rings are often visible. It takes *P. maximus* up to 4 years to grow to 10-11 cm, the Minimum Landing Size (MLS) for this species in Britain and Ireland (3).

P. maximus inhabits sand or gravel substrates from low water down to 100m depth (3). Growth rate can be affected by several factors including salinity, temperature, competition, water depth and food supply. Growth slows in older individuals and growth rings become closer together and more difficult to distinguish (3).

P. maximus can swim by rapidly clapping the valves and expelling the water on either side of the dorsal hinge and such adductions are also used to excavate the depression within which the scallop sits. Numerous small eyes are present around the mantle edge that are responsive to light (4). Scallops can accumulate poisons during toxic phytoplankton blooms and therefore can induce illnesses such as Paralytic Shellfish Poisoning (PSP) in humans (5).

P. maximus is a hermaphroditic species with a separate tongue-shaped orange / red (female) and white (male) gonad. In northern populations spawning is a single annual event, but several peaks of spawning can occur in southern populations. The trigger for spawning in the wild is not known with certainty but there may be an element of lunar periodicity (1). Laboratory observations indicate that male gametes are usually expelled first and there is a short rest period before eggs are released. Larvae are planktonic for 3-8 weeks and, after initial settlement, post-larvae can become further dispersed by byssus drifting (6). Details of the processes involved between initial spat settlement on filamentous substrates and subsequent recruitment as juveniles onto adult scallop beds remain elusive. The dispersal of larvae and spat is influenced by factors such as local hydrography, suitability of substrates and the longevity and survival of larvae. Consequently, *P. maximus* exhibits an aggregated distribution with major fishing grounds quite widely separated allowing environmental conditions to produce noticeable differences in population parameters (1).

Population genetics

Two allozyme studies of *P. maximus* (7, 8) revealed very little stock structure within the UK or France. A mitochondrial DNA marker in *P. maximus* (*Pma1*) was developed which also failed to reveal any significant population structure except at one site, Mulroy Bay in Ireland, which differed significantly from all other sites (9). Other mtDNA and RAPD markers studies (10, 11) also showed the Mulroy Bay population clustering separately from others. Norwegian *Pma1* haplotype frequencies are rather different to those in UK sites, but no differentiation has been identified between Norwegian populations (12).

There is therefore little evidence of substantial genetic differentiation of *P. maximus* populations throughout its range apart from Mulroy Bay. Mulroy Bay has been a regular source of scallop spat for aquaculture enterprises elsewhere in Ireland (13) but scallop recruitment may now be suffering due to extensive mussel rope culture in the bay.

As with other bivalves, heterozygote deficiencies have been reported at a number of loci in *P. maximus* and the most likely causes are selection and/or the presence of null alleles at the scored allozyme loci (14). A significant positive relationship between allozyme polymorphisms and growth or other fitness parameters, the so-called "Heterozygosity-Fitness Correlation" (HFC), has been demonstrated in many bivalves but studies on scallops have generally failed to find a significant HFC (14).

Taxonomic relationship between P. maximus and P. jacobaeus
Although there are morphological distinctions between *P. maximus* and *P. jacobaeus*, various genetic markers have failed to identify deep genetic separation (15, 16, 17, 18). The most recent study using mtDNA suggests that the two species shared a common ancestor fairly recently in the Pleistocene (19).

Breeding and culture practices

Production
Scallop culture started late in Europe compared with other species of molluscs. In 1984 the total aquaculture production of scallop was 78 600 tonnes of which 94% came from Japan. Recently China has surpassed Japan and in 2003 China alone produced 76% of the world aquaculture production of 1.17 million tonnes. In Europe, Spain, France, Ireland, UK and Norway have been producers of scallop and the aquaculture production reached a peak in 1998 with 512 tonnes followed by a reduction to 213 tonnes in 2004 (Tab.1). The estimated value of the European production in 2004 was 852 000 € (4€/kg).

Country	Highest production in 1990s	Production in 2004
Spain	207	0
UK	188	64
France	150	0
Norway	132	46
Ireland	67	103

Tab. 1. *Aquaculture production of* Pecten maximus *in Europe, tonnes (2, 20)*

Hatchery practices
The production of *P. maximus* is still mainly based on wild captured spat. However, the proportion of spat produced in hatcheries has increased over recent decades. Adult scallops can be conditioned in water enriched with microalgae and can be induced to spawn as the water temperature is increased. Larval culture of scallops is essentially similar to the well tried method used commercially for oysters. After 3-4 weeks, spat are collected on a settlement substrate and are later moved to nursery tanks or put into trays and cultured on sea-based longlines.

Grow-out
After about 2 months the spat should reach about 10 mm and may be on-grown by a variety of methods such as (a) hanging culture using lantern nets, pearl nets, or ear hanging, (b) bottom culture using a fenced area on the sea bed and (c) bottom ranching, putting large scallop spat directly onto the sea bed in unprotected areas with few predators. The most serious predators for scallops are starfish and crabs, but also fish (Ballan wrasse, *Labrus bergylta*) prey on juvenile scallops (21).

There are several possibilities for scallops to escape from the hatchery, from longlines and in particular from sea ranching activities. Since domestication is at an early phase, the effect on wild populations is probably not significant, but hatchery-reared scallops have been extensively re-seeded into bays in northern France.

Selective breeding

Few quantitative genetic studies have been performed on scallops. In Japan, broodstock of *Patinopecten yessoenses* were collected from the wild, and later they were selected from farmed specimens, but it is not known how selection was practised, which traits were considered, nor the intensity of selection. Some selfing possibly occurs in the wild but it is very difficult to avoid it completely in hatchery activities. Selfed larvae exhibit significantly reduced growth in *P. maximus* (22) and lower growth and survival in the Mexican scallop, *Argopecten ventricosus* (23).

A cross between two populations of *A. ventricosus* tested in two different environments did not show "useful heterosis" for growth or survival in either environment (24). However, the genotype – environment interaction was significant for four growth traits and for survival. Selection experiments (breeding from the best 10%) have demonstrated a 16% gain in weight per generation (25) with a realized heritability for weight of 0.33 ± 0.08 to 0.59 ± 0.13 and for shell width of 0.10 ± 0.07 to 0.18 ±0.08. A correlated response in adductor muscle weight, the most important trait in scallop, was predicted to give up to 19 % per generation increase when selecting for total shell weight (25).

Heritabilities ranging from 0.21 to 0.37 have been reported for growth rate in the American bay scallop, *Argopecten irradians irradians,* (26, 27) and a 9% per generation genetic gain has been achieved (28). The results from these studies on *A. irradians irradians* and *A. ventricosus* indicate large genetic variation in scallops which is encouraging for *P. maximus* aquaculture and is in agreement with conclusions elsewhere (29).

There is no breeding programme for *P. maximus* but in 2002 a breeding programme for *Argopecten purpuratus* was started in Chile by the Chilean scallop producers Association (30).

There is good evidence that induction of triploidy in scallops could be used to increase muscle growth relative to diploids at market size (31, 32).

Interaction studies

At present there has probably been very little, if any, genetic impact of aquaculture on wild populations of *P. maximus* due to the low level of aquaculture activity. The one exception may be the French re-seeding programme.

It is important to investigate the population substructure of *P. maximus* in order to be able to estimate any genetic impact of aquaculture activity. Some substructure has been identified but much may remain hidden. There are possible inbreeding effects in scallop aquaculture product due to unintentional selfing. This would add to the normal reduction in effective genetic population size when using hatchery broodstock.

Conclusions / Implications

- Efforts should be made using a suite of molecular markers to establish the population structure of *P. maximus* across its whole range, with special reference to localised adapted populations at the extremes of its distribution.
- Breeding experiments should be carried out to investigate quantitative genetic parameters of commercial importance. This is a prerequisite for the development of efficient breeding programmes for the enhancement of *P. maximus* aquaculture.
- Selection experiments should be carried out to study possible genetic gain in fitness traits.

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