

The History of Oyster Farming in Australia

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Introduction

Oyster production in Australia, involves five species, namely the Sydney rock oyster, *Saccostrea glomerata*, formerly known as *S. commercialis*; Pacific oyster, *Crassostrea gigas*; flat oyster, *Ostrea angasi*; and two tropical species, the coral rock or milky oyster, *Saccostrea cucullata*, and the black-lip oyster, *Striostrea (Parastriostrea) mytiloides*, formerly known as *Saccostrea echinata*. The Sydney rock, Pacific, and flat oysters have been farmed. Before Europeans settled in Australia, flat oysters

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and Sydney rock oysters were collected for consumption by Aborigines along the coastal regions of eastern Australia; some of the shell deposits in Aboriginal kitchen middens can be quite substantial, up to 400 m long and 4 m high (Bailey, 1975). Middens in northern New South Wales (NSW) (Bailey, 1975) and southern Queensland (Catterall and Poiner, 1987) consist largely of Sydney rock oysters and in central NSW, where flat oysters are now rare, they consist of a mix of flat and Sydney rock oysters. However in southern Australia, the middens consist largely of flat oyster shells (Sullivan, 1984). Obviously, the Aborigines consumed the species that were abundant and easy to collect. Until the 1820's, most lime for making mortar in NSW was produced from seashells, including those from Aboriginal middens (Pearson,

1981) and natural oyster beds (Malcolm, 1987). As Europeans increased in numbers, they depleted the natural oyster stocks. Government officials banned the burning of oyster shells for lime in NSW in 1868 (Malcolm, 1987), and soon after, oyster farming began (Roughly, 1925; Smith, 1985).

Commercial production of oysters in Australia began simultaneously with the farming of the Sydney rock oyster in NSW and southern Queensland around 1870 (Roughley, 1922; Smith, 1985). It began with the exploitation by dredging of oyster beds (5–20 m deep) and harvesting of oysters by hand from intertidal beds, and with placement of a range of catching and growing substrata such as sticks, slabs of rock, and shell placed on intertidal mudflats to exploit natural recruitment. As dredge beds were depleted, problems with silt accumulation attracting the invasive mudworm, *Polydora* sp., which kills oysters, increased. Therefore, the industry progressively adopted stick and tray culture on intertidal racks in the early 1900's. To a large extent, this farming system protects oysters from the mudworm. Dredge bed culture (a most effective way of oyster farming) has disappeared from NSW because of siltation and the mudworm.

In South Australia, an extensive flat oyster fishery existed between 1860 and 1885. About 30 sailing vessels and some 80 fishermen harvested the oysters with dredges at 5–20 m depth (Olsen, 1994). The harvesting depleted the beds, and only a few vessels remained after 1885. By 1905 the fishery barely existed (Olsen, 1994). Similar oyster dredging existed in Victoria (Saville-Kent, 1891) and Tasmania (Sumner, 1972) around the same time. This was a huge industry; in Tasmania alone, 1.9 million dozen oysters were landed annually between 1860 and 1870

ABSTRACT—Aboriginal Australians consumed oysters before settlement by Europeans as shown by the large number of kitchen middens along Australia's coast. Flat oysters, *Ostrea angasi*, were consumed in southeastern Australia, whereas both flat and Sydney rock oysters, *Saccostrea glomerata*, are found in kitchen middens in southern New South Wales (NSW), but only Sydney rock oysters are found in northern NSW and southern Queensland. Oyster fisheries began with the exploitation of dredge beds, for the use of oyster shell for lime production and oyster meat for consumption. These natural oyster beds were nearly all exhausted by the late 1800's, and they have not recovered. Oyster farming, one of the oldest aquaculture industries in Australia, began as the oyster fisheries declined in the late 1800's. Early attempts at farming flat oysters in Tasmania, Victoria, and South Australia, which started in the 1880's, were abandoned in the 1890's. However, a thriving Sydney rock oyster industry developed from primitive beginnings in NSW in the 1870's.

Sydney rock oysters are farmed in NSW, southern Queensland, and at Albany, Western Australia (WA). Pacific oysters, *Crassostrea*

gigas, are produced in Tasmania, South Australia, and Port Stephens, NSW. Flat oysters currently are farmed only in NSW, and there is also some small-scale harvesting of tropical species, the coral rock or milky oyster, *S. cucullata*, and the black-lip oyster, *Striostrea mytiloides*, in northern Queensland. Despite intra- and interstate rivalries, oyster farmers are gradually realizing that they are all part of one industry, and this is reflected by the establishment of the national Australian Shellfish Quality Assurance Program and the transfer of farming technology between states.

Australia's oyster harvests have remained relatively stable since Sydney rock oyster production peaked in the mid 1970's at 13 million dozen. By the end of the 1990's this had stabilized at around 8 million dozen, and Pacific oyster production reached a total of 6.5 million dozen from Tasmania, South Australia, and Port Stephens, a total of 14.5 million dozen oysters for the whole country. This small increase in production during a time of substantial human population growth shows a smaller per capita consumption and a declining use of oysters as a "side-dish."

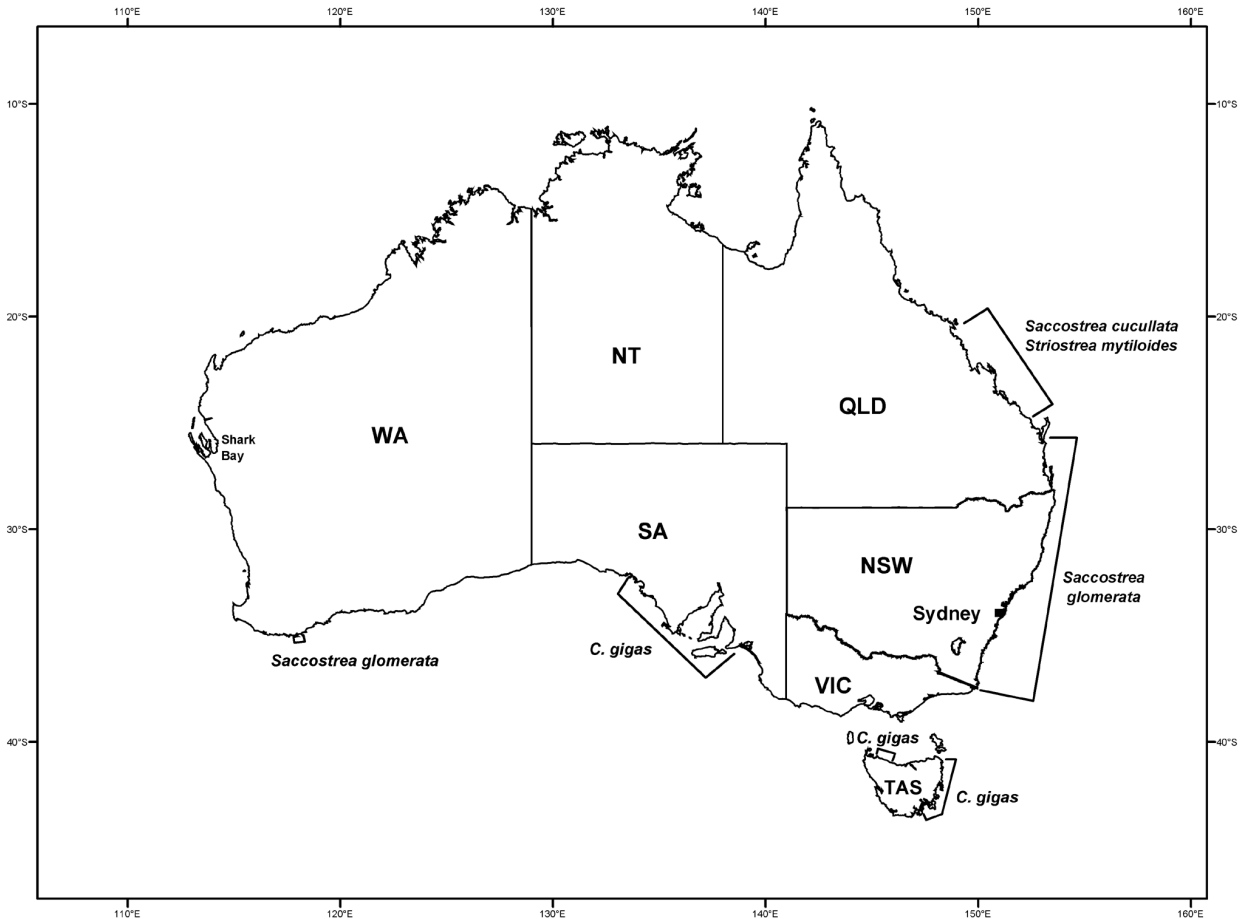


Figure 1.—Oyster growing areas in Australia.

(Royal Commission of the Fisheries of Tasmania, 1883).

In the late 1800's, the flat oyster fisheries in Victoria, Tasmania, and South Australia were fished out and attempts in the early 1900's to culture these oysters failed (Sumner, 1980a). Sydney rock oyster farming in NSW (Roughley, 1925) and southern Queensland (Smith, 1981/82) began in the 1870's. The Sydney rock oyster industry had a slow start and attempts to culture on the dredge beds were unsuccessful. In their place, farmers developed the intertidal stick and tray culture system (Nell, 1993) to avoid problems with the mudworm and developed a thriving industry. Pacific oyster farming began in Tasmania in the 1960's (Wilson, 1970), in South Australia in the 1970's (Olsen, 1994), and in Port Stephens, NSW, in 1991 (Nell, 1993) (Fig. 1). Some experimental farming of flat oysters in NSW, Sydney rock oysters

in Western Australia, and tropical species, the coral rock or milky oyster and the black-lip oyster, in northern Queensland also now occurs (Fig. 2).

Sydney Rock Oysters

A continuous distribution of Sydney rock oysters exists from the Victoria/NSW border (lat. 37°S) on the east coast through temperate NSW, subtropical Queensland, across the tropical north and along the west coast as far south as Shark Bay in Western Australia (lat. 25°S) (Slack-Smith¹). The Sydney rock oysters along the NSW coast do not differ genetically from each other (Buroker et al., 1979). The genetics of the oysters in Shark Bay on the west coast and those farmed on the east coast in NSW and southern Queensland have not been

¹Slack-Smith, S. Western Australian Museum, Perth, W. Personal commun., 2001.

fully compared. The Sydney rock oyster does best in intertidal estuarine habitats such as rocks, mangroves, and man-made structures, but it also occurs subtidally on natural dredge beds.

Oyster cultivation began in NSW around 1870 when oyster farmers began to set out sticks, stones, and shells to catch and grow oysters in the intertidal zone (Roughley, 1922). Around 1888, spat from the New Zealand rock oyster, *S. glomerata*, (which is the same species as the Sydney rock oyster (Anderson and Adlard, 1994)), were imported into NSW to replenish depleted oyster stocks (Roughley, 1922). The mudworm, *Polydora* sp., appeared in NSW concurrently with the introduction of New Zealand oysters, and farmers developed intertidal farming methods using sticks (Fig. 3) and trays (Roughley, 1922) to provide some protection against mudworm infestation. This was the dominant growing system



Figure 2.—From left to right, at the top, Sydney rock (66–86 mm shell height), coral rock or milky (59–79 mm), and flat oysters (71–77 mm) and at the bottom, black-lip (73–97) and Pacific oysters (76–104 mm).



Figure 3.—Frames of sticks bearing two year old oysters on an intertidal rack in Merimbula Lake, NSW. Photograph by I. R. Smith, NSW Fisheries.

from the 1950's until the 1990's. The structural remains of the early farming methods, such as wooden pegs driven into the mud bottom, rock culture (slabs of rocks standing upright in the mud), and bottom culture (shell spread out on a prepared base) can still be seen in some estuaries and a few dredge bed areas are still operational today.

The southern Queensland oyster industry flourished from the 1870's to 1910 but declined after that (Smith, 1981/82). Although originally largely a dredge bed industry, it also involved the harvesting of oysters that occur naturally in the intertidal zone, which was called "bank oystering" (Smith, 1981/82), and is referred to as "bottom culture" in NSW. Some Queensland farmers also experimented with rocks, shells, and sticks as alternative substrata on which to grow oysters (Smith, 1981/82).

Disaster struck the industry in 1895 when mudworms killed large numbers of oysters (Smith, 1981/82). The industry also suffered oyster mortalities from floods in the rivers, theft, and the lack of secure oyster bank tenure. However, the mudworm was the single largest cause of production decline (Smith, 1981/82). In the 1970's outbreaks of QX disease caused by the haplosporidian parasite *Marteilia sydneyi* (Perkins and Wolf, 1976) led to a further decline (Nell, 1993). Since 1936, Queensland oyster farmers have imported half-grown oysters from NSW to grow them to market size (Smith, 1981/82).



Figure 4.—Trays supporting fourth generation breeding lines of Sydney rock oysters, Port Stephens, NSW.

The Sydney rock oyster industry in NSW and Queensland is wholly dependent on natural spatfall, which has always been abundant and reliable (Nell, 1993; Beattie, 2001). The industry, therefore, has been reluctant to selectively breed oysters (Nell et al., 2000) or use triploid oysters (Nell, 2002) since the financial outlay for all hatchery-produced spat is larger than for natural spat. It takes the Sydney rock oyster on average 3½ years to reach plate size (50 g whole weight), the most popular size grade. The larvae of Sydney rock oysters are set on tarred hardwood sticks and they grow intertidally on timber frame trays (1.8 × 0.9 m) (Fig. 4) with plastic mesh bottoms which are placed on timber racks. Alternative growing systems, such as baskets and tumblers, are also being used, and some

oysters are grown subtidally on rafts or on floating culture (Fig. 5) (Nell, 1993). To reduce the amount of tarred timber used in the construction of oyster racks, the intertidal longline system, with horizontally suspended plastic tubes of 41 × 91 cm, developed by South Australian oyster farmers, is being used by an increasing number of farmers in NSW (Fig. 6).

During the 1950's and 1960's the NSW Sydney rock oyster industry exhibited consistent growth as production methods improved and total lease area increased. However, around 1970, production rapidly increased from about 10 to 14 million dozen or 6,000 to 8,400 t (wet weight including shell). Much of this increase was attributed to the rise in the number of farmers who transported oysters from estuary to estuary to take



Figure 5.—Frames of sticks suspended below PVC pipes in floating culture, Wallis Lake, NSW. Photograph by I. R. Smith, NSW Fisheries.

advantage of differences in the timing of prime growing or fattening conditions. This practice, known as “highway oyster farming,” developed from the mid 1960’s onwards. Production rates stabilized during the 1970’s at around 13 million dozen (7,800 t) per year. Highway oyster farming was particularly prominent in Port Stephens, which produced a lot of spat which were taken by truck to other estuaries for growing. In autumn, large quantities of oysters were taken to the northern rivers of NSW for winter “fattening” and returned to Port Stephens for marketing in the spring (Nell, 1993). Unfortunately, when Pacific oysters were found in Port Stephens in 1984 (Holliday and Nell, 1985), the transfer of oysters to the northern estuaries was greatly restricted to prevent the spread of Pacific oysters further north.

Attempts to grow Sydney rock oysters in Tasmania and South Australia failed owing to poor spatfall and slow growth rates (Olsen, 1994). Since 1997, one company with its own hatchery in Albany, WA, has been successfully producing spat from a strain of Sydney rock oysters obtained from Shark Bay. The oysters are successfully farmed near Albany (lat. 35°S), far south of the limit of their natural distribution in Shark Bay (lat. 25°S), WA.

Pacific Oysters

The Pacific oyster was introduced into Tasmania, Victoria, South Australia, and Western Australia in five shipments from 1947 to 1970 (Medcof and Wolf, 1975). None of the oysters transplanted to South Australia and Western Australia survived; however, some of the oysters in Tasmania survived (Medcof and Wolf, 1975), as did a small isolated population in Victoria (Coleman and Hickman, 1986). The Pacific oyster was illegally introduced into Port Stephens, NSW, in 1984 (Holliday and Nell, 1985).

Farming of the Pacific oyster in Tasmania began in the 1960’s (Wilson, 1970; Sumner, 1974; Dix, 1975). Wild caught spat were collected and grown using the same stick and tray system as used in NSW at that time (Wilson, 1970; Sumner, 1980a, b). With the development of hatchery production of spat in the 1980’s, the industry in Tas-



Figure 6.—Intertidal longline culture of Pacific oysters, Franklin Harbour, Cowell, South Australia.



Figure 7.—Intertidal basket culture of Pacific oysters, Little Swanport, Tasmania.

mania rapidly expanded (Dix, 1991). It developed its own way of growing and handling oysters and adopted the basket culture system (Fig. 7). The baskets are made of folded plastic mesh and are generally around 28 cm wide and 47 cm long. Some farmers also use plastic trays (93 x 93 cm) for intertidal culture (Fig. 8). These trays can be stacked 6–14 high for subtidal culture.

The Tasmanian oyster hatcheries produce almost exclusively “black” Pacific oysters, which have a black mantle and shell, but they also maintain and produce some “golden” oysters, which have an orange/bronze or “golden” mantle and shell. They are rather slow growing, presumably because they have been derived from only a few oysters and are most likely inbred. It is claimed



Figure 8.—Plastic oyster trays (93 × 93 cm), suspended from an intertidal longline, Georges Bay, St. Helens, Tasmania.

(Cameron²) that after several generations of selective breeding these oysters breed “true” for the “golden” color and only produce “golden” oysters. A small niche market for “golden” oysters has been developed in Asia.

The industry in South Australia developed in parallel with the Tasmanian one. It began in the 1970’s with the importation of wild-caught spat from Tasmania and developed rapidly during the 1980’s with the import of hatchery-produced spat from Tasmania (Olsen, 1994). Oyster hatcheries were established in South Australia in the 1990’s, and the industry now uses local hatchery spat as well as spat purchased from Tasmania. South Australian farmers have been particularly innovative and have developed the intertidal longline oyster growing system which is now also used on a limited scale for Sydney rock and Pacific oyster cultivation in NSW (Fig. 6).

Pacific oyster production in Australia targets the half-shell market, which requires a uniform size oyster. Therefore the hatchery-produced Pacific oysters are regularly graded to achieve a uniform size grade. The Pacific oyster farmers in Tasmania and South Australia use conveyor belts and graders for grading and handling oysters in their sheds.

Oyster farmers collected Pacific oysters sporadically in NSW from 1967 (Medcof

and Wolf, 1975) until 1984, when they were illegally introduced into Port Stephens, NSW (Holliday and Nell, 1985). Before 1984/85, farmers in Port Stephens caught Sydney rock oyster spat near the mouth of their estuary and grew their oysters relatively free of overcatch (spat setting on oysters and growing equipment) in the upper half of the estuary. But as Pacific oyster spat settle throughout the estuary, farmers may need to take their Sydney rock oysters out of water once for up to 2 weeks during summer to kill off the overcatch of Pacific oysters.

In 1985, regulations were introduced to control the number and spread of Pacific oysters in NSW. In estuaries other than Port Stephens, oyster farmers are legally required to remove Pacific oysters from their leases. As a result of the overwhelming numbers of Pacific oysters in Port Stephens, farmers there were given permission by the NSW State government in 1991 to grow and market them. Cultivation of the species remains prohibited in other estuaries.

The proliferation of Pacific oysters in Port Stephens has greatly increased the overcatch of spat and thus the costs of handling Sydney rock oysters. The Pacific oyster has also spread to all oyster growing estuaries south of Port Stephens (lat. 32°S), including Georges River/Botany Bay (lat. 34°S) and Wonboyn River (lat. 37°S) but virtually none to the north of Port Stephens. In NSW estuaries, Pacific oysters are mainly found in the lower

intertidal zone in the upper reaches of estuaries. They do not suffer from either of the two haplosporidian diseases that afflict Sydney rock oysters, namely winter mortality, *Mikrocytos roughleyi* (Farley et al., 1988), and QX disease, *Marteilia sydneyi*.

Flat Oysters

Beds of flat oysters were extensively dredged in bays and inlets in Victoria (Saville-Kent, 1891), Tasmania (Sumner, 1972), and South Australia (Olsen, 1994) in the 1800’s and the early 1900’s, but they became exhausted and in most cases never fully recovered. After the natural oyster beds were depleted, attempts to farm flat oysters were made in Tasmania and Victoria but did not last more than 20 years because of siltation, disease, and a lack of government support needed to establish a new industry (Sumner, 1980a).

Experimental flat oyster farming has been tried in all Australian states except Queensland, but with the success of hatchery production of Pacific oyster spat during the 1980’s, flat oyster farming in Tasmania (Dix, 1980) and South Australia was abandoned and the much hardier Pacific oysters were grown. There were also short-lived attempts to farm flat oysters in Victoria and Western Australia during the 1990’s but no commercial leases were allocated (Hickman³).

³Hickman, N. Marine and Freshwater Resources Institute, Queenscliff, Vic. Personal commun., 2001.

²Cameron, G. Camerons of Tasmania, Dunally, Tasman. Personal commun., 2001.

When the disease *Bonamia* was discovered in 1991 (Adlard, 2000), all interest in farming flat oysters in Victoria waned, even though oysters grown off the bottom on subtidal longlines suffered little or no effect from this disease (Hickman³). However, hatchery-produced flat oysters have been produced and grown experimentally in NSW since 1998 and appear to have good market acceptance (Heasman⁴).

Tropical Oysters

In the northern waters of Queensland, the coral rock or milky oyster, *S. cucullata*, and the black-lip oyster, *Striostrea mytiloides*, are harvested from rocky foreshore areas where they have settled and grow naturally. Both these species have a strong flavor apparently due to a high iodine concentration and are very popular with north Queenslanders who are used to this flavor (Beattie, 2001). Production is limited to selective harvesting and retention of broodstock. No oyster farming structures are permitted in these areas. The majority of areas cover a maximum of 600 m foreshore length. Farming trials of the black-lip oyster in northern Queensland have been successful (Beattie, 2001).

Oyster Diseases

Winter Mortality

Winter mortality is caused by the parasite *M. roughleyi*, which occurs over the southern or cooler half of the range in which Sydney rock oysters are farmed. The parasite was once thought to be a haplosporidian, but current research is investigating the possibility that the parasite belongs to the *Bonamia* genus instead (Cochennec-Laureau et al., 2001). This disease was first observed in the early 1920's in Georges River, NSW (Roughley, 1926). Oysters in the area between Port Stephens and the Victorian border are particularly susceptible to winter mortality. Although, large numbers of oysters from infested estuaries were transferred for "fattening" during winter in the northern rivers of NSW from the mid 1960's to the mid 1980's, winter mortality has not

spread north of Port Stephens, suggesting that there is a northern limit to the spread of this parasite. Outbreaks of the disease are patchy within this range, and while mortality may occur in winter, most of the oysters do not die until the warmer spring weather of September or October.

Winter mortality may kill up to 80% of the oysters in an area, and those oysters in their third winter (just before they reach market size) are most susceptible. In severe outbreaks, small spat may also be affected (Nell, 2001). The severity of the kill can vary markedly between years, estuaries, adjacent leases, and even within leases.

Oysters grown on trays and sticks are about equally susceptible to winter mortality (Smith et al., 2000). Dry autumns (which cause high salinities), early winters, and low temperatures increase the likelihood of a severe kill. Farmers can reduce the impact of this disease by moving oysters further upstream to areas of lower salinity before the end of autumn (May) and by increasing the growing height of the oysters to 15 cm above normal elevation. Alternatively, farmers can also sell their oysters for consumption before the onset of mortality.

QX Disease

Outbreaks of "Queensland unknown" or QX disease (caused by another haplosporidian parasite, *Marteilia sydneyi*), results in the deaths of large numbers of oysters. The disease is more commonly found in northern, warmer estuaries and was responsible for a decline in the oyster industry in southern Queensland and in northern NSW during the 1970's. The life cycle of the parasite is thought to include an intermediate host, the identity of which remains unknown. While QX mortalities may occur throughout most of the year, mortalities are highest in early autumn (March and April). As a result of QX disease, production in the Tweed, Richmond, and Clarence Rivers in northern NSW during the past 26 years decreased from 379,200 dozen in 1974/75 to 168,504 dozen in 2000/01—a drop of 56%. In 1994, QX disease was first diagnosed in central NSW in Georges River (lat. 34°S) (Adlard and Ernst, 1995). The disease had a devastating effect on Georges River oyster production which

declined from 1,111,171 dozen in 1993–94 to 62,000 dozen in 2000–01, a drop of 94%, as the disease in this river kills up to 90% of all Sydney rock oysters annually. As the Pacific oyster is not affected by QX disease, it has partially displaced Sydney rock oysters in Georges River and now makes up 80% of the oysters on the foreshore of the upper reaches of the river.

An extensive three-year scientific survey of QX disease *Marteilia sydneyi* is now being made in 18 oyster producing estuaries. Samples are being stored for winter mortality *Mikrocytos roughleyi* testing at a future date. The farmers are being notified of the results so they can take appropriate steps to minimize any spread of the disease. These strategies will be refined in consultation with the industry. Since 1986, NSW Fisheries prohibits farmers from moving oysters from affected estuaries into disease-free estuaries.

The practice of farming oysters imported from QX disease-free estuaries may have inhibited the development of resistance in the local oysters in these estuaries. However, since the appearance of QX disease in Georges River, NSW Fisheries has bred oysters for resistance to this disease for two generations and reduced mortality by 22%.

Bonamia

Since 1986, mortalities as high as 80% in the bluff oyster, *Tiostrea chilensis*, in New Zealand have been caused by a *Bonamia* species different from *Bonamia ostreae* that afflicts *Ostrea edulis* in Europe (Hine, 1991). In the summer of 1991, this *Bonamia* species was detected in *Ostrea angasi* in Victoria, Tasmania, and Western Australia (Adlard, 2000). A survey for *Bonamia* in flat oysters in five estuaries in NSW, where experimental culture of flat oysters began in 1998, is planned for 2003/2004.

Mudworm

The mudworm *Polydora websteri* is the most damaging of four spionid polychaete worms which infest and kill large numbers of Sydney rock oysters (Nell and Smith, 1988). The mudworm also infests most commercial mollusks including Pacific and flat oysters. The adult mudworm is up to 25 mm long,

⁴Heasman, M. P. Taylors Beach, NSW. Personal commun., 2001.

1 mm wide and red in color. It lives on the inside of the oyster shell, where it gives rise to the formation of a mud blister, but maintains a tube across the lip of the shell to the outside. Healthy, rapidly growing oysters may be able to quickly cover the worm and its mud patch with shell, but weak oysters may die. Oyster losses due to mudworms are often high and the remaining infested oysters are unsaleable because of their poor condition and unsightly and foul smelling mud blisters, which rupture easily when the oysters are opened.

In NSW, infested Sydney rock oysters can be left out of water in the shade for up to 10 days to kill mudworms and flatworms (see below), and some oyster farmers wash mud from oysters on their leases using boom-sprays on punts to lower the risk of infestation (Fig. 9). Treating infested oysters in freshwater for two days will kill mudworms without harming healthy oysters (Beattie, 2001). Some farmers have successfully used an iodine bath to kill mudworms. Oysters are left out to dry for 4–5 days, followed by a 2–3 h bath in an iodine-based disinfectant solution (0.1 g of active iodine per liter of seawater), before returning to the lease. This treatment is more successful in treating bad mudworm outbreaks than drying alone.

Pacific oysters in Australia have been relatively free of most diseases, but they do suffer from mudworms. In Port Stephens, NSW, they are mainly affected by *P. websteri*. In Tasmania, farmers are concerned about mudworms in Pacific oysters, but they have not suffered serious problems so far. In Tasmania, the mudworm *Boccardia knoxi* is found in subtidally cultured Pacific oysters, whereas *P. websteri* and *P. hoplura* occur in intertidal oysters (Handler⁵). In South Australia the mudworm in Pacific oysters is a problem in some bays in some years. This is rather surprising, as these bays are very oceanic; the water is very clear, and there is no mud/silt on the bottom. The species of concern in South Australia are *P. websteri*, *P. hoplura*, and *Boccardia chilensis* (Hone and Tonkin, 1993).

⁵Handler, J. Department of Primary Industries, Water and Environment, Prospect, Tasman. Personal commun., 2001.

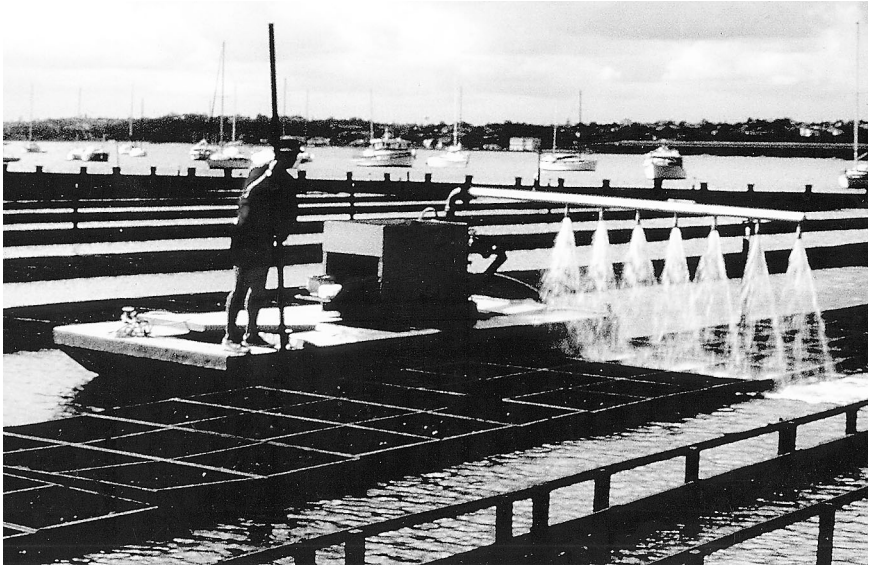


Figure 9.—Washing mud off oysters to control the mudworm, Botany Bay, Sydney, NSW. Photograph by I. R. Smith, NSW Fisheries.

Flatworm

Known as wafers or “leeches,” polyclad flatworms are common predators of oysters and other commercial bivalves around the world. In NSW the flatworm, *Imogine mcgrathi*, was identified as a threat to oyster production (Jennings and Newman, 1996) in the early 1900’s. Flatworms consume oysters at a rate of about 1 oyster/flatworm/month, and when they occur in high numbers, they have devastating effects (O’Connor and Newman, 2001). Since the use of fine mesh trays (Fig. 3), cylinders, and baskets for oyster nursery culture (farming of single seed oysters from 2–12 mm shell height), flatworm mortality has become a serious problem for Sydney rock, Pacific, and flat oyster production in NSW. During low tides, the fine mesh protects flatworms from desiccation, allowing them to feed on live spat. Regular inspection of spat in nursery culture and increasing the mesh size assist in controlling them. Worms can be killed by immersing oysters in hot water for 5–10 seconds or in fresh water for 5 min (Beattie, 2001).

Flatworms appear to be most abundant in periods of prolonged drought when estuarine salinities are relatively high. The reason for this is unclear, as adult

I. mcgrathi can tolerate reduced salinities for some time, but reduced salinity may affect reproductive behavior of the flatworm larvae (O’Connor and Newman, 2001). Exposure to fresh water or saturated brine for 15 minutes is an effective way to kill the adults.

Heat Kill

Summer temperatures on exposed leases can rise to 30–40°C and kill both Sydney rock and Pacific oysters. The problem is most acute when low tides coincide with the warmest period on a hot summer’s day (Potter and Hill, 1982). Some NSW farmers have installed irrigation sprinkler systems on their leases and spray salt water over the oysters to keep them cool. Other farmers use shade cloth over trays to keep oysters cool and predators out, but unfortunately this practice restricts water flow over the trays and increases the risk of mudworm infestations. Spraying oysters with seawater keeps the oysters cooler than the shade cloth does (Potter and Hill, 1982). The Sydney rock oysters that survive heat stress grow well (Potter, 1983); however, when flooding, as occurs in late summer (February/March) in some years in the northern rivers in NSW, follows heat stress, oyster mortalities from exposure

to prolonged periods of fresh water are increased.

In South Australia, Pacific oyster farmers face the twin hazards of “dodge” tides, which occur when the diurnal cycle is interrupted and there is no clear distinction between consecutive tides. A prolonged period of low tides can be a consequence and major heat kills of oysters can result. The intertidal longline system was developed to avoid them. It allows the farmer to quickly alter the growing height of the oyster cylinders to obtain some relief, catching the tide at an earlier time.

Genetic Improvement

Triploidy

In NSW (lat. 27–37°S), triploid Sydney rock oysters reach market size (50 g whole weight) on average 6 months earlier than the usual 3.5 years for diploids. Triploids also survive and hold their meat condition better than diploids in winter and spring (Nell et al., 1994; Hand et al., 1998a; Nell and Maguire, 1998). Triploids also grow faster than diploids at high water temperatures (Hand et al., 1998a), that is, in lower latitudes in Australia. In addition the mortality of triploid oysters is less than half that of diploid oysters that are exposed to winter mortality (Hand et al. 1998a, b). Although triploids may suffer some discoloration of meat in summer and autumn, for farmers who want to grow a winter crop that is partially resistant to winter mortality, triploid oysters may be a future option (Hand and Nell, 1999; Hand, 2002). Farmers want to purchase more triploid Sydney rock oyster spat, but the supply is limited because hatcheries lose many larvae when they are 2–8 days old and post-settlement mortality of spat (0.5–2.0 mm shell height at 1–6 weeks of age) is high (Heasman et al., 2000).

Farmers in Tasmania (lat. 42–43°S) (Maguire et al., 1994b) and South Australia (lat. 32–35°S) (Nell, 2002) had slow growth rates and poor meat condition in their triploid Pacific oysters in the 1990's. Taste tests showed that consumers liked triploids, but Maguire et al. (1994a) reported a 6% incidence of brown patches on their meats and none on the diploid controls during summer. However, the superior meat condition of the triploids in autumn, after the diploids

have spawned out, is considered to be an important marketing advantage, and the farmers are interested in growing triploid Pacific oysters.

Selective Breeding

Oyster breeding programs to select for fast growth in Sydney rock oysters in NSW (Nell et al., 2000) and Pacific oysters in Tasmania (Ward et al., 2000) were established in 1990 and 1994, respectively. Both programs have been successful in increasing the growth rates. Great success has been achieved in the selection of Sydney rock oysters for fast growth (Nell et al., 1996, 1999) and disease resistance (Nell and Hand, in press). Time to market size (50 g whole weight) for diploid and triploid progeny of a third generation breeding line was reduced by 7 and 10 months, respectively, out of 38 months for the diploid control (R. Hand, unpublished data, 2002). This study also showed that the growth advantages of triploidy and selective breeding are synergistic (Nell⁶). Preliminary data show that time to market was reduced by 7 months for progeny of fourth generation breeding lines selected for fast growth in Port Stephens, NSW. It is expected that a 12 month reduction in time to market will be achieved in another 4 generations, or 8 years, of selection.

Mortality from QX disease was reduced from 86% to 64% in progeny of a second generation disease resistance line as compared with controls, in Georges River, NSW (Nell and Hand, in press). On the basis of these and other results from overseas it is anticipated that 4 generations, or 8 years, of selection can reduce mortality rates from 64% to 10%, thus producing a “QX disease resistant” oyster. The 10% mortality level is an “acceptable” level for the Sydney rock oyster industry, and is the same as when the oysters are not afflicted by any disease. Unfortunately, the partially QX disease resistant oyster is a host for the parasite, *Marteilia sydneyi*.

Harvesting and Marketing

Oyster production has remained relatively stable since annual Sydney

⁶Nell, John A. Port Stephens Fisheries Centre, NSW Fisheries, Taylors Beach, NSW 2316, Australia. Unpubl. data., 2002.

rock oyster harvests peaked in the mid 1970's at 13 million dozen or 7,800 t (Nell, 1993), and Pacific oyster production in Tasmania was only 0.1 million dozen (Dix, 1991). Since then, production of Sydney rock oysters has declined (Nell, 1993) while that of Pacific oysters increased. By 1999/2000, annual production of Sydney rock oysters had stabilized at 8 million dozen, and annual production of Pacific oysters from Tasmania, South Australia, and Port Stephens, NSW, had climbed to 6.5 million dozen (Table 1). This amounts to only an 11% increase in total production of oysters in Australia over the past quarter of a century. During this time, Australia's population increased by 36% from 14 to 19 million people (Australian Bureau of Statistics, 2001). So these figures show a declining share of this market by oysters. In Australia, oysters are mainly consumed on the half-shell as an appetizer.

Exports of both Sydney rock oysters and Pacific oysters to various countries in Asia totals around AUD \$3 million or 6% of the value of oysters produced in Australia in 1999/2000 (ABARE, 2000). They are for the gourmet market. Australia imports frozen and chilled Pacific oysters on the half shell from New Zealand and canned smoked oysters from Asia. In 1999/2000, the total value of imported oysters was AUD \$5 million (ABARE, 2000).

Some specialization by the Sydney rock oyster farmers in NSW has long existed. They set and sell spat on sticks as “caught sticks” or single seed spat scraped off sticks or plastic slats. Some farmers sell half-grown oysters to those who specialize in finishing oysters to market size over a 6–12 month period. There are no uniform oyster grade specifications for Sydney rock oysters; however, traditional size grades for Sydney rock oysters are: Plate, Bistro, and Bottle grade oysters with an average whole weight of 50, 45, and 35 g, respectively, which equates to a shell height of around 77, 73, and 66 mm, respectively. More recently a “cocktail” grade has become commonly used to describe small oysters that do not meet traditional standards. These oysters are usually small, 25 g (58 mm), and are commonly sold in “all you can eat” seafood buffets.

Table 1.—The oyster industry¹ of Australia in 1999/2000.

State and species	Dozens of oysters	Weight/dozen (g)	Total oyster weight (t)	Avg. farm gate price/dozen	Million AUD \$	Area available for prod. (ha)	No. of oyster farming operations
New South Wales							
Sydney rock oyster	7,899,454	530	4,187	3.59	28.4	4,088	493
Pacific oyster	399,662	610	244	4.26	0.9	721 ²	63 ²
Queensland							
Sydney rock oyster	220,400	650	143	2.77	0.6	548	128
Tropical oysters ³	25,000	650	16	2.51	0.1	59 ⁴	109
South Australia							
Pacific oyster	2,516,000	750	1,887	3.73	9.4	1,900	94
Tasmania							
Pacific oyster	3,561,179	750	2,671	3.71	13.2	1,800	117
Total	14,621,695		9,148		52.6	9,116	1,004

¹ After ABARE (2000). There is also experimental production of the local strain of the Sydney rock oyster in WA and the flat oyster in NSW, Tasmania, and WA.

² These figures are also included above as many farmers in Port Stephens, NSW, grow both Sydney rock, *Saccostrea glomerata*, and Pacific oysters, *Crassostrea gigas*.

³ Coral rock or milky, *S. cucullata*, and black-lip oysters, *Striostrea mytiloides* combined.

⁴ There are an additional 61 km of foreshore leases.

Most Sydney rock oysters leave the farms live in the shell, packed in bags or boxes. Live Sydney rock oysters keep best at 8–15°C and, being a hardy intertidal species, will survive for 2–3 weeks. Live Pacific oysters should be held at the usual food refrigeration temperature, around 4°C, and have a typical shelf life of 7–10 days. Some farmers open their oysters and sell them on the half-shell directly to restaurants, clubs, and passing trade. Traditionally, smaller oysters in NSW were sold at about two dozen meats to a 250 ml glass jar; however, this market has declined as the market for small oysters on the half shell has been developed. Most oysters are sold in supermarkets or fish shops; the remainder is consumed in restaurants and clubs.

Similar specialization exists in the industries farming Pacific oysters in Tasmania and South Australia. Some farmers specialize in nursery culture and others in finishing oysters to market size, as in NSW. The size grades for Pacific oysters in Tasmania and South Australia are Jumbo (> 100 mm), Large (85–100 mm), Standard (70–85 mm), Buffet (60–70 mm), and Bistro (50–60 mm shell height) with approximate shell heights and whole weights (g) of Pacific oysters of 100 (93), 85 (75), 70 (57), 60 (45), and 50 (33) mm, respectively. Pacific oysters are sold in three forms: fresh unopened (by far the most common), fresh opened, and frozen opened. Both the unopened and opened oysters require refrigeration during storage and transport. These two industries also attempt to market oysters

according to meat quality employing three meat grades: export (top grade), premium, and thrifty. These grades are based on a meat/shell ratio and visual assessment of meats.

The main requirement for successful oyster culture is the availability of good quality water, which has sufficient plankton and good currents to promote growth and conditioning and, from a public health point of view, no pathogenic bacteria. The Australian Shellfish Quality Assurance Program (ASQAP), a national program, is modeled on the National Shellfish Sanitation Program of the United States, and requires that shellfish harvest areas be classified on the basis of a sanitary survey and the results of an ongoing water-sampling program. This program has been applied to aquaculture shellfish growing areas in Tasmania, South Australia, and Western Australia and to one harvest area in Queensland. Classification of the first harvest area in NSW was completed in June 2001, and in August 2002, over 25% of the State's production area was classified as Approved, Conditional Approved, Conditional Restricted, Restricted, or Prohibited Area for harvesting. The NSW program currently requires that all oysters harvested in that state be depurated for 36 h at ambient temperature 24–25°C before marketing for human consumption; however, with the implementation of the ASQAP, the requirement for depuration will be determined by the classification of a harvest area, as is the case in other Australian states.

Future

In NSW and southern Queensland, the number of oyster farmers and the area under cultivation will most likely decline, as small unprofitable operations leave the industry and "poor" leases are handed back to the government. The government allows farmers to exchange "poor" growing areas for "better" ones. Cultivation of Pacific oysters in Port Stephens, NSW, and flat oysters in southern NSW may increase. Once the hatchery production problems of the Sydney rock oyster have been resolved, the industry may take advantage of improved breeding lines for fast growth and disease resistance. Triploids will then be used for out-of season marketing of oysters in autumn and winter, when diploids are spawned out and have thin meats. Unfortunately, all attempts at producing tetraploid Sydney rock oysters have been unsuccessful. Therefore, triploid induction in this species will continue to rely on chemical methods of induction, rather than the simpler and more effective way of fertilizing eggs from diploids (2n) with sperm from tetraploids (4n) to produce batches of 100% triploid (3n) spat (Nell, 2002). It is important that either the trend to sell oysters at a smaller size (e.g. bistro instead of plate size) is reversed or the price for bistro oysters is increased, because the sale of small oysters for a small price has greatly reduced profitability within sections of the industry.

There is still some room for Pacific oyster cultivation to expand using subtidal longlines in Tasmania and South

Australia in 5–15 m depths. In NSW, there is also a need for farmers to exchange “poor” growing areas for “better” growing areas. As the Tasmanian and South Australian industries are totally reliant on hatchery production of spat, most oysters produced probably will be from improved breeding lines and their hybrids. As for Sydney rock oysters in NSW, triploids will be used for out-of-season oyster marketing of oysters. Fortunately in Australia, tetraploid broodstock is available to produce batches of 100% triploid Pacific oysters (Nell, 2002).

The industry in NSW, Queensland, Tasmania, and South Australia is keen to expand its markets by increasing oyster exports. This may improve local market prices of oysters. The implementation of the ASQP is facilitating oyster exports from Australia.

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