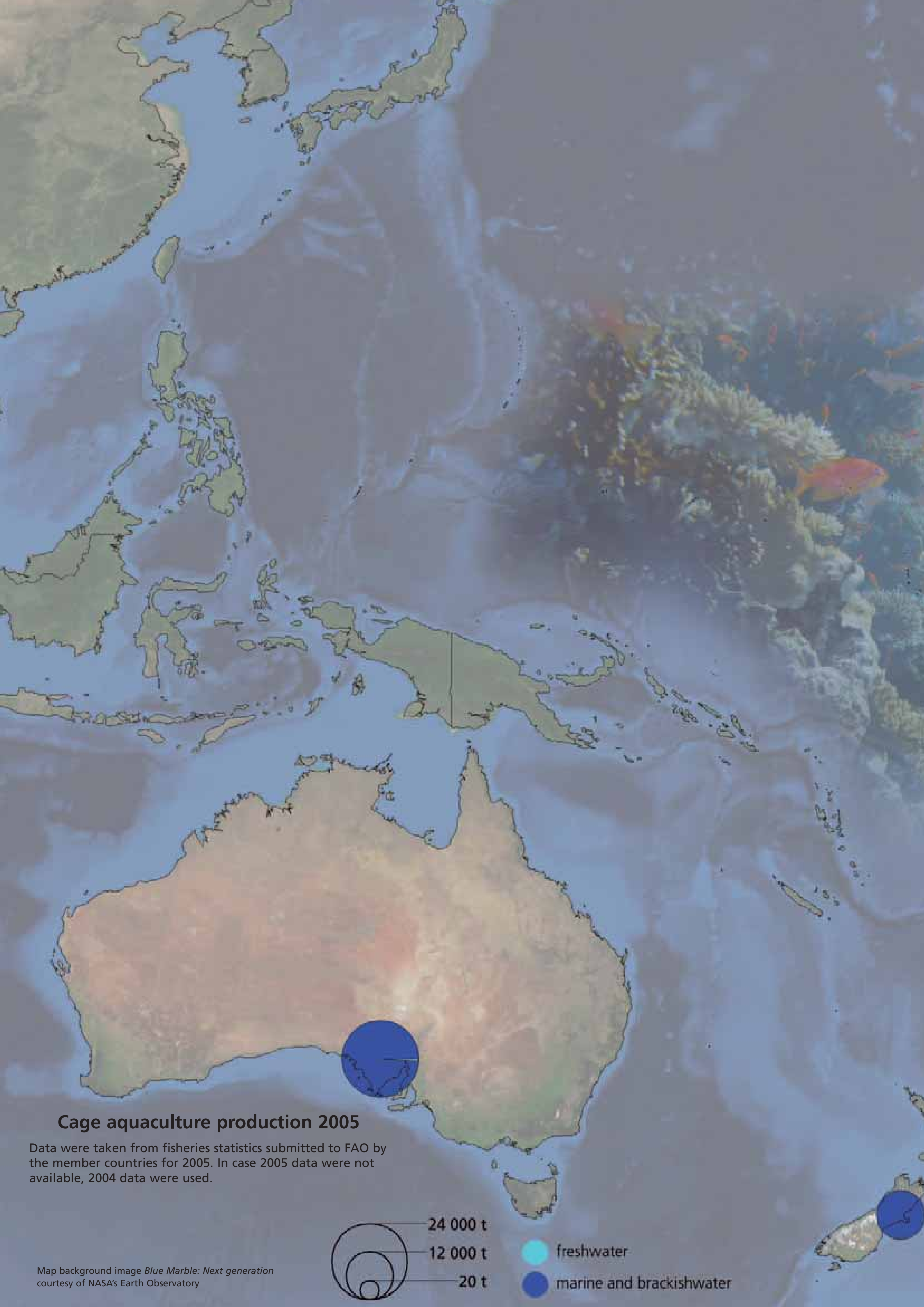

Cage aquaculture production 2005

Data were taken from fisheries statistics submitted to FAO by the member countries for 2005. In case 2005 data were not available, 2004 data were used.

Map background image *Blue Marble: Next generation* courtesy of NASA's Earth Observatory

A review of cage aquaculture: Oceania

A review of cage aquaculture: Oceania

Michael A. Rimmer[1] **and Benjamin Ponia**[2]

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ABSTRACT

Cage aquaculture is little practised in the Oceania region, compared with other regions. Total production for the Oceania region was only about 24 000 tonnes for 2003 (based on FAO production statistics which likely underestimate regional production). Most of this production is from Australia and New Zealand.

Major commodities for cage aquaculture production in the Oceania region are:

- Southern bluefin tuna (*Thunnus maccoyii*) which is farmed exclusively in South Australia.
- Salmonids, principally Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) in Australia (Tasmania and South Australia) and Chinook salmon (*Oncorhynchus tschawytscha*) in New Zealand.
- Barramundi (*Lates calcarifer*) which is farmed in sea cages and in cages in freshwater and brackishwater ponds in Australia (Queensland, Northern Territory, Western Australia), Papua New Guinea and French Polynesia.
- Yellowtail kingfish (*Seriola lalandi*) in Australia (South Australia).

In addition, there is some production of snapper (*Pagrus auratus*) and mulloway (*Argyrosomus hololepidotus*) in Australia and of tilapia (*Oreochromis niloticus*) and carp (*Cyprinus carpio*) in Papua New Guinea.

Some of the reasons for the limited development of cage aquaculture in the region are:

- In Australia, there is considerable community concern regarding the impacts of large-scale aquaculture. This concern has in some cases been exacerbated by effective lobbying by conservation groups, to the detriment of the reputation of aquaculture.
- In New Zealand, a moratorium on further development of marine aquaculture since 1991 has effectively halted industry growth.
- Many Pacific Island countries have low population bases and relatively poor infrastructure to support anything but basic cage aquaculture. In addition, transport links to targeted export markets are relatively poorly developed and transport costs are high.

A major feature of cage aquaculture development in Australia and New Zealand, compared with many other regions, is the strong emphasis on environmental management and reduction of environmental impacts. This in turn reflects the strong emphasis on maintaining high environmental quality in both Australia and New Zealand, if necessary at the expense of industry development.

1 Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, PO Box 5396, Cairns, Queensland, Australia;
2 Secretariat for the Pacific Community, B.P. D5 98848, Noumea Cedex, New Caledonia;

BACKGROUND AND AIM OF STUDY

This study was commissioned by the Food and Agriculture Organization of the United Nations (FAO) as one of a series of reports on the global status of cage aquaculture to be presented at the Second International Symposium on Cage Aquaculture in Asia held in Hangzhou, China, 3–8 July 2006.

This paper reviews the current status of cage aquaculture in the Oceania region, identifies a number of issues that impact on cage aquaculture development in that region, and summarises the needs to sustainably develop cage aquaculture in the region.

HISTORY AND ORIGIN OF CAGE CULTURE IN THE REGION

Cage aquaculture is little practised in the Oceania region, compared with other regions. Total production for the region was only around 24 000 tonnes for 2003, based on FAO data (FAO, 2006), although these data appear to underestimate total production. The bulk of production is from Australia and New Zealand.

Cage aquaculture commenced in the region in the 1980s with the development of Atlantic salmon (*Salmo salar*) aquaculture in Tasmania. Atlantic salmon were first introduced into Tasmania by Acclimatization Societies in the 1800s, these introductions were unsuccessful (Love and Langenkamp, 2003). More recently, Atlantic salmon were introduced from Canada to New South Wales in the mid-1960s for stocking purposes. In the late 1960s the Commonwealth government banned all imports of salmonid genetic material in order to prevent exotic diseases entering Australia. Tasmania acquired eggs from the New South Wales hatchery in the early 1980s and commercial production in Tasmania commenced in the mid-1980s (Love and Langenkamp, 2003).

In New Zealand, chinook salmon (*Oncorhynchus tschawytscha*) were successfully introduced by the Marine Department in the hope of starting a commercial rod fishing and canning industry. An initial attempt to introduce chinook salmon was made for a recreational fishery by the Hawkes Bay Acclimatisation Society in 1875 but this and several other attempts in various parts of New Zealand were unsuccessful. Chinook salmon were eventually introduced via a hatchery on the Hakataramea River, between 1901 and 1907 which sourced fish from the Baird Fish Station on the McLeod River, a tributary of the Sacramento River in California. Subsequently Chinook salmon became established with self-sustaining returns to rivers on the east coast of the South Island and to a minor extent on the west coast of the South Island. Further imports of live salmon into New Zealand have not been permitted for over 50 years.

Interest in salmon farming in New Zealand grew steadily during the 1970s as part of a worldwide trend towards commercial aquaculture. New Zealand's first commercial salmon farm was established in 1976 as an ocean ranching venture at Waikoropupu Springs in Golden Bay, and made its first sales of freshwater-reared salmon in 1978. Other early ocean ranching farms included an ICI/Wattie joint venture on the lower Clutha River, and larger-scale hatcheries on the Rakaia River and the nearby Tentburn coastal site. The first sea-cage salmon farm was established in 1983 in Stewart Island's Big Glory Bay by BP New Zealand Ltd. This was soon followed by the development of farms in the Marlborough Sounds.

Southern bluefin tuna (*Thunnus maccoyii*) aquaculture began in Australia in 1990 and by 2002 had developed into the largest farmed seafood sector in Australia (Ottolenghi *et al.*, 2004). The development of southern bluefin tuna aquaculture was driven by declining catches and a desire by fishers to value-add the limited volume of product available by growing the fish in pens. In the early 1960s the annual global catch of southern bluefin tuna reached 80 000 tonnes. However, by the mid-1980s, with catches falling and numbers of mature fish declining, it was apparent that stock management and conservation was needed. From the mid-1980s Australia, Japan and New Zealand, the main nations fishing the species at the time, began to apply quotas as a management and conservation measure to enable stocks to rebuild (Love and Langenkamp, 2003). Individual transferable quotas were introduced into the Australian tuna industry in 1984 and by 1987 South Australian quota holders had bought up most of the Australian quota. In 1988 the initial Australian quota of 14 500 tonnes was cut to 6 250 tonnes, and then in 1989 to its current level of 5 265 tonnes (Love and Langenkamp, 2003).

This large reduction in tuna supply prompted a move away from canning to value-adding through farming with a focus on the Japanese sashimi market. The first experimental farm was established at Port Lincoln in 1991 under a tripartite agreement between the Australian Tuna Boat Owners' Association of Australia, the Japanese Overseas

Fisheries Cooperation Foundation, and the South Australian government. Over the past decade the farmed sector has grown to the point where around 98 percent of the Australian southern bluefin tuna quota is now farmed (Love and Langenkamp, 2003; Ottolenghi *et al*. 2004).

Because of Australia and New Zealand's traditional linkages with Europe and the United Kingdom, much of the development of cage aquaculture has utilized technology adoption from European aquaculture. This also reflects the high labour costs in these countries, and hence a need to mechanize as much as operationally possible to reduce the labour component of production costs.

THE CURRENT SITUATION

Southern Bluefin Tuna

Southern bluefin tuna (*Thunnus maccoyii*) aquaculture is limited in geographical extent to South Australia, specifically the Port Lincoln area of the Eyre Peninsula. Although one company proposed to build a sea cage farm in Western Australia, this has not yet gone ahead (O'Sullivan *et al*., 2005) (Figure 1).

Initially, the sea cage sites were located relatively close inshore, within Boston Harbour at Port Lincoln. However, a mass mortality event in 1996 resulted in the loss of around 1 700 tonnes of tuna valued at AUD 40 m (US$30 million). Possible causes for the mortality event include: asphyxiation due to fine sediments that were stirred up during a storm, and the impacts of toxic micro-algae. Subsequently, the tuna cages were moved further offshore into deeper water where potential sediment impacts would be lessened (Ottolenghi *et al*., 2004; O'Sullivan *et al*., 2005).

FAO data record production of 3 500–4 000 tonnes for 2002–2004 (Figure 2). EconSearch (2004) provide figures of 5 300 and 5 400 tonnes for 2001–02 and 2002–03 respectively (Table 1), while O'Sullivan *et al*. (2005) note that 'recently production has stabilised to slightly over 9 000 tonnes'. The value of production has recently been around AUD 250 m (US$190 million) per annum, making this the most valuable aquaculture sector in Australia. However, in 2003-04 farm gate prices fell from over AUD 28 (US$21)/kg to around AUD 16 (US$12)/kg due to a strong

FIGURE 1
Map of Oceania showing location of southern bluefin tuna cage culture sites

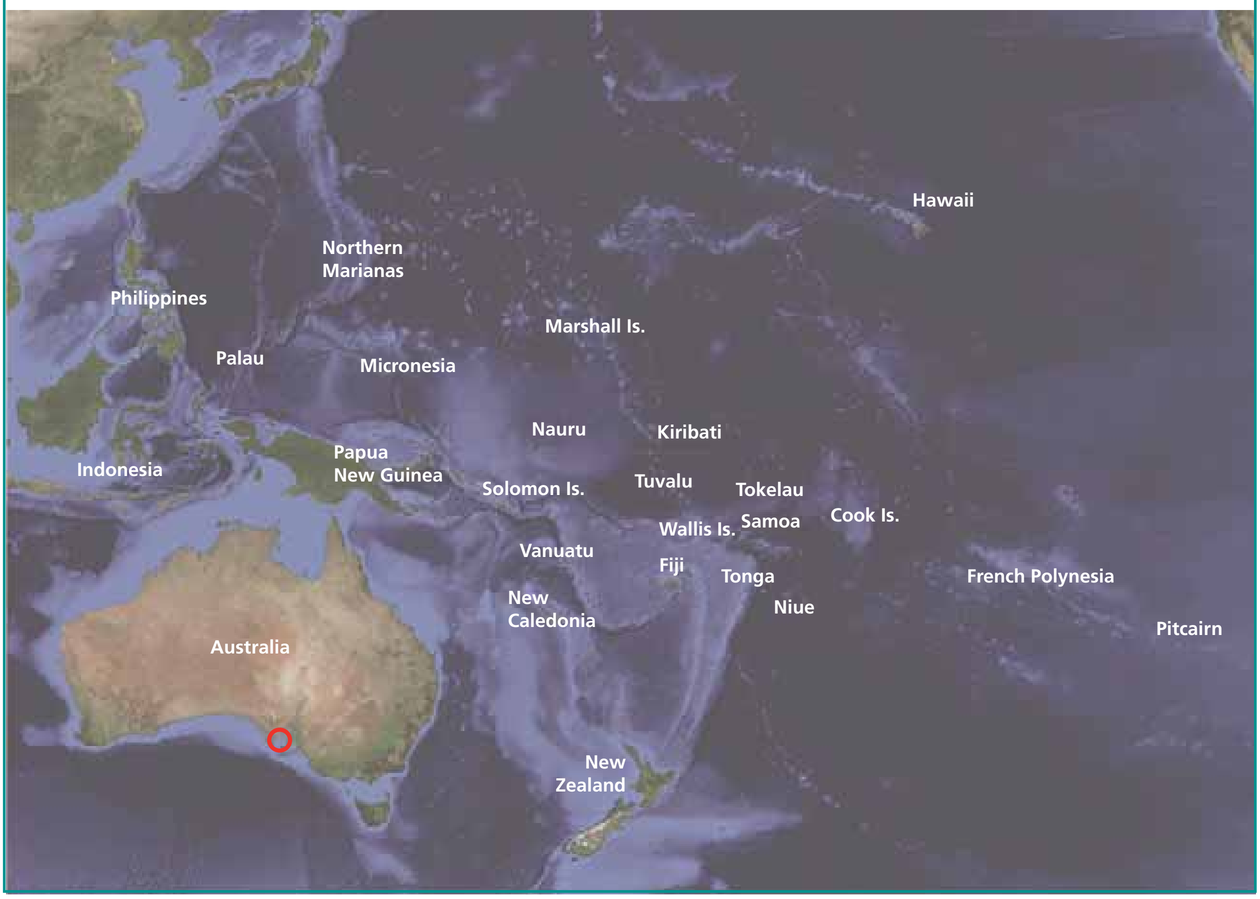
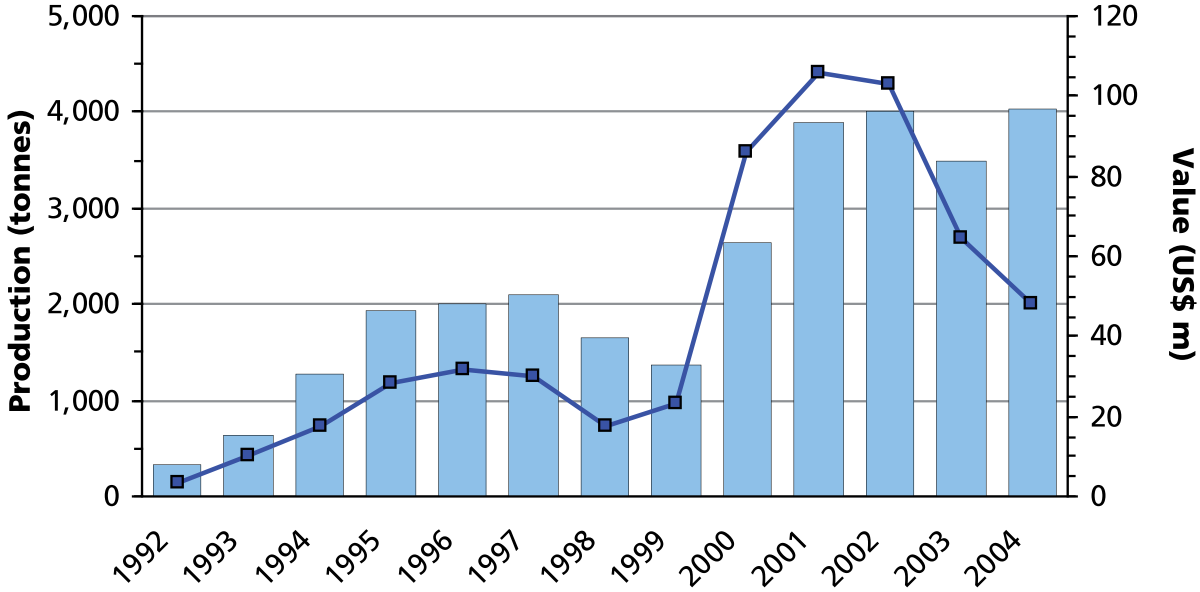


Figure 2
Annual aquaculture production (bars) and value (line) of southern bluefin tuna (*Thunnus maccoyii*) in Australia from 1992 to 2004



Source: FAO, 2006

Australian dollar and increased competition from overseas product, reducing the value of production to AUD 151 m (O'Sullivan *et al*., 2005).

TABLE 1
Production and value of farmed southern bluefin tuna from South Australia, 1996–97 to 2002–03 (EconSearch, 2004). The low output in 1995-96 was due to a large-scale mortality during 1996.

	Into farms	Farm output	
	Whole Weight	Processed Weight	Farm Gate Value
	'000 kg	'000 kg	AUD m
1995-96	3,362	1,170	29.3
1996-97	2,498	4,069	91.5
1997-98	3,610	4,927	120.7
1998-99	4,991	6,805	166.7
1999-00	5,133	7,750	240.0
2000-01	5,282	9,051	263.8
2001-02	5,296	9,245	260.5
2002-03	5,409	9,102	266.9

Southern bluefin tuna are caught in the Great Australian Bight (Southern Ocean) under a strict international quota system. The juvenile tuna are around 120 cm total length and weigh 15–20 kg (PIRSA, 2000). The fish are caught in purse seine nets and transferred to a 'towing cage'. The towing cage is towed slowly (1–2 knots) by vessel back to the grow-out cages – a journey of up to 500 km. The tuna are then transferred to the grow-out cages.

Tuna net cages range from 30 to 50 metres diameter and 12 to 20 metres depth. The inner nets are generally 60–90 cm mesh size. If an outer predator-exclusion net is used, it is generally 150–200 cm mesh size. Tuna are stocked at around 4 kg per cubic metre, or around 2 000 fish per cage (PIRSA, 2000; Ottolenghi *et al*., 2004).

Southern bluefin tuna are fed pilchards and mackerel once or twice daily, six or seven days per week (PIRSA, 2000). Food conversion ratios are high: around 10–15:1 (Ottolenghi *et al*., 2004). Attempts to develop cost-effective pellet diets for southern bluefin tuna are continuing but have had limited success to date (Ottolenghi *et al*., 2004). Tuna are cultured for 3–6 months until they reach the target harvest weight of 30 kg (PIRSA, 2000).

Australian farmed tuna is sold almost exclusively to the Japanese sashimi markets. All frozen product, representing around 75 percent of sales, and around half of fresh chilled product, is now sold direct rather than auctioned (Love and Langenkamp, 2003). Despite the recent declines in the Japanese economy, the demand for bluefin tuna remains high. However, it has become apparent to many producers that relying on a single market (Japan) is a risky strategy (Ottolenghi *et al*., 2004). Although demand in Japan remains high, the prices that

Japanese consumers are willing to pay is declining and there is an increasing trend towards the purchase of less expensive products (Ottolenghi *et al*., 2004). Southern bluefin tuna must compete with other, lower-priced tuna species such as big-eye (*Thunnus obesus*) and yellow-fin (*Thunnus albacares*) (Ottolenghi *et al*., 2004).

There is a substantial research effort into improving the sustainability of southern bluefin tuna aquaculture, much of it through the Cooperative Research Centre for Sustainable Aquaculture of Finfish (AquaFin CRC). The main research programmes deal with developing cost-effective feeds for southern bluefin tuna, and quantifying and reducing environmental impacts associated with sea cage aquaculture. Only one company has expressed an interest in developing hatchery production technology for southern bluefin tuna, with the bulk of the industry opposed to the high level of investment essential to address such a long-term and technically demanding aim.

Salmonids

Australia

In Australia, Atlantic salmon (*Salmo salar*) makes up the bulk of salmonid cage aquaculture production, though there is also some production of rainbow trout (*Oncorhynchus mykiss*) in sea cages. Some trials have also been undertaken with brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) (O'Sullivan *et al*., 2005). Most salmonid farming is in Tasmania, and there is one salmonid sea cage farm in South Australia (Figure 3).

FAO data indicate that production is generally increasing and reached 14 800 tonnes in 2004, valued at US$85 million (Figure 4). The Tasmanian Atlantic salmon industry has seen further mergers of aquaculture operations, leading to a reduced number of large and vertically integrated operations (O'Sullivan *et al*., 2005).

Salmon fingerlings are produced in freshwater hatcheries, then transferred to freshwater ponds when they reach about 40 mm total length (TL).

FIGURE 3
Map of Oceania showing location of salmonid cage farm sites

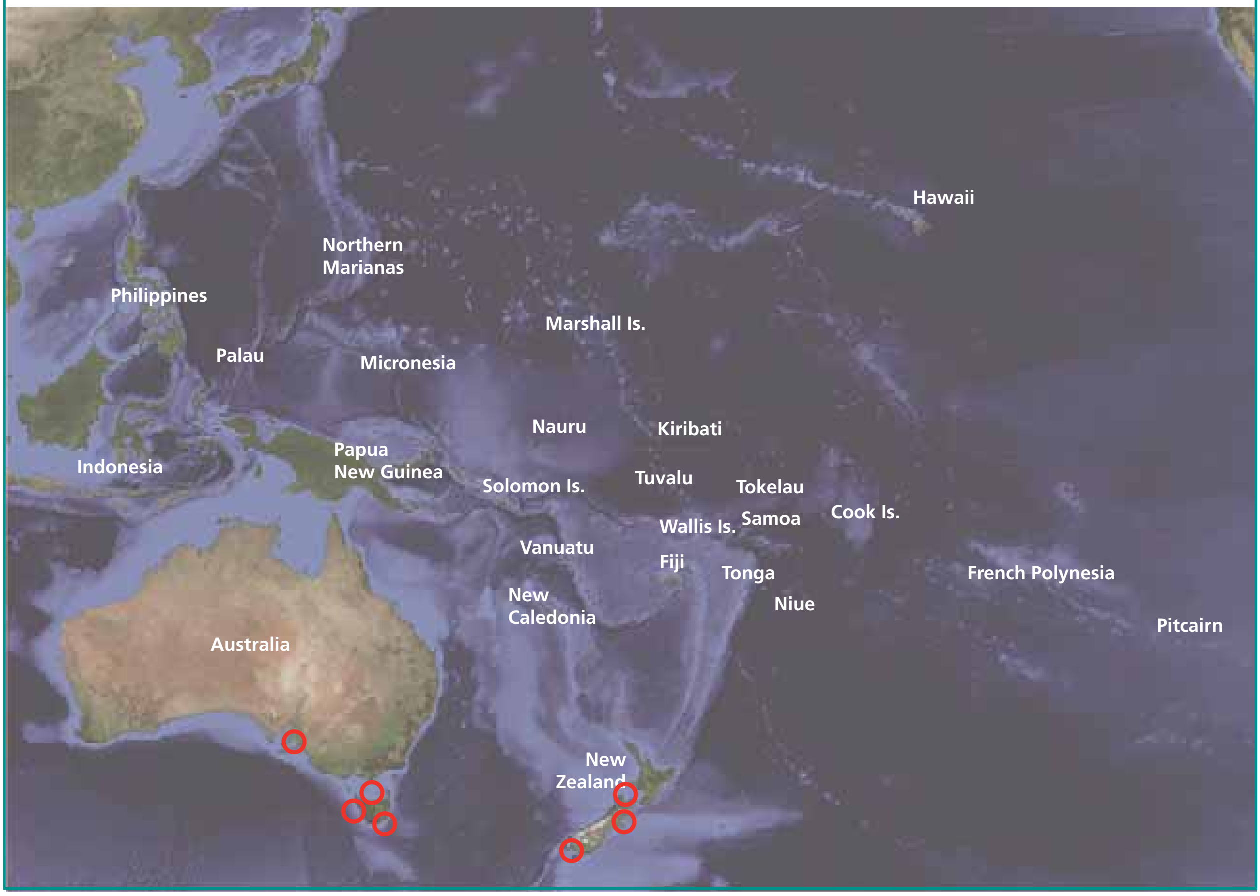
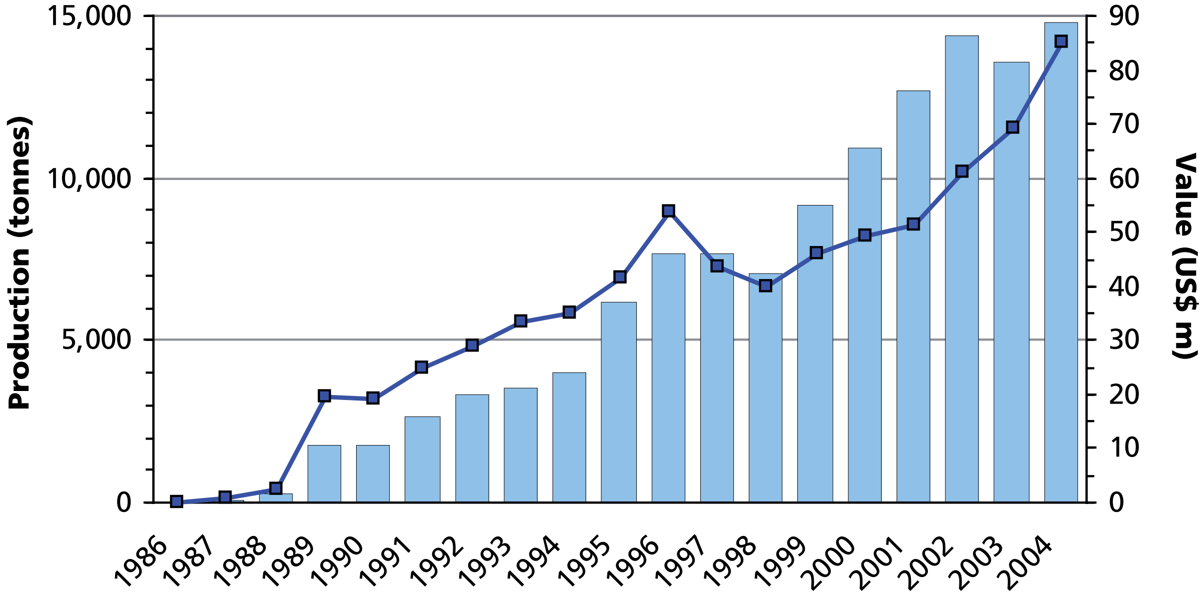


FIGURE 4
Annual aquaculture production (bars) and value (line) of Atlantic salmon (*Salmo salar*) in Australia from 1986 to 2004



Source: FAO, 2006 (brackishwater culture only)

They remain in the ponds for about one year, then the ‘smolts’ are transferred to sea cages for grow-out. Market preference is for 3–4 kg (2–3 years old) fish (PIRSA, 2002a).

As Tasmanian salmonid production has risen, an increasing proportion of production has been sold on the domestic market (Love and Langenkamp, 2003). In the mid-1990s around three-quarters of farmed salmon production was sold on the domestic market, and a quarter exported to Asian markets. More recently, the proportion sold on the domestic market is estimated to have increased to around 85 percent in 2000/01 (Love and Langenkamp, 2003). There are a range of product types available, including whole salmon, fillets and cutlets, as well as value-added products such as smoked salmon. A new product is salmon roe ‘caviar’, of which several tonnes have been sold to both domestic and export markets (O’Sullivan *et al.*, 2005).

Despite the opening of the once protected Australian market for fresh salmonid products to overseas producers, domestic prices for Atlantic salmon have remained relatively steady. For sea cage product, farm gate prices for ‘head-on gilled and gutted’ product were around AUD 7.35 (US$5.50) to AUD 13.20 (US$9.90) /kg in 2003/04 (O’Sullivan *et al.*, 2005). However, increasing competition in the global export market for salmon reduced demand for Australian product (O’Sullivan *et al.*, 2005).

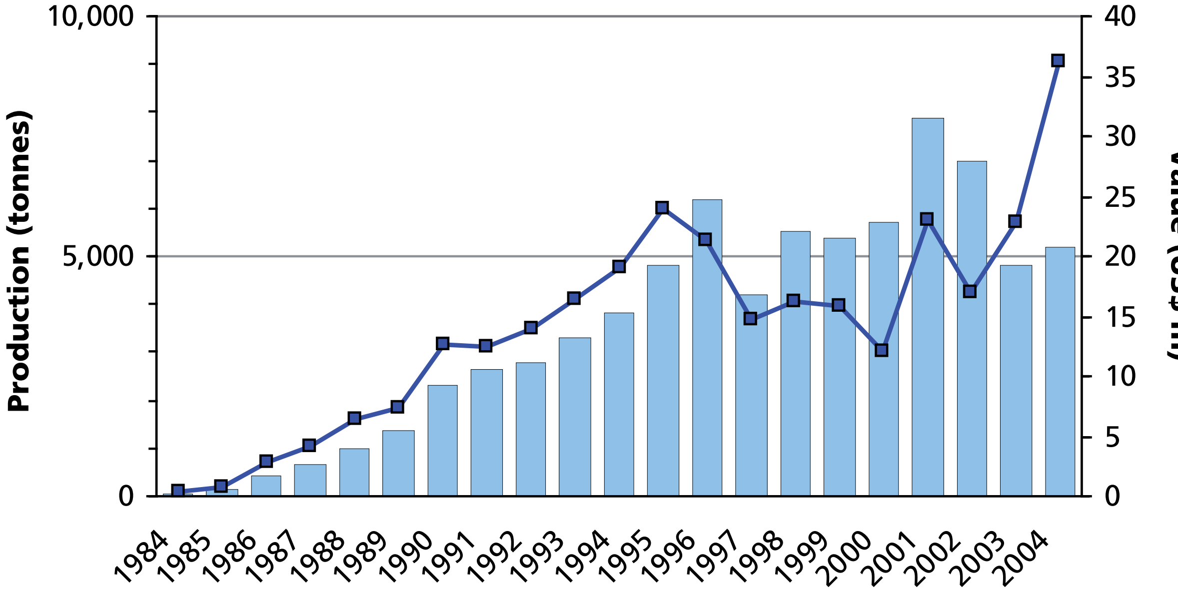
New Zealand

Effectively all production of salmon in New Zealand is of the Chinook salmon (*Oncorhynchus tschawytscha*). Two major production techniques are used: freshwater culture and sea cage culture. Seedstock are cultured using conventional methods: eggs and milt are collected from from captive broodstock, the fertilized eggs are incubated in a freshwater hatchery (usually at 10–12 °C), and the newly hatched fry are reared for a further 6–12 months before being transferred to larger sea cages or freshwater ponds for grow-out. The fish are cultured for two to three years, and are typically harvested at 2–4 kg.

Ocean ranching was trialled but is no longer undertaken commercially in New Zealand. Ocean ranching required large numbers of smolts to be released to the sea to fend for themselves before reaching adulthood, then relying on their homing ability to guide them back to their point of release to be harvested. Several companies attempted this potentially efficient style of farming during the 1980s, but abandoned it when marine survival rates proved too low and inconsistent to sustain a commercially viable return (Gillard and Boustead, 2005).

Production of farmed salmon in New Zealand in 2004 was about 7 450 tonnes worth approximately NZD 73 million (US$44 million), from less than 10 hectares of surface structures of seafarms plus

FIGURE 5
Annual aquaculture production (bars) and value (line) of Chinook salmon (*Oncorhynchus tschawytscha*) in New Zealand from 1984 to 2004



Source: FAO, 2006 (mariculture only)

freshwater farms. In comparison, FAO data list 5 200 tonnes valued at US$36 m (FAO, 2006). A time series of FAO production data suggests that production has remained relatively stable (though with significant annual fluctuations) since 1996, but that there has been an increase in relative product value in recent years (Figure 5). Most production originates from sea cage farms located in the Marlborough Sounds and Stewart Island. Individual farm sites produce up to approximately 1 500 tonnes of salmon (Gillard and Boustead, 2005) (Figure 3).

The existing production capacity of the New Zealand salmon farming industry is approximately 10 000 tonnes with an estimated capacity for expansion to at least 14 000 tonnes. Currently there are 14 ongrowing sites and 12 hatcheries/freshwater sites, with an estimated juvenile fish production capacity of 10 million smolts (Gillard and Boustead, 2005).

About 50 percent of salmon produced in New Zealand is exported. Japan is the major market, but other regional markets, including Australia, are targeted. Most product for the Japanese market is in the form of gilled and gutted, or headed and gutted. There is also some export of value-added products, such as smoked salmon. The local market demands value-added products such as steaks, fillets, smoked salmon, gravlax and kebabs.

Barramundi

Australia

Barramundi (*Lates calcarifer*) farming is carried out in all mainland states of Australia, but most production is from Queensland (mostly from freshwater ponds), the Northern Territory (sea cages and brackishwater ponds) and South Australia (freshwater tanks). Two types of cage farming are practised: sea cage farming, and cages in freshwater or brackishwater ponds. There are only three sea cage farms in Australia: one each in Queensland, the Northern Territory and Western Australia (Figure 6). Most freshwater pond production is from northeastern Queensland (Figure 6).

FAO data record 2004 production as 1 600 tonnes valued at US$9.9 million (Figure 7)). O'Sullivan *et al.* (2005) report 2003/04 production at 2 800 tonnes valued at AUD 23.6 m (US$17.7 million).

Barramundi seedstock is sourced entirely from hatchery production. There are two main techniques for seedstock production: intensive and extensive culture. Intensive culture generally has higher production costs than extensive culture, and fingerling quality may vary considerably. However, intensive culture can be carried out during the cooler time of the year (July to September) to provide fingerlings for grow-out during the warmer summer months. In contrast, extensive larval rearing has lower production costs but

FIGURE 6
Map of Oceania showing location of barramundi cage culture sites

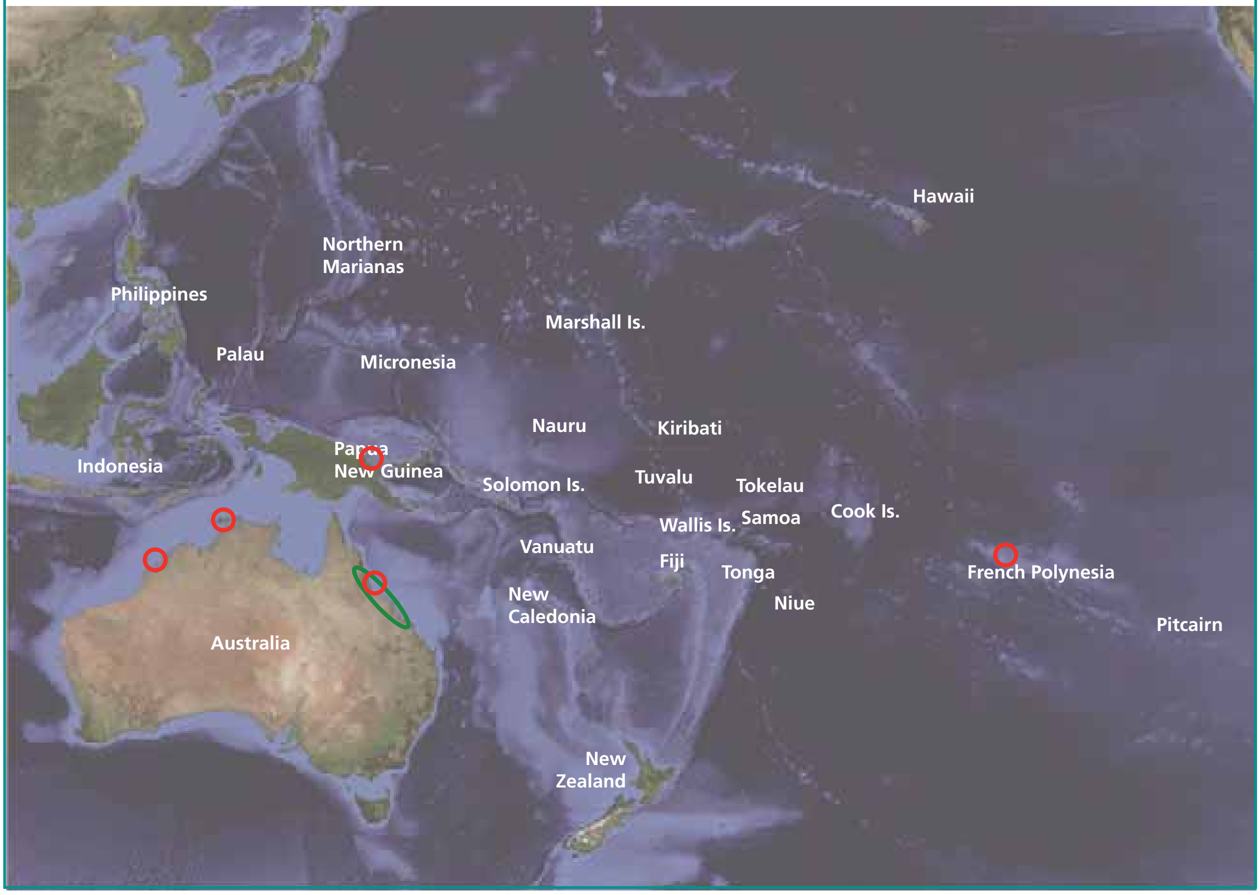
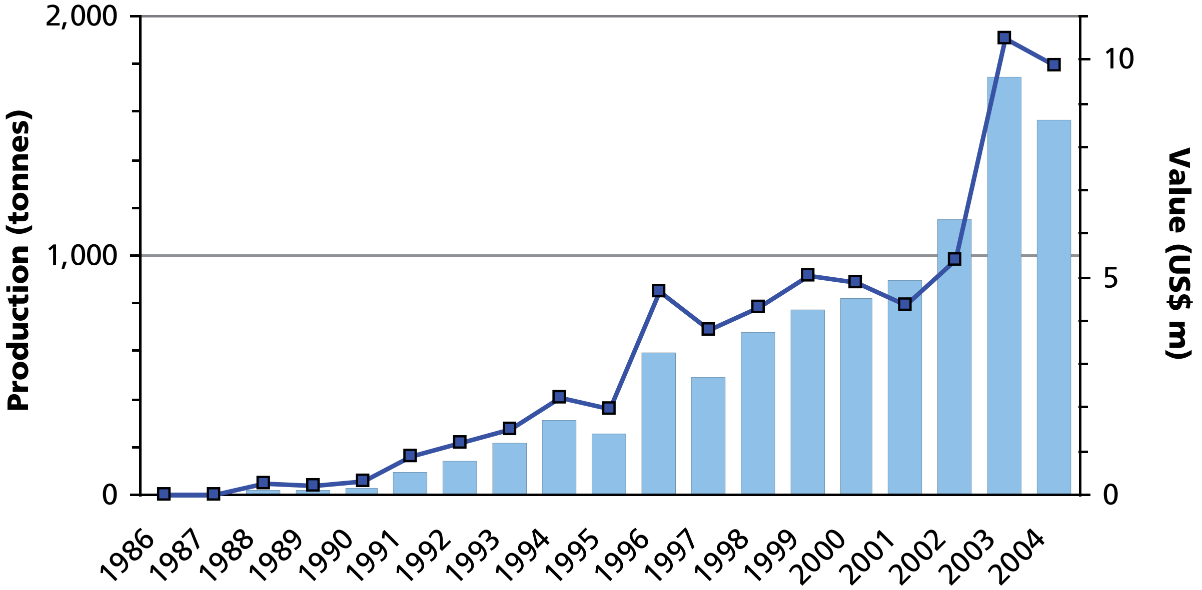


FIGURE 7
Annual aquaculture production (bars) and value (line) of barramundi (*Lates calcarifer*) in Australia from 1986 to 2004. These data are not disaggregated by production type, but a major proportion of this production is from sea cages or cages in freshwater ponds



Source: FAO, 2006

less certainty of production and is limited to warmer summer months (October – March). Some hatcheries use a combination of both techniques: intensive production early in the season, followed by extensive production during the summer (Rimmer, 2003; Tucker *et al*., 2005).

After larval rearing, barramundi are transferred to a nursery at between 1 cm and 4 cm TL. The role of the nursery is twofold: to allow regular grading to reduce mortality due to cannibalism, and to allow efficient weaning of the juvenile barramundi to inert diets. Nursery facilities usually comprise aboveground swimming pools, or fibreglass or concrete tanks, ranging from about 10 000 to 30 000 litres capacity. Small cages (about 1 m^3) made from insect mesh are floated in the tank and the fish are retained in the cages. Alternatively, the fish may be released into the tanks, but this makes grading difficult (Rimmer, 1995).

Barramundi can be weaned to artificial diets at a relatively small size, although the ease and success with which weaning can be accomplished depends primarily on the size of the fish. Larger fish are generally easier to wean than smaller fish, and fish smaller than about 16 mm TL are difficult to wean. Barramundi fingerlings may start feeding on inert diets within a few hours of harvesting from the larval rearing ponds, and most fish start feeding within a few days.

Cannibalism can be a major cause of mortalities during the nursery phase and during early grow-out. Barramundi will eat fish up to approximately 67 percent of their own length. Cannibalism is most pronounced in fish smaller than about 150 mm TL; in larger fish, it is responsible for relatively few losses. Cannibalism is reduced by grading the fish at regular intervals (as frequently as every 2–3 days) to ensure that the fish in each cage are similar in size (Rimmer, 1995).

Most barramundi culture is undertaken in net cages in freshwater or brackishwater ponds. Cages are square, rectangular or circular in shape, and range in size from 8 m^3 up to 150 m^3. Traditional cages for barramundi culture in ponds are constructed from a bag of knotless netting within which is placed a weighted square formed from PVC pipe and a floating square of the same material. Other designs, for larger cages, utilize more rigid structures.

Early barramundi sea cage farms in Australia used European-style circular cages, based on salmon farming technology. Gradually, these have been replaced with purpose-designed square or rectangular cages. A particular issue that has affected barramundi sea cage design in Australia is their location in high energy environments. There are only three barramundi sea cage farms in Australia and two of these are located in high-energy environments: the Northern Territory farm is subject to tidal movements up to 8 m, while the Queensland farm is situated in an estuary with lesser tidal amplitude (up to 3.5 m) but with high velocity currents during strong tides. The strong currents that the farms are exposed to have resulted in both farms moving away from traditional mesh cages to more rigid designs utilizing steel or plastic mesh cages.

Stocking densities used for cage culture of barramundi generally range from 15 to 40 kg/m^3, although densities may be as high as 60 kg/m^3. Generally, increased density results in decreased growth rates, but this effect is relatively minor at densities under about 25 kg/m^3 (Rimmer, 1995).

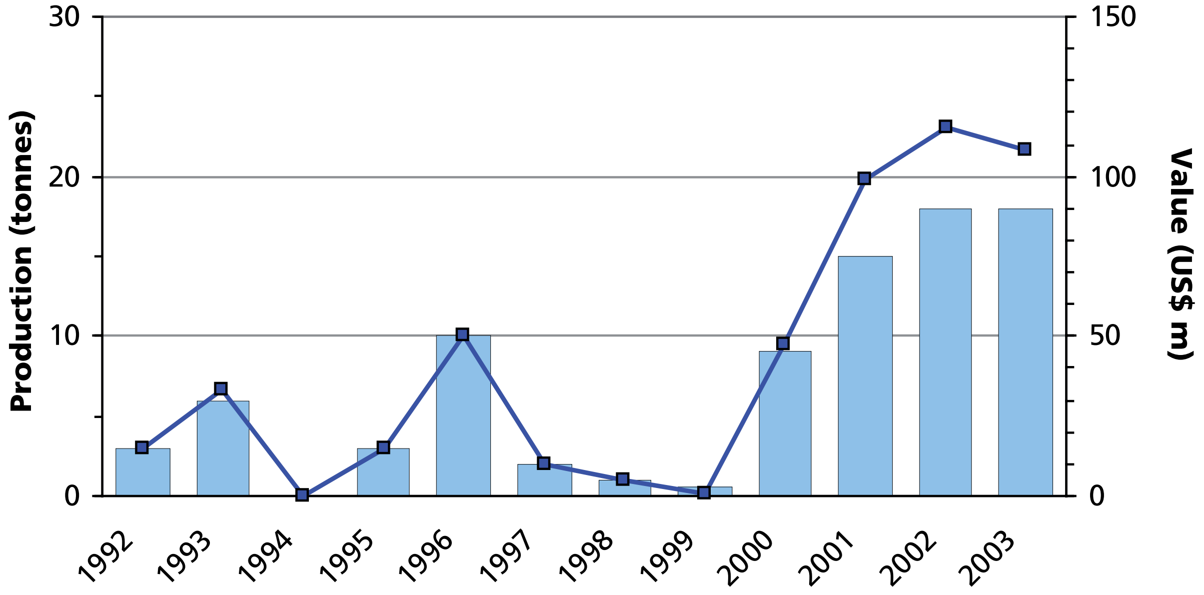
Barramundi are fed pellet diets, and there has been much research done on developing cost-effective diets, including high-energy diets. Although automated feeding systems have been used on the large-scale sea cage farms, most barramundi farmers feed manually. Juveniles are fed up to 6 times per day, and this is reduced gradually to two feeds (morning and evening) when the fish reach 40 g (Rimmer, 1995). Food conversion ratios for cage culture of barramundi vary widely, ranging from 1.3:1 to 2.0:1 during the warmer months, and increasing during winter.

Much farmed barramundi is marketed at ‘plate size’, i.e. 300–500 g weight. Although growth is highly variable, particularly in response to temperature, in general barramundi grow from fingerling to ‘plate’ size in 6–12 months. Larger farms are also producing larger fish (1.5 – 2 kg) for the fillet market; these take from 18 months to 2 years to reach market size (Rimmer, 1995; Love and Langenkamp, 2003; O’Sullivan *et al*., 2005). In 2003/04, farm gate prices for Australian barramundi ranged from AUD 7 (US$5.25) to AUD 10.60 (US $8)/kg (O’Sullivan *et al*., 2005). Most product is sold on the domestic market – in 2001/02 less than 2 percent of Queensland production was exported (Love and Langenkamp, 2003).

French Polynesia

Barramundi was introduced to French Polynesia from Singapore by IFREMER in the late 1980s (AQUACOP *et al*., 1990). Initial trials indicated that barramundi adapted easily and performed well, so IFREMER undertook a programme of

FIGURE 8
Annual aquaculture production (bars) and value (line) of barramundi (*Lates calcarifer*) in French Polynesia from 1992 to 2003



Source: FAO, 2006

research and development in hatchery production, nursery and grow-out to support the commercial development of barramundi aquaculture in French Polynesia (AQUACOP *et al*., 1990) (Figure 6).

There are currently only two barramundi farms in French Polynesia, and each operates their own hatchery. Barramundi are grown at a relatively low density (20 kg/m³) and consequently growth is rapid, reaching 400 g 'plate size' in six months. Annual production is around 15–20 tonnes per annum (Fig. 8). Most production is sold domestically, but one farm has attempted exports to Europe.

Papua New Guinea

Sea cage culture of barramundi commenced in Papua New Guinea in 1999, when a private company began production. By 2004, production reached 100 000 fish per annum (Middleton, 2004). Fingerling production techniques were similar to those used in Australia, and the fish were fed commercial pellet diets imported from Austalia. A notable feature of the production programme was that the seed and feed was provided by the company to local family-scale grow-out farms along the north coast of Madang (Figure 6). The family groups cared for the fish, then the company bought back the fish for sale on domestic and export (Australia) markets.

Yellowtail kingfish

Australia

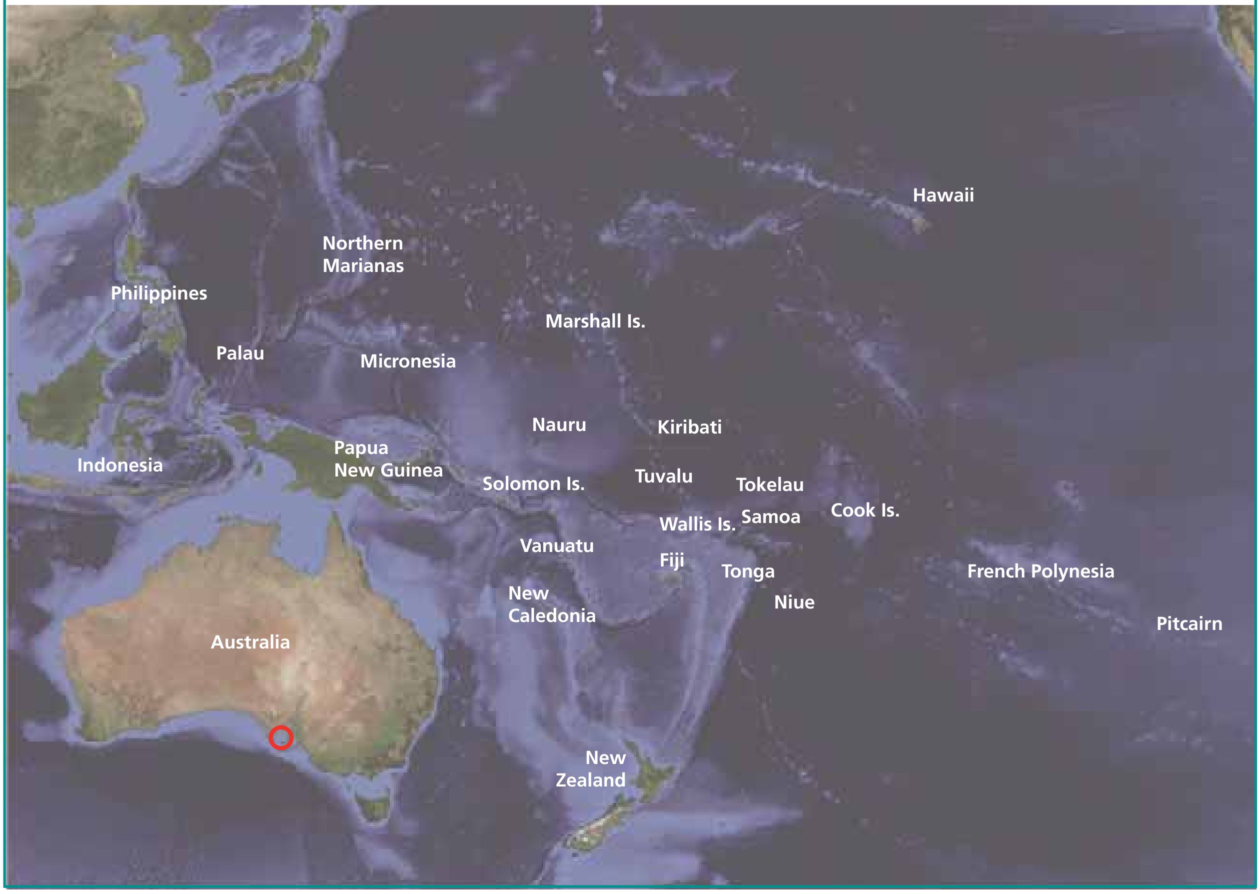
Yellowtail kingfish (*Seriola lalandi*) is a new species currently being developed for aquaculture in Australia. Yellowtail kingfish aquaculture developed from a desire for southern bluefin tuna aquaculture operations to diversify their production base and consequently is concentrated in the Eyre Peninsula region of South Australia at Fitzgerald Bay, Cowell and Port Lincoln (Figure 9).

Yellowtail kingfish production is not disaggregated in the FAO data, but Australian production in 2003/04 was estimated at 1 000 tonnes value at around AUD 8 m (O'Sullivan *et al*., 2005). In comparison, global production of Seriola species is around 140 000 tonnes (Ottolenghi *et al*., 2004).

Although culture of related species, such as *S. quinqueradiata* in Japan, is highly reliant on capture of wild fingerlings (Ottolenghi *et al*., 2004), yellowtail kingfish aquaculture in Australia is based on hatchery-produced seed. There are currently two commercial hatcheries in South Australia producing seed of this species (PIRSA, 2002b; Love and Langenkamp, 2003).

Broodstock (usually 10–40 kg) are netted from the wild and are maintained in large indoor tanks of at least 90 m³ volume and 2 m depth at densities below 20 kg/m³ (PIRSA, 2002b; Benetti *et al*., 2005). Broodstock were previously fed wet feed,

FIGURE 9
Map of Oceania showing location of yellowtail kingfish cage culture sites



including chopped fish and squid and vitamin and mineral supplements (PIRSA, 2002b), but concerns regarding vitamin deficiencies in the broodstock has led to the use of a vitamin-fortified semi-moist compounded feed for broodstock (Benetti *et al.*, 2005). Yellowtail kingfish spawn naturally in the tanks, without need for hormonal induction (PIRSA, 2002b). Some facilities use photothermal control to influence the reproduction and spawning of the captive broodstock (Benetti *et al.*, 2005). Spawning is variable, but generally occurs every 4–5 days (Benetti *et al.*, 2005).

Yellowtail kingfish larvae are reared using standard intensive techniques. Larval rearing tanks range in size from 2.5 to 10 m³ and are cylindroconical in shape (Benetti *et al.*, 2005). Larvae are stocked at around 100 larvae/l (Benetti *et al.*, 2005) and are initially fed rotifers, then enriched *Artemia metanauplii* from day 12 to day 28. Weaning onto inert diets begins at day 20 and is usually complete by day 40 (PIRSA, 2002b; Benetti *et al.*, 2005). Larval growth is rapid with larvae reaching 4–20 mm fork length by day 16, and up to 35 mm by day 25 (PIRSA, 2002b). Fish can be transferred to cages from 5 grams in weight (PIRSA, 2002b). Previously, many hatchery-reared juvenile yellowtail kingfish had significant skeletal deformities about the head region. This problem has been ascribed to vitamin deficiencies and has been largely resolved by improving broodstock nutrition (Benetti *et al.*, 2005).

Sea cages used for yellowtail kingfish culture are generally 25 metres diameter and 8 metres deep. Smaller nursery net cages (12 metres diameter, 4 metres deep) are used for smaller fish. South Australia limits culture density to a maximum of 10 kg / m³ (PIRSA, 2002b). Fish are fed formulated pellet diets and food conversion ratios (FCRs) of 1.0 – 1.5:1 have been achieved using a pellet diet originally developed for barramundi (Benetti *et al.*, 2005).

Growth of yellowtail kingfish is temperature dependent with best growth under tropical or sub-tropical conditions. Yellowtail kingfish can grow to 1.5–3 kg in 12–14 months, and may reach 1.5 kg in 6–8 months if growing conditions are ideal (PIRSA, 2002b; Love and Langenkamp, 2003; Ottolenghi *et al.*, 2004; Benetti *et al.*, 2005). Alternately, they can be grown out to 4–5 kilograms at eighteen months for sashimi (Love and Langenkamp, 2003; Benetti *et al.*, 2005).

Yellowtail kingfish are generally harvested as whole fish. Some products is sold domestically in fillet or cutlet form, and better quality fish may be sold for sashimi. In Japan it has been marketed under the Japanese name of the fish: hiramasa (Love and Langenkamp, 2003; Ottolenghi *et al.*, 2004). There is demand from export markets (Japan, other parts of Asia, the United States and the United Kingdom) particularly for sashimi product (PIRSA, 2002b, Ottolenghi *et al.*, 2004). Currently, demand for yellowtail kingfish sashimi product exceeds supply (Ottolenghi *et al.*, 2004).

New Zealand

Yellowtail kingfish aquaculture is currently at the research and development and pilot study phase in New Zealand (Benetti *et al.*, 2005). The National Institute for Water and Atmospheric Research has carried out substantial research into yellowtail kingfish aquaculture since 1998. Results of this work are summarized in Benetti *et al.* (2005).

Tilapia and carp

There has been some cage culture of tilapia (*Oreochromis niloticus*) and carp (*Cyprinus carpio*) in Yonki Lake, Eastern Highlands Province, promoted by the provincial government and the National Fisheries Authority (Figure 10). Yonki Lake is a hydroelectric impoundment about 50 km wide and holds 33 million cubic metres of water. In 2004, the cages in Yonki Lake were producing 500 kg of fish each month, and up to several thousands of fingerlings were being sold at the local markets. Local estimates of production potential are that the lake has potential to generate PGK 5 million (US$1.7 million) annually with 1 000 farmers producing 1 000 tonnes of freshwater fish per month. There is currently a small-scale research programme to support the development of cage aquaculture for tilapia at Yonki Lake, and to promote the use of locally-made fish feeds.

FIGURE 10
Map of Oceania showing location of tilapia and carp cage culture sites

Other species

Australia

In Australia, there has been some development of other marine finfish species for aquaculture, including snapper (*Pagrus auratus*) and mulloway (*Argyrosomus hololepidotus*). While there has been some limited production of snapper, difficulties with product quality and growth rates have led to decreasing production – in 2003-04 production was valued at just over AUD 200 000 (US$150 000) (O'Sullivan *et al*., 2005).

Mulloway culture is showing more promise with production in 2003/04 of over 500 tonnes value at AUD 4 m (US$3 million) (O'Sullivan *et al*., 2005).

Other species that have been trialled or are currently under development for marine aquaculture include: whiting (*Sillago* spp.), striped trumpeter (*Latris lineata*), black bream (*Acanthopagrus butcheri*), silver bream or tarwhine (*Rhabdosargus sarba*), greenback flounder (*Rhombosolea tapirina*), mangrove jack (*Lutjanus argentimaculatus*), fingermark (*Lutjanus johnii*), Australian salmon (*Arripis trutta*), Australian herring or tommy rough (*Arripis georgianus*), and snubnose garfish (*Arrhamphus sclerolepis*) (O'Sullivan *et al*. ,2005).

While there has been considerable interest in developing an aquaculture industry based on the high-value groupers in demand in Hong Kong and China, the development of this sector has been constrained by lack of effective government support to develop grow-out options, restrictive environmental legislation affecting potential sea cage grow-out sites, and antagonistic community attitudes to aquaculture development in coastal areas. Small numbers of barramundi cod (*Cromileptes altivelis*), estuary cod (*Epinephelus coioides*) and flowery cod (*E. fuscoguttatus*) fingerlings have been produced but to date there has only been limited commercial production of these species.

French Polynesia

FAO data for marine finfish species other than barramundi produced in French Polynesia range from 1 to 4 tonnes per annum (FAO, 2006). These are lagoon species which are being trialled to evaluate their aquaculture potential.

Species being trialled in French Polynesia include: moi or sixfinger threadfin (*Polydactylus sexfilis*), brassy trevally (*Caranx regularis*), golden trevally (*Gnathodon speciosus*), and batfish (*Platax orbicularis*).

Federated States of Micronesia

A company from the Republic of Korea has established a grow-out operation for wide-banded seaperch in the Federated States of Micronesia (Henry, 2005). Seed are imported from the Republic of Korea, but there is little other information available on this operation.

New Caledonia

There is currently no aquaculture production of marine finfish in New Caledonia. However, the New Caledonian Economic Development Agency, ADECAL, has a project in place to develop aquaculture of high-value marine finfish species, including groupers and snappers (A. Rivaton, pers. comm.).

MAJOR REGIONAL / COUNTRY ISSUES

Major issues with regard to cage aquaculture in Oceania differ between Australia and New Zealand, and the broader Pacific Islands region. Consequently, they are discussed separately in this section.

Technical

Seed supply

Seed supply for most forms of aquaculture in Oceania is from hatchery production. In Australia and New Zealand, fisheries management generally restricts the collection of juvenile fish for aquaculture. There are several notable exceptions to this, including southern bluefin tuna and eel (*Anguilla* spp.) aquaculture. This provides a significant constraint to aquaculture development in Australia and New Zealand, because any new aquaculture development is reliant on developing hatchery production technology as a first step. This can be a lengthy and costly process, and adds significantly to the costs of developing any given industry sector. In comparison, in Asia many aquaculture commodities are first investigated through the collection and grow-out of wild-caught seed. This enables farmers to evaluate the performance of the species concerned, and decide whether it will be cost-effective to produce them in hatcheries. It also enables the development of grow-out technology in parallel with, rather than in series with, hatchery production technology.

In the Pacific Islands, there are few traditional collection fisheries for juvenile fish to support grow-out operations. The exception is collection of milkfish (*Chanos chanos*) for pond grow-out in several Pacific Island countries, including Kirabati and Nauru.

Some recent developments in the Pacific and in the Caribbean have used light traps and crest nets to harvest pre-settlement juvenile or late larval fish and invertebrates for subsequent grow-out (Dufour, 2002; Hair *et al*., 2002; Watson *et al*., 2002). This mode of harvesting exploits the rationale that most fish and invertebrate species with pelagic larval stages are subject to extremely high mortality prior to and at settlement and that harvesting a proportion of these will have negligible impacts on recruitment (Doherty, 1991; Sadovy and Pet, 1998). In comparison, natural mortality of settled fingerlings may be relatively low and the fisheries for these larger fingerlings may be subject to the same harvesting constraints as fisheries for adult fish (Sadovy and Pet, 1998). To date, these capture techniques have shown promise for the collection of aquarium fish species, but may capture only small numbers of fish species in demand for grow-out for food fish (Hair *et al*., 2002).

Feeds and feeding

Feeds and feeding are a major issue in cage aquaculture in the Pacific. In Australia and New Zealand, formulated feeds are used almost exclusively for cage production of finfish. The notable exception to this is southern bluefin tuna aquaculture, which is still completely dependent on the use of wet fish as a feed.

There has been much research into the development of compounded feeds in Australia, particularly for finfish. In Australia, much of this research and development has been supported by the Fisheries Research and Development Corporation through its Aquaculture Nutrition Subprogram and by the Australian Centre for International Agricultural Research (ACIAR). Several commercial feed suppliers now produce a range of different feeds for finfish aquaculture.

As noted above, there is a major research and development programme underway to develop compounded feeds for southern bluefin tuna. Much of the wet fish used to feed bluefin tuna is imported into Australia, and biosecurity concerns have been raised regarding the potential introduction of new pathogens. An incident of mass mortalities of wild stocks of pilchards in Australia was ascribed to a virus that may have been introduced in pilchards imported into Australia to feed southern bluefin tuna (Gaughan *et al*., 2000).

In the Pacific Islands region, the lack of availability of compounded feeds has been one constraint to the development of sustainable aquaculture. High transport costs increase the cost of imported feeds, while small population and production bases restrict the development of locally-produced compounded feeds. On-going research, particularly funded by ACIAR, is building capacity and providing information for development of farm-made feeds for commodities such as tilapia.

Social and economic issues

Community perceptions of aquaculture

An important, but much ignored, facet of aquaculture development in the Oceania region is community perceptions of aquaculture. In Australia, much of the population is clustered along the coast, particularly the east coast, and there is considerable conflict regarding resource use in some areas. Community perception of the negative impacts of aquaculture has been instrumental in limiting many aquaculture developments in Australia, including a proposal for a sea cage farm in Queensland.

A recent study evaluated community perceptions to aquaculture in two districts: the Eyre Peninsula, South Australia, and Port Phillip Bay, Victoria (Mazur *et al*., 2005). The survey found important differences in responses between the two case study areas that suggested that particular features of regions are likely to have some influence on perceptions of and responses to aquaculture. These may include: population densities, economic diversity, competing uses of marine/coastal environments, the size and structure of the aquaculture industries, and the existence of aquaculture-related conflicts.

Findings from the interviews indicate that aquaculture is highly valued for its contribution to economic growth in rural areas, especially where there has been historic economic decline. Respondents identified a number of issues associated with aquaculture: the need to improve environmental and business practices; knowledge and frameworks to mitigate negative social and environmental impacts; strategic investment in aquaculture research and development; resource security; and community support (Mazur *et al*., 2005). Analysis of the South Australian mail survey data suggested that people recognise the economic benefits of aquaculture and feel the industry is concerned about environmental management. However, respondents were less trusting of and more concerned about the environmental risks of sea cage aquaculture. Respondents also felt that the aquaculture industry needs to listen more closely to community concerns (Mazur *et al*., 2005).

Based on these findings, Mazur *et al*. (2005) propose the use of more innovative participatory strategies and forums to complement existing community consultation activities. They also point out the need for more credible information to build public trust in aquaculture.

An extreme example of public antagonism toward cage aquaculture was the proposal to develop a sea cage farm in southern Queensland. The farm was proposed by a group with experience in the Tasmanian salmon aquaculture industry, who established a private company ('SunAqua') to farm marine finfish (snapper and yellowtail kingfish) in a sea cage facility to be sited in Moreton Bay, near Brisbane, Queensland. The company proposed to utilize off-the-shelf production systems similar to those used in salmonid farming.

Because parts of Moreton Bay are regarded as environmentally sensitive (the bay includes areas of Marine Park and RAMSAR listed sites) there was considerable opposition to the proposal by local conservation groups. By utilizing and adapting some of the more emotive arguments developed by anti-salmonid campaigners in the United Kingdom and Europe, the conservation bodies developed an effective campaign to prevent the SunAqua proposal going ahead. This included effectively utilizing local media, and holding mass rallies in Brisbane suburbs adjacent to Moreton Bay. Despite the SunAqua proposal being classified by the Queensland Government as a 'project of state significance', the conservation groups generated so much public concern regarding the proposal that it was eventually rejected.

Economic impacts of aquaculture

Most Australian states and territories collect production data which includes the gross value of production and some input data, particularly labour equivalents. However, there have been relatively few published studies on the socio-economic impacts of aquaculture in the broader community.

EconSearch (2004) evaluated the economic impacts of the South Australian aquaculture industry along the market chain in 2002/03, including:

- the farm gate value of production;
- the net value of local (SA) processing;
- the net value of local retail and food service trade; and
- the value of local transport services at all stages of the marketing chain.

The study found that the total value added value of aquaculture was AUD 331 m (US$250 million) representing 0.70 percent of Gross State Product. Direct employment was estimated to be 1 614 jobs in 2002/03 with 1 355 flow-on jobs, giving total employment of almost 2 970. Approximately 90 percent of these jobs were in regional South Australia. Direct household income was estimated to be around AUD 48 m (US$36 million) in 2002/03 and flow-on income approximately AUD 59 m (US$44 million), giving total household income of over AUD 107 m (US$80 million). In regional areas, the impact of the aquaculture industry in 2002/03 was concentrated in the Eyre Peninsula region, reflecting the dominance of tuna farming (EconSearch, 2004).

Marketing

A major disadvantage for aquaculture in the Oceania region is the low population base, and hence limited markets, in the region. Consequently, some commodities have been developed with a strong focus on export markets. An example of this is southern bluefin tuna, which is almost exclusively sold to the Japanese market. However, the distance to the lucrative large export markets of Europe, the United States and China and the poorly developed transport infrastructure in many parts of Oceania limit the ability of farmers to access these larger markets.

In many Pacific Island countries, such as French Polynesia, aquaculture product suffers from competition from cheap, good quality fish caught in the lagoon. However, there is potential for developing targeted markets such as restaurants and hotels which require a constant supply and guaranteed absence of ciguatera in their seafood products.

The largest local or domestic market in Oceania is Australia, and producers in Australia and other regional nations target the Australian seafood market. Like most seafood markets, aquaculture product competes with wild-caught seafood as well as imported products. Love and Langenkamp (2002) concluded that for aquaculture product (live and plate-sized fish) to be competitive against the wild caught product, aquaculture producers would need to work toward a price benchmark price of around AUD 9–10 (US$6.75-7.50)/kg.

A key issue for Oceania aquaculture producers is competition from imported product. Of relevance for salmon operations, for example, is the recent sharp fall in world salmon prices as a result of rapidly expanding world farmed salmon production, particularly in Chile. Barramundi currently faces competition from imported product from southeast Asia, and in the fillet market, from low priced imported Nile perch (Love and Langenkamp 2002). Many Asian producers do not face the stringent environmental and food safety requirements that are a significant cost to Australian and New Zealand producers, and are able to produce similar products at lower prices. The issue of import competition, in a global environment of reducing import protection and open markets, will be a major factor in the future development of cage aquaculture in the Oceania region.

Environmental

Environmental issues are a major feature of aquaculture development in Australia and New Zealand, particularly with regard to cage aquaculture.

In Australia, the focus is on development of Environmental Management Systems (EMS). An EMS puts in place a continual process of planning, implementing, reviewing and improving the actions that an organization undertakes to manage its risks and opportunities relating to: the environment, food safety and quality, occupational health and safety, profitability, public relations, and other aspects of the organization. EMS can be developed at the individual business level, for a group of businesses with a common interest, such as members of an industry association, or for all businesses in an aquaculture sector. EMS can be relatively simple, such as a code of best practice, or more comprehensive, such as ISO 14000 or other certification schemes.

EMS for the aquaculture industry in Australia is managed through the Aquaculture Industry Action Agenda, and takes into consideration the 'EMS Pathways' programme being undertaken by Seafood Services Australia seafood industry. Through the Action Agenda initiative, Codes of Practice and Customised Environmental Management Systems have been developed for several key aquaculture businesses that will champion the implementation of EMS for the Australian aquaculture industry.

The AquaFin CRC has a number of major research and development programmes to improve environmental management associated with sea cage farming (http://www.aquafincrc.com.au/).

Institutional

Australia

In Australia, the states are responsible for most management aspects of aquaculture. This includes:

- aquaculture farm licensing;
- appropriate environmental licensing;
- support for aquaculture technology development through research, development and extension activities;
- coordination and support for grower associations.

Federal responsibility for aquaculture is limited to broader areas such as national plans and, in particular, biosecurity. The National Aquaculture Development Committee has developed an Aquaculture Industry Action Agenda to promote aquaculture development in Australia. The ten key strategic initiatives of the Action Agenda are:

1. Making a National Aquaculture Policy Statement
2. Promoting a regulatory and business environment that supports aquaculture
3. Implementing an industry driven action agenda
4. Growing the industry within an ecologically sustainable framework
5. Protecting the industry from aquatic diseases and pests
6. Investing for growth
7. Promoting aquaculture products in Australia and globally
8. Tackling the research and innovation challenges
9. Making the most of education, training and workplace opportunities
10. Creating an industry for all Australian.

Key elements of the Aquaculture Industry Action Agenda are being implemented by the National Aquaculture Council, which is the peak body for aquaculture producer associations in Australia (http://www.australian-aquacultureportal.com/).

In conjunction with the Aquaculture Industry Action Agency, the Department of Agriculture, Fisheries and Forestry (DAFF) has developed 'AquaPlan' – a strategy to develop a national approach to emergency preparedness and response as well as to the overall management of aquatic animal health in Australia. AquaPlan was jointly developed by Government and private industry sectors, and links into existing State / Territory Government and industry health management arrangements.

A key feature of AquaPlan is the AquaVetPlan component, which provides a series of manuals and operational instruments which outline methods and protocols to manage emergency aquatic disease outbreaks in Australia. AquaVetPlan is based on the similar terrestrial model: AusVetPlan.

New Zealand

In New Zealand, a moratorium on the development of new marine farms was instituted in 1991. The Resource Management Act 1991 revoked the provisions in the Marine Farming Act 1971 relating to the issuing of new leases and licences.

The New Zealand Government has identified the need to update the legislative framework for aquaculture 'to provide more certainty for all participants, while at the same time not allowing adverse effects on the environment or undermining the rights of existing fishers'. The Ministry for the Environment, the Ministry of Fisheries, and the Department of Conservation are the main government departments involved in the development of the proposed new aquaculture legislation.

The ongoing impacts of the New Zealand Aquaculture Reform process have led to substantial frustration within the New Zealand aquaculture industry.

Pacific Island countries

The Secretariat for the Pacific Community (SPC) is an inter-governmental body with 22 member countries from the Pacific Islands region that works in collaboration with its member countries to develop work programmes to provide: technical assistance; professional, scientific and research support; and capability building for planning and management. SPC provides this support to the aquaculture industry in Pacific Island countries through their Aquaculture Programme.

The Pacific Islands region has a chequered history of aquaculture development, with relatively few successful ventures. To assist in developing aquaculture sustainably in the Pacific Islands region, SPC has developed an Aquaculture Action Plan (http://www.spc.int/aquaculture/site/publications/documents/spc-aquaplan.pdf). The Action Plan was the result of intensive consultation among some sixty regional and international specialists during the 1st SPC Aquaculture Meeting held in Suva, Fiji Islands, 11–15 March 2002.

The meeting reviewed seventeen commodities of interest to the region to identify a shortlist of priority commodities. Commodities were assessed on two criteria: potential impact and feasibility. From this process, the meeting agreed that the priority commodities for the region are: coral, giant clam, freshwater prawn, milkfish, pearl, sea cucumber, seaweed, and tilapia. In addition to focussing on a priority list of commodities, the plan identifies important cross-cutting issues for aquaculture development in the Pacific:

- Prior commitment needs to be made at country/institution/enterprise before sending people on training courses to actually put the training into practice on their return.
- There is a need for entrepreneurial skills and business training.
- It is critical that market and financial analysis is carried out for each priority commodity to determine the potential scale of production, cost of production and product specifications before actions are taken to establish each of the priority commodities.
- All development strategies need to include actions to minimise the threat of disease introduction and undertake preparations for control and management in the event of disease incursion outbreaks.
- There is an urgent requirement across the region to address policy and legislative frameworks for the successful introduction and management of the priority commodities.
- Country strategies, consistent with regional strategies, need to be developed focusing on policy, legislation, and development plans. It will be important that countries assemble as much objective information as possible in the process of addressing their own priorities.
- Sharing and updating information about aquaculture in the Pacific at regular intervals should be an important part of an ongoing regional effort.

A review of aquaculture legislation and policy in Pacific Island countries (Evans *et al*., 2003) indicated that there was a notable absence of specific aquaculture policies both at the regional and national levels. Commonly, plans for aquaculture were often incorporated into general fisheries plans/policies and had mainly an economic objective, such as increasing employment and economic returns. The review concluded that national aquaculture policies are needed in order to address and direct issues not only concerning industry development, but also encompassing the needs for subsistence and community-based aquaculture development, environmental integrity and food security (Evans *et al*., 2003).

The review found that legislation tended to be inadequate despite various levels of development in Pacific Island countries. While laws in the region are similar, several important issues addressed in some countries were absent from other national legislation. Moreover, no generalised relationship could be drawn between the nature of regulation and level of aquaculture development (Evans *et al*., 2003).

THE WAY FORWARD

The way forward for cage aquaculture in Oceania is by no means clear. Environmental sustainability and market competition are two major issues that need to be addressed if cage aquaculture is to expand from its current base. It is likely that cage aquaculture in Oceania will remain a relatively small industry by global standards because of the constraints discussed in this review.

To further develop cage aquaculture in Oceania will require a broad range of approaches to all aspects of aquaculture development and associated supply chains. Most agencies that support aquaculture development in the Oceania region have a strong focus on production issues, and put relatively little effort into post-harvest value-adding or development of supply chains.

Little effort has gone into community education regarding aquaculture, and social research impacting perceptions of aquaculture. Yet, these remain major constraints to the expansion of aquaculture in Oceania.

In Australia and New Zealand in particular, there is a need for cage aquaculture to establish its environmental credentials with the broader community. There are widespread community concerns regarding the environmental sustainability of aquaculture, including:

- the use of fisheries products (including fishmeal) to produce fish protein;
- impacts of nutrients from cage aquaculture on the local environment;
- impacts of escapees on local fish populations, including genetic impacts;
- potential disease translocation and epizootics.

As the work on community perceptions of aquaculture has demonstrated, an important component of aquaculture industry development is communicating the benefits as well as the negative aspects of aquaculture to the community (Mazur *et al*., 2005). Consequently, public information systems need to be an integral part of cage aquaculture development strategies.

Cage aquaculture in Oceania has significant competitive disadvantages compared with other regions. Labour costs in Australia and New Zealand are high, and are generally significant components of the production cost of most aquacultured commodities. In addition, economies of scale remain relatively low in Oceania because of low population density, limited availability of sites, and stringent licensing and environmental legislation. Consequently, cage aquaculture in Oceania needs to be developed taking into account competitive advantages compared with other regions, particularly Asia.

One aspect of comparative advantage that has been suggested for Oceania aquaculture results from the high level of biosecurity that is, or can be, instituted in Oceania countries. This provides opportunities for countries to exclude some of the more virulent diseases and to develop specific-pathogen-free (SPF) seedstock supplies. Under this model, Oceania could become an important provider of SPF seedstock to other regions, particularly Asia.

CONCLUSIONS

Cage culture in Oceania is likely to remain small by global standards. Its continued development, albeit at a relatively slow pace, depends on a range of social, economic and environmental issues being actively addressed by government and research and development agencies:

Economic issues

- Develop hatchery production technologies that reduce the cost of fingerling production while maintaining quality.
- Developing more cost-effective feeds to reduce production costs.
- Increase mechanization of production to offset high labour costs in Australia and New Zealand.
- Provide improved market intelligence, particularly of export markets for high value / low volume commodities.
- Develop value-added products for domestic markets.
- In Pacific Island countries, support the development of cage culture of commodities that

provide opportunities for income generation as well as food security.
- Develop advanced technologies for the control of disease.

Social issues
- Provide relevant and accurate information to the community in regard to the benefits and costs of aquaculture.
- Facilitate community participation in aquaculture planning and development at local, state and government levels.
- Develop production and harvest processes that meet consumer expectations of product quality and product safety.

Environmental issues
- Develop improved production technologies that reduce the environmental impacts of cage aquaculture.
- Develop or adapt production technologies for off-shore cage culture.
- Adequately quantify and report the environmental impacts of cage aquaculture.

Overall, the greatest need is for cage aquaculture in Oceania to look forward and to position itself with regard to other regions. Significant challenges lie ahead, particularly from competition with burgeoning cage aquaculture production in Asia, as well as the rest of the world. Oceania has significant disadvantages as a production base for cage aquaculture, and aquaculture managers and planners need to develop strategies to address the issues discussed in this review.

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