LOST AND FOUND: THE OYSTER REEF RESTORATION OPPORTUNITY

K Russell[1], C Gillies[2]
[1]NSW Department of Primary Industries, Port Stephens Fisheries Institute, NSW
[2]The Nature Conservancy, Melbourne, Vic

Oyster reefs were once prominent features in Australia's estuarine and nearshore environments, including in NSW. This is evidenced by aboriginal and early explorer accounts, shell middens and sediment cores. Shell middens dating back at least 6,000 years (Stockton, 1977) demonstrate that oysters have been a valuable food resource for Aboriginal people. It appears that the Aboriginal impact on oyster populations was relatively benign and some tribes may have even returned shell to the water to provide substrate for new spat.

Early maritime explorers regularly referred to extensive shellfish reefs in voyage reports and journals. During Captain Cook's first voyage of exploration in Australia in 1770, he reported abundant oyster resources in Port Jackson and Broken Bay, and the largest flat oysters he had ever seen in Botany Bay (Attenbrow, 2010). On entering Port Stephens in 1795, C. Grimes noted that *'there are mangroves and oysters as far up the river as we went'.* However, recognition of this historical loss is only recently emerging across Australia and rehabilitation of natural oyster reefs a rapidly expanding opportunity.

From early European settlement, vast quantities of oysters and mussels were harvested in an unsustainable manner by hand and by dredge fishery for food and as a source of lime used in construction of roads and buildings. Throughout the 1800s and early 1900s, oyster fisheries occurred in over 150 locations across eastern and southern Australia, including major coastal embayments (Gillies *et al.*, 2015). As shellfish resources closest to Australia's first settlements rapidly became depleted, shellfish fisheries expanded to include more distant bays and estuaries. Records indicate that oyster fishing constituted some of the largest and most valuable fisheries, and indeed one of the most valuable marine industries, of the 1800s (Gillies et al., 2015). However, a dramatic decline in the extent and condition of shellfish reefs occurred by the mid-1800s as a result of this over exploitation, and likely exacerbated by impacts from catchment changes affecting water quality and increases in sediment supply, and disease impacts such as *Bonamia* (mudworm).

Efforts to regulate the industry by the Government in NSW saw the introduction of the *Oyster-beds Act* in 1868, which encouraged the establishment of oyster fisheries by introducing a licensing system and prohibiting the burning of live oysters for lime. In 1876, following an audit of NSW estuaries, an Oyster Culture Commission was organised to discuss the best modes of cultivation and how to improve and maintain the natural oyster beds, and to suggest legislation to

manage these objectives (Oyster Culture Commission, 1877). The Commission report on the upper fishery in Port Stephens noted:

> *"This is by far our most important fishery, not only on account of its numerous fine natural oyster-beds, banks, and extensive oyster-grounds, but also on account of its amazing productiveness".... "From time to time forty-five boats at once have been at work sending spawning oyster and spat alike to market. It is plain that no beds however productive could possibly withstand such exhaustive treatment."* (Oyster Culture Commission, 1877).

Following the Commission, the *Oyster Fisheries Act* 1884 instituted a system of leases that were rented by the oyster farmers. This Act also established the Public Oyster Reserves, which were foreshore areas set aside for public access to oyster resources (Gillies et al., 2015). Despite these efforts to reduce harvest impacts, by the late 1800's oyster reefs had all but disappeared in NSW. Today, only a fraction of natural oyster reefs survive.

Concurrently, a similar pattern was occurring in other states, with the oyster industry the first (of any) fishery to be regulated by legislation in all States (Gillies et al., 2015). Yet regulation in these States also did little to halt the destruction of shellfish reefs, and by the late 20th century they too had all but disappeared. By 1960 all major oyster fisheries had closed across Australia (Gillies et al., 2015).

A 2009 report by Beck *et al* documented that this situation was not limited to Australia. Beck *et al,* 2009, found that over 85% of shellfish reefs have been lost from coastal areas globally, with 99% of shellfish reefs 'functionally extinct' in Australian coastal waters (Figure 1). For many, this report highlighted for the first time the very existence of a once common marine habitat and alarmingly, its near total loss across several continents, including Australia.

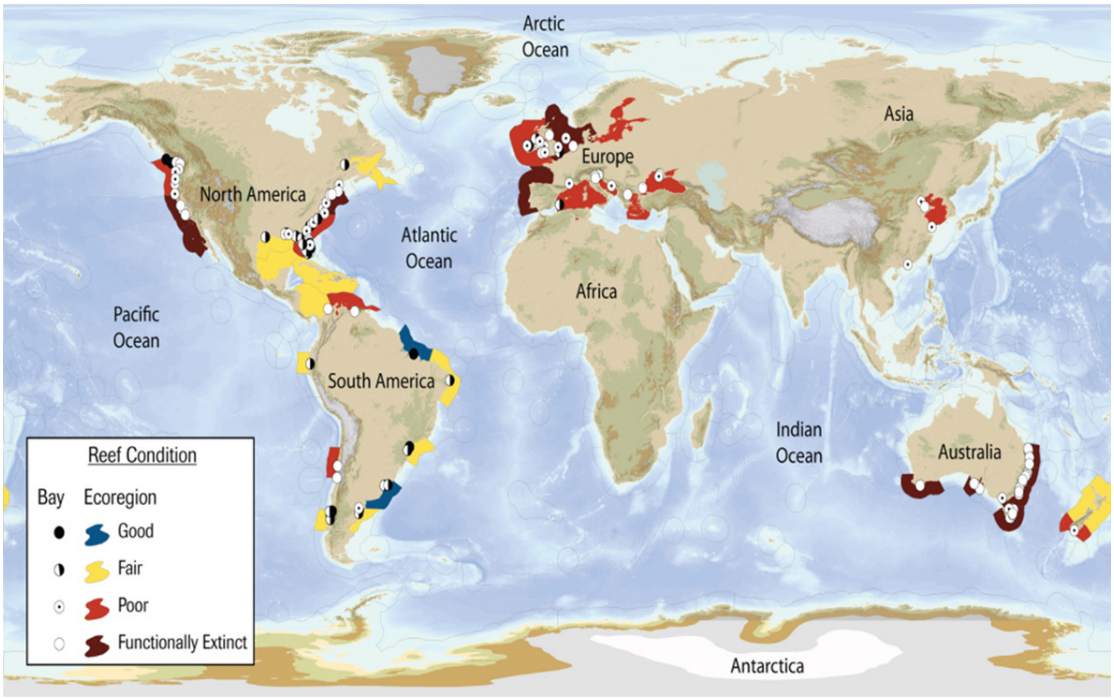

Figure 1. The global condition of oyster populations, with condition ratings based on the current abundance divided by the historical abundance of oyster reefs: < 50% lost (good); 50-89 % lost (fair); 90-99% lost (poor); > 99% lost (functionally extinct; Adapted from Beck et al. 2011).

In Australia, eight species of shellfish are identified as developing complex, three-dimensional reef structures over large scales in intertidal and subtidal areas in tropical, subtropical and temperate waters (Gillies *et al.,* 2015). Records show that Sydney rock oysters (*Saccostrea glomerata*) were extremely abundant historically in both intertidal and subtidal reefs in estuaries along Australia's east coast (Ogburn et al., 2007; Diggles, 2013), dominating these systems ecologically. *Ostrea angasi*, the native flat oyster were another widespread subtidal species in NSW waters (Gillies et al., 2015). However, knowledge on the extent, physical characteristics, biodiversity and ecosystem services of natural reefs in NSW remains extremely data poor. Furthermore, awareness amongst the general community of the existence and historic decline of shellfish reefs is low, leading to 'shifting baselines' and a general underappreciation of the ecosystem services provided by shellfish reefs. With the functional extinction of *S. glomerata* reefs (particularly subtidal) along Australia's east coast (Ogburn et al., 2007; Beck et al., 2011; Diggles, 2013), significant declines in fisheries productivity (Creighton et al., in prep) are to be expected.

Research has and continues to demonstrate the value of oyster reefs as habitat structures (Coull and Wells, 1983). A recent National Environmental Science Program project has confirmed oyster reef habitats are vital to the health of Australia's bays and estuaries (Creighton et al., in prep.). Similar to the demonstrated importance of other estuarine habitats, such as seagrass and

mangroves, oysters provide various “ecosystem engineering” services including food and habitat for fish and crustaceans (Brietburg, 1999; Coen *et al*., 1999), filtration of water (Newell, 2004; Zu Ermgassen *et al*., 2012), uptake of nitrogen and phosphorus (Dame *et al*.,1984, 1985), turbidity reduction (which assists seagrass recovery) (Wall et al., 2008), enhanced nutrient cycling (nitrogen fixation - reducing nutrient loading in the water through bentho-pelagic coupling) (Everett et al., 1995; Newell and Koch, 2004; Dame et al., 1984; Dame and Dankers, 1988; Asmus and Asmus, 1991), shoreline stabilisation (shoreline and seagrass protection) (Meyer et al., 1997), carbon cycling (Filgueria, 2015) and more (Newell, 2004). Examples from the United States and elsewhere have demonstrated that when restoration occurs at large scales, ecological function can be repaired and ecosystem services can be restored.

Research shows restoration of shellfish reefs in place of traditional artificial reef structures can provide improvements to water quality, fisheries habitat and fisheries productivity that exceed those generated by artificial reefs of similar size. For example, in NZ, subtidal mussel reefs had 13.7 times (1370%) more fish compared to control areas (McLeod et al. 2013), while researchers in the US examining oyster reefs have measured improvements in water clarity and a 275% increase in nitrogen uptake in comparison with adjacent sand/mud banks (Smyth et al., 2015). In view of this, the flow on benefits of the potential habitat and fisheries improvements to recreational fishing from shellfish reef restoration are obvious, with potential for significantly increased catch rates of key estuary reef dwelling species including bream, snapper and crabs.

In addition, international experience, particularly from the USA and NZ, has demonstrated the considerable social and economic benefits of restoration projects to local communities (Grabowski *et al*., 2012). This can be through both short-term (eg during construction) and long-term (eg on-going fishing tourism) employment opportunities. Established reefs can also provide other long-term economic gains for coastal communities, particularly in coastal protection. Strong support for rehabilitation has been demonstrated by recreational fishing groups and Indigenous communities.

Only in the last 10-15 years have Australian scientists realized the importance of actively restoring shellfish reefs in estuarine ecosystems, in order to try to regain the lost ecosystem services and fish productivity. Projects in Victoria, South Australia and Western Australia have recently begun and are already demonstrating the practicalities and benefits of large scale oyster reef restoration activities, particularly in creating new job and community involvement opportunities.

Barriers to the implementation of restoration programs in Australia include various Government policy gaps, legislative and biosecurity restrictions concerning what is a novel and emerging practice, and available resources to implement projects. Addressing these issues is imperative to facilitate effective

rehabilitation of shellfish reefs and realise the numerous benefits that would result.

Recently, a site in western Port Stephens has been identified (Figure 2) that provides a unique opportunity to support large scale oyster reef restoration in NSW with considerable environmental and community benefits and partnership opportunities. The site, near the mouth of Karuah River, meets a number of key ecological and management conditions and has demonstrated natural recruitment that is limited only by a lack of suitable substrate. The site is an old oyster lease site located away from the main boating channel (Figure 3). It is proposed to use clean waste oyster shell from aquaculture businesses in Port Stephens to provide additional substrate at the site for natural oyster recruitment and reef development.

Figure 2. Location (yellow pin) of proposed oyster reef restoration site in Port Stephens. Image; Google Earth

Figure 3. Current view of proposed oyster reef restoration site in Port Stephens at low tide. Image – S. McOrrie.

Consultation with local oyster farmers, Port Stephens-Great Lakes Marine Park management, aquaculture and biosecurity staff within the Department of Primary Industries, have provided preliminary support for the proposal. Introductory consultation with oyster farmers in Port Stephens has shown they are interested in the opportunities to supply the required oyster shell, currently a waste product for their businesses, and to participate in the logistics of delivery and construction activities.

Consideration of operating and logistical requirements, overall costs and funding sources for the Port Stephens site is being developed recognising these economic opportunities and expected on-going improvements in biodiversity, fisheries productivity and water quality. Monitoring arrangements are also being considered.

References:

Asmus RM and Asmus H (1991). Mussel beds: Limiting or promoting phytoplankton? Journal of Experimental Marine Biology and Ecology 148: 215-232.

Attenbrow V (2010). Sydney's Aboriginal Past: Investigating the Archaeological and Historical Records. University of New South Wales Press. 226 pp.

Beck MW, Brumaugh RD, Airoldi L, Carranza A, Coen LD, Crawford C, Defeo O, Edgar GJ, Hancock B, Kay MC, Lenihan HS, Luckenbach MW, Toropova CL, Zhang G and Guo X (2011) Oyster reefs at risk and recommendations for conservation, restoration, and management. Bioscience 61: 107-116.

Breitburg DL (1999). Are 3-dimensional structure and healthy oyster populations the keys to an ecologically interesting and important fish community. Pages 239-249 in M. Luckenbach, R. Mann, and J. E. Wesson, editors. Oyster reef habitat restoration: A synopsis and synthesis of approaches. VIMS Press, Gloucester Point, VA.

Coen LD, Luckenbach MW and Breitburg DL (1999). The role of oyster reefs as essential fish habitat: a review of current knowledge and some new perspectives. Pages 438-454 in L. R. Benaka, editor. Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22, Bethesda, Maryland.

Coull BC and Wells JBJ (1983). Refuges from fish predation: experiments with phytal meiofauna from the New Zealand rocky intertidal. Ecology 64: 1599-1609.

Creighton C et al. (in prep). Protection and repair of Australia's shellfish reefs. National Environmental Science Program Report.

Dame RF and Dankers N (1988). Uptake and release of materials by a Wadden Sea mussel bed. Journal of Experimental Marine Biology and Ecology. 188: 207-216.

Dame RF, Wolaver TG and Libes SM (1985). The summer uptake and release of nitrogen by an intertidal oyster reef. Netherlands Journal of Sea Research. 19: 265-268.

Dame RF, Zingmark RG and Haskin E (1984). Oyster reefs as processors of estuarine materials. Journal of Experimental Marine Biology and Ecology 83: 239-247.

Diggles BK (2013). Historical epidemiology indicates water quality decline drives loss of oyster (Saccostrea glomerata) reefs in Moreton Bay, Australia. New Zealand Journal of Marine and Freshwater Research 47: 561-581.

Everett RA, Ruiz GM and Carlton JT (1995). Effect of oyster mariculture on submerged aquatic vegetation: An experimental test in a Pacific Northwest estuary. Marine Ecology Progress Series 125: 205-217.

Filgueira R, Byron CJ, Comeau LA, Costa-Pierce B, Cranford PJ, Ferreira JG, Grant J, Guyondet T, Jansen HM, Landry T, McKindsey CW, Petersen JK, Reid GK, Robinson SMC, Smaal A, Sonier R, Strand O, and Strohneier T (2015). An integrated ecosystem approach for assessing the potential role of cultivated bivalve shells as part of the carbon trading system. Marine Ecology Progress Series. 518: 281–287.

Gillies CL, Creighton C and McLeod IM (eds) (2015) Shellfish reef habitats: a synopsis to underpin the repair and conservation of Australia's environmentally, socially and economically important bays and estuaries.

Grabowski JH, Brumbaugh RD, Conrad RF, Keeler AG, Opaluch JJ, Peterson CH, Piehler MF, Powers SP and Smyth AR (2012). Economic valuation of ecosystem services provided by oyster reefs. Bioscience 62: 900-909.

McLeod IM, Parsons DM, Morrison MA, Van Dijken SG, Taylor RB (2013). Mussel reefs on soft sediments: a severely reduced but important habitat for macroinvertebrates and fishes in New Zealand. NZ Journal of Marine and Freshwater Research 48: 48-59.

Meyer DL, Townsend EC and Thayer GW (1997). Stabilization and erosion control value of oyster cultch for intertidal marsh. Restoration Ecology 5: 93-99.

Newell RIE (2004). Ecosystem influences of natural and cultivated populations of suspension feeding bivalve molluscs: a review. J. Shellfish Res. 23: 51-61.

Newell RIE and Koch EW (2004). Modeling seagrass density and distribution in response to changes in turbidity stemming from bivalve filtration and seagrass sediment stabilization. Estuaries 27: 793-806.

Ogburn DM, White I, McPhee DM (2007). The disappearance of oyster reefs from eastern Australian estuaries – Impact of colonial settlement or mudworm invasion? Coast Man 35: 271-287.

Oyster Culture Commission (1877). Report of the Royal Commission, appointed on the 29th September, 1876 to inquire into the best mode of cultivating the oyster together with the minutes of evidence, and appendices. Charles Potter, Acting Govt. Pr., Sydney, NSW. 73 pp.

Smyth, AR, Piehler MF, Grabowski JH (2015). Habitat context influences nitrogen removal by restored oyster reefs. J Appl Ecol 52: 716–725.

Stockton ED (1977). Middens of the Central Coast, New South Wales. Australian Archaeology 7: 20- 31.

Wall, CC, Peterson, BJ, Gobler, CJ (2008). Facilitationof seagrass Zostera marina productivity by suspension-feeding bivalves. Marine Ecology Progress Series. 357:165-174.

zu Ermgassen PS, Gray MW, Langdon CJ, Spalding MD, Brumbaugh RD (2013). Quantifying the historic contribution of Olympia oysters to filtration in Pacific Coast (USA) estuaries and the implications for restoration objectives. Aquat. Ecol. 47: 149-161.