Aquaculture in Moreton Bay

Abstract

Moreton Bay prawn farmers have prospered over the past 20 years, despite endemic prawn diseases, broodstock shortages, and regulations on nutrient release into the surrounding environment. The established intensive prawn farms on the Logan River sustainably expanded in the early 2000s and successfully competed with a mass of seafood imports. However, the recent outbreak of the exotic white spot disease has been a major setback for the industry. The farmed oyster industry in Moreton Bay has also been challenged. Once a dietary staple of the Quandamooka People and South East Queensland's largest and single most important fishery, production of the native Sydney rock oyster dwindled during the twentieth century. The inefficiency of oyster areas has been linked to a short harvest season, disease, competition from the exotic Pacific oyster, a high proportion of hobbyist farmers and poor water quality in the Bay. Better economic opportunities in nearby Brisbane may negate regulators' plans to attract more ambitious farmers to the industry. Currently, within Moreton Bay, oyster farming requires improvements in efficiency, prawn farms have commenced restocking after closures due to disease outbreak and there are no sea cage farms. The future of aquaculture in Moreton Bay requires proactive management that recognises the complex ways in which present-day metropolitan and catchment development challenge sustainable growth of the industry. By careful consideration of these issues and applying recent advances in Australian aquaculture technologies, aquaculture enterprises in the region could achieve sustainable growth with an effective balance between economic success and conserving Moreton Bay's unique ecosystem.

Keywords: prawn, shrimp, oyster, farm, pond, sea cage, South East Queensland, Brisbane

Introduction

Aquaculture supplied ~40% ($120 million) of the total Queensland fisheries value in 2015–16, with ~91% of aquaculture value from prawn and barramundi (1). In 2015–16, aquaculture production in Queensland was 7,783 t, of which Moreton Bay contributed 1,172 t (1). Recently, oyster areas (Sydney rock oyster, *Saccostrea glomerata*) have contributed a relatively small proportion of this, with land-based prawn farms (black tiger prawn, *Penaeus monodon*) suppling the bulk of the production.

Oyster growing occurs in four areas of Moreton Bay Marine Park: Moreton Island, North Stradbroke Island, Pimpama River and Pumicestone Passage (Fig. 1) (2). Spat, mostly sourced from NSW but also from Moreton Bay, are generally grown to maturity and fattened with tray cultivation and adjustable longline systems. Harvesting occurs between August and April (2).

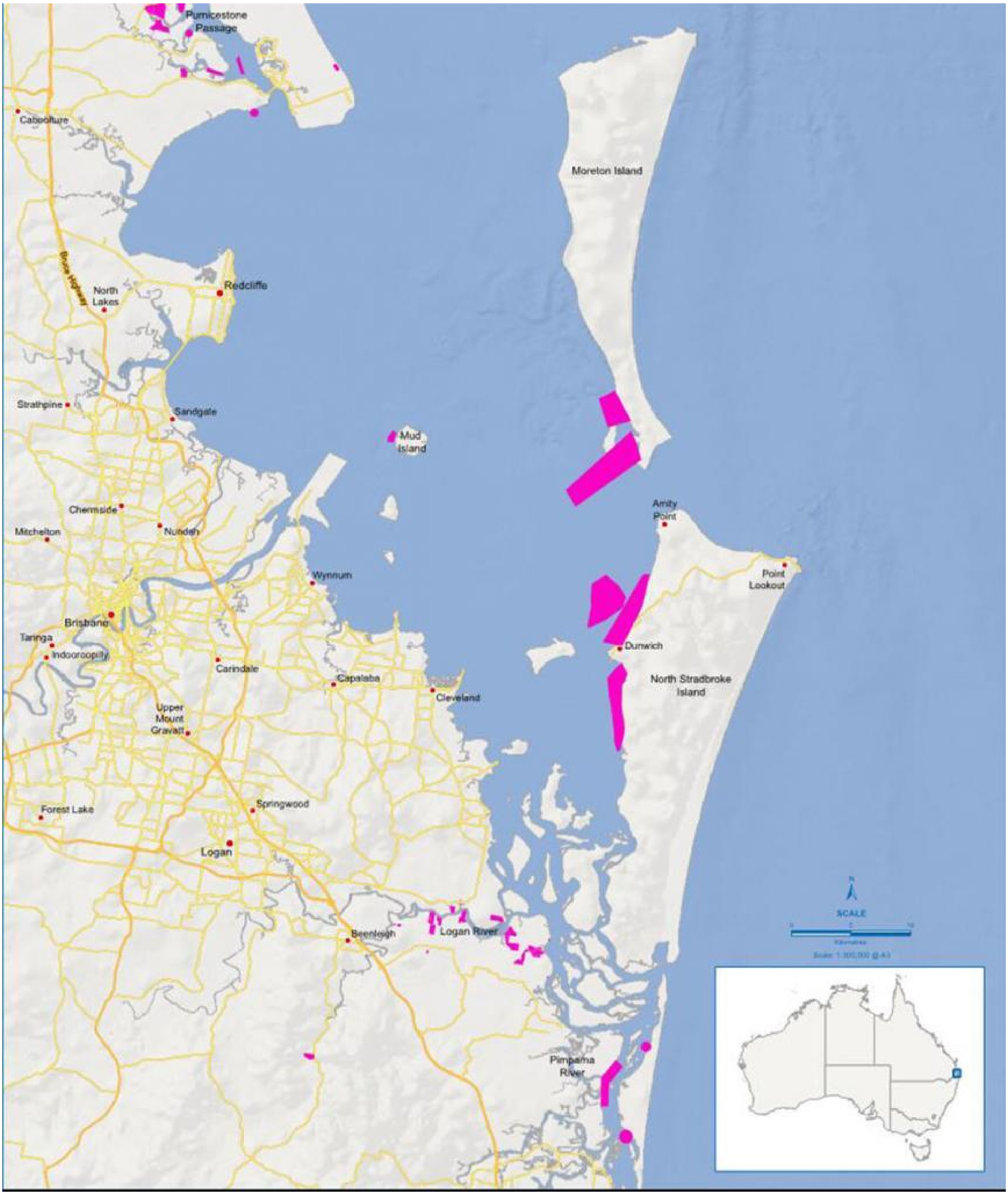

Figure 1. Aquaculture areas in Moreton Bay

Smaller (bistro-grade) oysters have shorter grow-out times (2 to 2.5 years) and tend to be produced in Moreton Bay to reduce risk of stock loss and maintain cash flow (2, 3). Sixty-seven oyster businesses operate the 97 approved areas that cover 435 ha of the

Bay (2). In 2015–16, the total annual production of oysters in Moreton Bay was 109,577 dozen, valued at $563,970 (1) (Fig. 2).

Seven prawn farms (total ~150 ha) have seawater ponds (generally 1 ha each) on flat farmland adjacent to the Logan estuary (Fig. 1). Post-larvae from Logan estuary hatcheries are stocked in ponds (at densities of 25 to 40 per m^2) and grown on a formulated diet to market size in approximately six months (4). Stocking generally occurs in October, and harvesting and sale from April to June (4). In 2014, Moreton Bay produced 1,384 t from the 116 ha of ponded area (Fig. 3, 4) and was worth more than $20 million per annum (5). However, in the summer of 2016–17, a breach in biosecurity impacted the prawn aquaculture industry when uncooked prawns infected with the exotic white-spot disease (WSD) were imported and distributed in the Moreton Bay region (6).

Brief history and current trends

Oyster aquaculture

The presence of shell middens confirms that oysters were harvested by generations of Aboriginal people inhabiting the region now called Moreton Bay (7, 8). The Quandamooka People probably also farmed oysters in Moreton Bay, as there is evidence in nearby northern New South Wales (NSW) of Aboriginal people returning shell material to estuaries to promote settlement of oyster spat (9).

Early settlers quickly exploited existing intertidal and subtidal oysters beds both for human consumption and to manufacture construction lime (10). During this time, Moreton Bay was considered to be an excellent oyster production area and exported spat to southern colonies (10). However, natural oyster beds were over-exploited which lead to government regulation (*Oyster Acts 1863*, *1874* and *1886*) early in the industry's history. This largely failed to control pressure on the resource. In addition, land practices resulted in increased sediment inputs to inshore areas by 1870. This was the likely cause of the decline of subtidal oyster reefs that were infested by spionid polychaete mudworms after major flood events in the late nineteenth century (11).

In response to depleted natural stocks, organised farming by bank oystering began in the 1870s (3, 10). Bank oystering initially used sticks, rocks, and shells to collect spat-fall and grow out natural oysters in the intertidal (10). Oyster production in Moreton Bay escalated from ~4,500 bags (281 t) in 1870 to its peak of ~21,000 bags (1,313 t) in 1891, when the greatest production came from bank oystering (10). In the early 1900s, farming infrastructure evolved to stick and tray culture in response to bed losses to floods and oyster pathogen incursions, particularly the mudworm, *Polydora* sp. (3, 10). This involved collecting spat on sticks, removing excessive spat and leaving the remaining oysters to mature on stick and/or fattening the oysters in grow-out trays.

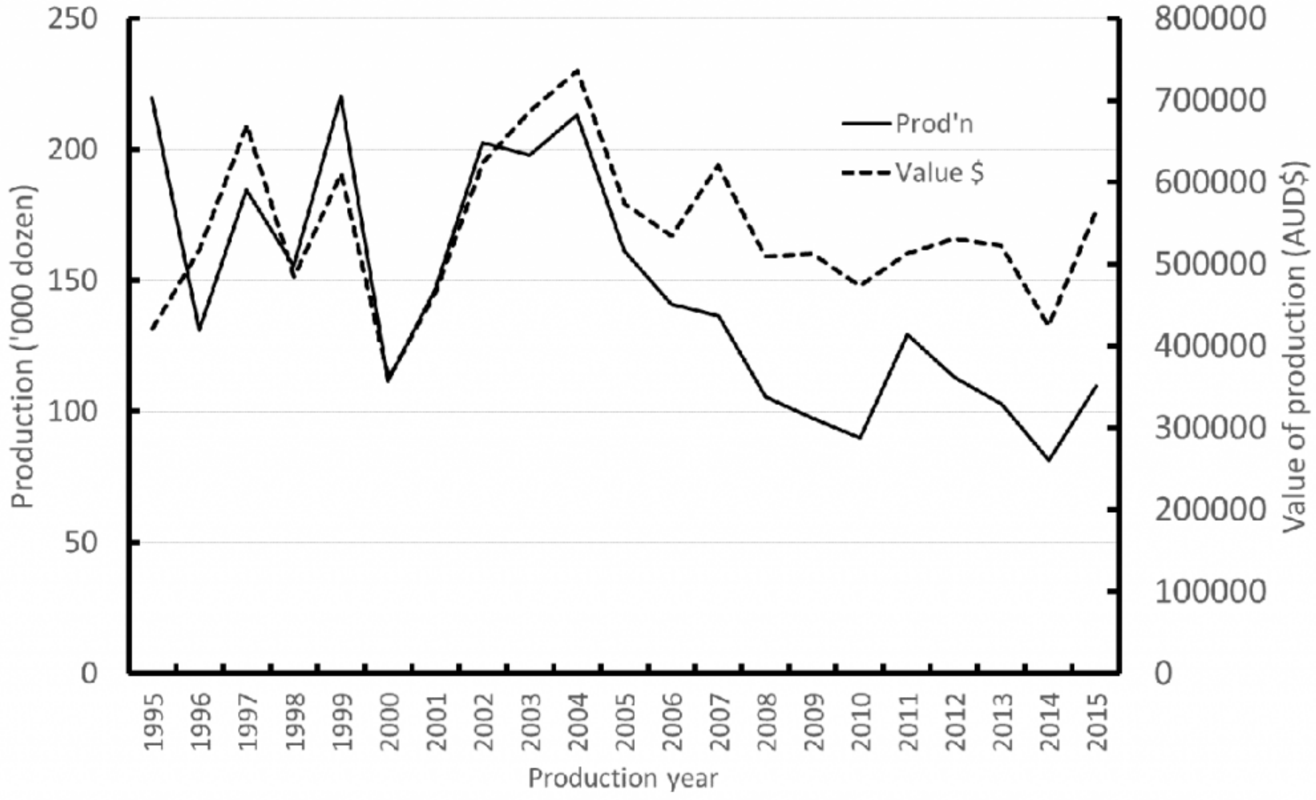

Figure 2. Production (’000 dozen) and value of the oyster industry in Moreton Bay (1995 to 2015 season)

Oystering was considered the largest and single most important industry in the region until the 1920s (10). However, mudworm, floods, stock theft and increasing competition from NSW and New Zealand challenged the industry (3, 10, 12). Uncertain tenure also meant Moreton Bay producers were reluctant to invest in the labour and equipment required for stick and tray cultivation (10). By the early 1920s, annual oyster production in Queensland had declined to ~2,000 bags (125 t) per annum (10, 13). Production has also been heavily reliant on spat from NSW since 1936 due to low natural recruitment (3).

While the oyster industry thrived in NSW from the 1960s, production in Queensland remained low (3). The industry suffered from QX disease caused by the parasite, *Marteilia sydneyi*, competition with the exotic Pacific oyster (*Crassostrea gigas*), and food safety concerns (14). Innovations from NSW and elsewhere, such as the sale of single seed oysters (individual ‘loose’ spat), selective breeding hatcheries, sterile triploid Pacific oysters and recyclable plastic culture trays for oyster cultivation, have not increased Moreton Bay oyster production. Recently, annual production has fluctuated between ~100,000 and 220,000 dozen, with the annual industry value between ~$400,000 and $700,000 (Fig. 2). If a 'bag' contains 120–130 dozen whole oysters (15), then that is less than 2,000 bags per annum in the old units, and less than 10% of peak historic levels.

Since 2007, production has fluctuated between ~80,000 and 130,000 dozen, though higher prices have seen industry value hold at ~$500,000 per annum. The inefficiency of production in existing oyster-growing areas is likely due to the short harvest season, QX disease, competition from Pacific oyster, poor water quality and the relatively high proportion of hobbyist farmers in the industry (3). An oyster industry plan for the Moreton Bay Marine Park was developed in 2008 and reviewed in 2015 (16). The plan provides the tenure needed for long-term investment and is accredited under the *Marine Parks Regulation 2006*. Individual oyster growers who conduct their operations within the framework of the plan do not require a Marine Parks permit. Some growers have increased production using the provisions allowing a working platform on the area. An industry renewal policy issuing resource allocation authorities was also developed which established minimum production levels for authority holders. Some notices have been issued, but even if authorities to operate oyster areas are surrendered, attracting ambitious growers and labour remains a major challenge given the close proximity to better economic opportunities nearby in Brisbane (17).

Prawn (shrimp) aquaculture

In the early 1970s, Australian agribusinesses considered the two models of prawn farming available: intertidal farms or high-density tanks. Traditional intertidal farms in Asia had poor yield, but high-density production in tanks on land was unproven and likely expensive (18). In 1971, one corporation tried hatching brown tiger prawn (*Penaeus esculentus*) in tanks near Cleveland, but attempts there and later in Port Douglas were unsuccessful and the trials were abandoned in 1976 (19). A pilot of indoor production at Southport was also unsuccessful (19).

In Taiwan, farmers found a middle path by culturing prawns in small outdoor ponds built on coastal farmland (20, 21). Taiwan's land-based prawn farms produced so many black tiger prawn (*P. monodon*) that feeding, aeration and massive seawater changes were essential (20, 21). Even though this industry crashed in Taiwan in the late 1980s due to an epidemic of unforeseen prawn diseases (22), land-based prawn farms expanded into several other countries (23, 24). When world sugar prices crashed in the mid-eighties, a number of cane farmers on the banks of the Logan estuary (southern Moreton Bay) also diversified into prawn farming (26).

Land-based prawn farming in Australia first appeared in NSW, but farms established shortly after in tropical Queensland quickly dominated national production (25, 26). Most ponds were built in the warmer climates in the north of the state, where two crops per year were possible. The returns per hectare for prawns were better than for agriculture. Risks, uncertainties and opposition from existing seawater users (25) eventually led the Australian Government to intervene using regulations developed to ensure prawn farms had no additional impact (in terms of point source discharge) to the Great Barrier Reef (GBR) (27). The total area of prawn ponds in northern Queensland decreased as early farms closed or diversified production to barramundi (Fig. 3). Nutrient and suspended sediment restrictions were also placed on the Logan estuary prawn farms. In response to these controls, Moreton Bay prawn farms made significant contributions to advances in global research into environmental management of prawn farms (28). Despite this, at its recent peak, only a small fraction of Queensland's coastal land was dedicated to prawn farming and a small part of that was in Moreton Bay (Fig. 3, Fig. 1).

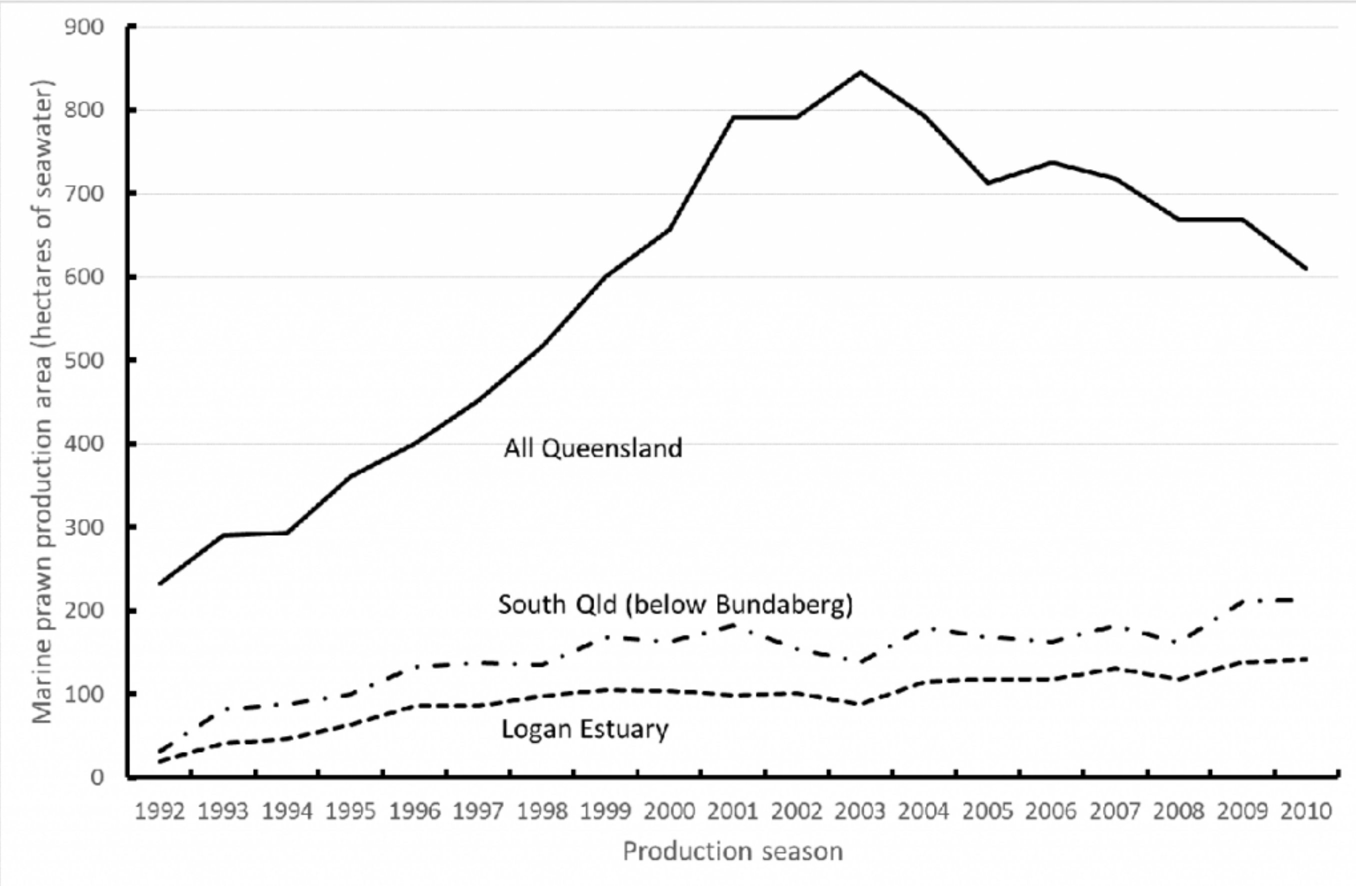

Figure 3. Area of ponds producing marine prawns in Queensland during each growing season from 1992–93 to 2010–11 (Data: Department of Agriculture and Fisheries)

In the mid-1990s, the dependence on wild broodstock caused production to lag behind pond construction (Figs 3, 4). Farmers discovered that visibly healthy wild prawns could still pass a suite of hidden pathogens to their offspring (29, 30). In 1993 and 1994 a mid-crop mortality syndrome (MCMS) stalled production in Queensland (Fig. 4). Northern farms that dried ponds to break the infection cycle then risked having little or no crop if hatcheries could not deliver post-larvae at the crucial time (31, 32). Elsewhere, production crashes in Asia followed outbreaks of new, extremely virulent pathogens, white-spot syndrome virus (WSSV) and yellow-head virus (YHV1) (29, 30). Queensland's wild black tiger prawn already hosted the pathogen linked to MCMS (i.e. YHV2, a milder variant of YHV1), thereby softening the impact of the local pathogen (33, 34).

Farmed prawn production in southern Queensland avoided many of the issues faced further north during the 1990s (Fig. 4). Farms in northern Queensland could produce 8–10 t/ha y^{-1} in back-to-back 4–5 t/ha crops (32, 35, 36). When the disease-affected northern farms resumed production in 1997, the increasingly efficient Logan River producers grew nearly one-third of Queensland's farmed black tiger prawn, using two-thirds of the ~86 ha of production ponds beside the estuary at the time (37). These farms were sustainably harvesting 6–7.5 t/ha crops (38–41).

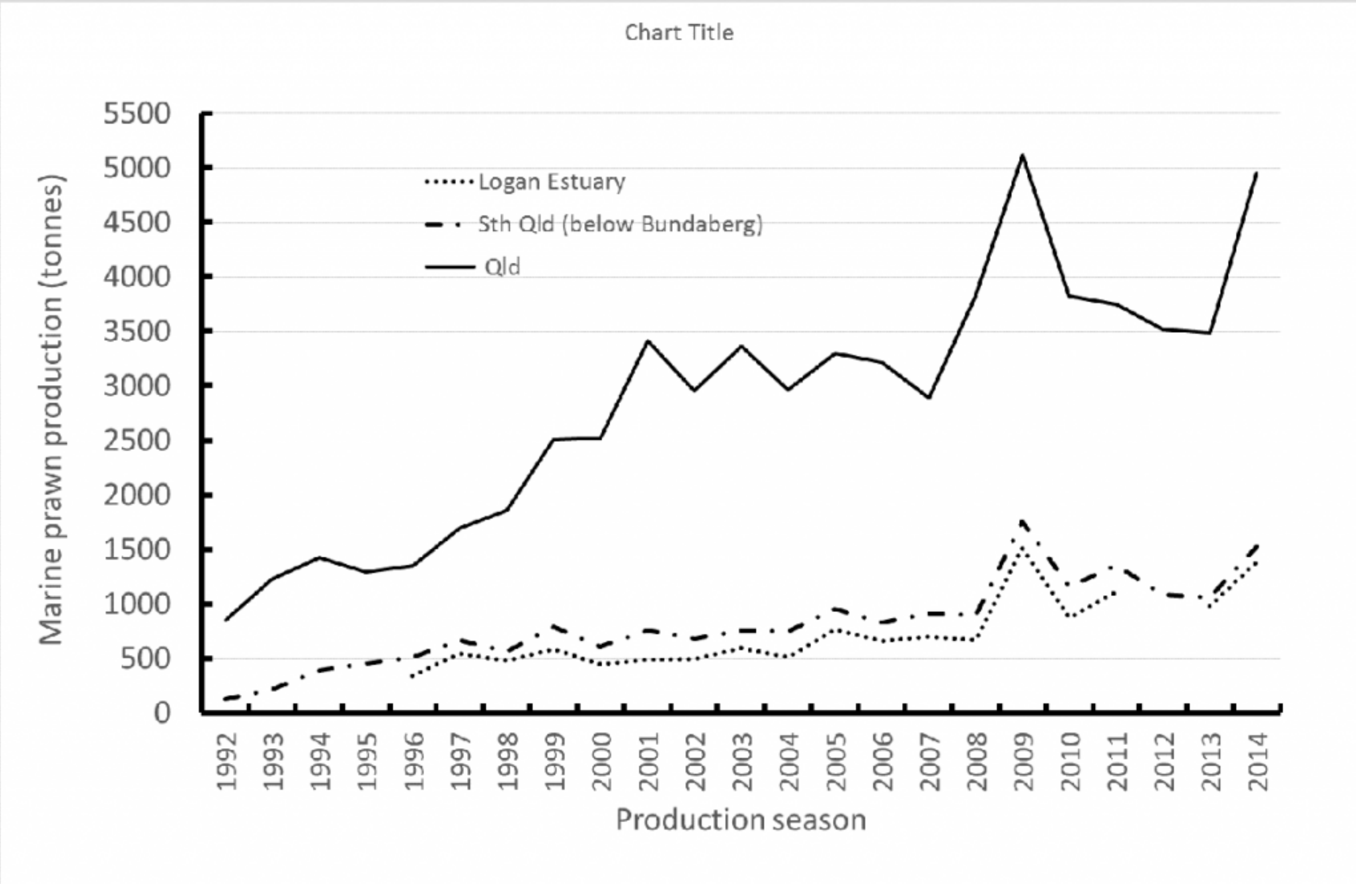

Figure 4. Farmed marine prawn production in Queensland from the 1992–93 season to the 2014–15 season. The gaps in production (1992–96, 2011–13) for the Logan area are to protect confidentiality when fewer than five farms produce that season. (Data: Department of Agriculture and Fisheries)

Australia's higher valued export brown tiger prawn (*P. esculentus*) and other species familiar to local consumers (i.e. the banana pawn *Penaeus merguiensis*) were occasionally cultured in the first few years (42), but Queensland prawn farmers ultimately chose black tiger prawn as techniques were established and feed was available (36, 40, 43). A small prawn farm near Cleveland also established live export of *Penaeus pulchricaudatus* [formerly *japonicus*], the local equivalent of Japan's prestigious prawn 'kuruma ebi' (44). By the mid-nineties, up to seven southern Queensland prawn farms were exporting live Queensland 'kurumas' (45). Overseas investors avoiding WSD in Asia built two kuruma farms, one near Bundaberg and another near Steiglitz in southern Moreton Bay, approximately 5 km south of the mouth of the Logan River (46). By then, unregulated translocation of northern hemisphere kuruma prawn amongst countries near Japan had spread WSD through nations bordering the Sea of Japan (29, 47). Queensland's kuruma production peaked at 250 t per annum in 1996 (from 60 ha), approximately half of southern Queensland's marine prawn output (Fig. 3). However, economic troubles in Asia quickly drove local prices down (48–50) and live export of kurumas from Queensland ceased in the 2005–06 season (51) due to the high costs of culture and export, and local viruses causing low stocking rates (52, 53).

Meanwhile local black tiger prawn production was impacted by another shortage of healthy breeders and post-larvae (54), resulting in insufficient broodstock to fill 800 ha of available ponds (54, 55) (Figs 3, 4). Broodstock collectors were also excluded from the best broodstock areas by the revision of the GBR marine park zones, with aquaculture competing with commercial fishing in the remaining areas (56, 57). In 2002, CSIRO started assisting one of the Logan estuary prawn farms to develop an in-house domestication and selective breeding program for black tiger prawn (58). One of Queensland's oldest farms, at Cardwell in North Queensland, also developed a domestication and selective breeding program for banana prawn, *P. merguiensis* (59). Regulated translocation of virus-tested wild black tiger prawn from prawn fisheries in the Northern Territory also began (60).

The appreciation of the Australian dollar in the mid-2000s resulted in an increase of farmed imports from South East Asia (61, 62). Disease-troubled producers in Asia switched to the relatively more bio-secure but low-value exotic prawn, *Penaeus vannamei*, using plastic-lined ponds pre-filled with seawater free of virus hosts and carriers (63, 64). The first result of increased imports was decreased domestic prices, so pond area in Australia decreased (Fig. 3), with some Queensland farms closing. Twenty-six Queensland black tiger prawn farms remained in 2006–07, eight fewer than at the peak (Fig. 4). Secondly, the imported prawns carried the same viruses that had impacted black tiger prawn production elsewhere in Asia (65).

An import risk assessment concluded that entry of uncooked, intact, farmed prawns posed the greatest risk, with surveys revealing some recreational fishers were using imported supermarket prawns as bait (66). An onerous testing regime commenced to prevent entry of WSSV and YHV-infected consignments of frozen, uncooked prawns into Australia (66); however, there was some backlash from seafood importers (67).

Domesticating and translocating broodstock from Northern Territory waters overcame the breeder bottleneck, increasing production by approximately 40% in two seasons (68) and briefly doubling production in the Logan estuary (Fig. 4). However, now that entry of exotic prawn viruses into Australian seas has been demonstrated, wild-caught breeders carry risks. By 2008, the development of domestication and breeding programs for black tiger prawn proved to be a cost-effective alternative to reliance on wild broodstock (69). Combining domestication with selective breeding enabled progressive, permanent genetic gains in growth rates and feed conversion efficiency resulting in the highest recorded yields of farmed black tiger prawn in the world (mean t/ha) (28). However, as with other agricultural sectors, production can be reduced by extreme weather events, such as the cyclones and widespread floods in coastal Queensland in 2011 (Fig. 4) (70).

In late December 2016, the exotic WSD caused a mass mortality of prawns at a farm bordering the Logan estuary (71). An eradication plan was activated in an attempt to maintain Australia’s long-defended, WSSV-free status (72). By early 2017, all Moreton Bay prawn farms had been destocked and disinfected (73). The importation of uncooked prawns to Australia was temporarily suspended and a movement control order extending from Caloundra to the NSW border was put in place to prevent dispersal of the virus (74). Prawn hatcheries in this region were contained in the movement control zone. Mass importation of uncooked WSSV-infected prawns indicated a failure of Australia’s biosecurity system (6). Surveillance testing in April 2018 returned positive for the virus at nine sites in Moreton Bay near Deception Bay and Redcliffe, but indicated that there had been no further spread throughout Moreton Bay or Queensland. Further surveillance testing in August and September 2018 were all negative for the virus, although testing during the same period in 2017 also returned negative results, which is likely to indicate WSSV is more prevalent in the warmer months. Three farms resumed operation in the 2018-2019 season, with additional biosecurity measures, including revised on-farm biosecurity plans, installation of water filtration for all incoming water, modified farm layouts, installed crab fencing and implementation of strict controls for the movement of equipment, staff and visitors (75).

Interaction with the environment

In the mid-1990s, the dependence on wild broodstock caused production to lag behind pond construction (Fig. 3, 4). Farmers discovered that visibly healthy wild prawns could still pass a suite of hidden pathogens to their offspring (29, 30). In 1993 and 1994 a mid-crop mortality syndrome (MCMS) stalled production in Queensland (Fig. 4). Northern farms that dried ponds to break the infection cycle then risked having little or no crop if hatcheries could not deliver post-larvae at the crucial time (31, 32). Elsewhere, production crashes in Asia followed outbreaks of new, extremely virulent pathogens, white-spot syndrome virus (WSSV) and yellow-head virus (YHV1) (29, 30). Queensland's wild black tiger prawn already hosted the pathogen linked to MCMS (i.e. YHV2, a milder variant of YHV1), thereby softening the impact of the local pathogen (33, 34).

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Opportunities, challenges and future of the industry

Aquaculture is one of the fastest growing primary production sectors in the world, accounting for approximately 45% of aquatic animal food produced for human consumption (94, 95). The rising demand for seafood produced through aquaculture provides a significant opportunity for the market to increase. However, industry growth faces significant challenges including water quality, diseases and competition (17).

Aquaculture is challenged by the potential environmental impacts to water quality in adjacent waterways. Each new intensive aquaculture development can add to existing diffuse pollution from the catchment (96, 97), requiring strict environmental regulations on the quality of this source of wastewater. This may be one of the reasons for the lack of any new major entrants to the Queensland industry in over a decade (98, 99). For example, the SunAqua proposal for snapper and yellowtail kingfish cages on the eastern side of Moreton Bay was refused permission to proceed by the Queensland Coordinator-General in 2004 (100). This project was refused due to concerns about nutrient discharges. A strong public campaign also objected to the project due to the potential impacts to environmentally sensitive areas (101). The rejection of this proposal has discouraged the establishment of, and investment in, Queensland aquaculture (98). Fortunately, Queensland policies have recently been put in place to support the sustainable expansion of the industry by focusing on defined Aquaculture Development Areas and adopting innovative technologies to treat the discharge wastes (102).

Currently, the major challenge for the Moreton Bay prawn aquaculture industry is the recent WSD outbreak. Prawn farms beyond Moreton Bay must also now review their vulnerability to the arrival of exotic pathogens, and consider innovations such as polychaete-assisted sand-filters and algal raceways to treat discharge water (103, 104). Accelerated adoption of filtration/remediation systems that assist in managing the WSD outbreak will be valuable additions to prawn farming environmental management technologies. Selective breeding programs producing pathogen-free prawns that are resistant to the disease are likely to assist in combatting WSD (105).

Diversifying aquaculture activities through additional species and products may also be an important risk management strategy to increase the economic viability of the aquaculture industry. Rather than resume prawn production following the WSD outbreak, one Logan estuary farm has begun trials to grow and market two new fish products, cobia (*Rachycentron canadum*) and Queensland groper (*Epinephelus lanceolatus*) (106). In Asia, replacing, supplementing or rotating prawn aquaculture with other high-value fish species has negated the risk and instability of disease outbreaks (107). In Moreton Bay, diversifying prawn farms to include finfish production to avoid WSD and/or diversifying oyster farms to Akoya pearls to negate food safety issues may enhance the economic viability of these industries. However, further research, aimed for example at supply and demand and environmental management of any new species, would be required.

Overall, the future of aquaculture in Moreton Bay requires proactive management of the whole system that recognises the complex ways in which present-day metropolitan and catchment development challenges sustainable growth of the industry. Careful consideration of these issues and applying recent advances in Australian aquaculture technologies could enable aquaculture enterprises in the region to achieve sustainable growth with an effective balance between economic success and conserving Moreton Bay's unique ecosystem.