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# THE CHANGING FACE OF OYSTER CULTURE IN NEW SOUTH WALES, AUSTRALIA

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***ABSTRACT*** Oyster farming is one of the oldest aquaculture industries in Australia and, in New South Wales (NSW), its history dates back some 130 y. Like other industries, it has evolved over time, but during the past 5 y, a number of significant changes have occurred. Although Sydney rock oysters (*Saccostrea glomerata* [SRO]) remain the most important commercial species, the culture of Pacific oysters (*Crassostrea gigas*), particularly triploids, has increased significantly. Interest in cultivating other commercially important species, such as flat oysters, *Ostrea angasi,* has also increased. Overall, hatchery-produced oyster seed has become more readily accessible, particularly for *S. glomerata,* which, prior to 2003, had been largely unavailable to the majority of the rock oyster industry. For both *S. glomerata* and *C. gigas*, breeding programs have become an integral part of industry development and have been the primary reason for hatchery seed uptake in NSW. Across the oyster industry, the emphasis placed on the importance of demonstrating environmental sustainability has increased, and both industry and government have been proactive in protecting the estuarine environments in which oyster farming occurs. Collectively, hatchery development, oyster breeding, and environmental research has ''spawned'' a number of new research initiatives that have increased fundamental oyster research during the past 5 y.

***KEY WORDS:*** oysters, *Saccostrea glomerata*, *Crassostrea gigas*, *Ostrea angasi*, breeding, hatchery production, disease

## INTRODUCTION

This article discusses changes in the edible oyster industry in New South Wales (NSW) that have occurred during the past 5 y. A detailed description and history of the NSW oyster industry has been provided in Nell (1993).

Australian farmed oyster production was once dominated by the production of Sydney rock oysters (SRO), *Saccostrea glomerata* (Fig. 1A). Today, production of this species is less than half its historical maximum at 4,053 t in 2007–2008 (NSW Department of Primary Industries 2009), with the vast majority grown in NSW. Currently, production is derived from 341 permit holders operating 2410 oyster leases occupying 2,922 ha spread over some 33 NSW estuaries (Table 1). The major oyster-producing estuaries in order of production in 2007–2008 were Wallis Lake (2.67 million dozen), the Clyde River (0.75 million dozen), and Port Stephens (0.61 million dozen) (Fig. 2). In total, the oyster industry in NSW produced more than 6.35 million dozen SRO valued at US$28.9 million (US$1 = AU$1.25). In the national context, production of SRO currently contributes approximately half the total value of the Australian edible oyster industry (US$61 million [Maguire & Nell 2007]). In addition, the industry also produced Pacific oysters, *Crassostrea gigas* (Fig. 1B), and flat oysters, *Ostrea angasi* (Fig. 1C), valued at US$1.79 million and US$0.22 million, respectively, in 2007–2008.

Seed supply to the NSW industry is derived largely from natural catch, although within the past 5 y, major progress in the hatchery supply of SRO has seen much more of the industry's total seed demand met by hatcheries. Production methods for SRO are diverse. Small quantities of oysters are still obtained from dredge beds, whereas the majority (>80%) are derived from spat settlement on intertidal sticks that are then transferred to trays for grow-out in the latter stages of production.

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The outlook for both the Australian oyster industry as a whole and the NSW industry is positive, with the Australian industry planning to expand significantly during the next 7 y (Seafood CRC, 2008). Several strategies will be used, but ongoing breeding program development will be crucial to this expansion and, nationally, both the SRO and Pacific oyster industries have developed commercial entities to manage this process.

## NSW OYSTER PRODUCTION

### *Sydney Rock Oysters*

Since the mid-1970s, there have been marked reductions in the overall production of SRO associated with a number of key events in the industry's history, including health scares, exotic species introduction, and disease outbreaks. Although not as marked, this downward trend has continued during the past 5 y, with the number of SRO produced decreasing from 8.00 million dozen to 6.35 million dozen (Fig. 3B). Central to this reduced production was the occurrence of QX disease (*Marteilia sydneyi*) in the Hawkesbury River in 2004. Prior to this disease outbreak, in 2002–2003 the Hawkesbury River was the third largest SRO-producing estuary, responsible for providing 0.85 million dozen oysters worth US$2.9 million, the equivalent of 10% of total industry production. The following year, production halved, and by 2005–2006, production of SRO in the Hawkesbury River had fallen by 94%.

For some time, decreasing production was also accompanied by a reduction in the size of oysters sold by industry. The proportion of oysters sold as larger size ''plate'' grade was reduced in favor of smaller ''bistro'' and ''bottle'' grade oysters. This, in turn, reduced the potential revenue for the industry because the smaller grades do not attract the prices that ''plate'' grade oysters attain. In 2007–2008, plate, bistro, and bottle oysters sold for an average of US$6.27, US$4.82, and US$3.39 per dozen, respectively. The causes for the move to selling smaller oysters are unclear, but have not solely been driven by

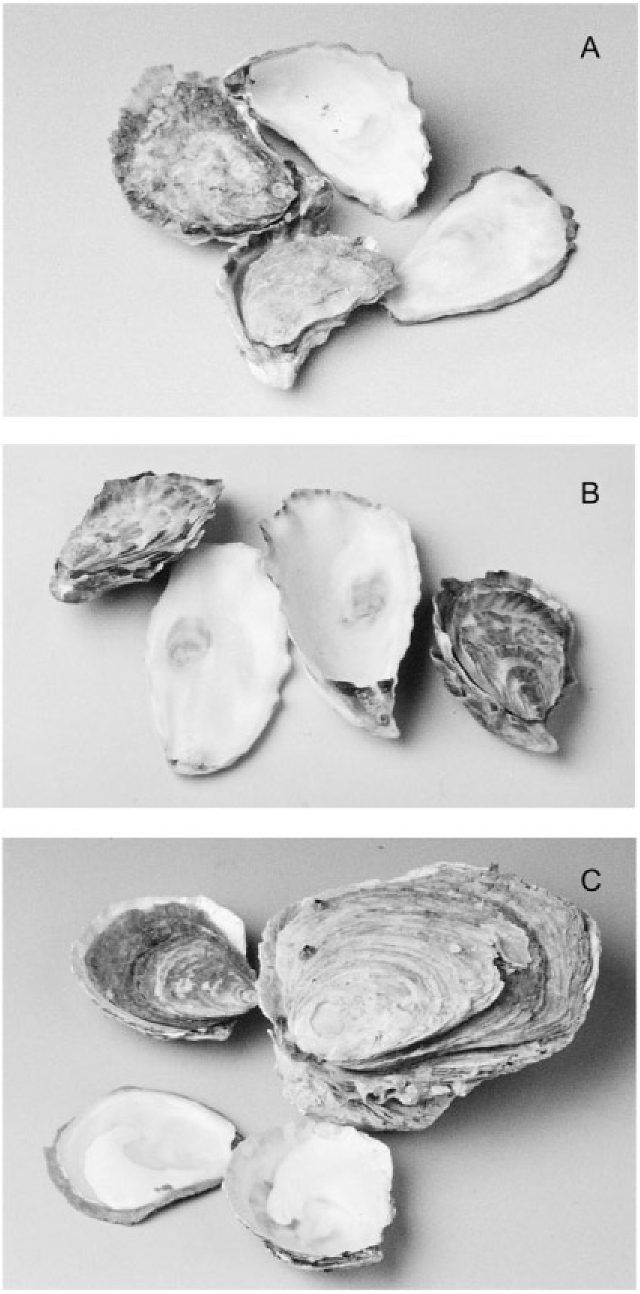


**Figure 1. Key Australian commercial oyster species: (A) Sydney rock oysters, *Saccostrea glomerata*, (B) Pacific oysters, *Crassostrea gigas*, and (C) flat oysters, *Ostrea angasi (Photos Ray Alley)*.**

market demand. The differing impacts of exotic species and disease on the various SRO-producing estuaries on the Australian east coast and the differing role of these estuaries within industry, in terms of the size of oysters traditionally produced, have been influential. Recently, however, this trend has reversed and there has been a gradual reduction (approximately 5%) in the number of "bistro" oysters reaching the markets (Fig. 3A,C). Again, this probably arises from a number of factors, including a move away from traditional stick cultivation, the impact that larger Pacific oysters have had on market perceptions, and the increasing adoption of single-seed oyster production during the past 5 years.

**TABLE 1.**

**Comparison of key oyster production statistics for Sydney rock oysters in New South Wales in the 2002–2003 and 2007–2008 financial years (July 1–June 30).**

| Measure | 2003–2004 | 2007–2008 |
|---|---|---|
| Permit holders | 402 | 341 |
| Leases | 2,387 | 2,410 |
| Lease area, ha | 3,321 | 2,922 |
| Production, dozens | 8,000,265 | 6,350,078 |
| Production, value in US$ | 288,606,304 | 28,851,874 |

### *Pacific Oysters*

Pacific oysters were introduced to NSW and became established in Port Stephens in the mid 1980s. At that time, the majority of SRO produced in NSW were initially collected as natural catch in Port Stephens then distributed to other estuaries. As a nonnative species, Pacific oysters were declared a "noxious fish" and their introduction halted all translocation of oysters from Port Stephens to attempt to prevent the spread of this species throughout the state. In 1991, farmers obtained permission to cultivate both diploid and triploid Pacific oysters in Port Stephens and, since that time, cultivation of triploid Pacific oysters has been extended to both the Georges River in 2004 and the Hawkesbury River in 2005. In 2008, a 3-y experimental permit was granted to allow the production of triploid Pacific oysters in the Crookhaven and Shoalhaven Rivers (Fig. 2).

Despite initial enthusiasm for Pacific oyster culture in NSW and the significant increase in availability of lease area suitable for production, total production value has increased only marginally from US$1.48 million in 2003–2004 to US$1.79 million in 2007–2008 (Table 2). In 2007–2008, "select," "bistro," and "mini" grades of Pacific oysters sold for an average of US$5.30, US$4.44 and US$3.52 per dozen, respectively.

In part, this slow increase has been the result of a reduction in the cultivation of diploid oysters in Port Stephens, but this is likely to be rapidly counteracted by increasing triploid Pacific oyster production elsewhere in the state. Triploid production in the Hawkesbury River only began in 2005, and harvests are steadily increasing. This is also expected to be boosted in the near future by Shoalhaven farmers, who under current approvals can collectively produce up to 5 million triploid Pacific oysters per year.

Although Pacific oysters have formed the basis of a new industry in NSW, they have also had an additional direct economic impact on oyster production in Port Stephens. Pacific oysters in Port Stephens spawn several months earlier than SRO (October–November) and significant "overcatch" (oyster settlement) can result, which leads to the need for additional expensive handling of oysters (Pacific and SRO) to kill this additional settlement. In the case of mature SRO, this can be achieved by immersing the hardier SRO until the Pacific oyster spat die, but for farmed Pacific oysters, overcatch removal requires hand culling or hot-water dips (approximately 80°C for several seconds).

### *Flat Oysters*

Like a number of oyster fisheries worldwide, the flat oyster fishery in southeastern Australia exhibited a history of

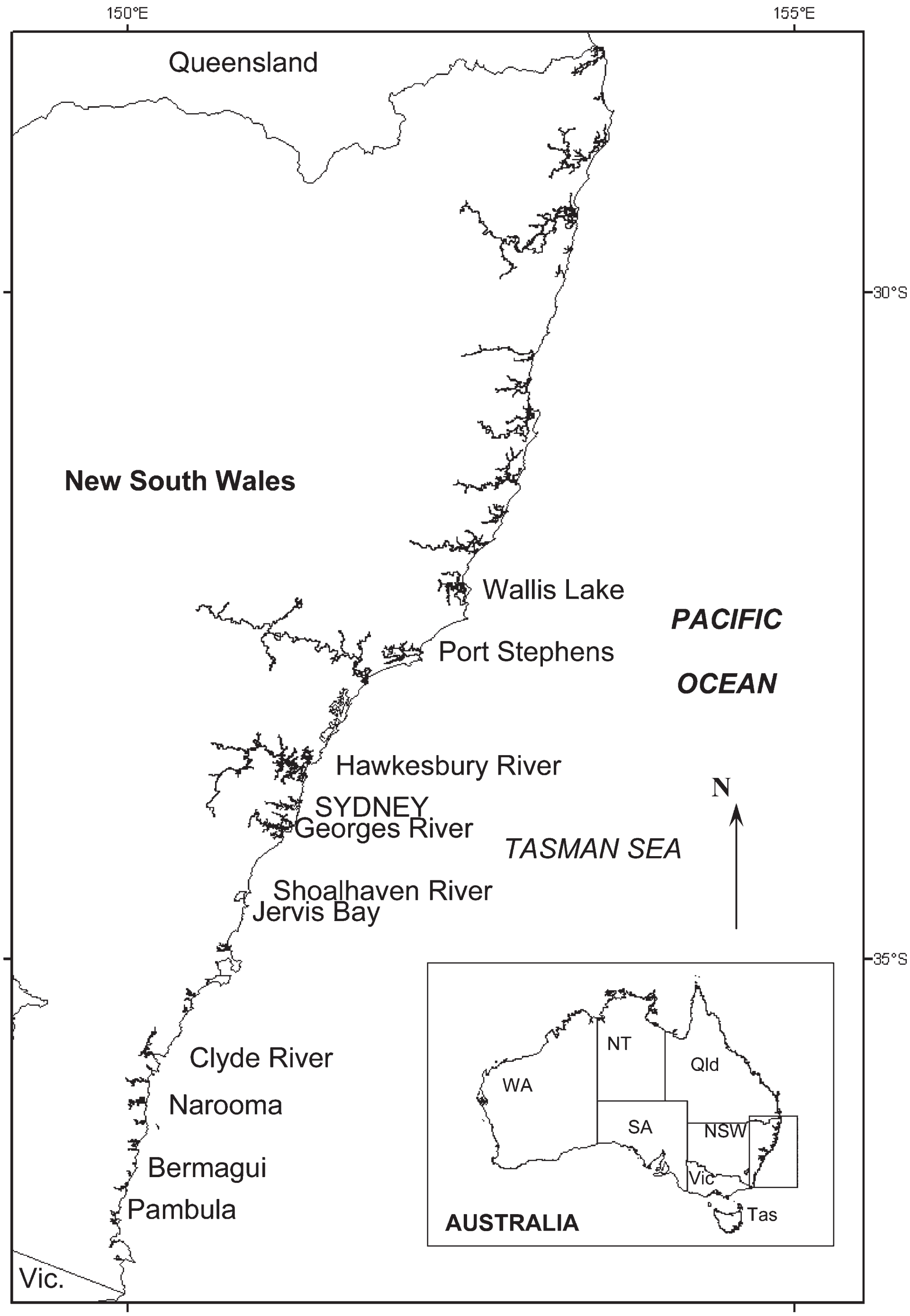


**Figure 2. Map of the NSW coast showing the locations of oyster producing estuaries referred to in this article.**

exploitation followed by fishery collapse and prolonged failure (McIntyre 1966, Olsen 1994). Subsequent attempts have been made to culture flat oysters along Australia's southeastern coastline from southern western Australia through to southern Queensland (Fig. 2), but they have met with variable success. Earlier attempts to culture the species failed because of limited spat availability, competition from other species, and disease (bonamiosis as a result of *Bonamia* sp.).

During the late 1990s, attempts to culture flat oysters in NSW were renewed, and small-scale, hatchery-based spat production began at the Port Stephens Fisheries Institute (PSFI). In 2000, a workshop was held to assist the development of the industry in NSW (Heasman & Lyall 2000). The potential for outbreaks of bonamiosis and the threat that hatchery production might pose to the gene pool of wild flat oyster stocks were recognized as the greatest impediments to industry development. A survey was then undertaken of flat oyster populations from 5 key farming estuaries in southern NSW (Clyde River to Pambula Lake, Fig. 2). A parasite, later confirmed to be *Bonamia* sp. (Corbeil et al. 2006), was found

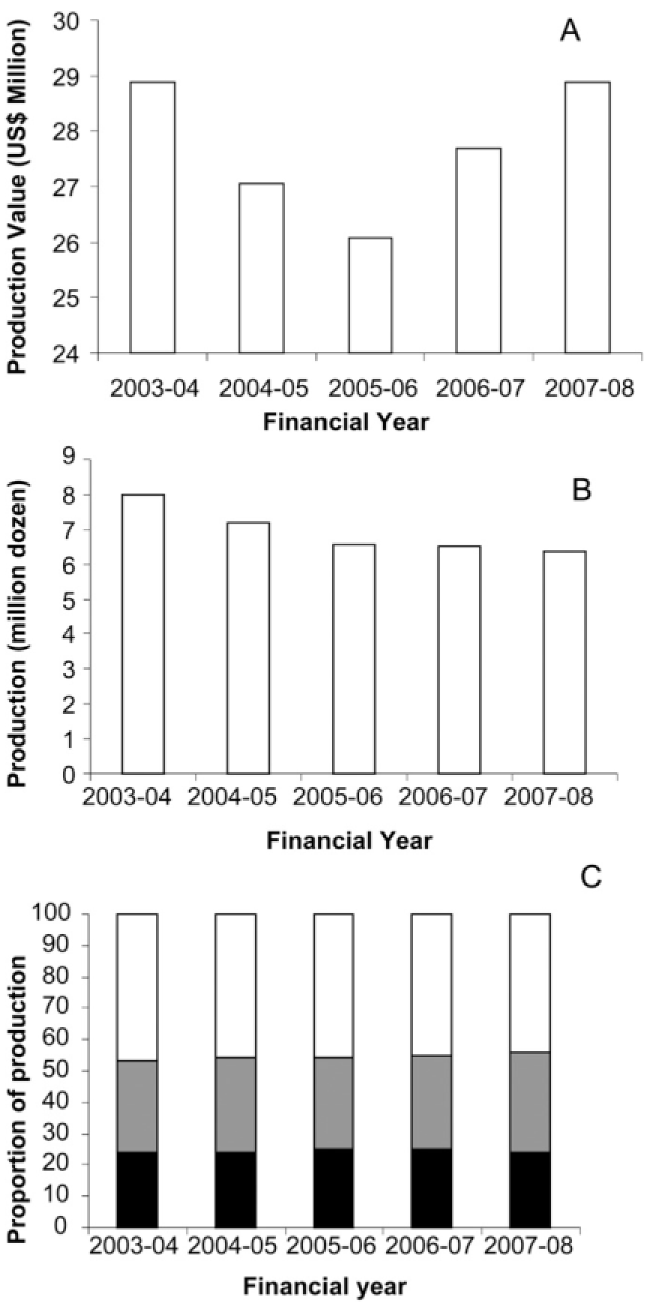


**Figure 3. Sydney rock oyster production for the past 5 financial years. (A) Dollar value ($US). (B) Total number of oysters produced (dozen). (C) Production (percent) by size class (mean weight per oyster, ■ plate, 60 g; ■ bistro, 55 g; □ bottle, 50 g).**

in oysters at all 5 locations, with the prevalence ranging from 13–44% (Heasman et al. 2004). Despite this apparently high prevalence, it is noteworthy that there has never been a mass mortality event reported in flat oysters resulting from bonamiosis in NSW (Heasman et al. 2004). In the same population survey, sequence analysis of the mitochondrial cytochrome oxidase I fragment found that the oyster samples collected from the 5 key farming estuaries represent a geographically homogeneous population. On this basis, there appear to be no potential constraints to brood stock collection and spat translocation within this region (Hurwood et al. 2005).

Prior to 2004, production statistics for flat oysters were not released in accordance with privacy legislation, which prevents publication of data collected from 5 or fewer growers. Regardless, there has been a gradual increase in flat oyster production during the past 5 years (Table 2). Recent estimates suggest production for consumption has now reached approximately 50,000 dozen, with a farm gate value of between US$6.4–8.0 per dozen, depending on size (D. Maidment, personal communication).

## HATCHERY AND NURSERY PROGRESS

Attempts by hatcheries to produce commercial quantities of SRO seed have occurred in NSW for well over 2 decades, but have been plagued by chronic failures. In a review of hatchery performance at the PSFI, the oldest and largest producer of SRO seed, Heasman et al. (2000) found that approximately 56% of SRO larval batches failed as a result of "larval anorexia," and of those runs that were successful, a further 58% suffered spat mass mortality syndrome (SMMS). Larval anorexia describes a syndrome that occurred within the first 8 days of the larval cycle and was characterized by a general reduction in larval feeding and swimming, with the eventual accumulation of larvae on the base of the tank. Although the larvae did not die immediately, growth halted and most of the batch would be lost. In successful larval batches, SMMS could then occur between 1 and 7 wk after settlement, before spat reached 2 mm in size, and losses of up to 95% could occur within 36 h. On several occasions, this syndrome occurred simultaneously among groups of spat from the same larval batch that had been separated and held at two locations.

Although inconsistent hatchery performance had not stopped the establishment of breeding programs, it had denied the SRO industry the opportunity to access reliably the advantages of selectively bred oysters. As the apparent value of selectively bred seed increased, so, too, did the pressure to overcome production failures and to increase the reliability of supply. A program began in 2003 to address systematically potential problems based on (1) a review of hatchery production technology, (2) a hatchery health workshop (Heasman 2002), (3) an independent hatchery audit, and (4) the preparation of a hatchery hazard and critical control point plan for the hatchery at PSFI.

Subsequently, this hatchery was upgraded and water supply systems were simplified (O'Connor et al. 2008a). Production protocols were refined (Dove & O'Connor 2007b, O'Connor et al. 2008b) and potential toxicants were identified (Dove & O'Connor 2007a). As a result, both growth and survival rates increased dramatically, and the occurrence of symptoms consistent with those previously ascribed to larval anorexia was reduced to less than 5% of batches. Settlement systems for SRO larvae were altered to remove shell cultch and instead rely on epinephrine-induced set thereafter. Since these changes were made in 2003, SMMS has not been observed at the PSFI.

Between 2004 and 2008, more than 70 million selectively bred SRO spat were distributed to industry. In the 2006–2007 production season, these oysters first began to figure significantly in sales when they accounted for 8.6% of NSW production. During that same year, the number of selectively bred seed climbed to nearly 40 million spat, equating to an estimated 30% of current industry spat demand.

Although initially the supply of SRO seed came from the PSFI, supply is now solely derived from hatcheries in southern

TABLE 2.

**Value (million $US) of Pacific oyster and flat oyster production in NSW over the 2002–2003 to 2007–2008 financial years (July 1–June 30).**

| Oyster | 2003–2004 | 2004–2005 | 2005–2006 | 2006–2007 | 2007–2008 |
|---|---|---|---|---|---|
| Pacific oysters | 1.476 | 1.538 | 1.122 | 1.261 (36%*) | 1.298 (40%*) |
| Flat oysters† | — | 0.079 | 0.081 | 0.222 | 0.218 |

* Proportion of the total value of production attributable to triploid Pacific oysters. Triploids were produced prior to this date, but production values were not reported.
† Flat oyster production values before 2004–2005 are not reported for privacy reasons.

Queensland ("Qld" in Fig. 2) and Port Stephens. The NSW oyster industry has now formed the Select Oyster Company to manage seed sales and eventually to manage the breeding program on behalf of industry.

To facilitate the supply of hatchery-produced seed to industry, a network of farmer-based nurseries was established to overcome barriers to intra- and interstate oyster movements. The translocation of SRO seed within NSW and southern Queensland is restricted according to legislative protocols designed to reduce the risks of Pacific oyster translocation and QX disease. To help meet demand for spat, there are currently more than 10 field nursery operations spread throughout the SRO growing range from southern Queensland to Pambula in southern NSW (Fig. 2). The nurseries can receive spat from the hatcheries between 0.75–1.5 mm (shell height) and then on-grow them in upwelling systems until they reach a size of at least 5 mm. At this size, SRO spat can be farmed on estuarine leases.

The supply of Pacific oyster and flat oyster seed has been less problematic. Diploid Pacific oysters can only be cultivated in Port Stephens in NSW and, if desired, spat can be collected directly from the wild in NSW (approximately 2 million spat per year). Despite this, the majority of diploid Pacific oysters grown are from hatchery-produced seed that are readily available from Tasmania ("Tas" in Fig. 2). Triploid Pacific oyster seed is entirely sourced from a single Tasmanian hatchery.

Until 2004, approximately 1 million flat oyster spat were produced per year (Maidment 2006), but this figure has subsequently increased to between 2–3 million annually. This supply originally came from the PSFI, which continues to supply small numbers of seed. However, 2 small-scale, farmer-operated hatcheries are being established in southern NSW (Fig. 2) to meet their own demands.

## BREEDING PROGRAMS

A selective breeding program for SRO has been ongoing in NSW since 1990. Based on mass selection, the program initially targeted faster growth and winter mortality (*Bonamia roughleyi*) resistance before it was expanded to include QX disease resistance in 1997 (Nell 2003). Initially, 4 breeding lines were established at 3 sites each in Port Stephens and the Georges River. After the advent of QX disease in the Georges River in 1994, the 3 sites originally selected were replaced with Quibray Bay, Woolooware Bay, and Lime Kiln Bar (Fig. 4). These locations were selected on the basis of their differing exposure to winter mortality or QX disease. In the Georges River, winter mortality typically affects sites in the lower, more oceanic, regions of the estuary (e.g., Quibray Bay), whereas QX disease typically occurs in the upper reaches (e.g., Lime Kiln Bar). Woolooware Bay is commonly affected by both winter mortality and QX disease, and has allowed the development of a QX- and winter mortality disease-resistance line (Nell 2003).

After 5 generations of selection at Port Stephens, selected lines produced oysters that were 36% heavier than nonselected controls, and this reduced the time to reach market size by 10 mo from the expected 38 mo (Nell 2006). The same results were also obtained in the Georges River in the absence of QX disease, but when present, QX disease severely stunted the growth of those control oysters that survived (Fig. 5), exaggerating the growth differences between the lines even further (Nell 2006). By the third generation, losses resulting from winter mortality in the Quibray Bay selected line was reduced by half (22% vs. 46%), whereas the Lime Kiln Bar line could be grown to market size in 2 y at QX-affected sites with minimal losses (22% vs. 80% in comparison with nonselected controls [Nell & Perkins 2006]). Given that background mortality for SRO ranges from 10–20% over a 2- to 3-y growing period, this represents full resistance; however, Nell and Perkins (2006) noted that substantial losses were incurred if the resistant lines were exposed to QX disease for a second season.

Although QX resistance has not inferred resistance to winter mortality, recent studies by Green et al. (2008) found that in the absence of QX disease, QX-resistant lines had significantly higher survival than wild-caught controls (0% vs. 32% mortality), and attributed the most likely cause of mortality in controls to disseminating hemocytic neoplasia, a contagious and often fatal condition reported in molluscs (Barber 2004).

Although the mass selection program continues, it has recently undergone a rationalization to allow for additional pedigreed family lines to be created. The 4 Port Stephens lines are to be amalgamated and held at 2 locations. Meanwhile, the Woolooware Bay and Lime Kiln Bar lines have been combined in an effort to increase dual resistance. The combined line, the Quibray Bay line, and a new QX line that was established in 2005 have now been moved from the upper to the lower reaches of the Georges River to expose oysters to both QX and winter mortality disease to develop further their resistance and utility for the SRO industry (Fig. 4).

To date, a total of 60 pedigreed SRO families have been produced. The first 30 of those families produced in 2007 were selected on the basis of their phenoloxidase phenotypes (Bezemer et al. 2006) and have been deployed in the Georges River to elucidate further the role of the phenoloxidase enzyme cascade in QX disease resistance. The remaining pair mated families were produced in January 2008 from within-line crosses of the Quibray Bay, Woolooware Bay, and Lime Kiln Bar lines,

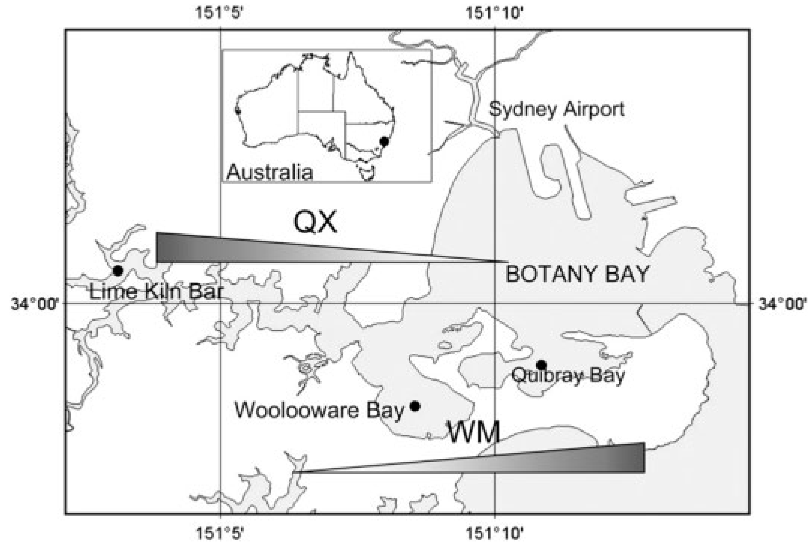


**Figure 4. Map of the Georges River estuary showing sites at which selectively bred Sydney rock oyster disease resistance lines are placed for disease exposure. This figure also indicates the graded spatial influence of QX disease (upper estuary) and winter mortality disease (WM, lower estuary) within the Georges River estuary system.**

and their performance will be assessed while being exposed to winter mortality and QX disease in the Georges River. Previously, performance assessments of selectively bred SRO were largely based on growth and survival, with meat yield assessed at the time of harvest. These performance criteria have now been expanded to include ongoing monitoring of condition index and shell shape. Preliminary observations of selected lines found differences in their reproductive/physiological responses to environmental conditions (Bayne et al. 1999, O'Connor & Dove 2006). A comparison of the responses of progeny of the 5$^{th}$ generation oysters selected for fast growth and nonselected, wild-caught oysters with hatchery conditioning found marked differences in both condition indices and reproductive capability (O'Connor & Dove 2006) that were later confirmed in field trials at 3 farming sites in NSW (Dove & O'Connor, submitted). Observations by oyster growers farming selectively bred lines are that selected oysters condition at a different rate and to a different extent compared with naturally (or wild-) caught oysters grown under similar conditions. We plan to undertake further research in this matter to understand better the environmental response of oysters selected for disease resistance.

**Figure 5. A comparison of growth and survival of QX disease-resistant oysters and control oysters held in the Hawkesbury River, NSW, Australia. Both trays were stocked with the same number of similar size oysters and were exposed to QX disease (*Marteilia sydneyi*). The tray in the foreground contains QX disease-resistant oysters. (Photo courtesy of Mike Dove).**

Triploid induction is another method that can reduce the growing time for SRO by an additional 3 mo, because the faster growth rate obtained from this process complements faster growth from selective breeding (Hand et al. 2004). Brown discoloration of the gonad surface in triploid SRO has been observed in the past during summer months and has affected market acceptance of these oysters (Hand & Nell 1999). In contrast, triploid SRO can have suitable meat condition for consumption during winter and spring months, when discoloration is not common, and diploids generally have poor meat quality, thus extending the marketing season for farmers (Hand & Nell 1999).

## ENVIRONMENTAL RESEARCH

Increasing pressure on the environment from expanding coastal populations in NSW will continue to be a challenge for this state's oyster industry. Declines in water quality caused by human fecal contamination, outflows from acid sulfate soils, turbid waters, agricultural and industrial pollutants, and intense rain periods or prolonged freshwater events severely affect oyster production (White 2002). Furthermore, the environmental management of estuaries in NSW is spread over multiple government agencies.

The NSW oyster industry has strongly influenced the setting of environmental goals for water quality management in estuarine systems. For example, the oyster industry increased awareness in local and state government agencies of the threats to their industry caused by estuarine acidification from acid sulfate soil outflows (Dove & Sammut 2007). Increasingly, oyster farmers are recognized as an "interest" group and stakeholder in ecological risk assessment because they continually monitor estuarine health through the performance of their stock.

In recognition of the importance of the Australian oyster industry, a number of state and federal initiatives have been undertaken to secure the industry's future, in particular to protect the environment in which oyster farming occurs. One of the most significant of these initiatives has been the development of the Oyster Industry Sustainable Aquaculture Strategy (OISAS) in NSW, a strategy that is now being closely studied for adoption in other states. OISAS was developed with the aims of recognizing and protecting oyster growing areas, improving environmental performance of the industry, and providing greater certainty for industry.

The NSW Department of Primary Industry (NSW DPI) estimated the sustainable production level for oysters in NSW estuaries as 120,000 bags (8,500 t), or about twice its current level of production. To achieve this growth, all current and potential lease area in the state was inspected and evaluated against a list of locational, environmental, and socioeconomic suitability criteria. Each suitable area was then designated as a "priority oyster aquaculture area." Although this designation does not prevent oyster culture in other areas, the regulatory approvals process for "priority" areas has been significantly streamlined (NSW Department of Planning 2007).

Central to OISAS is the acknowledgment of the importance of the environment to oyster aquaculture. OISAS has begun to establish a set of water quality (Table 3) and flow objectives for oyster aquaculture areas that, if met, will provide for the healthy growth of oysters that are safe for human consumption. OISAS also outlines management and operational boundaries for oyster farmers in a set of best practice standards, which are supported by a commitment to environmentally sustainable practices. Finally, OISAS provides a legislative requirement that development consent authorities in NSW must now consider the implications of any development that may adversely affect oyster aquaculture. Development consent authorities are required to refer these applications to NSW DPI for comments that are then considered during their determination.

**TABLE 3.**

**Water quality guidelines for oyster aquaculture areas (NSW Department of Planning 2007).**

| Parameter | Guideline | Source |
|---|---|---|
| Fecal (thermotolerant coliforms) | 90th percentile of randomly collected fecal coliform samples do not exceed 43 MPN or 21 MF/100 mL | ASQAP Operations Manual 2002 (ASQAAC 2002) and the NSW Shellfish Program Operations Manual (SafeFood NSW 2001) |
| pH | 6.75–8.75 | Shumway (1996) |
| Salinity | 20.0–35.0 g/L | ANZECC (2000) |
| Suspended solids | <75 mg/L | |
| Aluminium | <10 μg/L | |
| Iron | <10 μg/L | |
| Other parameters | — | Sections 4.4 and 9.4 of the ANZECC (2000) guidelines |

To complement OISAS, a large number of co-operative programs are also underway that have seen oyster farmers work closely with government agencies, Catchment Management Authorities (CMAs) and stakeholder groups to achieve significant improvements in water quality. The NSW Department of Environment and Climate Change has commenced preparation of a Diffuse Water Pollution Strategy, which aims to provide a coordinated framework for limiting and reducing diffuse source water pollution. As an action under this strategy, NSW DPI is preparing a set of guidelines for measures to protect oyster harvest areas, titled Healthy Estuaries for Healthy Oysters. This will be complemented by an existing intergovernmental incident response protocol to deal with emerging water quality issues in oyster harvest zones.

Collectively, oyster farmers have undertaken a number of initiatives to improve industry environmental performance. The use of tar to protect timber infrastructure in the marine environment is now being phased out, and recycled plastic products are becoming common replacements. Australian plastic oyster culture equipment is now sold worldwide. Since 2003, the use of tarred timber posts by industry has reduced by more than 200%, whereas the percentage of the states' oyster crop produced on plastic trays has grown from 3–32% (NSW Department of Primary Industries 2003).

At a local estuary level, significant funding is being devoted to specific water quality improvement issues. Water quality testing on the NSW north coast will assist the aquaculture industry in identifying sources and origin of water pollutants/contaminants, especially bacterial pathogens in problem river systems, and will lead to changes in land use and management either to avoid or reduce contaminant loads in waterways. Funding from the National Landcare Program has been granted to the Hawkesbury and Hunter CMA regions to assess land management practices that may affect estuarine water quality and habitat. Both individually and collectively, these state and regional programs are having a positive impact. In areas such as Wallis Lake, which is responsible for about 30% of NSW's oyster production, initiatives such as riparian zone protection and revegetation and wetland rehabilitation have led to measurable increases in water quality during the past 5 y (O'Sullivan 2008). In addition, particular estuaries are implementing environmental management systems that aim to protect the environment, maintain access to estuarine resources, improve water quality, and adopt more sustainable farming practices (McAsh 2008).

## OTHER RESEARCH

After a prolonged period of decreasing SRO production, the stabilization of total output and an increase in industry value during the past 5 y have seen renewed optimism within the industry. Accompanying this more positive outlook has been a number of new oyster research programs and a greater degree of farmer involvement in those programs. Research has begun at a number of institutions across a range of topics that deal with aspects of SRO biology. Studies of estuarine carrying capacity have been completed (Rubio 2008). Groups at Macquarie University and the University of Queensland have been investigating proteomic and genomic responses of SRO to disease (Butt & Raftos 2008, Green et al. 2008, Simonian et al. 2009).

Researchers at the universities of Newcastle and the Sunshine Coast have been investigating the effects of endocrine-disrupting chemicals on SRO (Andrew et al. 2008) and developing methods for the use of the oysters as biomonitors of estrogenic pollutants. With the increased opportunity to farm triploid Pacific oysters and selectively bred SRO, work is underway at the University of Technology, Sydney, to investigate the broader ecosystem effects of farming a native and introduced oyster species alongside one another. In further acknowledgment of the ecological and economic importance of these oysters, researchers at University of Western Sydney have begun assessing the potential effects of climate change on both species (Parker et al. in press).

Farmer participation in oyster research is increasing. At the NSW state level, the Aquaculture Research Advisory Committee, a statutory board involving oyster farmers, helps guide the NSW government's aquaculture research effort. At the federal level, the Oyster Consortium, again involving NSW oyster farmers, has been formed within the Seafood Cooperative Research Center (Seafood CRC, 2008) to determine national oyster research priorities. In addition to their role in determining research direction, NSW farmers are also increasingly directly involved in the programs themselves. This is exemplified in the role the Select Oyster Company has taken in the development of SRO breeding and in the number of smaller estuary-based research programs. An example of such programs occurs in the Hawkesbury River, where farmers, researchers, and the local shire council have established a field laboratory, run by farmers, to monitor the presence of *M. sydneyi* using cytological techniques. This work assists oyster growers in disease management at the farm level and provides valuable information on which to base business decisions in regard to species selection and marketing their product.

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## LITERATURE CITED


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