Review of the incidence of pearling in the mussel, *Mytilus edulis*:

With reference to the mussel beds of the Walney Channel, Barrow-in-Furness, Cumbria, England

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Review on the incidence of pearling in the blue mussel, *Mytilus edulis*:
With relevance to the mussel beds of the Walney Channel, Barrow-in-Furness, Cumbria, England

Rebecca Wilcox

Abstract

The blue or edible mussel, *Mytilus edulis*, is economically and commercially valuable as a food and bait source, with mussel fisheries in many locations across the UK. This report focusses mainly on the blue mussel beds of the Walney Channel, Barrow-in-Furness, England. Since the late 1800s, it has been noted that the mussels in the channel form pearls, causing them to lose their commercial value, and having serious effects on the mussel fishery. Pearls are formed in marine bivalves due to contamination of the mantle (the layer of tissue that secretes the shell), sometimes by inorganic matter such as sand or gravel grains. The pearls in *M. edulis* however, are believed to be caused by the presence of a parasitic distomid trematode, the metacercarial stage (encysted late larval) of which causes pearl formation. Sea ducks, such as the eider and scoter, both common in UK waters, are believed to be intermediate hosts for the parasite. The purpose of this review is to inform the management strategies of the North Western Inshore Fisheries and Conservation Authority (NWIFCA) who manage the mussel fisheries of the Walney Channel.

Introduction

Mytilus edulis, or the blue mussel, belonging to the family Mytilidae, is a marine bivalve of strong ecological and economic importance (Bayne, 1976); perhaps best known for its commercial value as seafood and bait. *Mytilus edulis* has a wide distributional pattern, mainly due to its ability to withstand wide fluctuations in environmental factors such as salinity, desiccation and temperature (Goulletquer, 2004). Blue mussels are found in marine intertidal and subtidal habitats world-wide, also in some brackish waters, and form dense colonies known as mussel beds. Mytilids attach to hard substrata using a series of glands secreted by the foot, known as byssal threads. They are predominantly sessile organisms however, they can use their foot to move to different locations if necessary. Mytilids feed by filtering detritus and plankton from the water column when submerged; those in the upper littoral part of the shore tend to grow more slowly than those in the sublittoral, due a limitation on their feeding time that is dictated by the tide (Bayne, 1976). Characteristics such as their high fecundity, mobility and free living larval phase have contributed to the development of mussel culture (Goulletquer, 2004). Mussel aquaculture is now an established method of mussel production; the most common methods used are suspended culture and bottom culture. The earliest experiments of suspended mussel culture, where mussel seed are attached to ropes which are suspended from rafts and left to grow naturally, were in Spain, firstly on the Mediterranean coast (Andreu, 1958), and later on the Galician coast. These experiments were extremely successful and allowed Spain to fast become the world's leading producer of mussels (Bayne, 1976). Bottom culture is a method which uses reduced densities of mussels on the sea floor to achieve high growth rates. In both suspended and bottom culture, mussel seed is collected from areas of high, regular spatfall but poor culture conditions, and transferred to a site deficient in mussel settlement. Bottom culture is less expensive than suspended culture (with regards to equipment) but extra attention and careful site selection is important as the influences of temperature, primary productivity, siltation, predation and competition can have great effects on the mussel crop (Morse and Rice, 2010). The bottom culture method was used by Dare and Davies in 1975, where spat of *M. edulis* were transferred from intertidal settlement grounds in Morecambe Bay, Lancashire, to the Menai Strait, north Wales, where they were relayed. Although overcrowding, fast currents and turbulence caused some loss, growth was sufficient enough for some of the relayed populations to produce marketable crops after about 16 months. This method is now used commercially in the Menai Strait. Marine mussel aquaculture is something which could be explored further in the UK. With the current decline of many finfish species, shellfish could likely become a more prominent part of the UK diet, with mussels offering a one of the most sustainable options.

There are significant blue mussel beds in Morecambe Bay that are important both for ecological reasons and for the local economy. The formation of pearls in *M. edulis* has become a pertinent issue for the existing mussel fishery and also for the potential for development of aquaculture in the Walney Channel, Barrow-in-Furness. Pearling can be extremely damaging for mussel fisheries as once they develop pearls, mussels lose their commercial value as seafood. This presents a big problem for the local economy. The pearling of mussels in the Walney Channel was noticed in the late 1800s (Herdman, 1904) and was thought to be due to the presence of a parasitic trematode worm, which uses both cockles and sea ducks as intermediate hosts. Figure 1 shows the Foulney mussel bed (south Walney Channel).

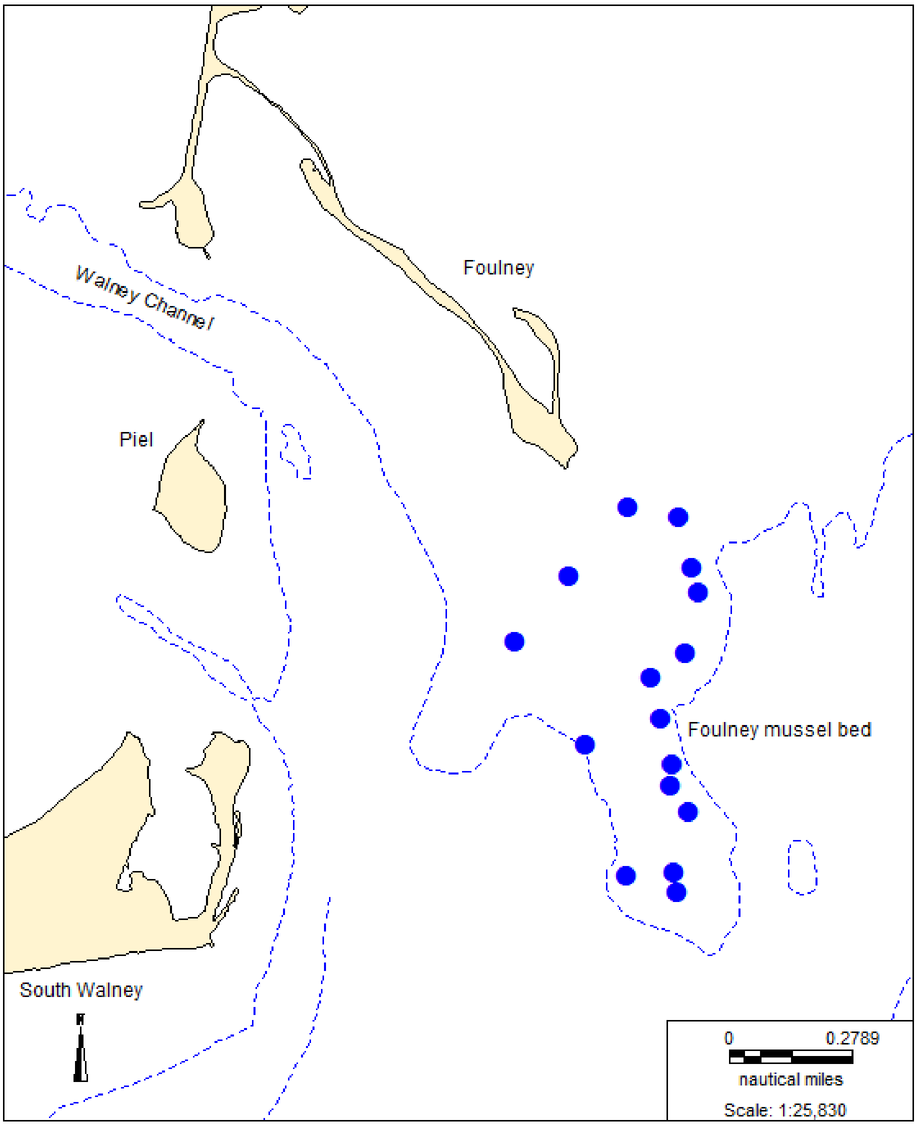

Figure 1 – Position of the Foulney mussel bed in the South Walney Channel
Blue circles indicate NWIFCA survey points from March 2012. Image supplied by NWIFCA.

The collection of seed mussels for culture at another location, or simply harvesting mussels before they reach a certain age, are suggested methods of avoiding pearl formation and could be explored further in the Walney Channel, due to the severity of the pearling that occurs in this area. Mussel relaying has already been trialled here (Figure 2a-c) and there are applications before Defra for the implementation of Several Areas for mussel aquaculture. However, the pearling issue affects the potential for the development of growing mussels for the live market, the most profitable market. The outlook for operators is to relay the mussels, which are grown on until a certain age (around 18 months), and then sell them as 'part-grown' mussel for on-growing in another location.

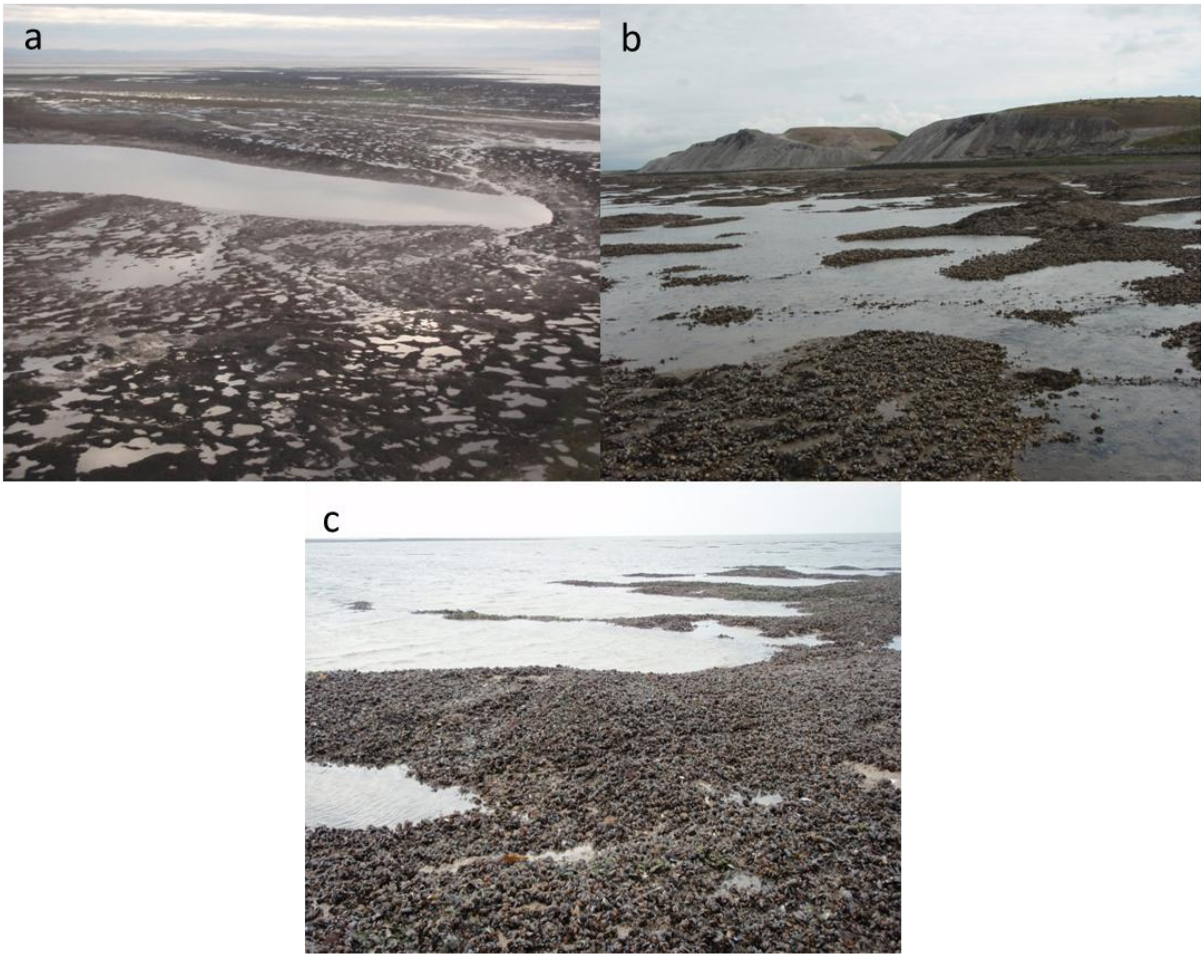

Figure 2a-c – Mussel relaying trial in the Walney Channel
Images supplied by NWIFCA.

The objective of this review is to provide up-to-date information on the incidence of mussel pearling in the Walney Channel in order to inform the management practices of the shellfish fisheries of Morecambe Bay. The NWIFCA have applied for a 30 year Hybrid Fishery Order for bivalve molluscan fisheries in Morecambe Bay which, if granted, will allow for the development of leased Several Areas for mussel lays. Operators interested in leasing Several Area plots have requested this background research in order to help answer the question of how to solve the problem of mussel pearling and increase profitability.

Discussion

The parasitic origin of pearls is a topic which has been widely researched, however the majority of this research was undertaken during the late 1800s and early 1900s and unfortunately, not much research has been conducted since the 1970s. The literature on trematode-induced pearl formation in mussels was reviewed by Stunkard and Uzmann in 1958. The aim here was to collate and update the information on pearl formation with relevance to the mussel beds of the Walney Channel. Due to the limited recent and relevant research available, I would recommend that more research is undertaken in this area to produce a more thorough understanding of the issue.

Pearl formation in marine bivalves is usually used as a defence mechanism. The nacre (mother of pearl) is produced by the outermost layer of the mantle which lines the shell. If a foreign body gets between the epithelium and the shell, the mantle will secrete a pearly coat around it (Dakin, 1913). Previously, it was thought that pearls were only formed around inorganic foreign bodies such as sand grains or gravel. However, research has shown that the presence of pearls in marine mussels is more likely associated with the presence of a parasitic trematode worm (Garner, 1872). Pearls can be classified into three categories: "1) those which are not formed within closed sacs of the shell-secreting epithelium, but lie in pockets, or ampullae, of the epidermis. The nuclei may be sand grains or any other foreign particles introduced through breaking or perforation of the shell; 2) 'Muscle pearls', which are analogous to gallstones, formed around calcospherules at or near the insertion of the muscles; and 3) 'Cyst pearls', in which concentric layers of nacre are deposited on cysts containing parasitic worms in the connective tissue of the mantle and within the soft tissues of the body" (Shipley and Hornell, 1904-5; Jameson, 1912). The latter two forms are 'true' pearls, i.e. bodies that have developed independently of the shell, which are not in any way continuous with the shell. One exception to this is where, owing to the rupture or absorption of the intervening tissues, the bodies may become secondarily covered over with nacre continuous with the lining of the shell; this is known as an 'attached' pearl (Shipley and Hornell, 1904-5).

Some research has been carried out concerning parasites in bivalve molluscs. Kelaart (1859) with Humbert, related the presence of vermean parasites to the origin of pearls in Ceylon pearl oysters. He found many parasitic worms infesting the viscera and other parts of the oyster. European and American oysters have also been found to be parasitised by larval trematodes of the genus Bucephalus. *Bucephalus haimeanus* was first found in European oysters in the Mediterranean Sea, reported by Lacaze-Duthiers (1854), and *B. cuculus* was described by McCrady (1874), found in American oysters from South Carolina. Sporocysts occur in the gonad and digestive gland of the oyster and sterilise the host. The life cycle of the parasite includes minnows (Cyprinidae) or mullets (Mugilidae) as second intermediate hosts, and gars (Lepisosteidae) as definitive hosts (Tennent, 1906).

Invasion by larval trematodes is thought to be responsible, at least in part, for pearl formation in *M. edulis*. The relation between pearls in blue mussels and trematode parasites was first described by Garner (1872) and later by Dubois (1901; 1903; 1907; 1909) who proposed the name (syn.) *Distomum margaritarum* (now *Gymnnophallus margaritarum*) for parasites found in reddish brown spots which served as foci for pearl formation in mussels from the French coast. Jameson (1902) believed that most mussel pearls resulted from encystment of metacercariae and encapsulation by the host. Herdman (1904), who studied blue mussels at Piel in the Walney Channel, found that pearls were very common here and attributed them to invasion by the larvae of *Gymnophallus somateriae* (syn. *Distomum somateriae*). Jameson (1902) stated that the larval trematodes resembled *D. somateriae* which had been described as an adult from the intestines of the eider sea duck, *Somateria mollissima* (Levinsen, 1881) and also the scoter sea duck, *Melanitta nigra*. These sea ducks act as intermediate hosts for the trematodes and some wading birds have also been found to host trematode parasites; adults of the trematode *Lacunovermis Macoma* have been found in knot, *Calidris canutus*, and oystercatcher, *Haematopus ostralegus* (Jennings and Soulsby, 1957). These birds are all common in the waters around the Walney Channel and therefore, could be involved in the lifecycle of the trematode parasites responsible for mussel pearling.

Jameson and Nicoll (1913) referred the parasite to the genus Lecithodendrium and described the process of pearl formation by the mantle of the mussel around the metacercariae. Giard (1903; 1907) confirmed these observations on pearl formation while Odhner (1905) designated the larvae causing pearl formation in mussels as *Gymnophallus bursicola*. Similar metacercariae were found by Stafford (1912) in mussels from the Gulf of Saint Lawrence, Canada. Jameson and Nicoll (1913) reviewed pearl formation in mussels and concluded that several gymnophallid larvae were involved. Since then, other gymnophallid cercariae have been associated with metacercariae in mussels (Palombi, 1924; Cole, 1935; Rees, 1939). Stunkard and Uzmann (1958) fed mussels from Long Island, USA, to newly hatched eider ducks and recovered adult gymnophallids, most likely *G. bursicola*. It is firmly believed that the life history of these organisms involves three hosts: a sea duck (most commonly scoter but sometimes eider) which contains the mature form, a mollusc (often the grooved carpet shell, *Tapes decussatus*, or the common cockle, *Cerastoderma edule*) which contains the first larval stage, and finally another mollusc (often *M. edulis*) which contains the second larval stage (Figure 3).

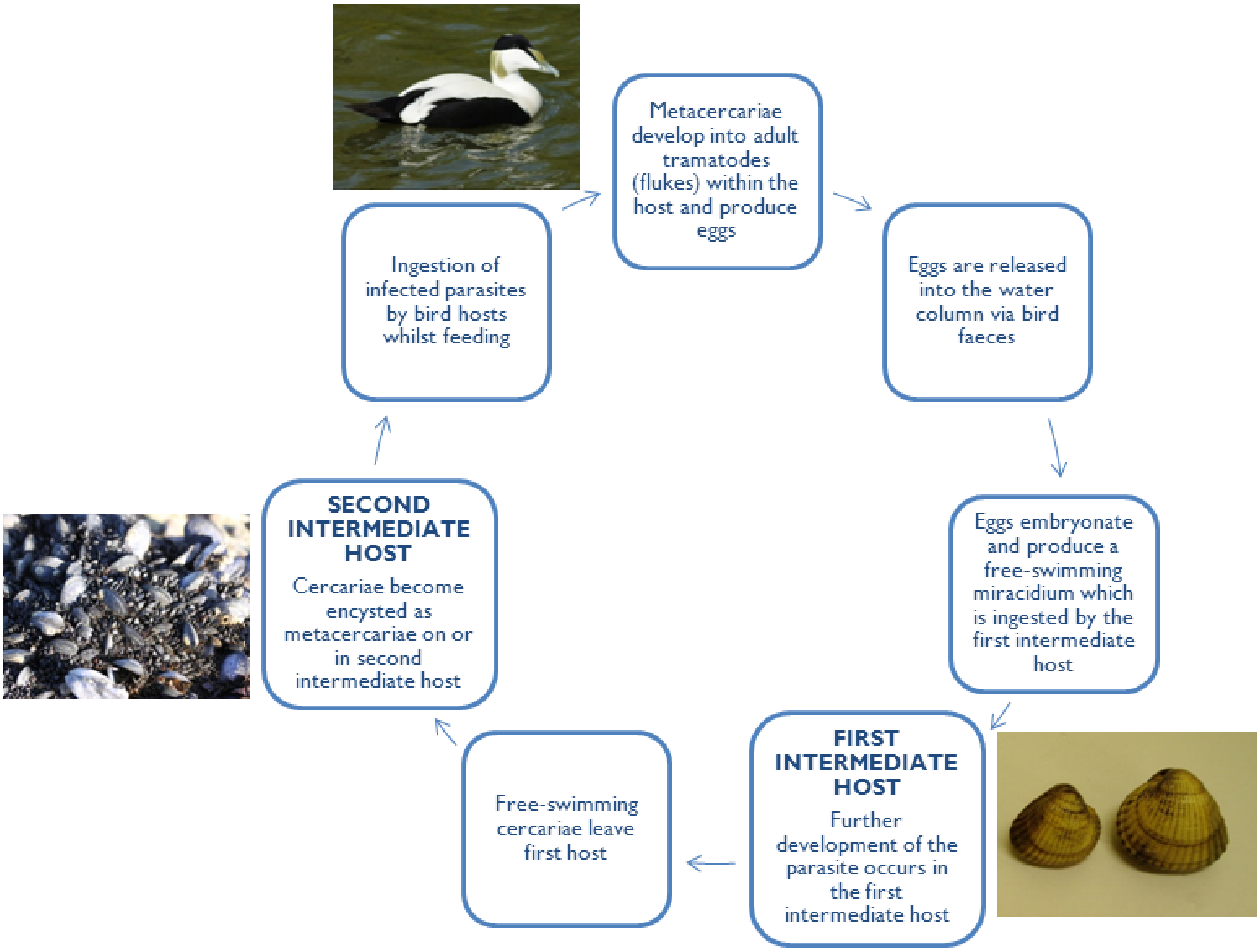

Figure 3 – The life cycle of a trematode: *Mytilus edulis* acts as the second intermediate host
Adapted from a figure by Friend and Franson, 1999. Photo credits: Eider duck ©Gillian Day; cockles ©NWIFCA; blue mussel ©Kent Wildlife Trust.

Jameson's (1902) theory on the manner in which the pearls are developed is that: "The trematode enters *Mytilus edulis* as a tail-less cercaria and at first may be found between the mantle and shell. After a while, the larvae enter the connective tissue of the mantle where they remain, assuming a spherical form visible to the naked eye as yellowish spots about half a millimetre in diameter. At first the worm occupies only a space lined by connective-tissue fibrils, but soon the tissues of the host give rise to an epithelial layer, which lines the space and ultimately becomes the pearl-sac. If the trematode larva completes its maximum possible term of life, it dies and the tissues of the body break down to form a structure-less mass which retains the form of the parasite, owing to the rigid cuticle. In this mass arise one or more centres of calcification and the precipitation of carbonate of lime goes on until the whole larva is converted into a nodule with calcospheritic structure. The granular matter surrounding the worm, if present, also undergoes calcification. The epithelium of the sac then begins to shed a cuticle of conchiolin; from this point the growth of the pearl probably takes place on the same lines and at the same rate as the thickening of the shell." It is believed that these larvae need only to be swallowed by the sea ducks to quickly grow to become adult trematodes, capable of laying eggs. The eggs then make their way from the duck, via excretion, into the water column where they hatch into free-swimming larvae that are able to swim about until they find another suitable host (Shipley, 1908).

It has been calculated that the alimentary canal of a healthy scoter duck can contain as many as six thousand adult trematodes (Shipley, 1908) and trematode parasites have also been found in some wading birds. Although larvae already encased in a pearl cannot become adult trematodes, those that are not encased and those that live in other hosts such as *C. edule*, where no pearl is formed, may do so. Once in the new host, the larvae begin budding off numerous secondary larvae, known as sporocysts. The 'egg hatching' or 'free swimming larvae' have never been observed, however, Jameson (1902) produced evidence to show that the sporocyst stage was present in two other marine bivalves: *T. decussatus* and *C. edule*. These sporocysts contained larvae that were closely related to the larvae found in *M. edulis* and entirely similar sporocysts were found in about fifty percent of the *C. edule* population in the Walney Channel (Shipley, 1908). Due to the high abundance of both bivalves and birds using the area, the incidence of pearling is likely to be a continuing problem. The high ecological importance of these species and habitats means that both an ecologically and economically viable method for the mitigation of mussel pearling needs to be investigated, whether it be via mussel culturing, harvesting or other means. As blue mussel beds in Walney Channel and Morecambe Bay of local economic value, it is clear that further, more in depth, research into trematode-induced pearling in *M. edulis* should be undertaken in an aim to determine: 1) more about the life cycle of the trematode and how the larvae enter the mussel; 2) if it is possible to prevent pearling; and 3) if there are better or easier ways to avoid or reduce the effects of pearling.

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